TCB

## GRANT OF EQUIPMENT AUTHORIZATION

TCB

**Certification**
**Issued Under the Authority of the**
**Federal Communications Commission**
**By:**

**UL Verification Services Inc. (formerly UL CCS)**
**47173 Benicia Street**
**Fremont, CA 94538**

**Date of Grant: 04/19/2022**

**Application Dated: 04/19/2022**

**University of Hawaii**
**1000 POPE RD**
**MARINE SCIENCE BLDG 402**
**HONOLULU, HI 968222336**

**Attention: Pierre Flament , Researcher**

**NOT TRANSFERABLE**

EQUIPMENT AUTHORIZATION is hereby issued to the named GRANTEE, and is VALID ONLY for the equipment identified hereon for use under the Commission's Rules and Regulations listed below.

**FCC IDENTIFIER:** 2A562-MK3-PW-PA-TX
**Name of Grantee:** University of Hawaii
**Equipment Class:** Licensed Non-Broadcast Station Transmitter
**Notes:** Oceanographic High Frequency Doppler Radar

| Grant Notes | FCC Rule Parts | Frequency Range (MHZ) | Output Watts | Frequency Tolerance | Emission Designator |
|---|---|---|---|---|---|
| | 90 | 4.438 - 4.488 | 23.66 | 100.0 PM | 48K4F1N |
| | 90 | 5.25 - 5.275 | 25.23 | 100.0 PM | 23K1F1N |
| | 90 | 13.45 - 13.55 | 15.17 | 100.0 PM | 98K6F1N |
| | 90 | 16.1 - 16.2 | 15.0 | 100.0 PM | 98K7F1N |
| | 90 | 24.45 - 24.65 | 16.14 | 100.0 PM | 192KF1N |
| | 90 | 26.2 - 26.42 | 15.6 | 20.0 PM | 211KF1N |

Output power listed is EIRP. This device must be installed to provide a separation distance of at least 10.66m, 3.55m and 2.3m for device operating below 10MHz, between 10-20MHz and above 20MHz from all persons, respectively. It must not be collocated or operating in conjunction with any other antenna or transmitter except in accordance with FCC multi-transmitter product procedures. End-Users must be provided with transmitter operation conditions for satisfying RF exposure compliance.

# University of Hawaiʻi at Mānoa

**School of Ocean and Earth Science and Technology**
**Department of Oceanography**
**Radio Oceanography Laboratory**
1000 Pope road • Honolulu, Hawai'i 96822


Date: 3/21/2022

UL Verification Services Inc.
47173 Benicia Street
Fremont, CA 94538, USA

To whom it may concern:

I, the undersigned, hereby authorize UL Verification Services Inc. to act on our behalf in all manners relating to application for equipment authorization, including signing of all documents relating to these matters. Any and all acts carried out by UL Verification Services Inc. on our behalf shall have the same effect as acts of our own.

I, the undersigned, hereby certify that we are not subject to a denial of federal benefits, that includes FCC benefits, pursuant to Section 5301 of the Anti-Drug Abuse Act of 1988, 21 U.S.C. 853(a).

In authorizing UL Verification Services Inc. as our representative, we still recognize that we are responsible to:

a. fulfill the requirements for the scope of certification requested, including implementing any appropriate changes requested by UL Verification Services Telecommunications Certification Body (TCB) and / or the FCC;

b. supply any and all information needed for the evaluation of the products for which certification is sought;

c. make claims regarding certification only in respect of the scope for which certification has been granted;

d. not use our product certification in such a manner as to bring the TCB or FCC into disrepute and to not make any statement regarding product certification which the TCB or FCC may consider misleading or unauthorized;

e. discontinue use of all advertising matter that contains any reference thereto and complies with any and all actions required by the FCC upon suspension or cancellation of certification;

f. use certification only to indicate that products are certified in conformity with specified standards;

g. endeavor to ensure that no certificate or report or any part thereof is used in a misleading manner, and any copies of the grants/certificates shall be reproduced in their entirety;

h. comply with the requirements of the TCB and FCC, including the use of marks and label information prescribed for the scope of certification, when making reference to product certification in communication media such as documents, brochure or advertisements;

i. comply with the requirements for certification, supply any information needed for evaluation of products to be certified and, where applicable, make provision for the participation of observers;

j. ensure that products marketed under the scope of the requested certification continue to comply with the certification requirements;

k. provide a sample of a production unit for testing within 30 days of the request should this product be selected as part of either the TCB's or the FCC's market surveillance requirements;

l. keep a record of all complaints relating to product's compliance with requirements of relevant standard; make records available to UL or FCC when requested; take appropriate action with respect to such complaints and any deficiencies found in the product that affect compliance with requirements for certification; document the actions taken with respect to complaints and/or deficiencies;

m. inform the TCB immediately of any changes that may affect its ability to comply with the certification requirements.

This authorization is valid until further written notice from the applicant.

Pierre Flament, Ph.D. pflament@hawaii.edu
Principal Investigator
Radio Oceanography Laboratory

# University of Hawaiʻi at Mānoa

**School of Ocean and Earth Science and Technology**
**Department of Oceanography**
**Radio Oceanography Laboratory**
1000 Pope road • Honolulu, Hawai'i 96822


Date: 3/21/2022
Attn: FCC Office of Engineering and Technology / UL Verification Services TCB
Subject: Limiting of Sales to Customers Aware of Licensing Requirements

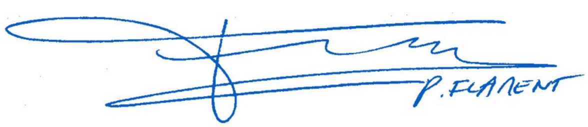
To Whom It May Concern:

This letter is provided to explain that the Radio Oceanography Laboratory of the University of Hawaiʻi at Mānoa limits the sales of its Generic Oceanographic High Frequency Doppler Radar system (G-HFDR, FCC ID: 2A562-MK3-PW-PA-TX), to non-commercial customers who understand that by operating such system, they are performing measurements of distance, direction and speed of ocean currents and waves by means of radio-location.

Before being delivered such a system, customers must demonstrate competence in radio and radar technology by participating in a training workshop organized by the Radio Oceanography Laboratory of the University of Hawaiʻi at Mānoa.

Customers must also certify that they will apply for a license through the FCC Universal Licensing System and that they understand that their authority to transmit through any radiating antenna or structure is contingent on their license have been awarded.


Pierre Flament, Ph.D. pflament@hawaii.edu
Principal Investigator
Radio Oceanography Laboratory

University of Hawai'i at Mānoa
School of Ocean and Earth Science and Technology
Radio Oceanography Laboratory

# Generic High Frequency Doppler Radar Synthesizer-Transmitter Unit Model MK3-PW-PA-TX Operational Description

April 2022

v. 10

radlab@satlab.hawaii.edu
Marine Sciences Building
1000 Pope road
Honolulu Hawai'i 96822

## FCC Supplier's Declaration of Conformity

University of Hawai'i Generic High Frequency Doppler Radar Synthesizer-Transmitter Unit, model *MK3-PW-PA-TX.*

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions:

(1) this device may not cause harmful interference, and

(2) this device must accept any interference received, including interference that may cause undesired operation.

Changes or modifications not expressly approved by University of Hawai'i could void the user's authority to operate the equipment.

University of Hawai'i at Mānoa
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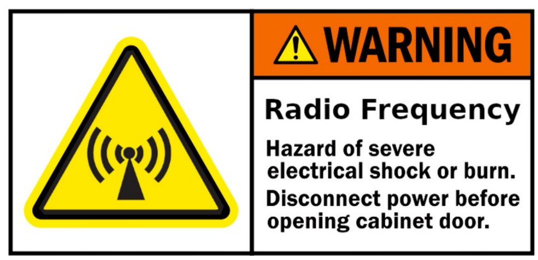
## Warnings


This device contains potentially dangerous high voltages and high frequency radiation. Operation and servicing is restricted to properly trained and certified personnel.

Maximum output power is 50 W (+0.5dB) for frequencies 8 MHz and below and 30 W (+0.5dB) for frequencies 12 MHz and above.

The user's authority to operate this device if connected to any radiating antenna or structure in the United States is contingent on applying for and being awarded a valid license through the FCC Universal Licensing System before transmitting. This device may not be powered up for testing unless connected to a non-radiating resistive load.

## Table of Contents

## Generic High Frequency Doppler Radar (G-HFDR)

### 1. Physical principles

The G-HFDR is an Oceanographic High Frequency Doppler radar designed with bare minimum features to ensure low production cost, low power requirement, and easy maintenance.

The operation of the G-HFDR 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. The back-scattered radio waves are shifted in frequency by the Doppler effect due to the sum of the surface wave velocities and the surface current. The velocity of the radial currents in the direction of the G-HFDR is estimated from this Doppler shift.

For "Region 2", the Americas, the International Telecommunication Union (ITU) has recommended and the Federal Communication Commission has allocated dedicated secondary frequency bands for operating High Frequency Doppler radars (Table 1).

*Table 1. Allocation for Oceanographic High Frequency Doppler radars in Region 2.*

| *Center* | *Occupied bandwidth* |
|---|---|
| *(MHz)* | *(kHz)* |
| 4.463 | 50 |
| 5.2625 | 25 |
| 13.500 | 100 |
| 16.150 | 100 |
| 24.550 | 200 |
| 26.310 | 220 |

The G-HFDR consists of two units or subsystems: the Synthesizer-Transmitter Unit, and an optional Receiver-Digitizer Unit.

The Synthesizer-Transmitter Unit is based on commercial off-the-shelf modules and contains: (i) an ultra-low phase noise reference oscillator (OCXO), (ii) direct digital signal synthesizers (DDS-FPGA), (iii) a power amplifier (PA), (iv) an anti-harmonic filter (LPF), (v) power supplies (PS) and power line filters (RFI). This unit is the subject of the present technical document.

The optional Receiver-Digitizer Unit is based on schematics and engineering drawings published by the Radio Oceanography Laboratory and released in the public domain as Open Design/Open Source. It is a passive homodyne quadrature demodulator to baseband and does not contain any oscillator, frequency synthesizer or RF power amplifier. This unit is the subject of a separate technical document.

The units exchange information with the outside world through ethernet links. Absolute timing, if required, can be provided by the precision network time protocol (*ptp*), encompassing master network-based GPS clocks or atomic clocks.

## 2. System description and schematics

The following modules are integrated to form the Synthesizer-Transmitter Unit (Figure 1):

1. an ultra-low phase noise oven-controlled crystal oscillator (OCXO) fitted with a thermal-inertia bell, providing the clock signal to the digital synthesizer. Features: 100 MHz frequency, single side-band phase noise -148dBc/Hz. Manufacturer: Bliley (United States), model N79A-optA. The technical specification are found in appendix 1.

2. a clock-remapping direct digital synthesizer (DDS-C) to correct for frequency offset, aging and drift of the OCXO with a precision of 1 mHz, based on initial factory-calibration against a rubidium clock or optional real-time calibration against network clocks.

3. a two-channel quadrature (I, Q) direct digital synthesizer (DDS-A/B) providing frequency-modulated (chirped) signals. Features: internal frequency 300MHz after base clock multiplication, 48-bit phase register yielding 1 µHz tunability, 12-bit digital-to-analog converter, 80 dB SFDR, 27MHz analog low-pass filters resulting in an operating frequency extending to 27MHz. Both the clock-remapping DDS-C and the chirping DDS-A/B are based on Analog Devices' model AD9854 CMOS DDS, integrated by D-Tacq Solutions (Scotland/UK), model RAD-CELF. The technical specifications of this triple DDS radar controller are found in appendix 2 and its schematics are shown in Figure 2 and 3.

4. an embedded processor, combining on the same integrated circuit, a programmable logic gate array (FPGA) and a dual-core sequential processor operating under Linux (ARM Cortex-A9) based on Xilinx' model Zynq-7000. Mother-board integrated by D-Tacq Solutions (Scotland/UK), model ACQ-1001Q.

5. a solid state Class AB MOSFET RF power amplifier (PA) operated in continuous mode (CW). Features: input signal level -10dBm, Maximum output power is 50 W (+0.5dB) for frequencies 8 MHz and below and 30 W (+0.5dB) for frequencies 12 MHz and above. Stable operating range from 0.5 to 150 MHz. Manufacturer: Tomco Technologies (Australia), Model BTM00250-AlphaSA. The technical specifications are found in appendix 3.

6. a 9th order Butterworth power low-pass filter to cancel spurious signal harmonics and aliases. Manufacturer: DLW associates (Missouri, USA). The low-pass filter is built to the specific operating frequency and factory-fit at time of manufacture. The technical specifications are found in appendix 4.

7. switching power supplies manufactured by Traco, including 12V model for the digital electronics (TSP-070-112) and 26V model for the RF power amplifier (TSP-360-124 coupled with TSP–BCM24 battery controller module). The Traco power supplies are rated for an input voltage range 85V to 260V. They feature oscillator dithering to reduce spurious radiated peaks. The technical specifications are found in appendix 5. AC and DC power line filters (RFI) are inserted to mitigate spurious radiated emissions. Standard circuit breakers are added for protection.

8. a custom-built enclosure rated IP65 in white lacquered aluminum 20x60x75 cm protecting all electronic modules from weather and electromagnetic interference, including 6-point grounding harness for the door. The Synthesizer-Transmitter Unit operates without an active cooling device over an ambient temperature range of -30C to +50C.

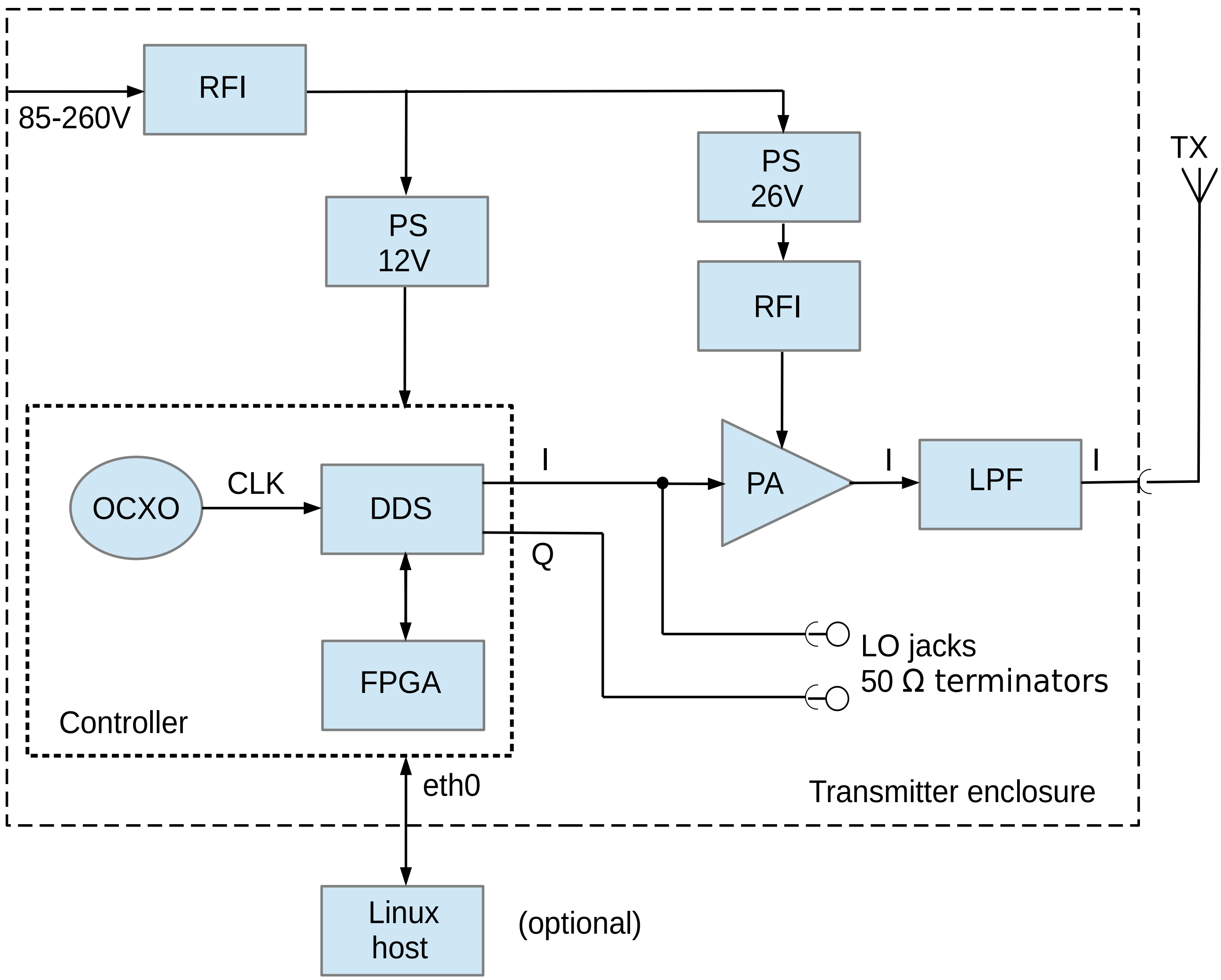



*Figure 1. Schematics of the Synthesizer-Transmitter Unit.*
*See Table 2 for list of components and references.*

*Table 2. List of commercial modules incorporated in the Synthesizer-Transmitter Unit*

| *Tag* | *Description* | *Reference* | *Manufacturer* |
|---|---|---|---|
| OCXO | Oven-controlled crystal oscillator, 100 MHz | N79A-optA | Bliley Technologies Inc. 2545 W Grandview Blvd, Erie PA 16506 USA |
| FPGA | Carrier with embedded FPGA&ARM processors | ACQ1001 | D-TACQ Solutions Ltd., International House Stanley Blvd, Blantyre G72 0BN Scotland UK |
| DDS | Triple DDS Radar Controller | RAD-CELF | *id.* |
| PA | Radio-frequency power amplifier | BTM00250-AlphaSA | Tomco Technologies 38 Payneham Rd, Stepney, Australia 5069 |
| LPF | Power low-pass filter | FLxxMLP-HFDR | DLW Associates 6 Woodford place, St. Charles MO 63301 USA |
| PS12V | Industrial power supply | TSP-070–112 | Traco Electronic AG Sihlbruggstrasse 111, CH-6340 Baar |
| PS26V | Industrial power supply | TSP-360–124 | *id.* |
| RFI-DC | EMI Filter with High Attenuation Performance | FN2030M-Z-20-06 | Schaffner Holding AG Nordstrasse 11, CH-4542 Luterbach |
| RFI-AC | EMI Filter with High Attenuation Performance | FN9266-10-06 | *id.* |

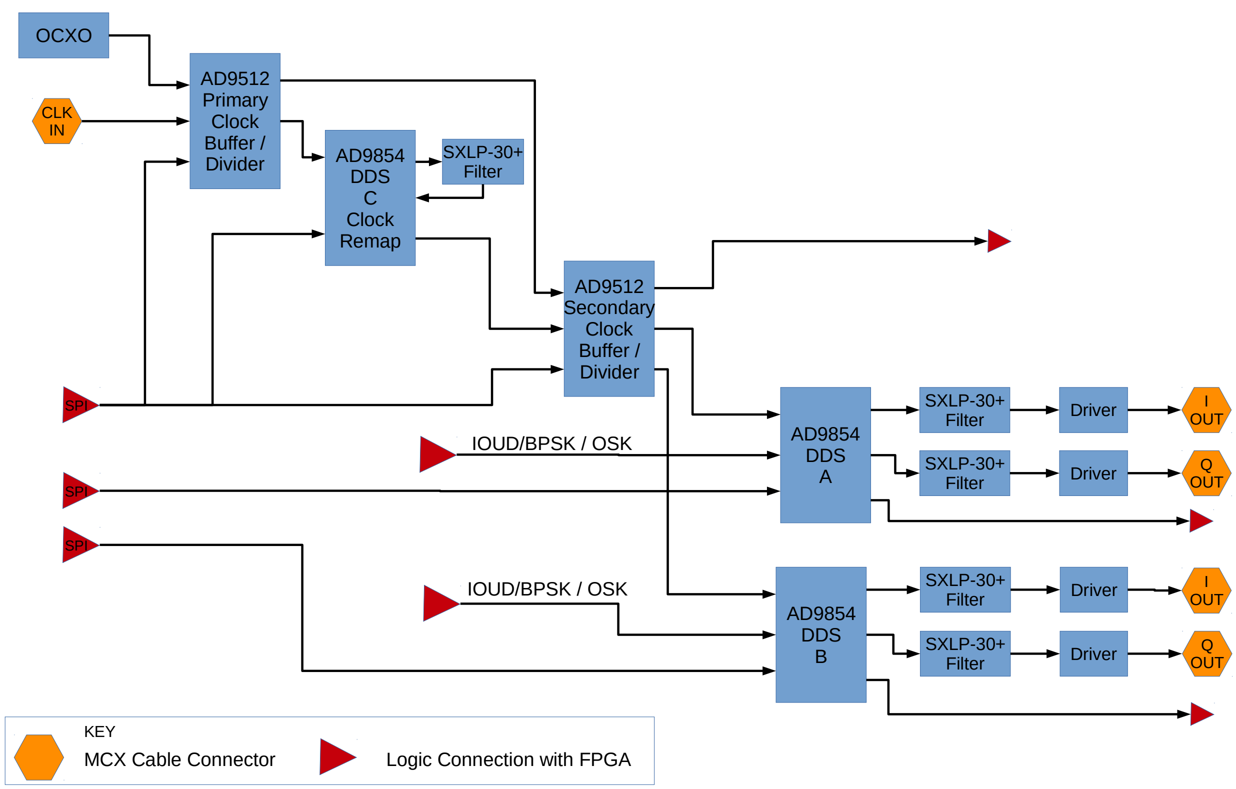



*Figure 2. Schematics of the Triple DDS Radar Controller.*
*See Table 3 for list of components and references.*

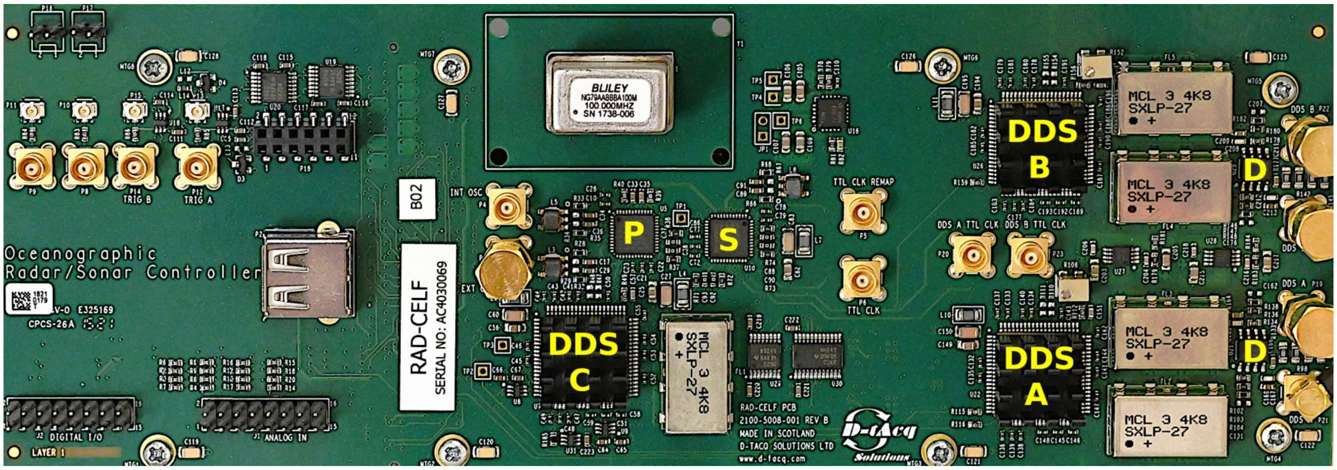



*Figure 3a. Photo of the Triple DDS Radar Controller board (top face).*

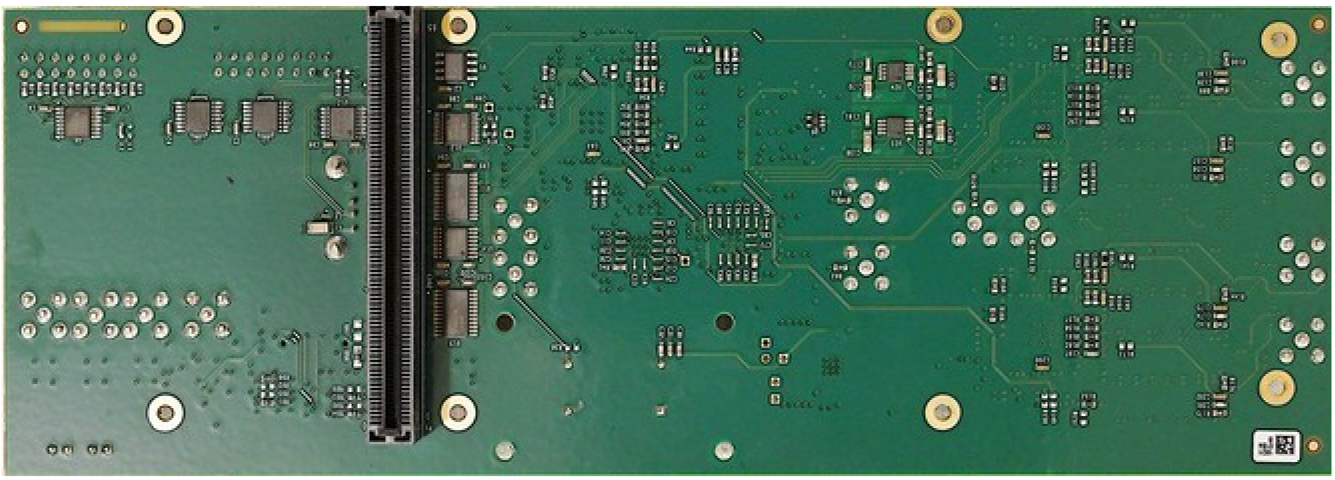


*Figure 3b. Photo of the Triple DDS Radar Controller board (bottom face).*

*Figure 3c. Photo of the carrier board with FPGA (top face; bottom face not accessible).*

*Table 3. List of functional integrated circuits used in the Triple DDS Radar Controller*

| *Tag* | *Description* | *Reference* | *Manufacturer* |
|---|---|---|---|
| **P**rimary | Clock/buffer divider | AD9512BCPZ | Analog Devices<br>One Analog Way, Wilmington MA 01887 USA |
| **S**econdary | Clock/buffer divider | AD9512BCPZ | *id.* |
| **DDS-A** | Direct digital synthesizer | AD9854ASVZ | *id.* |
| **DDS-B** | Direct digital synthesizer | AD9854ASVZ | *id.* |
| **DDS-C** | Direct digital synthesizer | AD9854ASVZ | *id.* |
| Filter | Lumped LC low-pass filter | **SXLP-27**+ | Mini-Ciruits<br>13 Neptune Ave, Brooklyn NY 11235 USA |
| **D**river | Operational amplifier | OPA2694D | Texas Instruments<br>12500 TI Blvd., Dallas TX 75243 USA |

Note: commodity components (inductors, capacitors, resistors, regulators) used on the Radar controller board have passive functions and do not contribute to the signal generation.

## 3. Summary of specifications

| | |
|---|---|
| *Signal characteristics:* | FMCW linear sweep (chirp) |
| *Emission designation:* | F1N |
| *Design operating frequencies:* | 3 MHz to 27 MHz |
| *Modulation bandwidth:* | Max. 2% of operating frequency |
| *Restricted operating frequencies/bandwidth:* | firmware-restricted to FCC/ITU allocations |
| *Sweep (chirp) rate, radar mode:* | 1-5 Hz |
| *Sweep (chirp) rate, call-sign mode:* | 1 kHz |
| *Master reference clock:* | OCXO 100 MHz SC-cut |
| *Single side-band phase noise:* | 148 dBc/Hz @ 1 kHz or better |
| *Clock frequency stability:* | 300 ppb or better (1-year, full temp. range) |
| *Conducted output power < 10 MHz:* | 50 W |
| *Conducted output power > 10 MHz:* | 30 W |
| *Harmonics at rated power:* | 2*$f0$ < -70 dB; 3*$f0$ < -80 dB |
| *Supply voltage range:* | 85 V to 260 V AC, 50-60 Hz |
| *Supply power:* | 250 W AC |
| *Operating temperature range:* | -30°C to +50°C |

## 4. Tune-up procedure

This device has no adjustments to tune output power and reference frequency because these are digitally programmed during the manufacture of the system and drifts are non-existent within the precision of measurements.

Programming the unit is password-protected and reserved to factory-authorized personnel. There are no user-accessible controls to modify the programming of the unit.

## 5. Configuration and operation

The unit is programmed to emit a repetition of frequency sweeps (chirps), typically at a rate of 1Hz to 4Hz and an occupied bandwidth of 25 to 220kHz determined by the ITU frequency allocation (see Table 1), resulting in a frequency-modulated continuous wave (FMCW mode, emission designation F1N).

The unit is factory-programmed to start transmitting automatically upon power up at the ITU frequency for which a low-pass filter is factory-fitted. To avoid any erroneous operation that could damage the power amplifier and/or the low-pass filter, or result in unlicensed transmissions, all frequencies are factory-disabled, except the ITU frequency for which a low-pass filter is actually factory-fitted to the unit. Programming the unit to other frequencies is password-protected and reserved to factory-authorized personnel.

If a FCC call sign has been provided at the time of factory-configuration, a full-bandwidth broadcast of the call sign is automatically scheduled every 20 min. Chirps at a rate of 1 kHz are transmitted over the same occupied bandwidth, for short periods corresponding to the dots and dashes of the Morse code, resulting in a similar frequency-modulated continuous wave (emission designation F1N).

The unit can be powered-up in two modes of operation: (a) a test mode, for which the output is connected to a 50Ω non-radiating resistive load, or (b), a live mode, for which the output is connected to a radiating antenna or structure. The user's authority to operate this device in the live mode (b) from a location within the United States is contingent on being awarded a license through the FCC Universal Licensing System. In the absence of a valid FCC license, the device may only be operated in the test mode (a).

The firmware allows programming all operations of the digital synthesizer, including chirping, calibration tones and full-bandwidth call-sign broadcast, using a single ethernet web server interface, configured through the Dynamic Host Configuration Protocol (DHCP; Figure 4). The actual settings of the digital synthesizers are continuously read back from the DDS registers and displayed on a separate diagnostic web page (Figure 5).

### *5.1. Start-up procedure*

The following steps must be performed in the order given:

1. open enclosure and verify that the frequency of the low-pass unit fitted (figure 9) corresponds to the factory-configured frequency marked on the label (figure 8).
2. verify that all breakers are off in the down positions (figure 9).
3. for mode (a), connect a power attenuator such as a a Bird 100-SA-FFN-30 to the N-type RF output of the unit (figure 12).
4. for mode (b), connect the cable to the TX antenna, with a minimum attenuation of 5 dB (figure 12).
5. connect a CAT-6e cable from a local network to the RJ45 jack of the unit (figure 12);
6. connect a grounded power cable to the IEC-C13/C14 power inlet (figure 12) and plug into a 120 or 240V outlet (the unit auto-detects the voltage).
7. connect the power adapter of the heat-exchanger shown in figure 5 into a 120 or 240V outlet (the unit auto-detects the voltage).
8. power up the unit and the heat exchanger.

9. enable the power surge suppressor by flipping its breaker to the up position (lower DIN rail, figure 9).
10. enable the power supplies by flipping all remaining breakers in sequence from right to left to the up position (middle DIN rails, figure 9).
11. tie the 6 grounding connections of the door and close the enclosure.
12. verify that the network router has provided an IP address through DHCP (waiting 2-3 minutes may be necessary to let the boot sequence complete).
13. open browser on this IP address, verify that a screen similar to figure 4 is obtained.
14. click on “Status”, verify that a popup screen similar to figure 5 is obtained and that the entry shown for ---DDS-A--- under /FREQ displays the expected factory-configured frequency.

The unit is now operating and transmitting the required signal.

## *5.2. Toggling between signal types*

Two signal types are allowed: standard frequency-modulated continuous wave chirp for normal radar operation, and continuous tones for calibration. Continuous tones can be programmed at three distinct frequencies: at the lower limit of the allocated bandwidth $f0-bw/2$, at the center frequency $f0$ and at the upper limit of the allocated bandwidth $f0+bw/2$.

To toggle between signal types:

1. open a browser on the unit’s IP address, obtain a screen similar to figure 4.
2. to change between signal types, click on the appropriate button.
3. wait 15 sec for the command to execute.
4. verify with the “Status” screen that the frequency has been updated.

The unit is now transmitting the required signal.

## *5.3. Power-down procedure*

The following steps must be performed in the order given:

1. open a browser on the unit’s IP address, obtain a screen similar to figure 4.
2. click on the “Stop” button.
3. wait 15 sec for the command to execute.
4. verify with the “Status” screen that the frequency has been updated to 0.
5. open enclosure.
6. disable the power supplies by flipping all breakers in sequence from left to right to the down position (middle DIN rails, figure 9).
7. power down the unit and the heat exchanger.
8. close enclosure and stow unit.

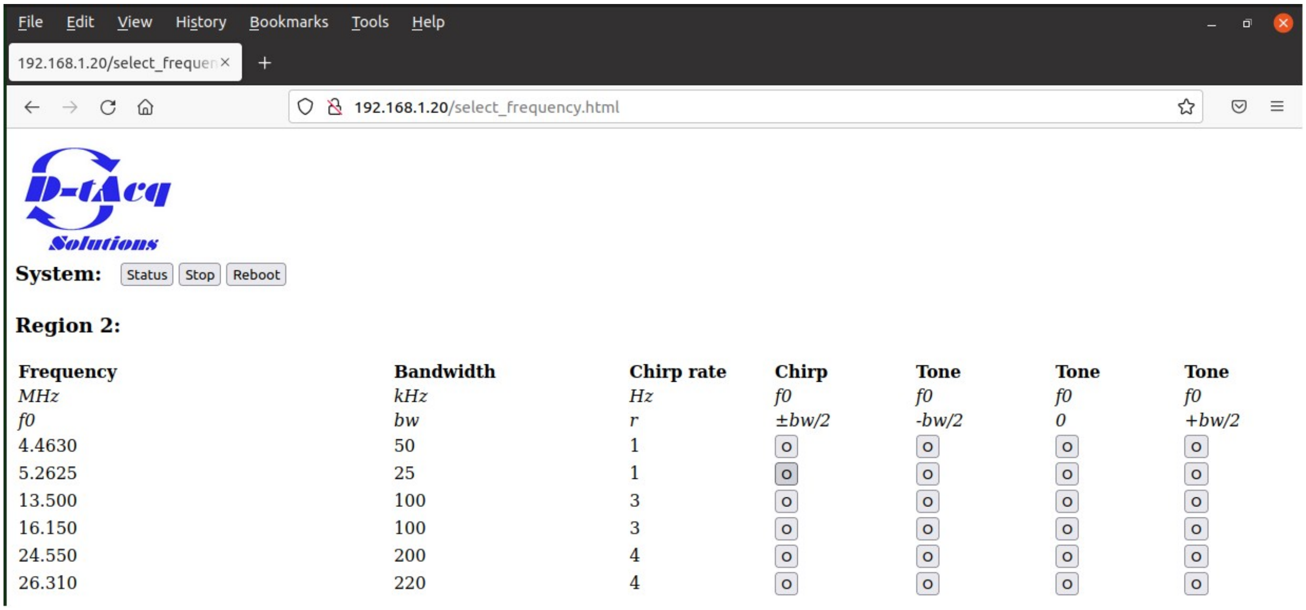



*Figure 4. Web interface for programming the synthesizer/transmitter.*

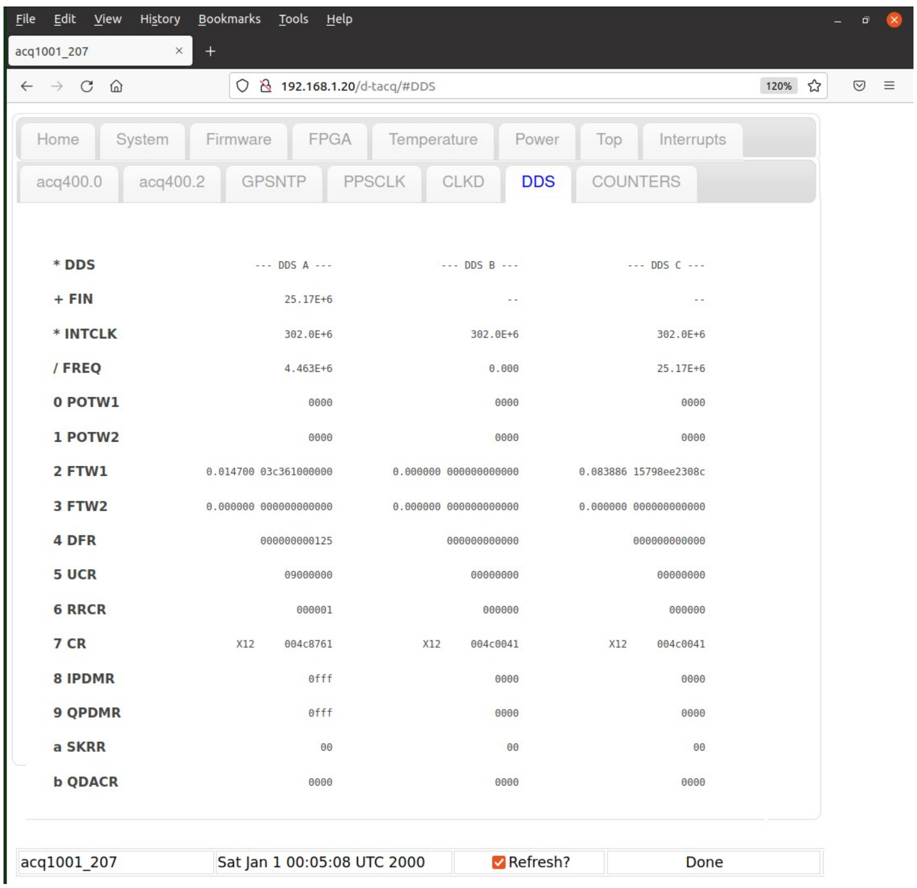



*Figure 5. Diagnostic page with DDS registers read-back.*

## 6. Antenna design

The transmit antennas are normal-mode helical monopoles (Kraus, J.D., “The Helical Antenna”, *Proc. I.R.E.* 1949 pp. 263-272). They consist of an AWG-16 vertical wire of length λ/4 wound over a mast of height λ/8 and diameter λ/300, a 3-loop tuning air-coil, and a network of 4 underground radials of length λ/4 (λ is the electromagnetic wavelength). The air-coil diameter is adjusted to achieve resonance using a standard commercial VSWR meter.

The customer-provided mast may be built of any non-conductive material, such as fiberglass, PVC, bamboo, wood. The typical gain of a normal-mode helical monopole is approximately 2 dBi.

*Figure 6. Normal-mode helical monopole with air-coil on a fiberglass mast (8 MHz).*

*Figure 7. Normal-mode helical monopole with air-coil on a PVC mast (16 MHz).*

*Table 5. Dimensions of the antenna components as function of ITU frequency (metric)*

| *F* | *Wavelength* | *Vertical wire* | *Radial wires* | *Pole height* | *Diameter* |
|---|---|---|---|---|---|
| *(MHz)* | *(m)* | *(m)* | *(m)* | *(m)* | *(cm)* |
| 4.4630 | 67.22 | 16.80 | 16.80 | 8.40 | 22.4 |
| 5.2625 | 56.01 | 14.00 | 14.00 | 7.00 | 18.7 |
| 13.500 | 22.22 | 5.55 | 5.55 | 2.78 | 7.4 |
| 16.150 | 18.58 | 4.64 | 4.64 | 2.32 | 6.2 |
| 24.550 | 12.22 | 3.05 | 3.05 | 1.53 | 4.1 |
| 26.310 | 11.40 | 2.85 | 2.85 | 1.43 | 3.8 |

The coaxial cable connecting the synthesizer/transmitter unit in the shack to the remote antenna, preferably deployed at the water edge, is specified as standard RG-213U, with a typical attenuation of at least 5 dB, depending on the frequency.

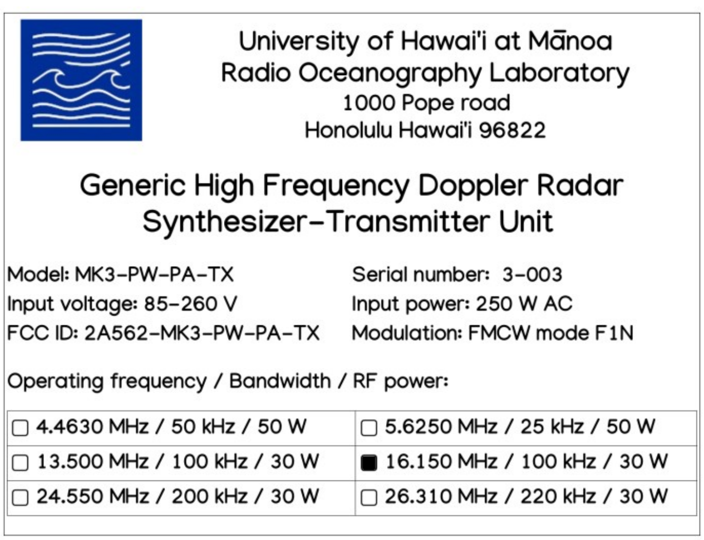
To comply with FCC RF exposure requirements, the antennas must be installed to ensure a minimum separation distance from persons while operating:

*Table 6. Minimum separation distance to comply with FCC RF exposure requirements*

| *Operating Frequency* | *Minimum Separation Distance* |
|---|---|
| *(MHz)* | *(m)* |
| 4.463 | 10.66 |
| 5.2625 | 10.66 |
| 13.500 | 3.55 |
| 16.150 | 3.55 |
| 24.550 | 2.30 |
| 26.310 | 2.30 |

## 7. Photos of unit

*Figure 8. Above: Synthesizer-Transmitter Unit model MK3-PW-PA-TX, serial 3-003 (March 2022), door closed. Below: device identification label, affixed to the top right of the enclosure door. The factory-programmed operating frequency and output power are marked, here 16.150 MHz/30W.*



University of Hawai'i at Mānoa
Radio Oceanography Laboratory
1000 Pope road
Honolulu Hawai'i 96822

Generic High Frequency Doppler Radar
Synthesizer–Transmitter Unit

Model: MK3–PW–PA–TX
Serial number: 3–003
Input voltage: 85–260 V
Input power: 250 W AC
FCC ID: 2A562–MK3–PW–PA–TX
Modulation: FMCW mode F1N

Operating frequency / Bandwidth / RF power:

| | |
|---|---|
| ☐ 4.4630 MHz / 50 kHz / 50 W | ☐ 5.6250 MHz / 25 kHz / 50 W |
| ☐ 13.500 MHz / 100 kHz / 30 W | ■ 16.150 MHz / 100 kHz / 30 W |
| ☐ 24.550 MHz / 200 kHz / 30 W | ☐ 26.310 MHz / 220 kHz / 30 W |

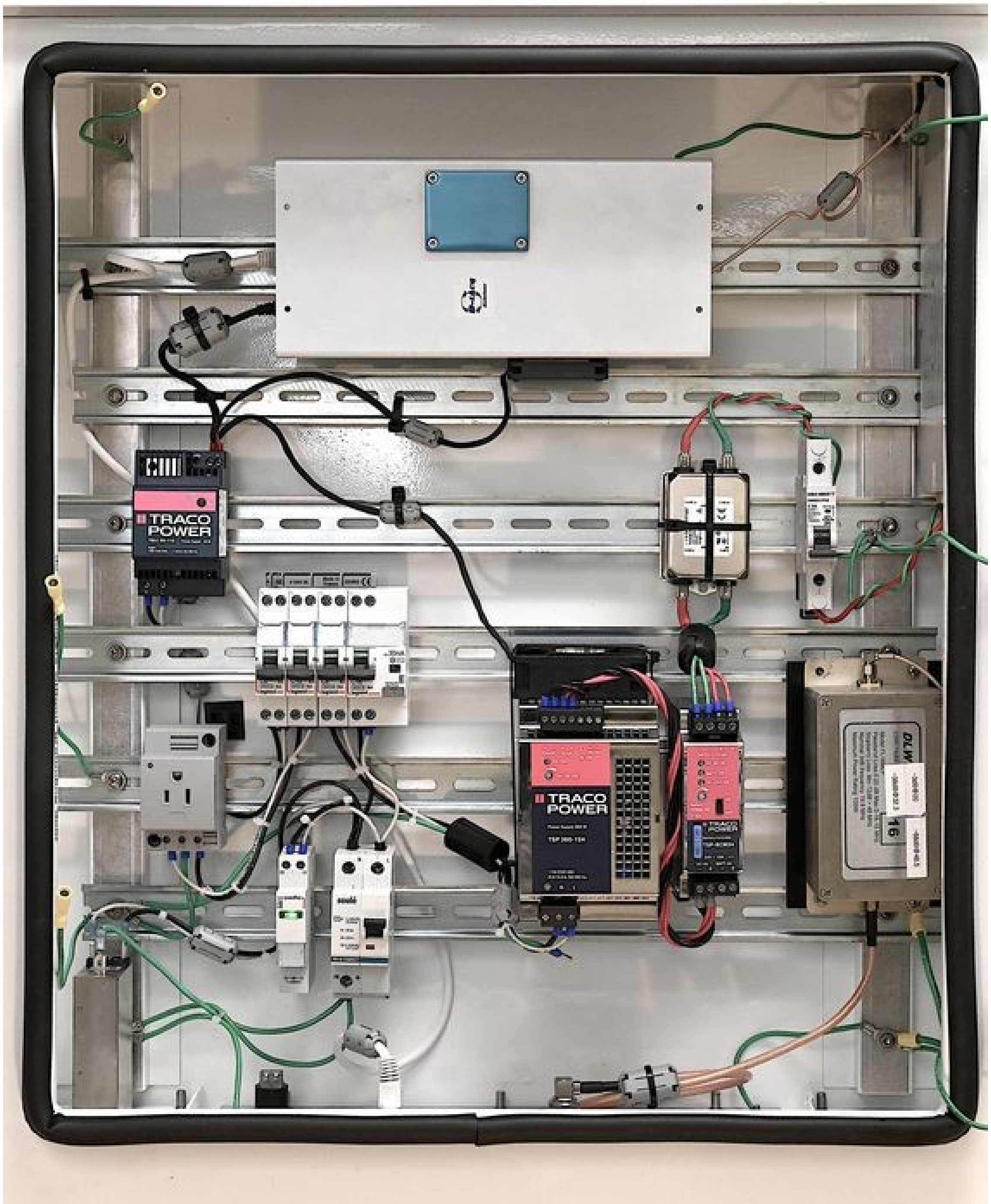



*Figure 9. Synthesizer-Transmitter Unit, door open.*
*Bottom rails: power supplies with circuit breakers.*
*Upper rail: digital synthesizer and controller with blue thermal bell.*
*On the right wall: the power amplifier module and the low-pass filter.*


*Figure 10. Synthesizer-Transmitter Unit, door open, slanted view. The power amplifier module (top) and the low-pass filter (bottom) are seen on the right inner wall.*

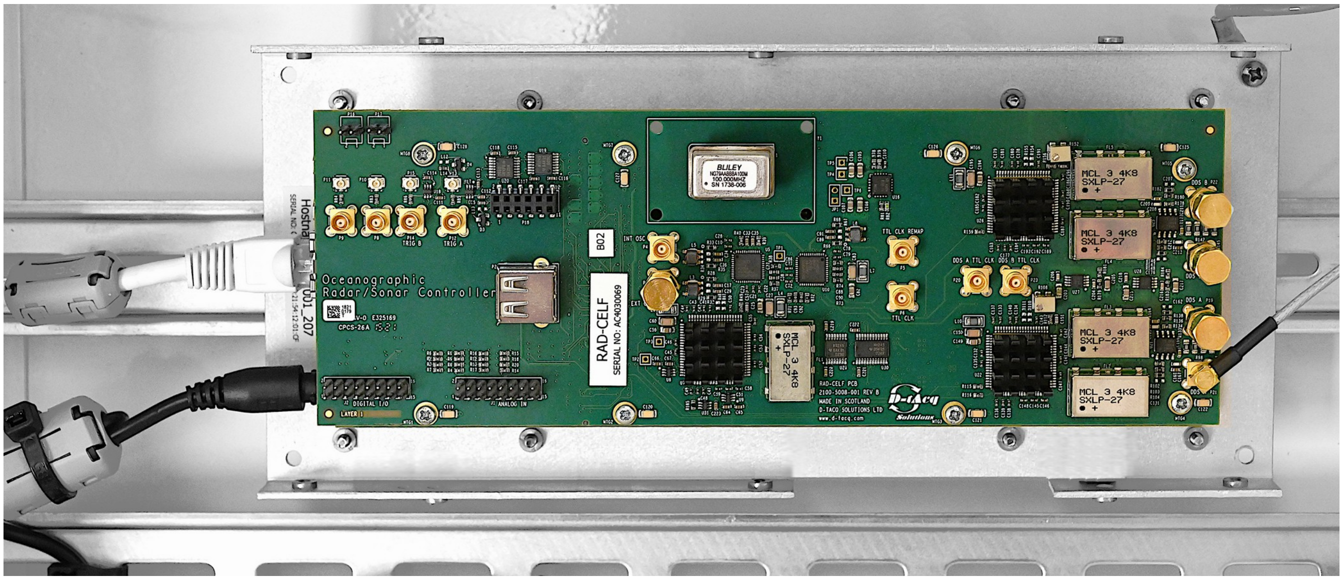



*Figure 11. Upper rail enlarged from Figure 9 and 10, after removal of the aluminum lid and thermal bell, showing the Triple DDS Radar Controller board.*

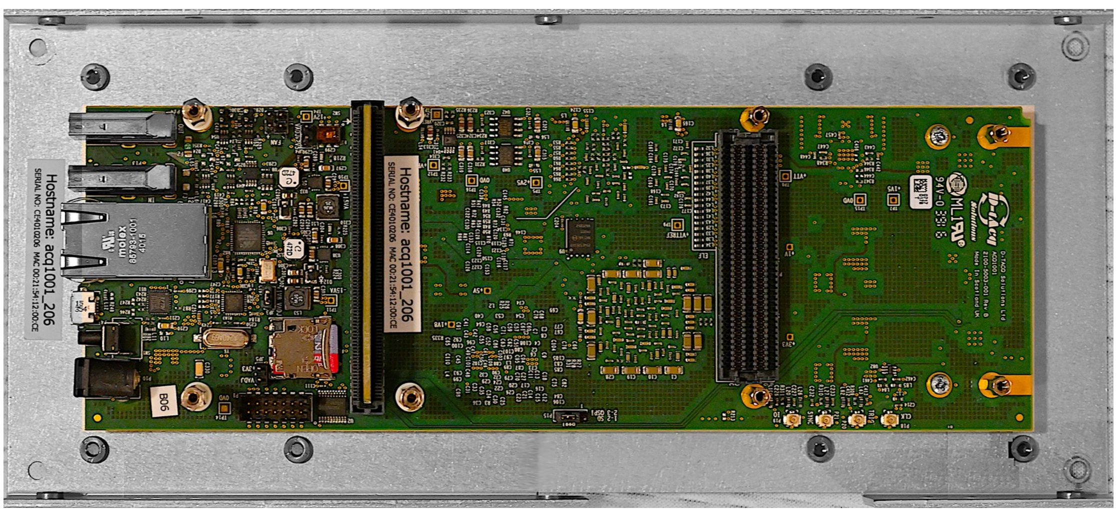



*Figure 12. Carrier board with FPGA, after removal of the Triple DDS Radar Controller board (top face; bottom face not accessible).*

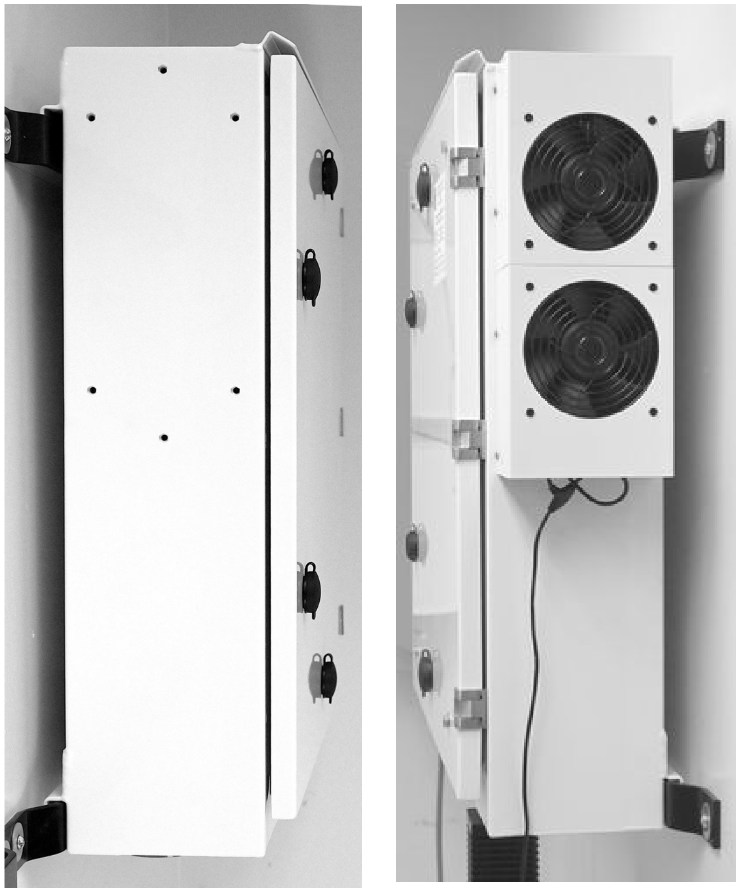


*Figure 13. Synthesizer-Transmitter Unit, left and right side views.*
*The twin-fan forced air flow heat exchanger unit is seen on the right side.*

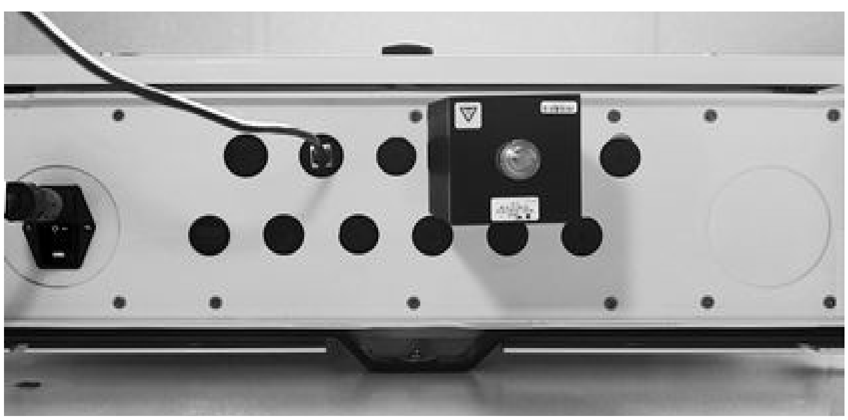


*Figure 14. Synthesizer-Transmitter Unit, bottom view.*
*Connector plate with IEC-C13/C14 power inlet, RJ45 jack for CAT6 Ethernet, N-type bulkhead adapter for cable to antenna (a Bird 100-SA-FFN-30 power attenuator is attached).*

*Fig. 14. Synthesizer-Transmitter Unit, top view.*
*The twin-fan forced air flow heat exchanger unit is seen on the right side.*

*Fig. 15. Synthesizer-Transmitter Unit, back view*
*(after removing unit from wall supports).*

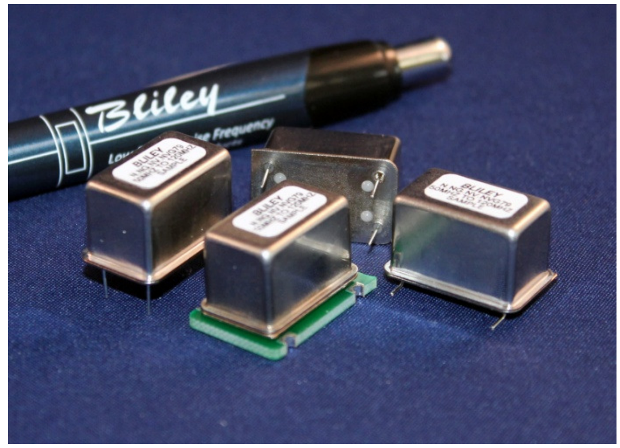
## Appendix 1 : specifications of the ultra-low phase noise oscillator (OCXO)

# High Freq. 20x13mm
# NV79 DIP OCXO

Bliley Technologies Inc.
2545 W Grandview Blvd
Erie, Pa 16506
Factory +1-814-838-3571

**Features:**

- **50MHz to 120MHz Output Frequency's**
- **Standard Frequency of 100 MHz.**
- **Excellent Stability and Noise in a miniature size**
- **Options for Phase noise, and FVT**
- **Available in surface mount, through hole or gull wing package styles.**
- **RoHS-6/Lead free Compliant**
- **Storage Temperature Range of -55°C to +85°C**
- **Manufactured in Erie, Pa. USA**




**Description:**

**The NV79 Series Ovenized Crystal Oscillator offers high stability Frequency vs. Temperature performance and SC Cut Crystal Phase Noise performance in a DIP configuration. It is ideally suited for base station, test equipment, synthesizers, and digital switching applications. It is available in three different package styles as well as custom frequencies between 50 to 120 Mhz. Standard frequency is 100 MHz.**

## Electrical Specifications

### 1. Output Characteristics

| | Parameter | Min. | Typ. | Max. | Unit | Test Conditions |
|---|---|---|---|---|---|---|
| 1.1 | Frequency Range | 50 | | 120 | MHZ | |
| 1.2 | Initial Accuracy | | | ±50 | PPB | |
| 1.3 | Output Type | | | | | |
| | Sinusoidal | | | | | |
| | Output Level | 3 | 5 | | dBm | |
| | Load Impedance ±5% | 45 | 50 | 55 | Ω | |
| | Harmonic Content | | -25 | | dBc | |
| | Spurious Modulation | | | -60 | dBc | |
| 1.4 | Acceleration Sensitivity* | | | 1 | PPB/g | @100MHz |

*Please consult factory for acceleration sensitivity options regarding other frequencies.

## 2. Frequency Stability

| | Parameter | Min. | Typ. | Max. | Unit | Test Conditions |
|---|---|---|---|---|---|---|
| 2.1 | Frequency vs. Temperature | | | | | Referenced to Frequency @+25˚C |
| | 0°C to +50°C | ±70 | | | PPB | See Table 2 For Ordering Options |
| | -20°C to +70°C | ±100 | | | PPB | See Table 2 For Ordering Options |
| | -40°C to +85°C | ±150 | | | PPB | See Table 2 For Ordering Options |
| 2.2 | Aging | Typical for 100MHz after 30 days of continuous operation | | | | |
| | Per day after 30 days | | | ±5 | PPB | Typical at 100MHz after 30 days of continuous operation |
| | 1st Year** | | | ±300 | PPB | |
| | 10 Years** | | | ±650 | PPB | |
| 2.5 | Short Term | | 8 | | 10e-11 | τ = 1 Second |
| 2.6 | Warm-up | | ±50 | | PPB | Within 3 minutes |
| 2.7 | Static Phase Noise | See Table 2 for Ordering Options | | | | |
| | | Option A | Option B | Option C | | Tested @ +25˚C±1˚C Static Environment |
| | $\mathcal{L}$(f)@10Hz | -95 | -90 | -85 | dBc/Hz | |
| | $\mathcal{L}$(f)@100Hz | -127 | -120 | -115 | dBc/Hz | |
| | $\mathcal{L}$(f)@1KHz | -148 | -145 | -140 | dBc/Hz | |
| | $\mathcal{L}$(f)@10KHz | -158 | -155 | -150 | dBc/Hz | |
| | $\mathcal{L}$(f)@100KHz | -160 | -155 | -150 | dBc/Hz | |

**Values listed above are typical performance of a (100.000) MHz Fo**

****Long term aging projection is calculated per MIL-PRF 55310 f(t) = A(ln(Bt+1))+Fo**

## 3. Input Characteristics

| | Parameter | Min. | Typ. | Max. | Unit | Test Conditions |
|---|---|---|---|---|---|---|
| 3.1 | Supply Voltage | 4.75 | 5 | 5.25 | Vdc | See Table 2 for Ordering Options |
| 3.2 | Power Dissipation | | | | | |
| | Warm-up | | | 800 | mA | @25°C ±1°C ambient |
| | Steady State | | | 300 | mA | @25°C ±1°C ambient |

# High Freq. 20x13mm NV79 DIP OCXO

Bliley Technologies Inc.
2545 W Grandview Blvd
Erie, Pa 16506
Factory +1-814-838-3571

## 3. Input Characteristics (Continued)

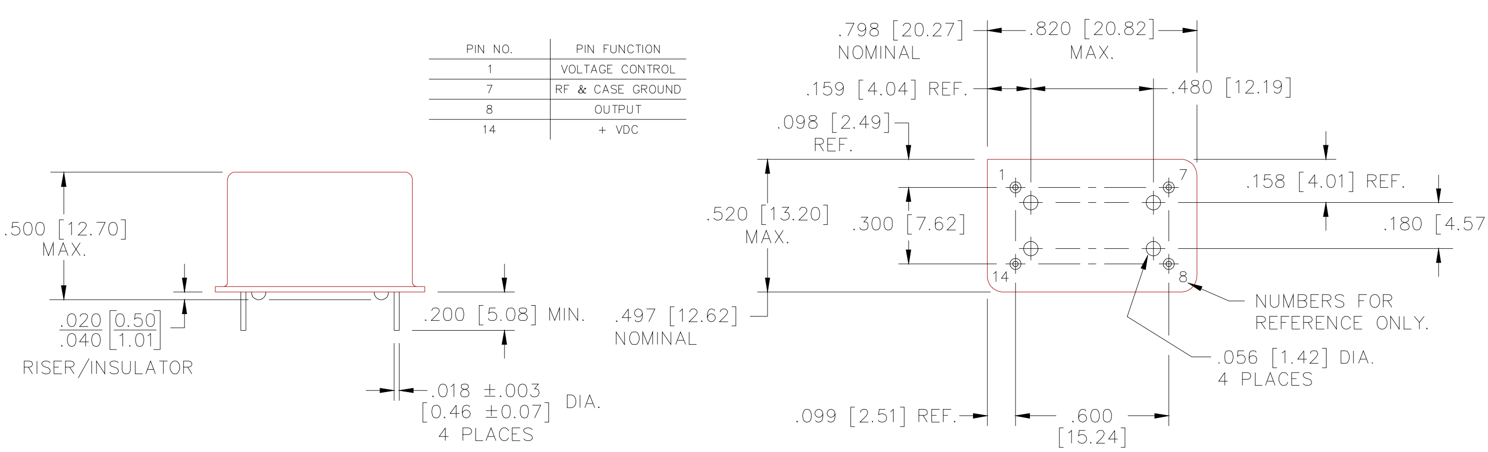
| | Parameter | Min. | Typ. | Max. | Unit | Test Conditions |
|---|---|---|---|---|---|---|
| 3.3 | Electronic Frequency Control | | | | | |
| | Voltage Range | 0 | | 5.0 | Vdc | |
| | Center Voltage | | 2.5 | | Vdc | |
| | Frequency Range | ±0.8 | | | PPM | Consult Factory for Wide Pull Range |
| 3.4 | Slope | | Positive | | | |
| 3.5 | Input Impedance | 100K | | | Ω | |
| 3.6 | Linearity | | | 10 | % | |

## 4. Environmental, Reliability and Mechanical Specifications

| | Parameter | Min. | Typ. | Max. | Unit | Test Conditions |
|---|---|---|---|---|---|---|
| 4.1 | Operational Temperature | -40 | | +85 | ˚C | See Table 2 For Ordering Options |
| 4.2 | Storage Temperature | -55 | | +85 | ˚C | |
| 4.3 | Shock Mil-Std 202G | Survive | | | | 1000 Single, 100 Repeated |
| 4.4 | Sinusoidal Vibration Mil-Std 202G | Survive | | | | 50G's rms 10 to 2000Hz |

## Mechanical Dimensions, and Pin Functions

### Standard Package Style (79A):



## Appendix 2 : specifications of the digital synthesizer (DDS) module

# RADCELF

# TRIPLE-DDS RADAR SIGNAL GENERATOR
# Product Specification

*High Performance Simultaneous Data Acquisition*

# Table of Contents

# 1 Product Description

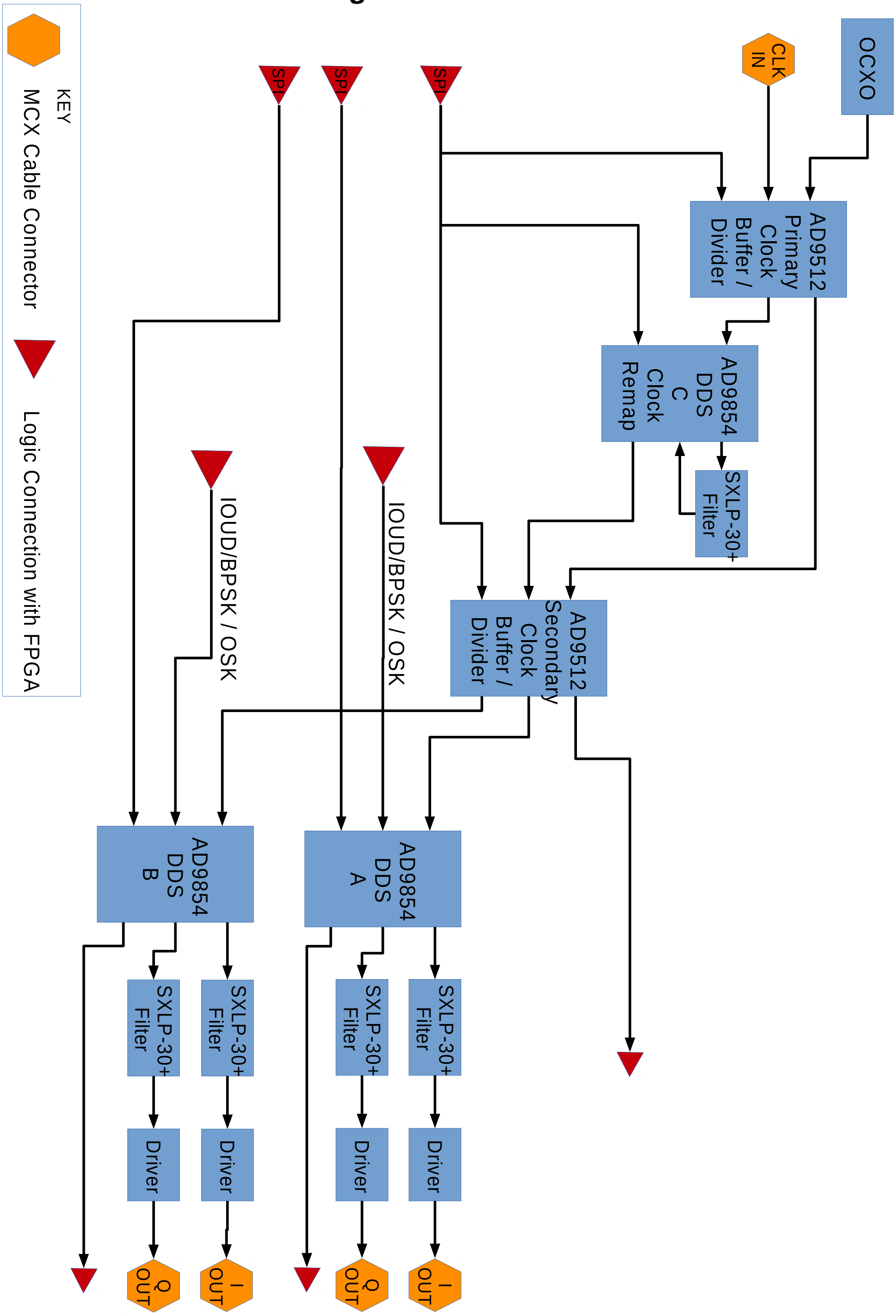
1. RADCELF is a complete clocking system suitable for HF RADAR and SONAR
2. Circuit board forms the top layer of a 3-layer stack comprising
    1. ACQ1001Q base unit with ZYNQ FPGA
    2. Optional digitizer module.
    3. RADCELF
3. Includes 3 x AD9854 DDS devices
    1. ddsA : I+Q outputs, for main system control.
    2. ddsB : I+Q outputs for system calibration.
    3. ddsC : I output for clock remapping
4. Includes 2 x AD9512 CLKD Clock divider/buffer devices
    1. clkdA : Select Oven Local Oscillator or CLK-IN
    2. clkdB : Select Clock source for ddsA, ddsB.
5. All 5 devices are controlled from SPI from the ACQ1001. Multiple SPI channels are used to potentially provide simultaneous register update.
6. Key signal inputs to DDS are provided from the FPGA. All output clocks feed back to the FPGA for monitoring.
7. Provision for Oven Local Oscillator (power supply, socket and space for thermal management) or external clock
8. Signal inputs and outputs on MCX connectors. ddsA, ddsB TRG inputs.
9. Outputs filtered by Minicircuits SXLP filters.
10. I/O expansion:
    1. P18: PMOD connector. (12 pin header with FPGA IO)
    2. J1: VMON (16 pin header, 8 x slow ADC channels, 1Hz, 10bit)
    3. J2: DIO (16 pin header, 8 slow DIO)
    4. USB 2.0, type A port, suitable for USB stick or remote devices.

RADCELF?

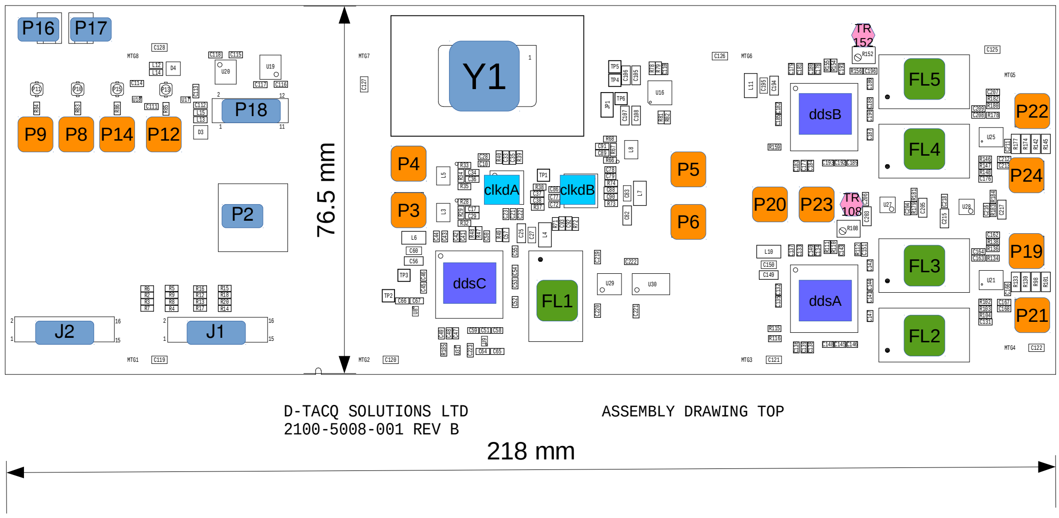
RAD : Radar

CELF : “Carrier Elf”, D-TACQ definition for 3 layer stacking board.

## *1.1 Functional Block Diagram*



# 2 Physical




## *2.1 Devices*

- ddsA, ddsB, ddsC : AD9854 DDS devices
- clkdA, clkdB: AD9512 CLK divider/distributors.
- FL1..FL5 DDS output filters
- Y1 DIL socket for LO
- TR152, TR108 : DDS output level match trimpots.

## *2.2 MCX Connectors*

| ID | IO | Description | Opt? |
|---|---|---|---|
| P3 | I | EXT CLK INPUT | |
| P4 | O | OCXO LO Monitor | |
| P5 | O | REMAP CLK Monitor | X |
| P6 | O | clkdB Monitor | X |
| P8 | IO | Link tee with uFL P10 | X |
| P9 | IO | Link tee with uFL P11 | X |
| P12 | IO | DDS A Trigger tee with uFL P13 | |
| P14 | IO | DDS B Trigger tee with uFL P15 | |
| P19 | O | DDS A I output | |
| P20 | O | DDS A monitor output | X |
| P21 | O | DDS A Q output | |
| P22 | O | DDS B I output | |
| P23 | O | DDS B monitor output | X |

| ID | IO | Description | Opt? |
|---|---|---|---|
| P24 | O | DDS B Q output | |

### 2.2.1 Misc Connectors

| ID | Type | Description | Opt? |
|---|---|---|---|
| P2 | USB-A | USB 2.0 Master | |
| P16 | 2-pin HDR | 3V3 external | X |
| P17 | 2-pin HDR | 5V external | X |
| P18 | 12 pin HDR | PMOD Header | |
| J1 | 16 pin HDR | AI 8 slow monitor | |
| J2 | 16 pin HDR | DIO 8 slow control/monitor | |

## *2.3 RADCELF Dimensions*

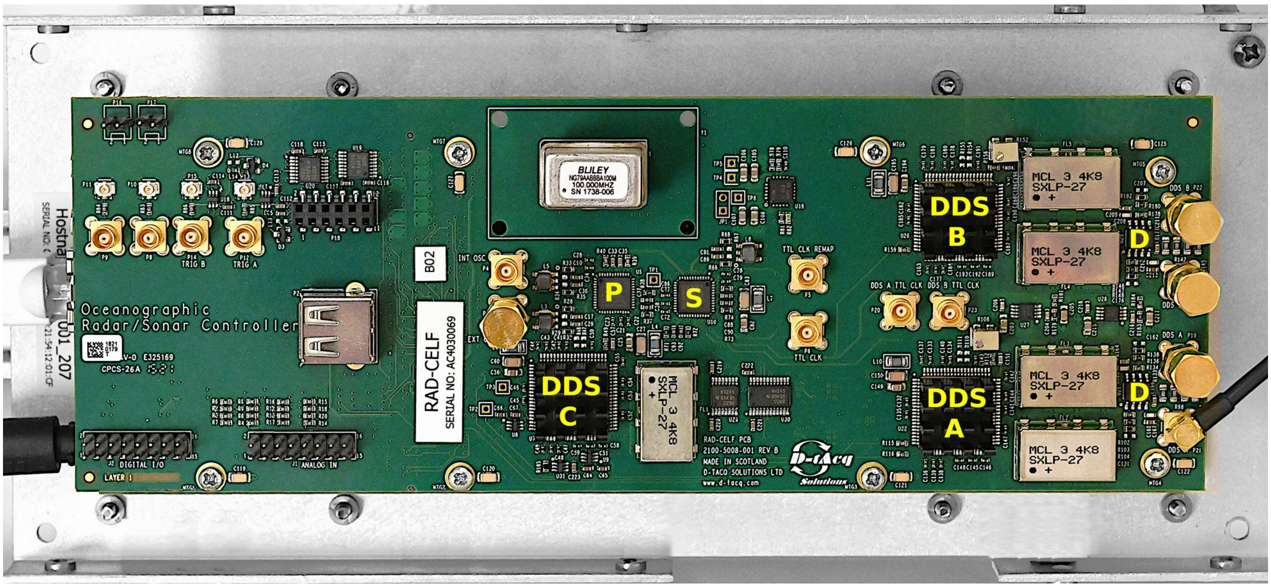
### 2.3.1 Length 218mm

### 2.3.2 Width 76.5mm

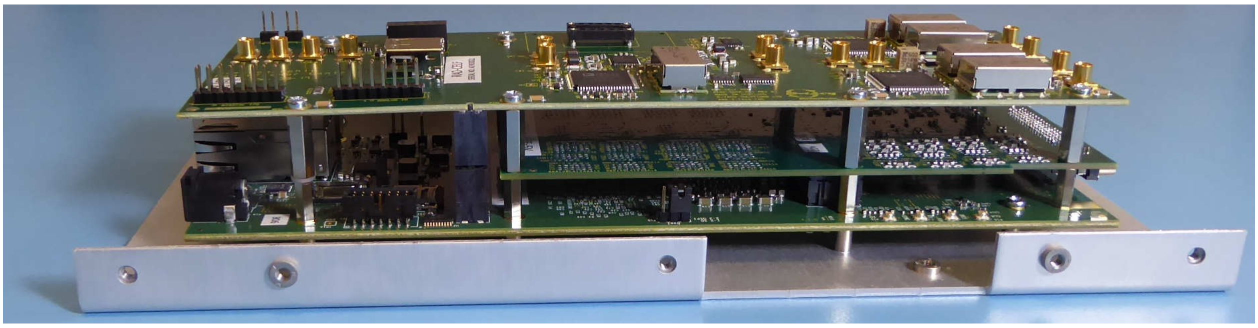
### 2.3.3 Stack Height 50mm

## *2.4 Appearance*

### 2.4.1 Plan View




### 2.4.2 Side view of Stack up



Top to Bottom:

- RADCELF
- ACQ1001: FPGA/Computer control module.
- Plinth base.

# 3 Interface Specification

## *3.1 OCXO socket*

Standard 14 pin socket is provided for a OCXO.

Linear regulated 5V power at up to 1A (warm up) and 500 mA (steady state)

Sine or Square Wave output 2-7 dBm

Tested with Bliley NV79A.

Physical separation with mounting holes to allow the OCXO to be encased for thermal separation

## *3.2 I/O Connectors*

### 3.2.1 I& Q Output MCX Connectors

All outputs are a nominal 7dBm output with 50 Ohm impedance

### 3.2.2 Clock Input

Connector P3 transformer coupled 2-7dBm 50 Ohm input Square or Sine Wave input.

### 3.2.3 Trigger Inputs

The two trigger input functionality is application dependent. These are 5V TTL compatible inputs with optional output functionality.

## *3.3 Clock Monitors*

P4 allows the oscillator to be monitored it is a direct connection to the output of the OCXO Oscillator

P5 is a TTL output monitor of the square wave frequency of the Clock Remapping DDS – DDS C. This is the square-wave produced by the AD9654 comparator.

P6 is a TTL output monitor of the input Clock to the two main DDS devices DDS A and DDS B. This signal is controlled from the secondary AD9512 device  and can therefore be overridden under software control to produce a divide by N output if desired.

P20 and P23 are TTL monitors of the square wave frequency of DDS A and DDS B. This is the square-wave produced by the AD9654 comparator.

## *3.4 Misc Connectors*

### 3.4.1 P16 3V3 External

Auxiliary 3V3 output 100 mA max.

### 3.4.2 P17 5V External

Auxiliary 5V output 100 mA max.

### 3.4.3 P18 PMOD Header

12 pin 0.1” box header socket for use with PMOD modules.

PMOD is a simple low-cost expansion standard.

Using the PMOD requires FPGA customization depending on PMOD chosen. Please contact D-TACQ with requirements.

### 3.4.4 J1 AI 8 Slow monitor

16 pin 0.1” box header plug for monitoring slow AI signals.

Input range: 0..5V, 10 bit conversion, 1Hz typical rate. 20K input impedance.

Access through Linux device driver.

2x LM7417 devices include temperature monitor.

| **Pin** | **Channel** |
|---|---|
| 2 | AI1 |
| 4 | AI2 |
| 6 | AI3 |
| 8 | AI4 |
| 10 | AI5 |
| 12 | AI6 |
| 14 | AI7 |
| 16 | AI8 |
| 1,3,5,15 | GND |

### 3.4.5 J2 DIO control

16 pin 0.1” box header plug for slow DIO control.

5V TTL. Access through Linux device driver.

| **Pin** | **Channel** |
|---|---|
| 2 | DIO1 |
| 4 | DIO2 |
| 6 | DIO3 |
| 8 | DIO4 |
| 10 | DIO5 |
| 12 | DIO6 |
| 14 | DIO7 |
| 16 | DIO8 |
| 1,3,5,15 | GND |

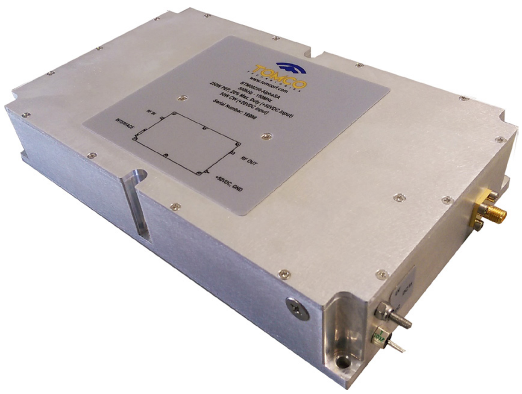
## Appendix 3 : specifications of the power amplifier (PA) module

# RF Amplifier Module Data Sheet

TOMCO

## BTM00250-AlphaSA
## 500kHz-150MHz
## 250W Pulsed/50W CW

• Scientific and Industrial Applications



The BTM-AlphaSA series is a range of class AB RF power amplifier modules covering the 500kHz to 150MHz frequency range.

- Rugged, solid-state design - high reliability
- Extremely high phase and amplitude stability
- Very fast pulse rise/fall times
- High linearity
- Very low interpulse noise
- Competitively priced

Can be supplied as amplifier module only or with optional heatsink and cooling fans

**RF Specifications**

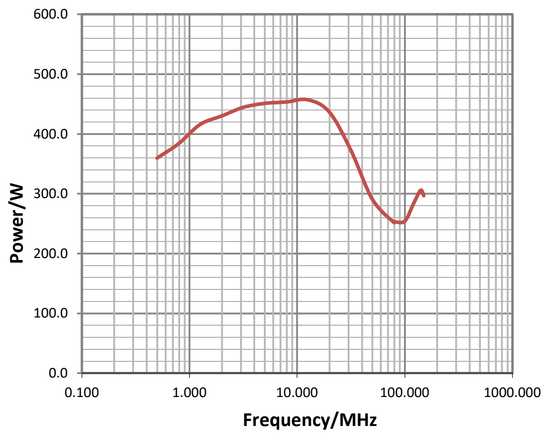
| | |
|---|---|
| Rated Power | 250W minimum in pulsed mode<br>50W minimum in CW mode<br>PEP for input power of 0dBm |
| P1dB | 200W minimum in pulsed mode<br>40W minimum in CW mode<br>Minimum output power at P1dB compression |
| Gain | 54dB minimum in pulsed mode<br>47dB minimum in CW mode |
| Type | Class AB MOSFET |
| Frequency | 500kHz-150MHz |
| Gain flatness | ±2dB maximum (measured at 1/10th rated output power) |
| Max. duty cycle | 20%<br>Maximum GATE duty cycle in pulsed mode |
| Max. pulse width | 100ms<br>Maximum GATE pulse width in pulsed mode |
| Pulse droop | 0.5dB maximum<br>Measured at max. pulse width at P1dB level |
| Pulse rise and fall times | Risetime: 200ns typical<br>Falltime: 100ns typical<br>using a pre-gated RF input signal |
| Gate rise and fall times | Risetime: 300ns typical<br>Falltime: 150ns typical |
| Gate delay | Rising edge: 1µs typical<br>Falling edge: 500ns typical<br>Rising edge measured from rising edge of GATE pulse to 90% RF output voltage.<br>Falling edge measured from falling edge of GATE pulse to 10% RF output voltage |
| Harmonics | Odd: -20dBc typical, -10dBc max.<br>Even: -30dBc typical, -20dBc max.<br>Measured at 1dB below rated output power |
| Spurious | <-70dBc maximum |
| Output noise (blanked) | <10dB above thermal (100kHz bandwidth) |
| Phase change/power | <10˚ from -40dB to full power |
| Phase stability | <1˚ across 100ms pulse |
| Input/output impedance | 50 Ω nominal |
| Load VSWR | Tolerates at least 3:1 @ full rated power without damage<br>External mismatch protection is recommended<br>No internal mismatch protection included |
| Gain control range | 10dB minimum for 0-5V control voltage<br>Control via parallel interface |
| RF Input | 0dBm nominal, +10dBm for no damage |
| GATE (blanking) | Logic low = Blank, logic high = unblank. CMOS and TTL compatible |

**Electrical Specifications**

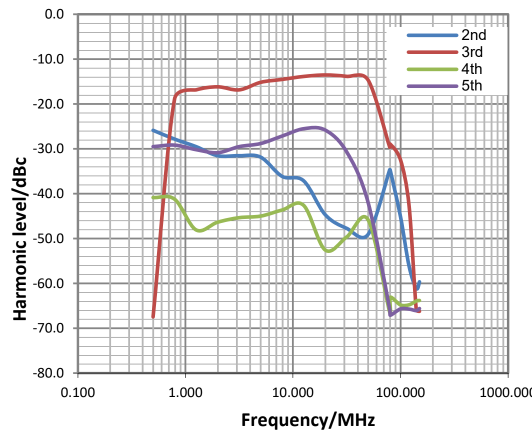
| | |
|---|---|
| DC supply voltage | Pulsed mode: +50V at approx. 3.3A<br>CW mode: +28V at approx. 8A |
| DC connection | Solder pin |

### Typical Performance Plots

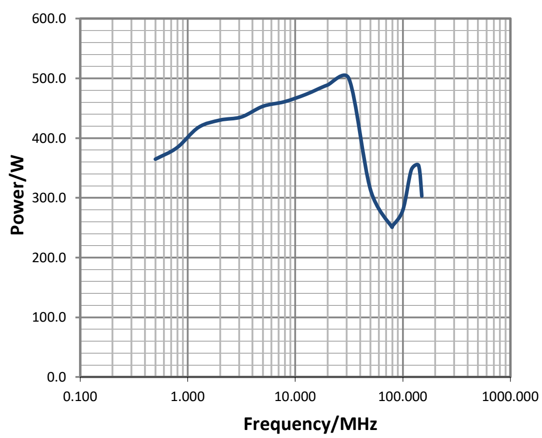
Peak input power for 0dBm RF drive



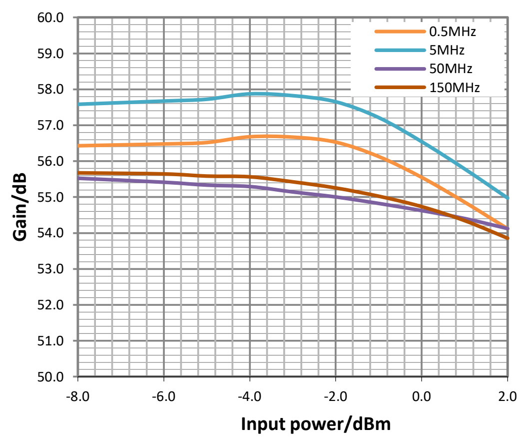

Harmonics



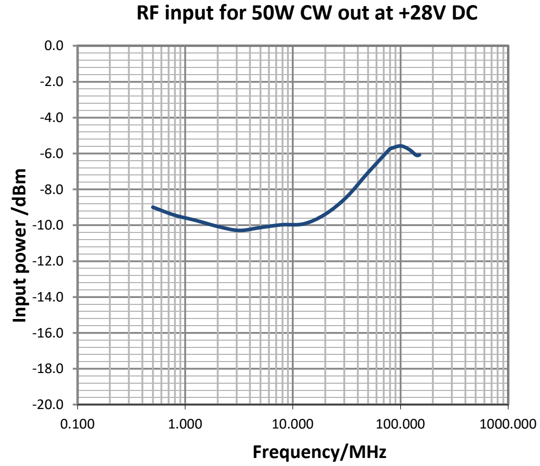

Peak output power at 1dB compression



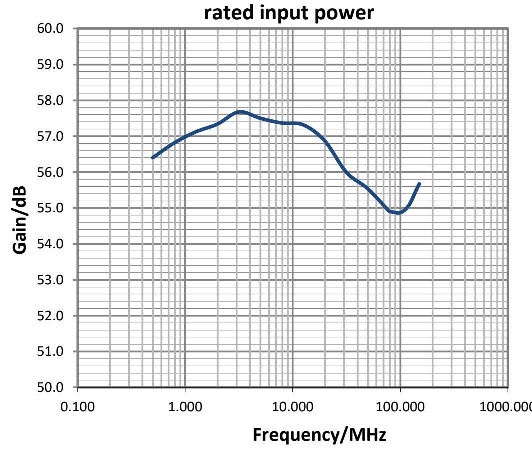

Gain as a function of input power




RF input for 50W CW out at +28V DC

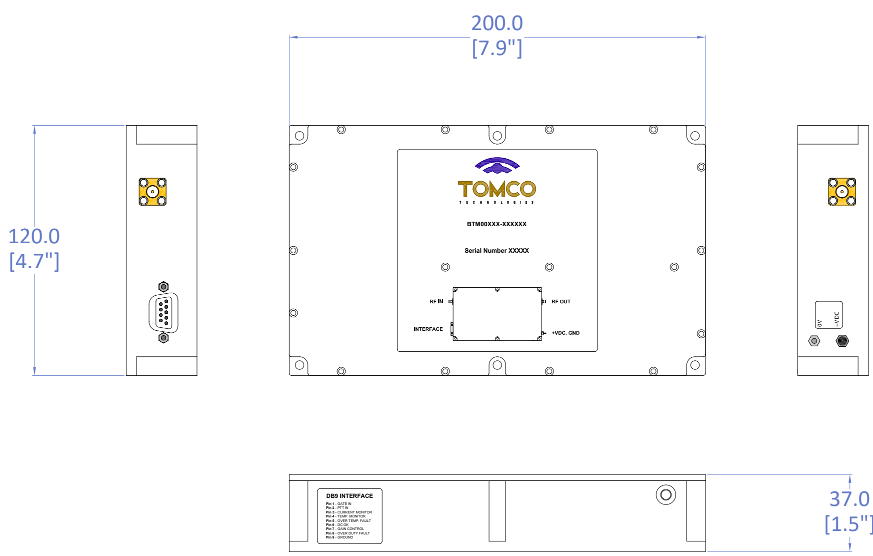


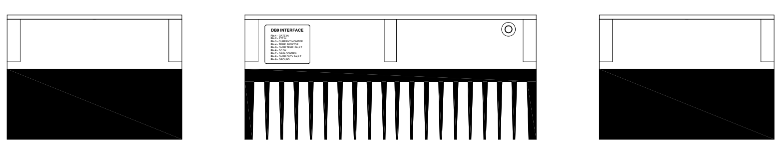

Small signal gain measured at 10% of maximum rated input power



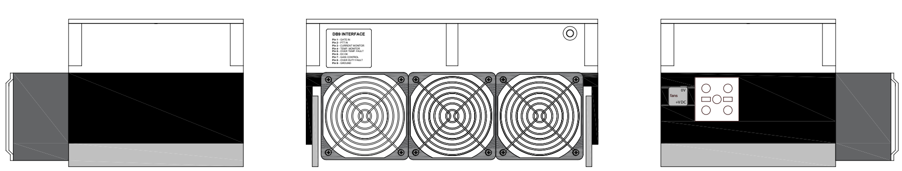
### Mechanical Specifications

| | |
|---|---|
| Connectors | RF IN: SMA<br>RF OUT: SMA<br>INTERFACE: DB9 female |
| Dimensions | Module only: 200mm (7.9”) x 120mm (4.7”) x 37mm (1.5”)<br>Module with heatsink: 200mm (7.9”) x 120mm (4.7”) x 85mm (3.3”)<br>Module with heatsink and fan assembly: 200mm (7.9”) x 168mm (6.6”) x 85mm (3.3”) |
| Weight | approx. 1.3kg (2.8lbs), module only |
| Enclosure classification | IP20 |



With optional heatsink



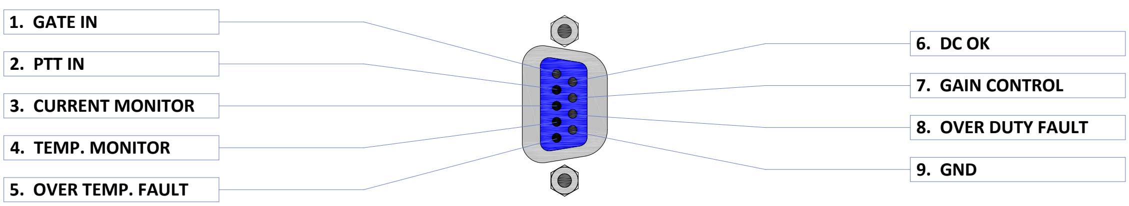
With optional heatsink and fan assembly

### Protection

| | |
|---|---|
| Over temperature | Self-resetting shutdown protection activates if thermal limits are exceeded |
| Reverse polarity | Reverse-current protection circuitry |
| Input/output transients | High voltage transient protection circuitry |

### Monitoring and Control

| | |
|---|---|
| Parallel Interface | 9-pin D-connector female |




### Environmental

| | |
|---|---|
| General | Intended for use only in controlled, indoor environment. Non-consumer product for industrial and scientific use |
| Cooling | Requires heatsink and/or external fan (optional extras) |
| Operating temperature | +5⁰C to +40⁰C |
| Storage temperature | -20⁰C to +60⁰C |
| Humidity | 80% for temperature up to 31⁰C, decreasing linearly to 50% relative humidity at 40⁰C |
| Operating altitude | Up to 2000m |
| Pollution degree | 2 |
| Electromagnetic compatibility | In line with IEC61326-1:2012<br>ISM sub-assembly, Group 1, Class A |
| Safety | In line with IEC61010-1:2010 |
| Electromagnetic field strength | In line with ICNIRP Guidelines: 1998, occupational limits |



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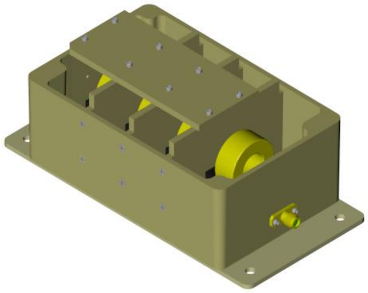
## Appendix 4 : specifications of the low-pass filter (LPF) module

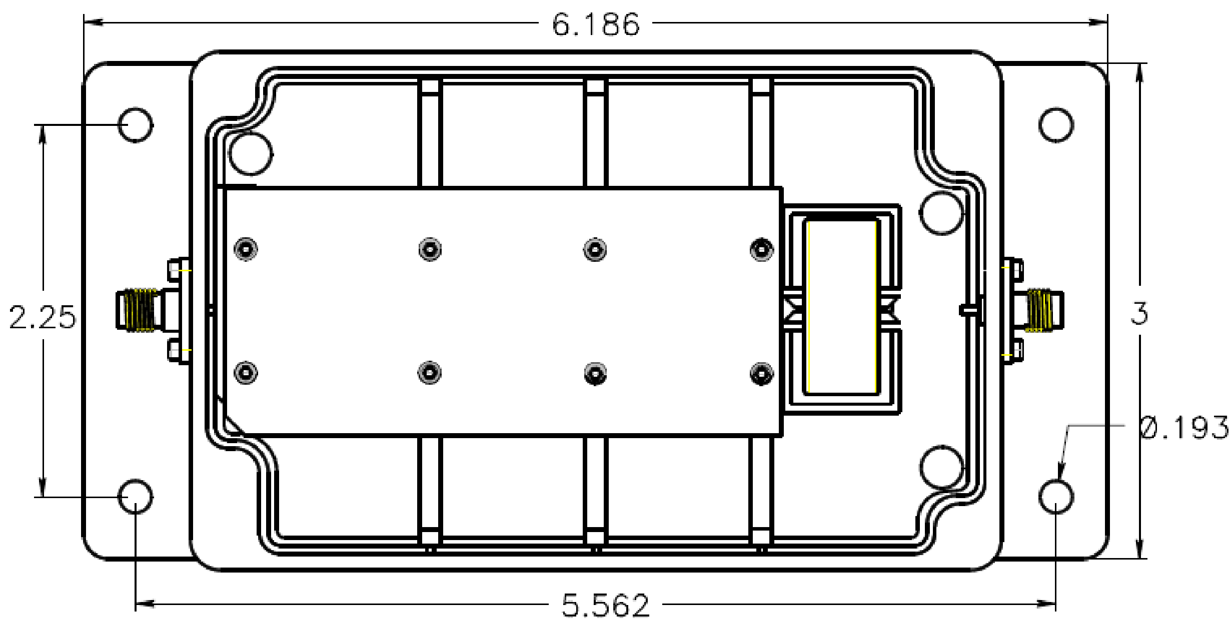
March 29, 2022

BASIC COMMON SPECIFICATIONS:



- Maximally Flat (Butterworth) 9th Order Response
- Return Loss 20 dB min over Passband
- Power Rating: 100W max Continuous
- Connectors: SMA, Gold Plated
- Mounting Bracket
- Impedance 50 Ohms
- Cast Aluminum NEMA 4 Rated Enclosure & Gasketed Cover
- Alodine Conversion Coat
- Coils Sealed with Q-Dope
- 18-8 Stainless Assembly Hardware
- Weight: 1.6 lbs

| Part No | Insertion Loss dB | F-3dB (MHz) | F-60dB(MHZ) | F-100dB ()MHz) |
|---|---|---|---|---|
| FL5MLP-HFDR | 0.25 | 6.4 | 13.8 | 23 |
| FL9MLP-HFDR | 0.29 | 11.25 | 24.25 | 40.6 |
| FL13MLP-HFDR | 0.3 | 16.25 | 35 | 58.7 |
| FL16MLP-HFDR | 0.3 | 19.7 | 42.5 | 71.3 |
| FL25MLP-HFDR | 0.3 | 30.5 | 65.7 | 110 |
| FL26MLP-HFDR | 0.53 | 31.7 | 67.8 | 114.5 |




Installation Drawing (Inches)

*DLW ASSOCIATES*
*6 Woodford place*
*St. Charles, MO 63301 USA*
*PH: 314-537-6579*
*FX: 314-649-8989*

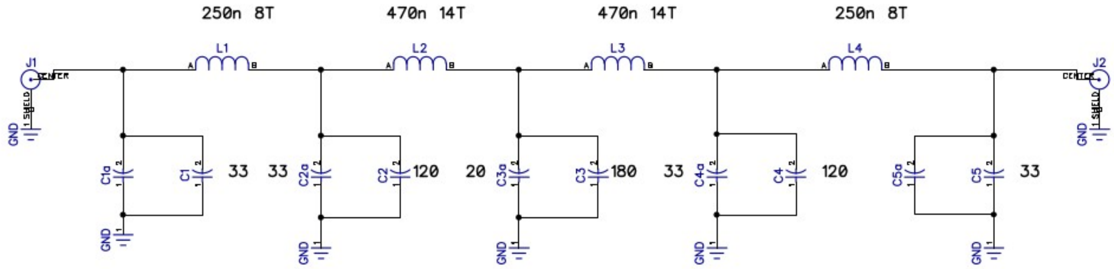
| REVISIONS | | | | |
|---|---|---|---|---|
| ZONE | REV | DESCRIPTION | DATE | APPROVED |
| | | | | |

Notes:

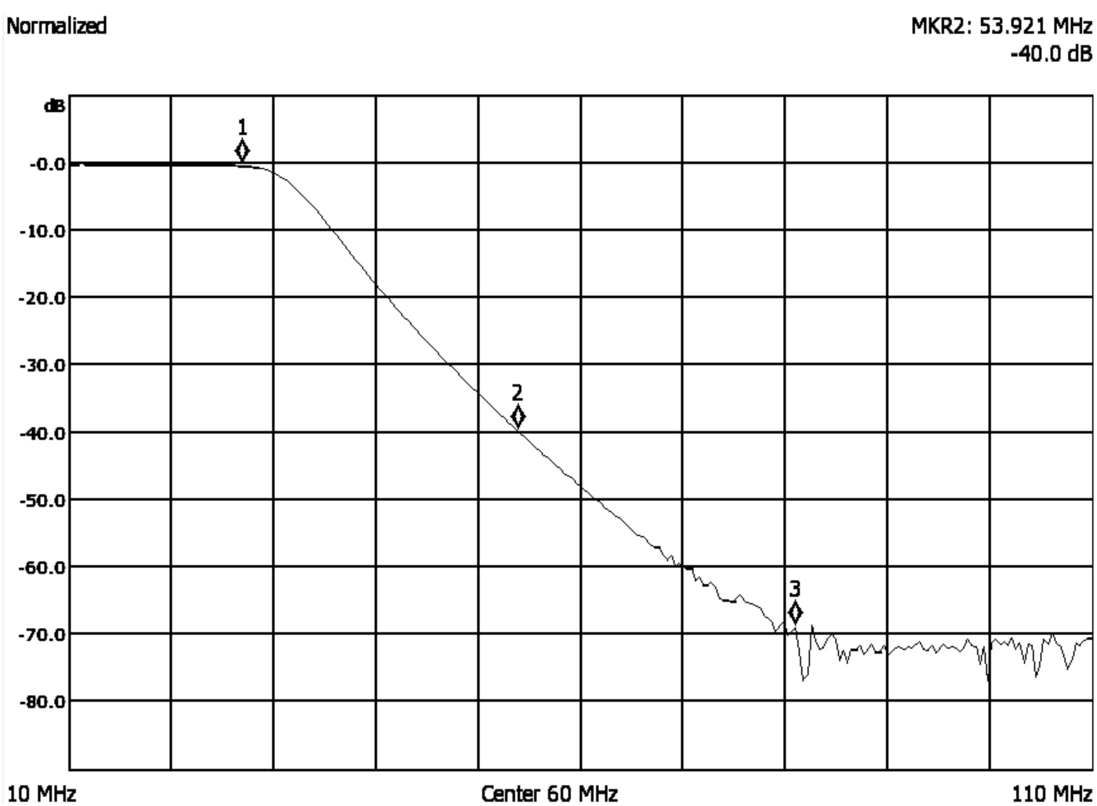
Inductors wound on T106-0 toroidal cores

#18AWG magnet wire

Connectors are gold plated two hole flange mount sma with extended dialectric and solder post




| | |
|---|---|
| DLW ASSOCIATES<br>6 WOODFORD PLACE<br>ST. CHARLES MO 63301<br>PH 314-537-6579<br>FAX 314-649-8989 | SCHEMATIC DIAGRAM<br><br>FILTER, LOW PASS 26 MHZ,<br>BUTTERWORTH -3dB = 31.8 MHz |
| SIZE A / FSCM NO. / DWG NO. DSFL26MLP-HFDR / REVB | SCALE none / Sheet 1 |



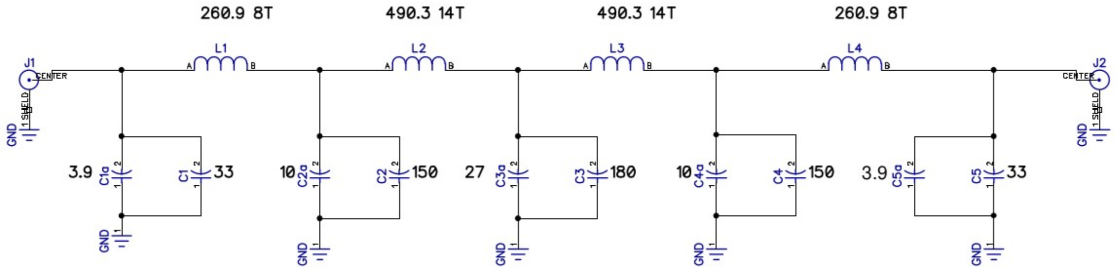
| REVISIONS | | | | |
|---|---|---|---|---|
| ZONE | REV | DESCRIPTION | DATE | APPROVED |
| | | | | |

Notes:

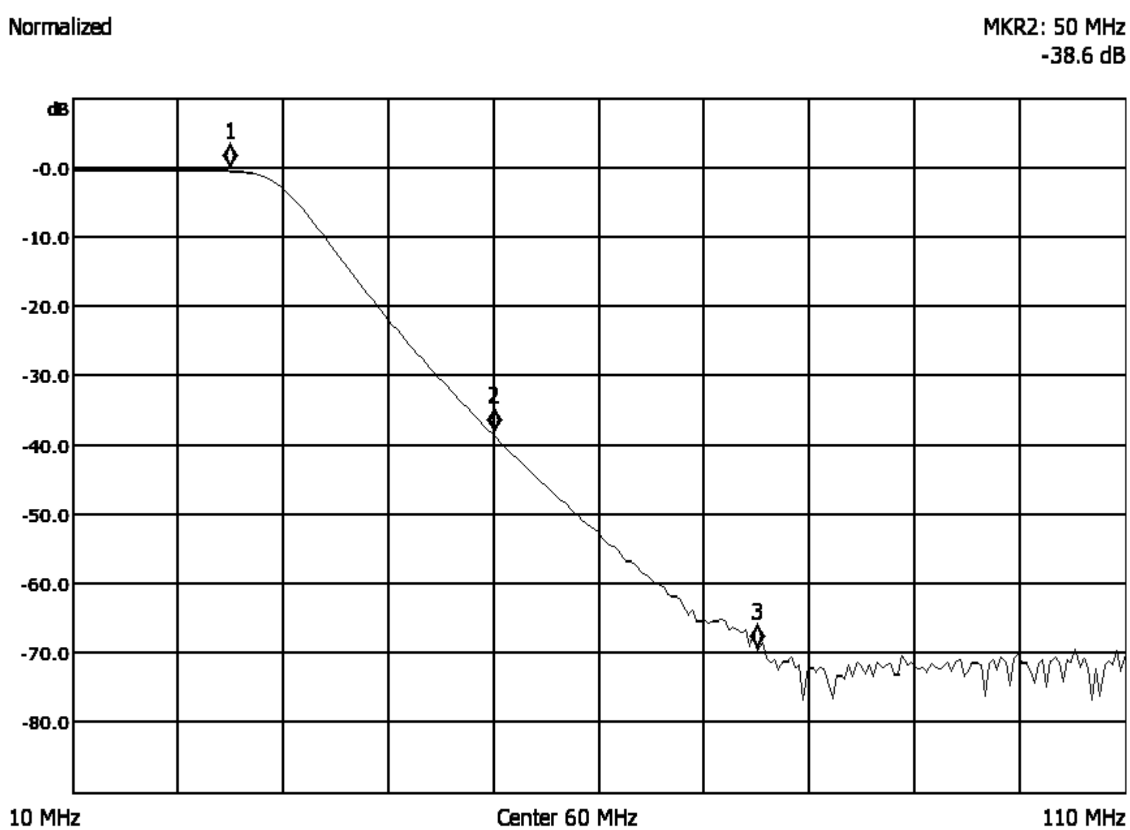
Inductors wound on T106-0 toroidal cores

#18AWG magnet wire

Connectors are gold plated two hole flange mount sma with extended dialectric and solder post




| | | | | |
|---|---|---|---|---|
| DLW ASSOCIATES<br>6 WOODFORD PLACE<br>ST. CHARLES MO 63301<br>PH 314-537-6579<br>FAX 314-649-8989 | SCHEMATIC DIAGRAM | | | |
| | FILTER, LOW PASS 25 MHZ,<br>BUTTERWORTH -3dB = 30.5 MHz | | | |
| | SIZE A | FSCM NO. | DWG NO. DSFL25MLP-HFDR | REVB |
| | SCALE none | | Sheet 1 | |



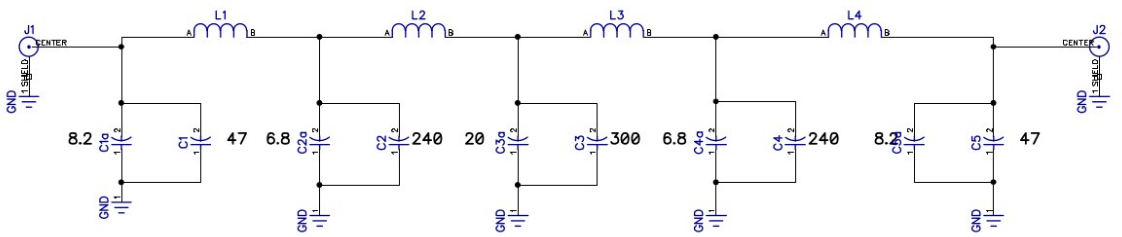
| REVISIONS | | | | |
|---|---|---|---|---|
| ZONE | REV | DESCRIPTION | DATE | APPROVED |

Notes:

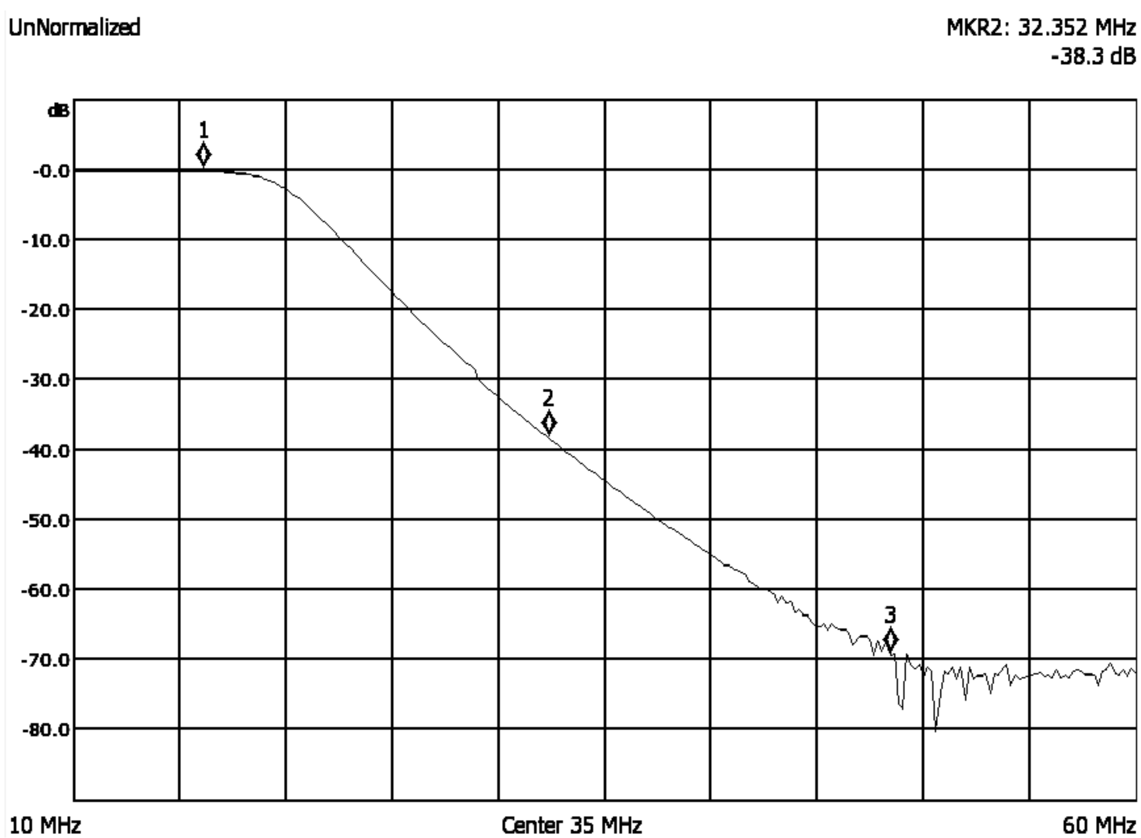
Inductors wound on T106-6 toroidal cores

#18AWG magnet wire

Connectors are gold plated two hole flange mount sma with extended dialectric and solder post




| | |
|---|---|
| DLW ASSOCIATES<br>6 WOODFORD PLACE<br>ST. CHARLES MO 63301<br>PH 314-537-6579<br>FAX 314-649-8989 | SCHEMATIC DIAGRAM |
| | FILTER, LOW PASS 16 MHZ,<br>BUTTERWORTH -3dB = 19.8 MHz |
| | SIZE A \| FSCM NO. \| DWG NO. DSFL16LPUH \| REV C |
| | SCALE none \| Sheet 1 |



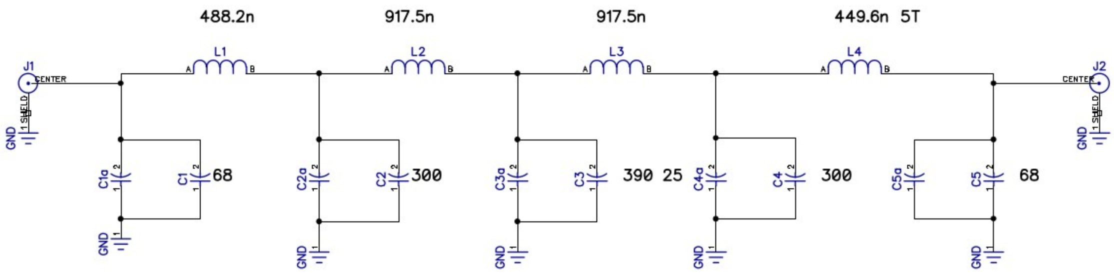
| REVISIONS | | | | |
|---|---|---|---|---|
| ZONE | REV | DESCRIPTION | DATE | APPROVED |

Notes:

Inductors wound on T106-6 toroidal cores

#18AWG magnet wire

Connectors are gold plated two hole flange mount sma with extended dialectric and solder post

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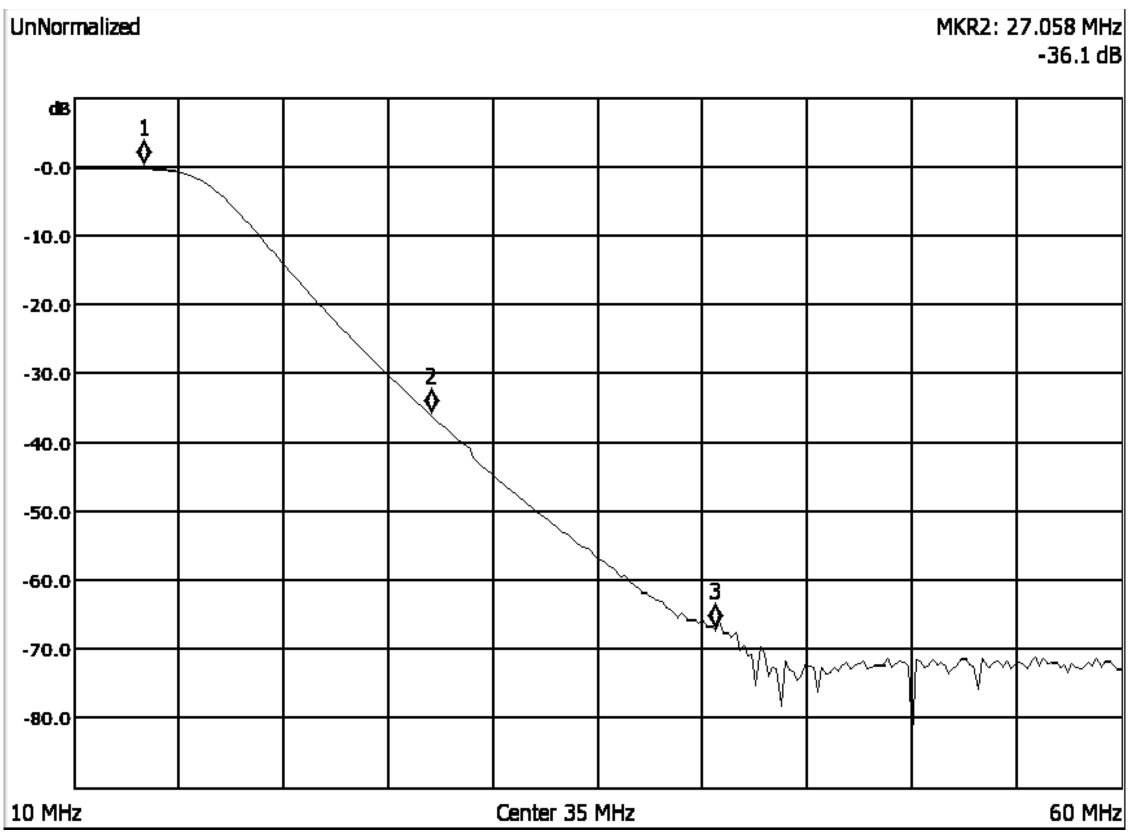
ST. CHARLES MO 63301
PH 314-537-6579
FAX 314-649-8989

SCHEMATIC DIAGRAM

FILTER, LOW PASS 13 MHZ,
BUTTERWORTH -3dB = 16.3 MHz

| SIZE | FSCM NO. | DWG NO. | REV |
|---|---|---|---|
| A | | DSFL13MLP-HFDR | |

SCALE none | Sheet 1



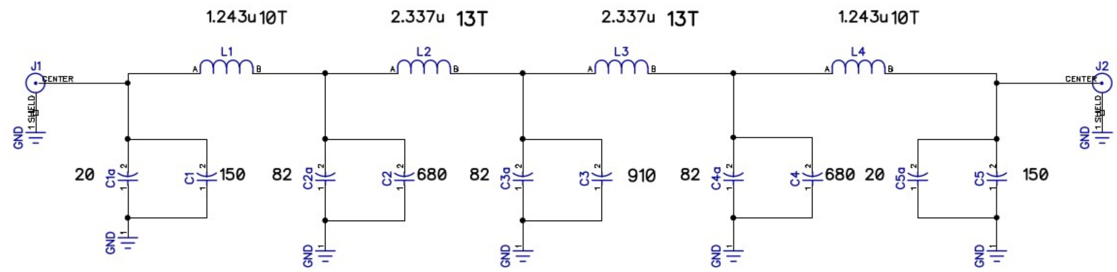
Notes:

Inductors wound on T106-2 toroidal cores

#18AWG magnet wire

Connectors are gold plated two hole flange mount sma with extended dialectric and solder post

| REVISIONS | | | | |
|---|---|---|---|---|
| ZONE | REV | DESCRIPTION | DATE | APPROVED |
| | | | | |





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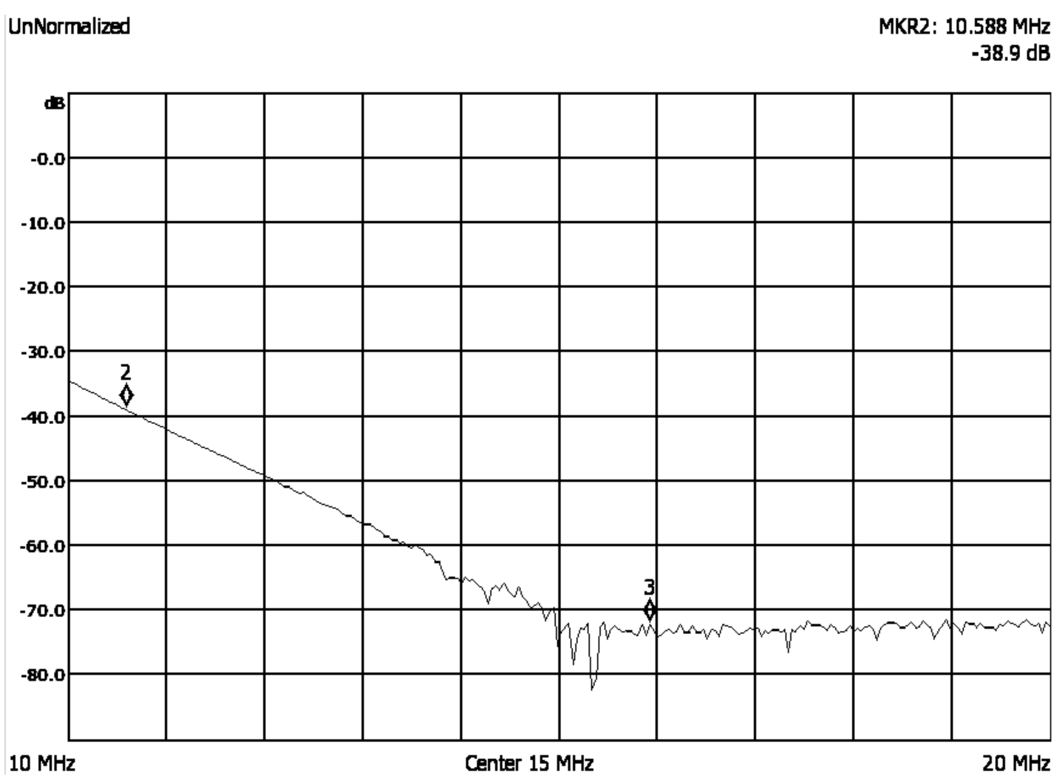
PH 314-537-6579
FAX 314-649-8989


SCHEMATIC DIAGRAM

FILTER, LOW PASS 5 MHZ,
BUTTERWORTH -3dB = 6.4 MHz

| SIZE A | FSCM NO. | DWG NO. DSFL5MLP-HFDR | REV C |
|---|---|---|---|
| SCALE none | | Sheet 1 | |



## Appendix 5 : specifications of the power supply (PS) module

TRACO® POWER

# Industrial Power Supplies

## TSP-Series

### Innovative and Powerful Features!

- Rugged metal case for harsh industrial environments
- Shock and vibration proof
- Worlwide Safety approval package.
- ATEX certification tested in accordance to IECEX (opt. EX)
- Model TSP 090-124N meets NEC class 2
- Industrial operating temperature range: –25°C to +70°C
- Adjustable output voltage
- Protection against short-circuit, overvoltage and over-temperature
- Power OK signal, Remote On/Off
- Wall mounting (opt.)
- 3-year product warranty

EMC
LVD

CB Scheme
IEC 60950-1

SIQ Type Approved Bauart Geprüft Factory Surveillance

UL 60950-1
UL 508
UL 60079-15

ATEX II3G

The TSP series comprises high performance DIN-rail mount power supplies designed for reliable operation under difficult factory floor conditions. High immunity against electrical disturbances and rugged metal casing make these modules the best choice to power sensitive loads in industrial process control systems, machine tools or other demanding industrial applications. They provide a DC-OK signal and external shut down function. Detachable screw terminal blocks make the connection easy.

### Function Modules (see page 5)

This power supply line is accompanied by a wide range of function modules for reliable system solutions:

**Redundancy modules** for true current sharing in parallel operation and for redundant systems.
**Battery controller modules** to configure high reliable UPS systems for 12, 24 and 48 VDC. Selection of battery packs available.
**Buffer modules** for protection against short time AC power loss. Maintenance free! No batteries required.

### Models

| Order Code | Output Power (Pmax) | **Output Voltage (Vnom) | ***Output Current (Imax) |
|---|---|---|---|
| **TSP 070–112*** | 72 W | 12 VDC | 6.0 A |
| **TSP 090–124*** | 90 W | 24 VDC | 3.75 A |
| **TSP 090–124N** | 90 W | 24 VDC | 3.75 A |
| **TSP 090–148*** | 96 W | 48 VDC | 2.0 A |
| **TSP 140–112*** | 144 W | 12 VDC | 12.0 A |
| **TSP 180–124*** | 180 W | 24 VDC | 7.5 A |
| **TSP 180–148*** | 192 W | 48 VDC | 4.0 A |
| **TSP 360–124*** | 360 W | 24 VDC | 15.0 A |
| **TSP 360–148*** | | 48 VDC | 7.5 A |
| **TSP 600–124*** | 600 W | 24 VDC | 25.0 A |
| **TSP 600–136** | | 36 VDC | 16.5 A |
| **TSP 600–148*** | | 48 VDC | 12.5 A |

* For ATEX compliant models add appendix -EX to order code.
** Output voltage adjustable 12–14 VDC, 24–28 VDC and 48–56VDC
*** Max. current at nominal output voltage and operating temperature up to +40°C max.

## Input Specifications

| | | | |
|---|---|---|---|
| Input voltage range | TSP 070/090 | **85 – 264 VAC** universal input | |
| | other models: | **85 – 132 / 187 – 264** VAC autoselect | |
| | output current derating at operation below 100 VAC | see graph B, page 4 | |
| Input voltage frequency | | 47 – 63 Hz | |
| Harmonic limits | | EN 61000-3-2, Class A (for limited output power) | |
| Holdup time | 230 VAC | 20 ms | |
| | 115 VAC | **10 ms** at full load, **20 ms** at 66% load | |
| Inrush current | | 115 VAC | 230 VAC |
| | TSP 070/090 | < 12 A | < 20 A |
| | TSP 140/180 | < 13 A | < 25 A |
| | TSP 360 | < 16 A | < 25 A |
| | TSP 600 | < 25 A | < 30 A |
| Recommended circuit breaker, characteristic B | TSP 070/090/140/180 | 6.0 – 16.0 A | |
| | TSP 360 | 10.0 – 16.0 A | |
| | TSP 600 | 16.0 – 25.0 A | |
| Efficiency | | 87 % typ. | |

## Output Specifications

| | | | |
|---|---|---|---|
| Output voltage adj. range | | 12 VDC models: | 12 – 14 VDC |
| | | 24 VDC models: | 24 – 28 VDC |
| | | 36 VDC model: | 36 – 42 VDC |
| | | 48 VDC models: | 48 – 56 VDC |
| | | | At output voltage higher than nominal output voltage max. output current has to be reduced accordingly, in order not to exceed max. output power. |
| Regulation | – Input variation | | 0.5 % max. |
| | – Load variation (10–100 %) | | 0.5 % max. |
| Ripple and Noise (20MHz bandwidth) | | | **100 mV pk-pk typ.** (200 mV pk-pk max. at Imax) |
| Electronic short circuit protection | | | current limitation at Imax.<br>constant current, automatic recovery |
| Output overvoltage protection | | 12 VDC models: | 20 V |
| | | 24 VDC models: | 35 V |
| | | 36 VDC model: | 43 V |
| | | 48 VDC models: | 60 V |
| Overload protection | | | electronic overload protection |
| Overtemperature protection | | | switch off at overtemperature, automatic restart |
| Power back immunity | | 12 VDC models: | 16 V |
| | | 24 VDC models: | 35 V |
| | | 36 VDC model: | 48 V |
| | | 48 VDC models: | 63 V |
| Status indicator | | | dual color LED (green: DC ok, red: DC off) |
| Power OK signal | – trigger threshold: | 12 VDC models: | 9 – 11 V |
| | | 24 VDC models: | 18 – 22 V |
| | | 36 VDC model: | 27 – 34 V |
| | | 48 VDC models: | 36 – 46 V |
| | – active output signal: (reference to –Vout) | 12 VDC models: | **11.0 V ±1.0 V**<br>(20 mA max. for TSP 070, 40 mA max. for TSP 140) |
| | | 24 VDC models: | **22.0 V ±2.0V / 20 mA max.**<br>(10 mA max. for TSP 090, 20mA max. for others) |
| | | 36 VDC model: | 34.0 V ±2.0 V / 20 mA max. |
| | | 48 VDC models: | 44.0 V ±4.0 V / 15 mA max. |
| | – relay output | | **DC OK = contact closed**<br>rated: 30 VDC/1.0 A for 12/24 VDC models<br>rated: 30 VDC/2.0 A for 36 VDC model<br>rated: 48 VDC/0.5 A for 48 VDC models |

## General Specifications

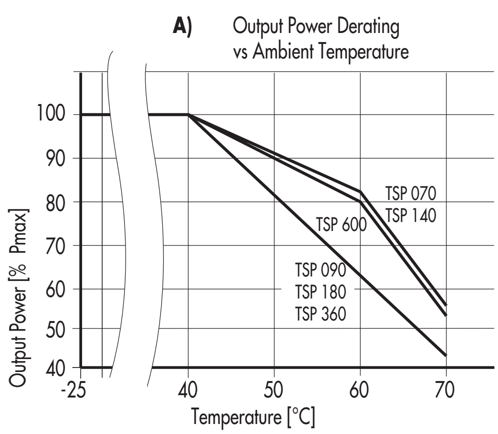
| | | |
|---|---|---|
| Max. capacitive load | | unlimited |
| Temperature range | – Operating<br>– Storage | –25°C to +60°C max. (with derating)<br>(for derating see graph A on page 4)<br>–25°C to +85°C |
| Cooling | | convection cooling, no internal fan |
| Humidity (non condensing) | | 95 % rel. H max. |
| Pollution degree | | 2 |
| Altitude during operation | | 2'000 m max. |
| Temperature coefficient | | 0.02 %/K |
| Reliability, calculated MTBF (at +25°C acc. to IEC 61709) | – TSP 070/090<br>– TSP 140<br>– TSP 180/360/600 | >1.8 Mio h<br>>1.2 Mio h<br>>0.9 Mio h |
| Remote On/Off | | by ext. contact.<br>DC on: -S contact open<br>DC off: -S connectetd via 1Kohm to -Vout |
| Isolation (60 s) | – Input to output<br>– Input to PE<br>– Output to PE | 3'000 VAC<br>1'500 VAC<br>500 VAC |
| Safety standards | – Information technology equipment<br>– Measurement, Control & Laboratory<br>– Industrial control equipment<br>– Electrical equipment for machines<br>– Electronic equipment for power installation<br>– Safety transformers for SMPS<br>– Limited power source (model TSP 090-124N)<br>– Control equipment for hazardous location | IEC/EN 60950-1, UL 60950-1, CSA-C22.2 No. 60950-1-03<br>IEC/EN 61010-1, IEC/EN 61010-2-201<br>UL 508, CSA-C22.2 No. 107<br>EN 60204<br>EN 50178<br>EN 61558-2-16<br>EN 60950 sect. 2.5 and NEC Class 2<br>UL 60079-15<br>(Class I, Division 2, Groups A,B,C,D AEx n C II C T4 U)<br>IEC/EN 60079-15 (Class I, Zone 2, EEx nC II C T4 U),<br>(Ex II3G EEX nAC IIC T4 (T3 with limited power) |
| Safety approvals and certifications | – CB report<br>– UL approvals<br>– CSA certification<br><br><br>– Ex II3G ATEX 94/9/EC<br>– BG certification<br>– Certification documents | for IEC/EN 60950-1, IEC/EN 61010-1 & 61010-2-201<br>UL 60950-1 rec. File: e181381, UL 508 listed File: e210002<br>(file no. 219759) for UL 60950-1, UL 508, UL 60079-15-02,<br>ANSI/ISA 12.12.01, CSA-22.2 No. 60950-1-03,<br>CSA C22.2 No. 107, CSA 60079-15-02<br>certificate no. EPS 12 ATEX 1 424 X (option -EX only)<br>EN 60950-1, EN 60204-1, EN 61558-2-16, EN 50178<br>www.tracopower.com/overview/tsp |
| Class of protection | | safety class I (IEC 536) |
| Degree of protection | | IP 20 (IEC/EN 60529) |
| Electromagnetic compatibility (EMC), Emissions | <br>– Conducted RI suppression on input<br>– Radiated RI suppression | EN 61000-6-3, EN 61204-3<br>EN 55011 class B, EN 55022 class B,<br>EN 55011 class B, EN 55022 class B, |

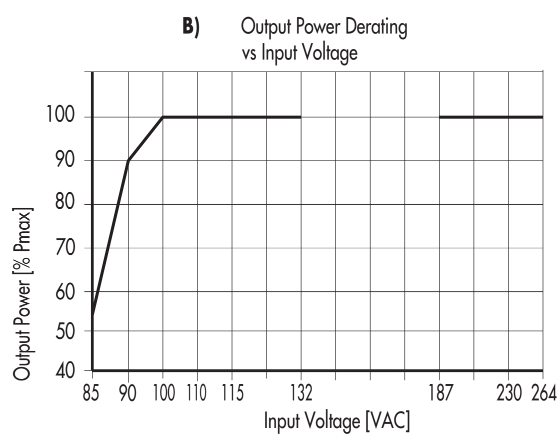
| | | | | |
|---|---|---|---|---|
| Electromagnetic compatibility (EMC), Immunity | | EN 61000-6-2, EN 61204-3 | | |
| | – Electrostatic discharge (ESD) | IEC / EN 61000-4-2 | 4 kV / 8 kV | criteria B |
| | – Radiated RF field immunity | | | |
| | TSP 070/140/360 models: | IEC / EN 61000-4-3 | 10 V / m | criteria A |
| | TSP 090/180/600 models: | IEC / EN 61000-4-3 | 10 V / m | criteria B |
| | – Electrical fast transient / burst immunity | IEC / EN 61000-4-4 | 2 kV | criteria B |
| | – Surge immunity | IEC / EN 61000-4-5 | 1 kV / 2 kV | criteria B |
| | – Immunity to conducted RF disturbances | IEC / EN 61000-4-6 | 10 V | criteria A |
| | – Power frequency field immunity | IEC / EN 61000-4-8 | 30 A / m | criteria A |
| | – Mains voltage dips and interruptions | IEC / EN 61000-4-11 | | criteria B/C |
| | – Voltage sag immunity | SEMI F47 | | |
| | | www.tracopower.com/overview/tsp | | |

## General Specifications

| | | |
|---|---|---|
| Environment | – Vibration acc. IEC 60068-2-6;<br>– Shock acc. IEC 60068-2-27 | 3 axis, sine sweep, 10 – 55 Hz, 1 g, 1 oct/min<br>3 axis, 15 g half sine, 11 ms |
| Enclosure material | | **aluminium** (chassis) **/ stainless steel** (cover) |
| Mounting | – DIN-rail mounting<br><br>– Wall mounting (option) | **for DIN-rails as per EN 50022-35x15/7.5**<br>(snap-on with self-locking spring)<br>with **wall mounting bracket** - see page 9 |
| Connection | | **detachable screw terminals (plugs included)**<br>**2 terminals per output** |
| Remote On/Off connection | – 2 pin molex male terminal KK series | mating connector information (cable not included)<br>www.tracopower.com/products/tsp-jc.pdf |
| Installation instructions | | www.tracopower.com/overview/tsp |

## Output Power Derating




All specifications valid at nominal input voltage, full load and +25°C after warm-up time unless otherwise stated.

## Function Modules Overview

### Redundancy Module:

With this module and two power supplies of the TSP series a highly reliable, true redundant power system can be configured without any additional components. This module provides:

– Operation with true current sharing
– Alarm outputs and redundancy OK signal
– Hot swappable inputs can be loaded up to 15 A each (resp. 25 A with model TSP REM600)

TSP-REM360
TSP-REM600

| Models | | |
|---|---|---|
| **Order Code** | **Output Voltage adj.** | **Output Power** |
| **TSP–REM360** | 24 VDC (24 – 27 VDC) | 360 W |
| **TSP–REM600** | | 600 W |

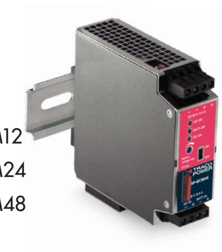
TSP-REM datasheet: www.tracopower.com/products/tsp-rem.pdf

---

### Battery Controller Modules + Batteries:

This module provides a professional battery controller to charge and monitor an external lead-acid battery. Together with a power supply of the TSP series and a battery pack a perfect DC-UPS system can be configured. This module provides:

- Battery protection for over voltage, deep discharge, short circuit and reverse connection
- Remote On/Off for battery and power supply
- Alarm outputs for input, output and battery condition
- Controlled end of charge voltage by temperature sensor
- Redundant inputs for two indepedant sources **(TSP-BCMU360 only)**



TSP-BCM12
TSP-BCM24
TSP-BCM48

TSP-BCM24A
TSP-BCM48A

TSP-BCMU360

| Models | | |
|---|---|---|
| **Order Code** | **Output Voltage** | **Output Power** |
| **TSP-BCM12** | 12 VDC | 180 W |
| **TSP–BCM24** | 24 VDC | 360 W |
| **TSP-BCM24A** | | 600 W |
| **TSP–BCM48** | 48 VDC | 360 W |
| **TSP-BCM48A** | | 600 W |
| **TSP-BCMU360** | 24/48 VDC | 360 W |

TSP-BCM datasheet: www.tracopower.com/products/tsp-bcm.pdf
TSP-BCMU datasheet: www.tracopower.com/products/tsp-bcmu.pdf

---

### Buffer Module:

This module will maintain the output voltage of a 24 VDC power supply during typical mains faults, short time blackouts or voltage dips of up to ten full 50 Hz cycles. During this buffer period no deterioration of the 24 VDC output voltage will occur. This module provides:

- Capacitor bank for energy storage, no battery needed!
- Maintenance free, long lifetime, high performance also at low temperature.
- Guaranteed Hold-up-time 200 ms/25 A to 4 s/1.2 A max.
- Output 24 to 28 VDC, 600 W max.
- Active ready and inhibit signals

TSP-BFM24

| Models | | |
|---|---|---|
| **Order Code** | **Output Voltage** | **Output Power** |
| **TSP–BFM24** | 24 – 28VDC | 600 W |

TSP-BFM datasheet: www.tracopower.com/products/tsp-bfm.pdf

University of Hawai'i at Mānoa
School of Ocean and Earth Science and Technology
Radio Oceanography Laboratory

# Generic High Frequency Doppler Radar Synthesizer-Transmitter Unit Model MK3-PW-PA-TX User Manual

April 2022
v. 2

radlab@satlab.hawaii.edu
Marine Sciences Building
1000 Pope road
Honolulu Hawai'i 96822

## FCC Supplier’s Declaration of Conformity

University of Hawai'i Generic High Frequency Doppler Radar Synthesizer-Transmitter Unit, model *MK3-PW-PA-TX.*

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions:

(1) this device may not cause harmful interference, and

(2) this device must accept any interference received, including interference that may cause undesired operation.

Changes or modifications not expressly approved by University of Hawai'i could void the user's authority to operate the equipment.

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Radio Oceanography Laboratory
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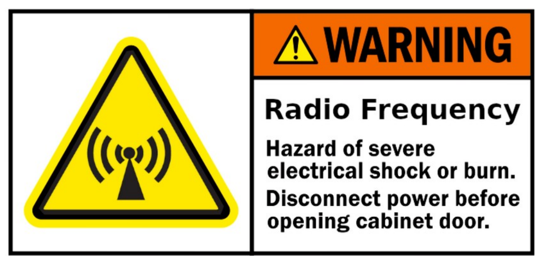
Honolulu, HI 96822, U.S.A
Phone  (808) 956 7098

## Warnings


This device contains potentially dangerous high voltages and high frequency radiation. Operation and servicing is restricted to properly trained and certified personnel.

Maximum output power is 50 W (+0.5dB) for frequencies 8 MHz and below and 30 W (+0.5dB) for frequencies 12 MHz and above.

The user’s authority to operate this device if connected to any radiating antenna or structure in the United States is contingent on applying for and being awarded a valid license through the FCC Universal Licensing System before transmitting. This device may not be powered up for testing unless connected to a non-radiating resistive load.

## Table of Contents

## User operation of Synthesizer-Transmitter Unit, model *MK3-PW-PA-TX*

## 1. Overview

The unit is programmed to emit a repetition of frequency sweeps (chirps), typically at a rate of 1Hz to 4Hz and an occupied bandwidth of 25 to 220kHz determined by the ITU frequency allocation (see Table 1), resulting in a frequency-modulated continuous wave (FMCW mode, emission designation F1N).

*Table 1. Allocation for Oceanographic High Frequency Doppler radars in Region 2.*

| *Center* | *Occupied bandwidth* |
|---|---|
| *(MHz)* | *(kHz)* |
| 4.463 | 50 |
| 5.2625 | 25 |
| 13.500 | 100 |
| 16.150 | 100 |
| 24.550 | 200 |
| 26.310 | 220 |

The unit is factory-programmed to start transmitting automatically upon power up at the ITU frequency for which a low-pass filter is factory-fitted. To avoid any erroneous operation that could damage the power amplifier and/or the low-pass filter, or result in unlicensed transmissions, all frequencies are factory-disabled, except the ITU frequency for which a low-pass filter is actually factory-fitted to the unit. Programming the unit to other frequencies is password-protected and reserved to factory-authorized personnel.

If a FCC call sign has been provided at the time of factory-configuration, a full-bandwidth broadcast of the call sign is automatically scheduled every 20 min. Chirps at a rate of 1 kHz are transmitted over the same occupied bandwidth, for short periods corresponding to the dots and dashes of the Morse code, resulting in a similar frequency-modulated continuous wave (emission designation F1N).

The unit can be powered-up in two modes of operation: (a) a test mode, for which the output is connected to a 50Ω non-radiating resistive load, or (b), a live mode, for which the output is connected to a radiating antenna or structure. The user’s authority to operate this device in the live mode (b) from a location within the United States is contingent on being awarded a license through the FCC Universal Licensing System. In the absence of a valid FCC license, the device may only be operated in the test mode (a).

The firmware allows programming all operations of the digital synthesizer, including chirping, calibration tones and full-bandwidth call-sign broadcast, using a single ethernet web server interface, configured through the Dynamic Host Configuration Protocol (DHCP; Figure 2). The actual settings of the digital synthesizers are continuously read back from the DDS registers and displayed on a separate diagnostic web page (Figure 3).

To comply with FCC RF exposure requirements, the antennas must be installed to ensure a minimum separation distance from persons while operational as shown in the table below:

*Table 2. Minimum separation to comply with FCC RF exposure requirements*

| *Operating Frequency* | *Minimum Separation Distance* |
|---|---|
| *(MHz)* | *(m)* |
| 4.463 | 10.66 |
| 5.2625 | 10.66 |
| 13.500 | 3.55 |
| 16.150 | 3.55 |
| 24.550 | 2.30 |
| 26.310 | 2.30 |

## 2. Start-up procedure

The following steps must be performed in the order given:

1. open enclosure and verify that the frequency of the low-pass filter fitted (figure 4) corresponds to the factory-configured frequency marked on the label (figure 3).
2. verify that all breakers are off in the down positions (figure 4).
3. for mode (a), connect a  power attenuator such as a  a Bird 100-SA-FFN-30 to the N-type RF output of the unit (figure 6).
4. for mode (b), connect the cable to the TX antenna, with a minimum cable attenuation of 5 dB (figure 6).
5. connect a CAT-6e cable from a local network to the RJ45 jack of the unit (figure 6).
6. connect a grounded power cable to the  IEC-C13/C14 power inlet (figure 6) and plug into a 120 or 240V outlet (the unit auto-detects the voltage).
7. connect the power adapter of the heat-exchanger shown in figure 5 into a 120 or 240V outlet (the unit auto-detects the voltage).
8. power up the unit and the heat exchanger.
9. enable the power surge suppressor by flipping its breaker to the up position (lower DIN rail, figure 4).
10. enable the power supplies by flipping all remaining breakers in sequence from right to left to the up position (middle DIN rails, figure 4).
11. tie the 6 grounding connections of the door and close the enclosure.
12. verify that the network router has provided an IP address through DHCP (waiting 2-3 minutes may be necessary to let the boot sequence complete).
13. open browser on this IP address, verify that a screen similar to figure 1 is obtained.
14. click on “Status”, verify that a popup screen similar to figure 2 is obtained and that the entry shown for ---DDS-A--- under /FREQ displays the expected factory-configured frequency.

The unit is now operating and transmitting the required signal.

## 3. Toggling between signal types

Two signal types are allowed: standard frequency-modulated continuous wave chirp for normal radar operation, and continuous tones for calibration. Continuous tones can be programmed at three distinct frequencies: at the lower limit of the allocated bandwidth *f0-bw/2*, at the center frequency *f0* and at the upper limit of the allocated bandwidth *f0+bw/2.*

To toggle between signal types:

1. open a browser on the unit’s IP address, obtain a screen similar to figure 1.
2. to change between signal types, click on the appropriate button.
3. wait 15 sec for the command to execute.
4. verify with the “Status” screen that the frequency has been updated.

The unit is now transmitting the required signal.

## 4. Power-down procedure

The following steps must be performed in the order given:

1. open a browser on the unit’s IP address, obtain a screen similar to figure 1.
2. click on the “Stop” button.
3. wait 15 sec for the command to execute.
4. verify with the “Status” screen that the frequency has been updated to 0.
5. open enclosure.
6. disable the power supplies by flipping all breakers in sequence from left to right to the down position (middle DIN rails, figure 4).
7. power down the unit and the heat exchanger.
8. close  enclosure and stow unit.

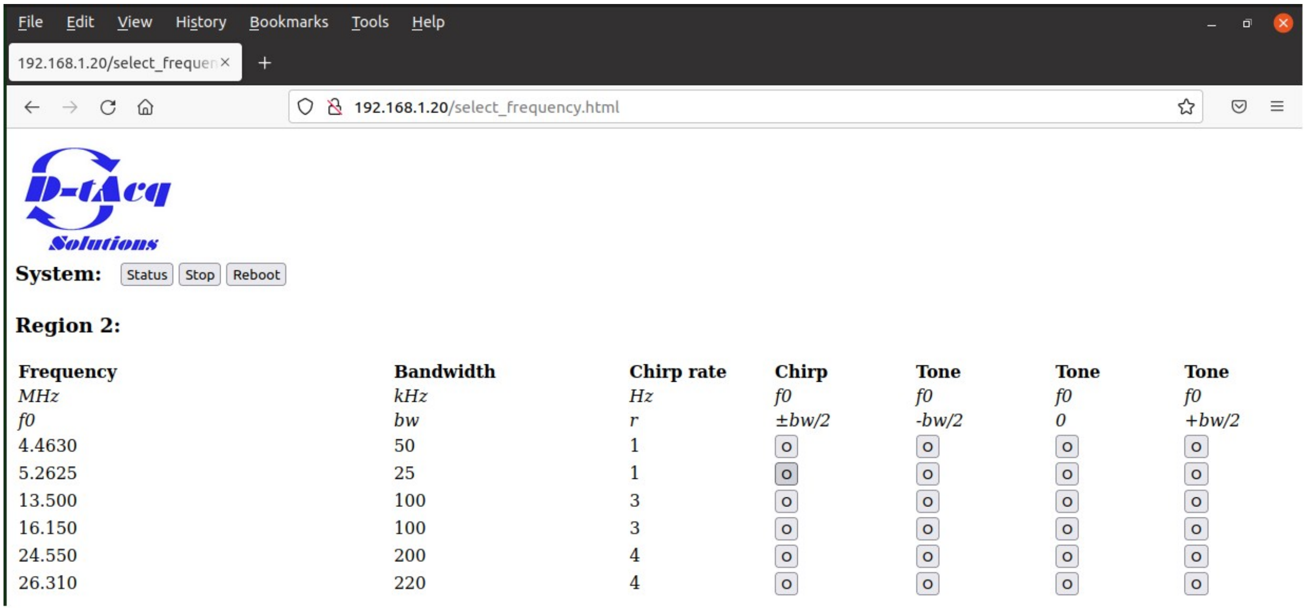



*Figure 1. Web interface for programming the synthesizer/transmitter.*
*Only the frequency for which a low-pass filter has been installed can be selected.*

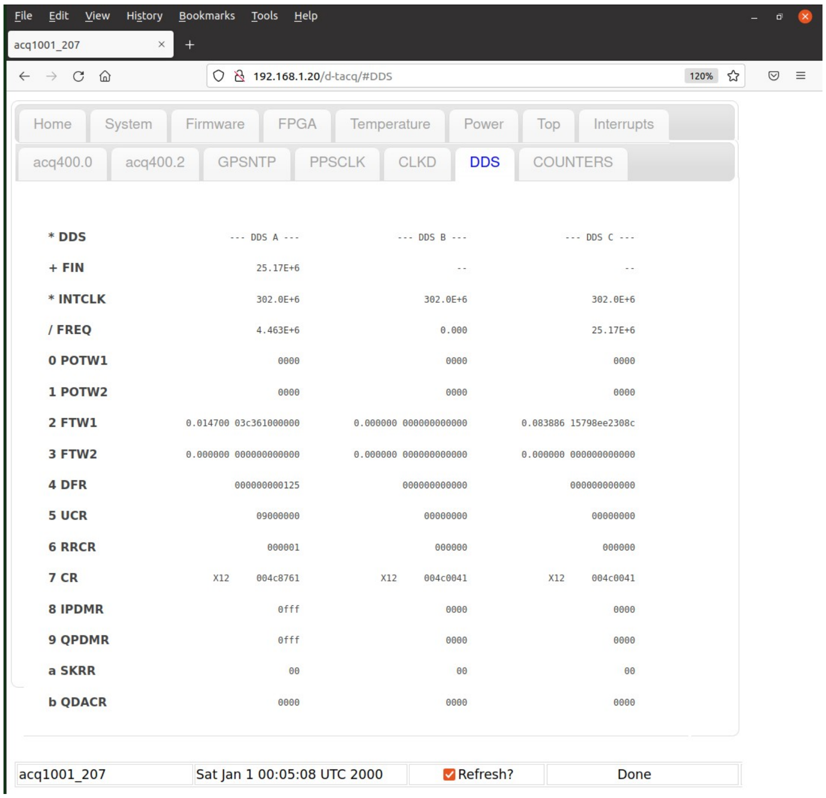
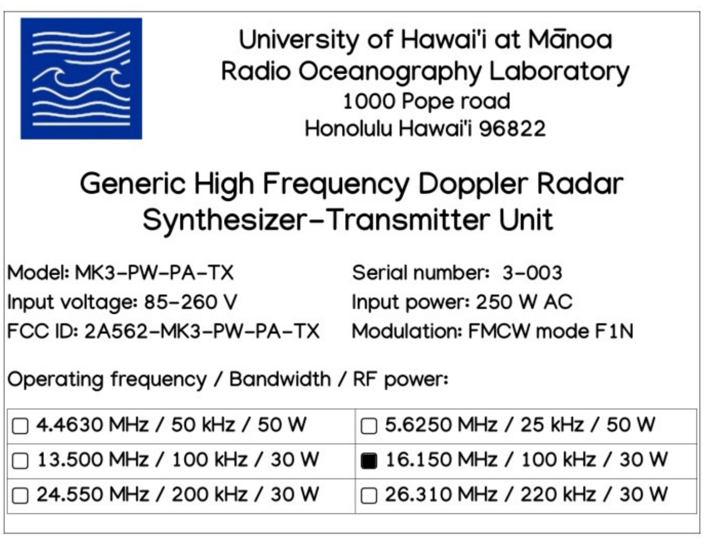



*Figure 2. Diagnostic page with DDS registers read-back.*

## 5. Illustrations

*Figure 3. Above: Synthesizer-Transmitter Unit model MK3-PW-PA-TX, door closed. Below: device identification label, affixed to the top right of the enclosure door. The factory-programmed operating frequency and output power are marked, here 16.150 MHz/30W.*



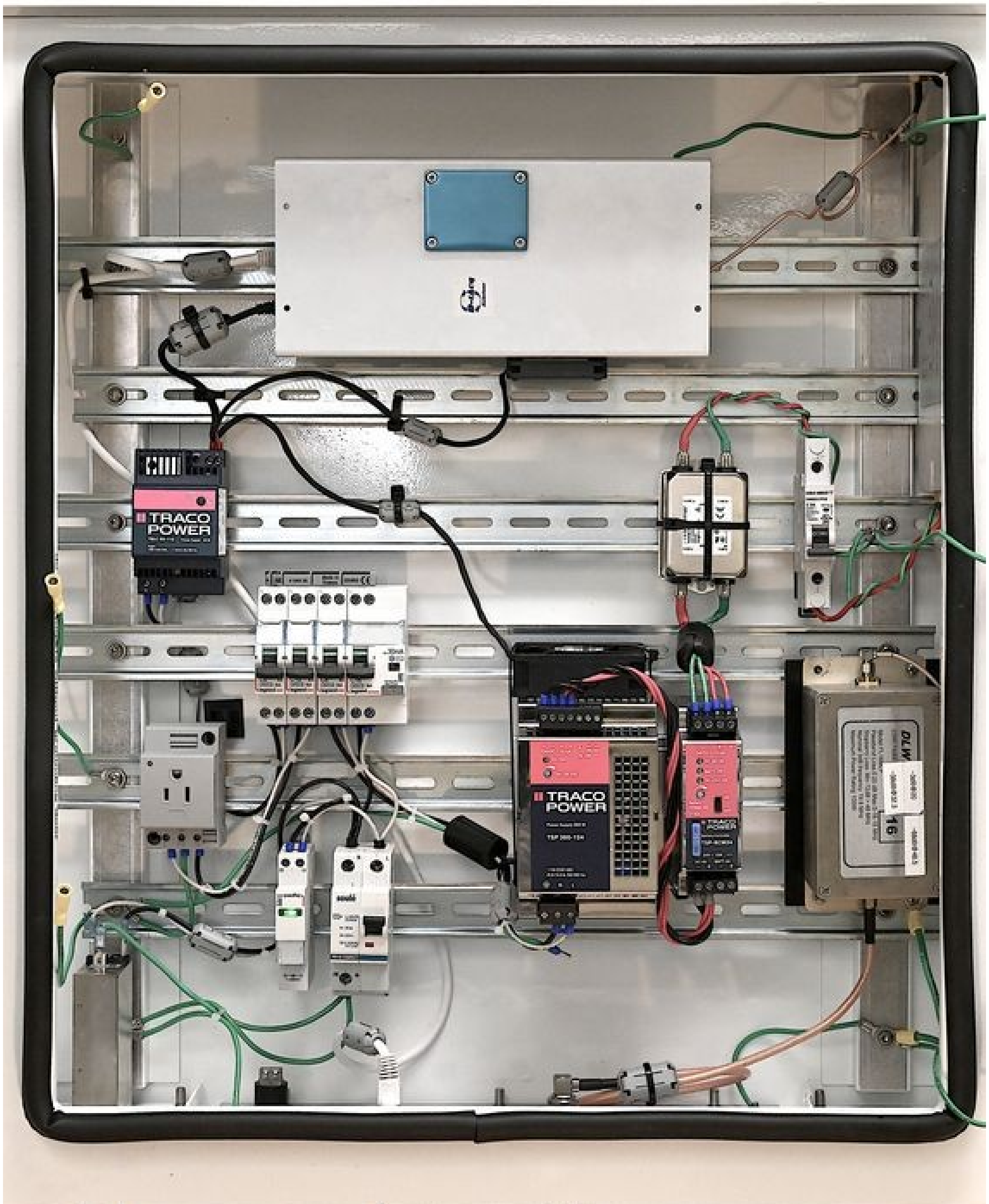



*Figure 4. Synthesizer-Transmitter Unit, door open.*
*Bottom rails:  power supplies with circuit breakers.*
*Upper rail: digital synthesizer and controller processor.*
*On the right wall: the power amplifier module and the low-pass filter.*

*Figure 5. Synthesizer-Transmitter Unit, right side view.*
*The twin-fan forced air flow heat exchanger unit is seen.*

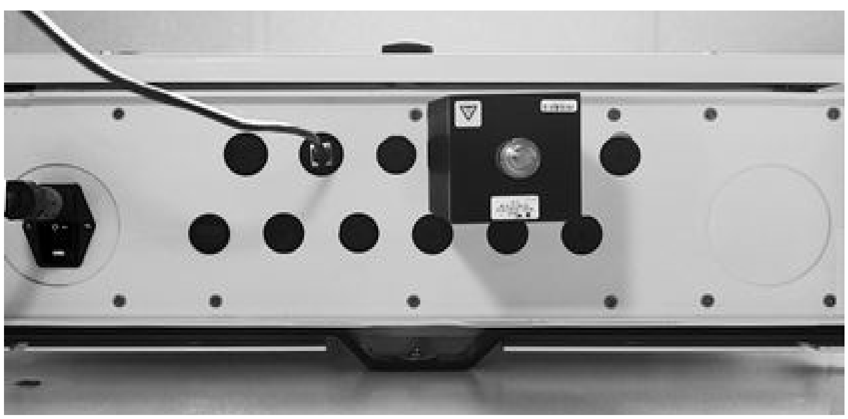


*Figure 6. Synthesizer-Transmitter Unit, bottom view.*
*Connector plate with IEC-C13/C14 power inlet, RJ45 jack for CAT6 Ethernet, N-type bulkhead adapter for cable to antenna (a Bird 100-SA-FFN-30 power attenuator is attached).*

## Schematics of Synthesizer-Transmitter Unit, model *MK3-PW-PA-TX*

The Synthesizer-Transmitter Unit is based on commercial off-the-shelf modules and contains: (i) an ultra-low phase noise reference oscillator (OCXO), (ii) direct digital signal synthesizers and controller (DDS-FPGA), (iii) a power amplifier (PA), (iv) an anti-harmonic filter (LPF), (v) power supplies (PS) and (vi) power line filters (RFI).

A detailed description of the modules is provided in companion technical report "*Generic High Frequency Doppler Radar Synthesizer-Transmitter Unit: Operational Description", April 2022* issued by the Radio Oceanography Laboratory of the University of Hawai'i at Mānoa.

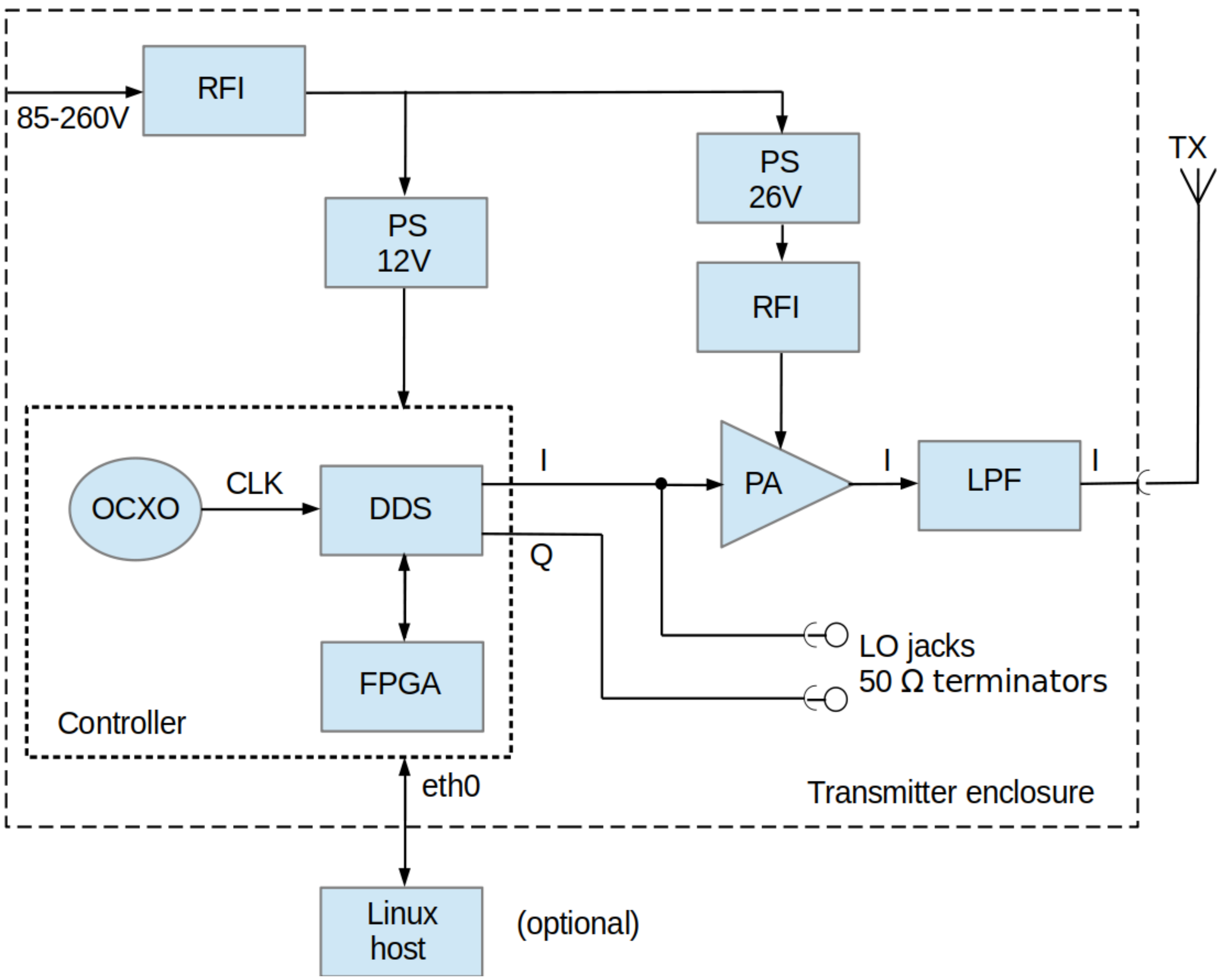



*Figure 1. Schematics of the Synthesizer-Transmitter Unit.*
*See Table 1 for list of components and references.*

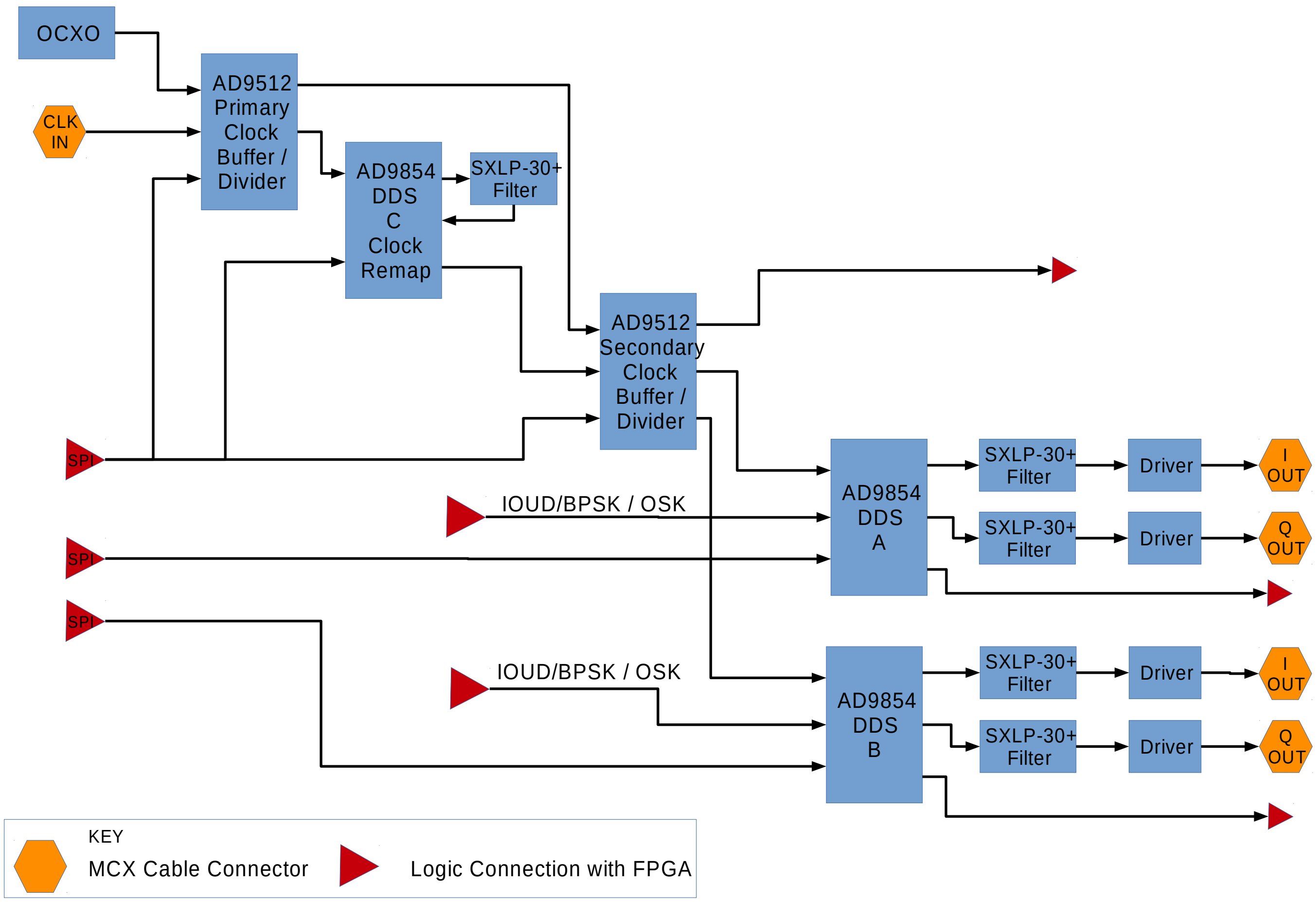



*Figure 2. Schematics of the Triple DDS Radar Controller.*
*See Table 2 for list of components and references.*

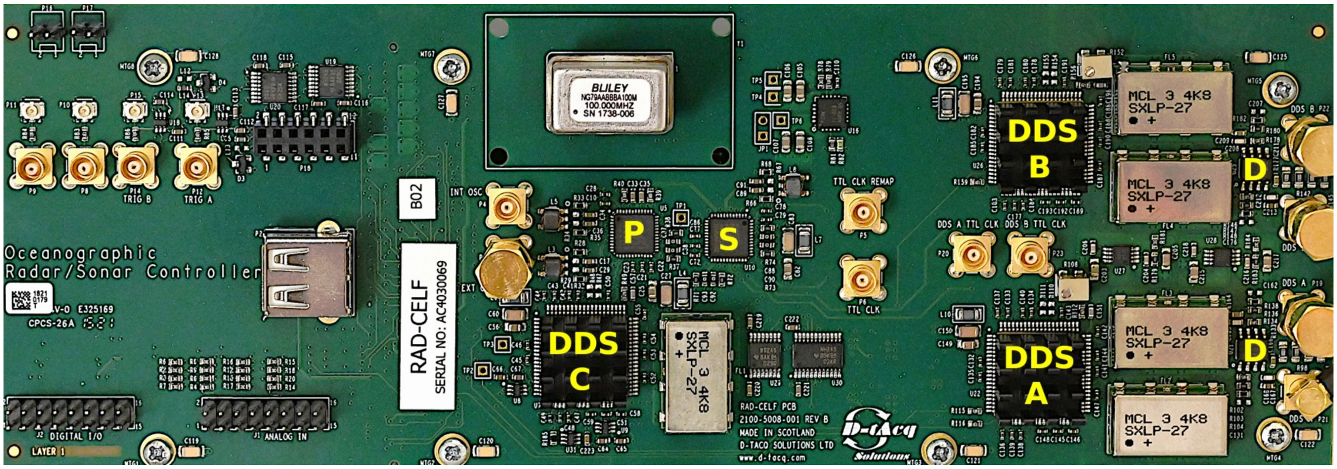



*Figure 3. Photo of the Triple DDS Radar Controller board.*

*Table 1. List of commercial modules incorporated in the Synthesizer-Transmitter Unit*

| *Tag* | *Description* | *Reference* | *Manufacturer* |
|---|---|---|---|
| OCXO | Oven-controlled crystal oscillator, 100 MHz | N79A-optA | Bliley Technologies Inc.<br>2545 W Grandview Blvd, Erie PA 16506 USA |
| FPGA | Carrier with embedded FPGA&ARM processors | ACQ1001 | D-TACQ Solutions Ltd., International House<br>Stanley Blvd, Blantyre G72 0BN Scotland UK |
| DDS | Triple DDS Radar Controller | RAD-CELF | *id.* |
| PA | Radio-frequency power amplifier | BTM00250-AlphaSA | Tomco Technologies<br>38 Payneham Rd, Stepney, Australia 5069 |
| LPF | Power low-pass filter | FLxxMLP-HFDR | DLW Associates<br>6 Woodford place, St. Charles MO 63301 USA |
| PS12V | Industrial power supply | TSP-070–112 | Traco Electronic AG<br>Sihlbruggstrasse 111, CH-6340 Baar |
| PS26V | Industrial power supply | TSP-360–124 | *id.* |
| RFI-DC | EMI Filter with High Attenuation Performance | FN2030M-Z-20-06 | Schaffner Holding AG<br>Nordstrasse 11, CH-4542 Luterbach |
| RFI-AC | EMI Filter with High Attenuation Performance | FN9266-10-06 | *id.* |

*Table 2. List of functional integrated circuits used in the Triple DDS Radar Controller*

| *Tag* | *Description* | *Reference* | *Manufacturer* |
|---|---|---|---|
| **P**rimary | Clock/buffer divider | AD9512BCPZ | Analog Devices<br>One Analog Way, Wilmington MA 01887 USA |
| **S**econdary | Clock/buffer divider | AD9512BCPZ | *id.* |
| **DDS-A** | Direct digital synthesizer | AD9854ASVZ | *id.* |
| **DDS-B** | Direct digital synthesizer | AD9854ASVZ | *id.* |
| **DDS-C** | Direct digital synthesizer | AD9854ASVZ | *id.* |
| Filter | Lumped LC low-pass filter | **SXLP-27**+ | Mini-Ciruits<br>13 Neptune Ave, Brooklyn NY 11235 USA |
| **D**river | Operational amplifier | OPA2694D | Texas Instruments<br>12500 TI Blvd., Dallas TX 75243 USA |

Note: other commodity components (inductors, capacitors, resistors, voltage regulators) used on the Triple DDS Radar signal synthesizer board have passive functions and do not contribute to the signal generation.

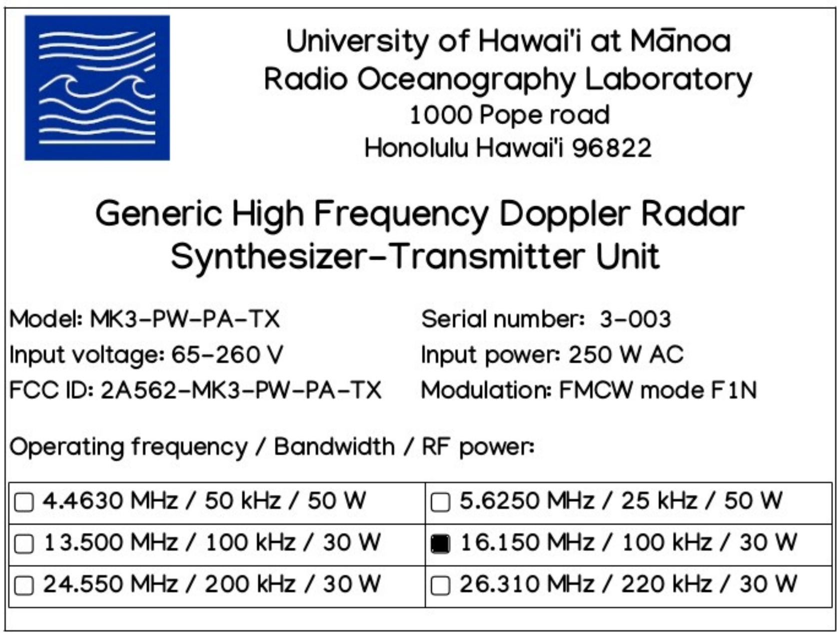
## Tune-up procedure of Synthesizer-Transmitter Unit, model *MK3-PW-PA-TX*

This device has no adjustments to tune output power and adjust reference frequency because these are digitally programmed during the manufacture of the system and drifts are non-existent within the precision of measurements.

Programming the unit is password-protected and reserved to factory-authorized personnel. There are no user-accessible controls to modify the programming of the unit.

## Device identification label

The operating frequency and output power which have been factory-programmed are marked. The label is affixed to the top right of the enclosure door. Example for 16.150 MHz.



University of Hawai'i at Mānoa
Radio Oceanography Laboratory
1000 Pope road
Honolulu Hawai'i 96822

Generic High Frequency Doppler Radar
Synthesizer–Transmitter Unit

Model: MK3–PW–PA–TX
Serial number: 3–003
Input voltage: 65–260 V
Input power: 250 W AC
FCC ID: 2A562–MK3–PW–PA–TX
Modulation: FMCW mode F1N

Operating frequency / Bandwidth / RF power:

| | |
|---|---|
| ☐ 4.4630 MHz / 50 kHz / 50 W | ☐ 5.6250 MHz / 25 kHz / 50 W |
| ☐ 13.500 MHz / 100 kHz / 30 W | ■ 16.150 MHz / 100 kHz / 30 W |
| ☐ 24.550 MHz / 200 kHz / 30 W | ☐ 26.310 MHz / 220 kHz / 30 W |

## External photos of Synthesizer-Transmitter Unit, model *MK3-PW-PA-TX.*

*Figure 1. Above: High Frequency Doppler Radar Synthesizer-Transmitter Unit model MK3-PW-PA-TX, serial 3-003, door closed. Below: device identification label, affixed to the top right of the enclosure door. The factory-programmed operating frequency and output power are marked, here for example 16.150 MHz/30W.*

University of Hawai'i at Mānoa
Radio Oceanography Laboratory
1000 Pope road
Honolulu Hawai'i 96822

Generic High Frequency Doppler Radar
Synthesizer–Transmitter Unit

Model: MK3–PW–PA–TX　　Serial number: 3–003
Input voltage: 65–260 V　　Input power: 250 W AC
FCC ID: 2A562–MK3–PW–PA–TX　　Modulation: FMCW mode F1N

Operating frequency / Bandwidth / RF power:

| | |
|---|---|
| ☐ 4.4630 MHz / 50 kHz / 50 W | ☐ 5.6250 MHz / 25 kHz / 50 W |
| ☐ 13.500 MHz / 100 kHz / 30 W | ■ 16.150 MHz / 100 kHz / 30 W |
| ☐ 24.550 MHz / 200 kHz / 30 W | ☐ 26.310 MHz / 220 kHz / 30 W |

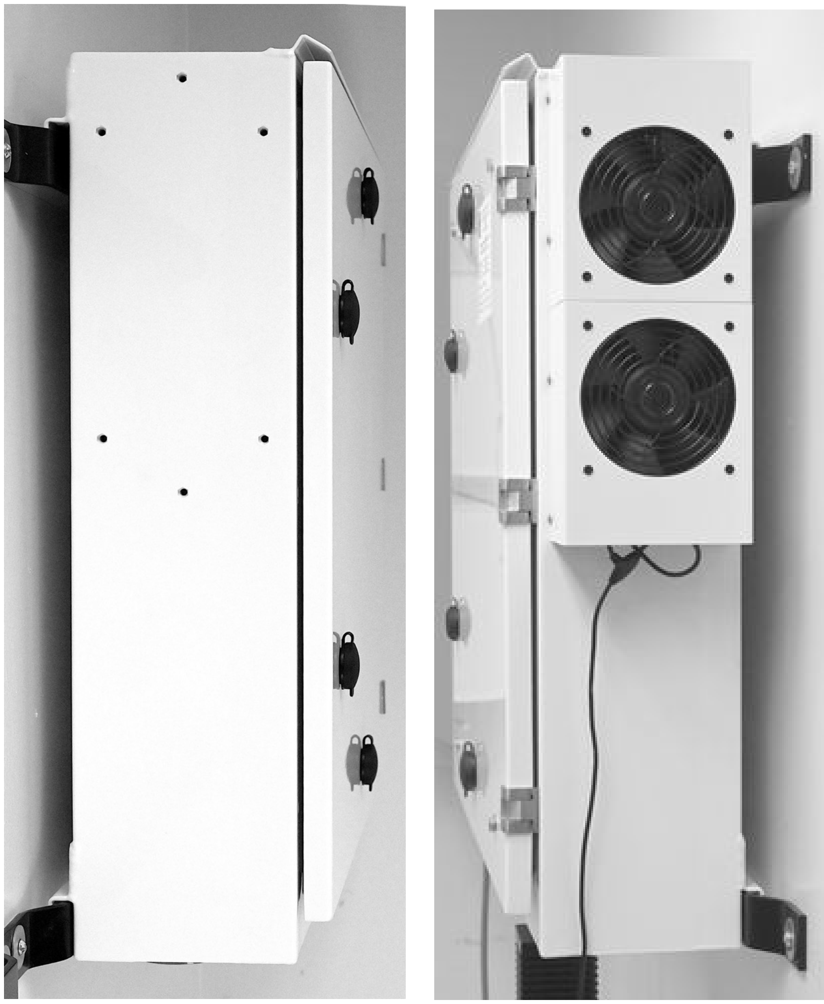


*Figure 2. Synthesizer-Transmitter Unit, left and right side views.*
*The twin-fan forced air flow heat exchanger unit is seen on the right side.*

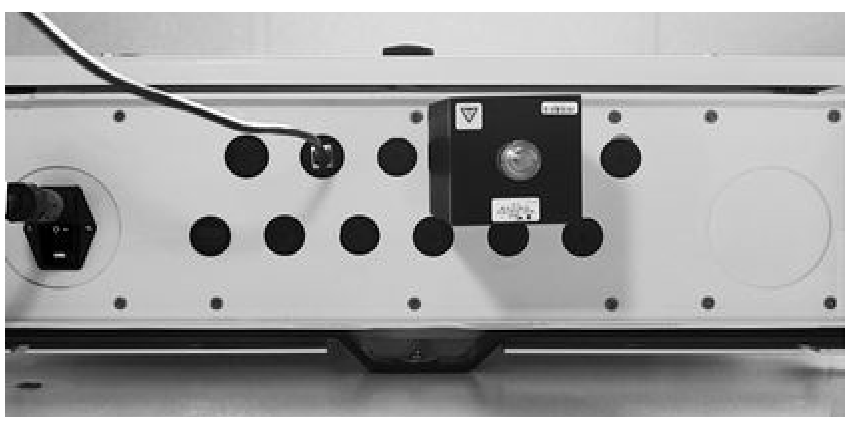


*Figure 3. Synthesizer-Transmitter Unit, bottom view.*
*Connector plate with IEC-C13/C14 power inlet, RJ45 inlet for CAT6 ethernet, N-type bulkhead adapter for cable to antenna (a Bird 100-SA-FFN-30 power attenuator is attached).*

*Fig. 4. Synthesizer-Transmitter Unit, top view.*
*The twin-fan forced air flow heat exchanger unit is seen on the right side.*

*Fig. 5. Synthesizer-Transmitter Unit, back view*
*(after removing unit from wall supports).*

## **Internal photos of Synthesizer-Transmitter Unit, model *MK3-PW-PA-TX.***

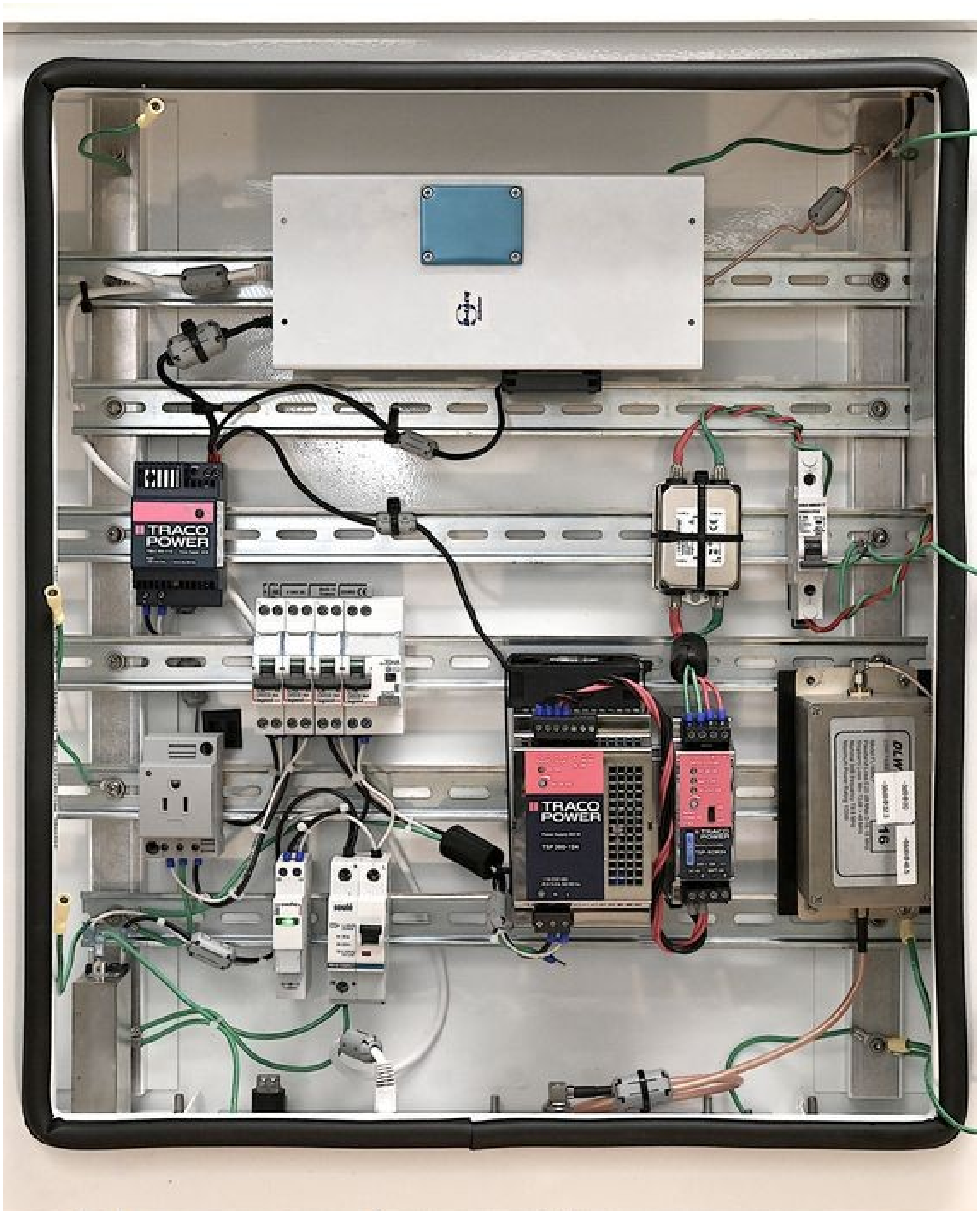



*Figure 1. Synthesizer-Transmitter Unit, door open.*
*Bottom rails:  power supplies with circuit breakers.*
*Upper rail: digital synthesizer and controller processor with blue thermal bell.*

*On the right wall: the power amplifier module and the low-pass filter.*


*Figure 2. Synthesizer-Transmitter Unit, door open, slanted view. The power amplifier module (top) and the low-pass filter (bottom) are seen on the right inner wall.*

*Figure 3. Upper rail enlarged from Figure 1 and 2, after removal of the aluminum lid and thermal bell, showing the Triple DDS Radar Controller board.*

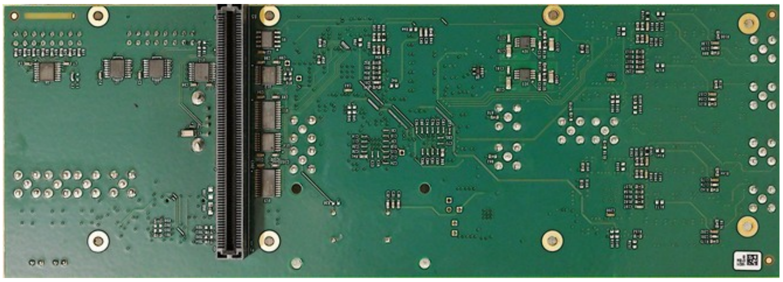


*Figure 4. Bottom face of the Triple DDS Radar Controller board.*

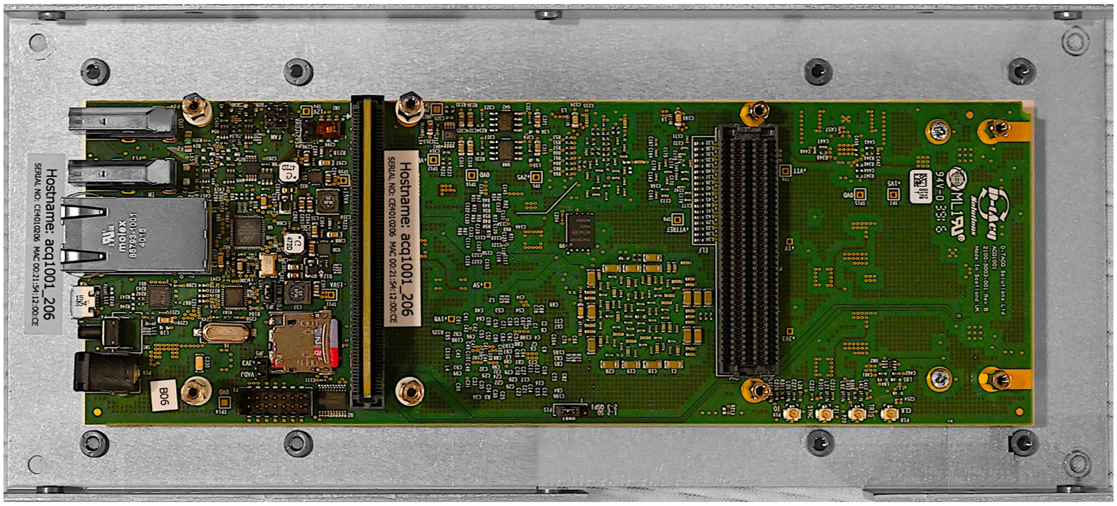
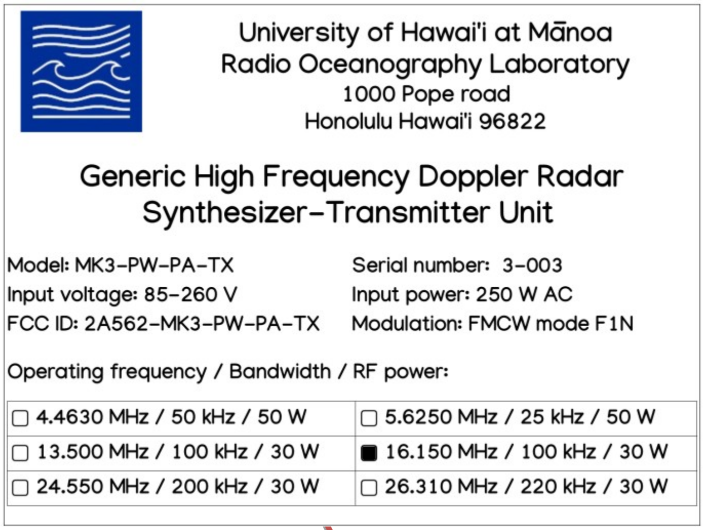


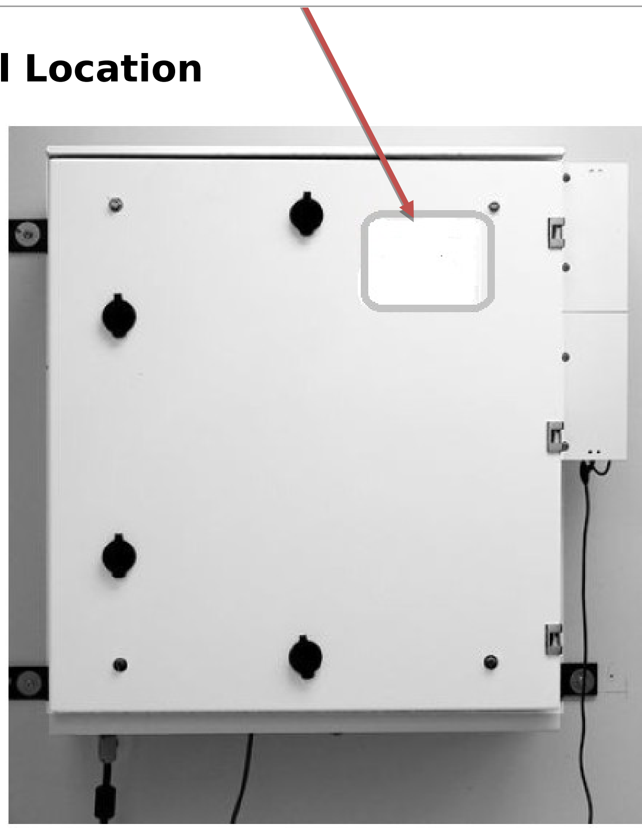

*Figure 5. Carrier board with FPGA, after removal of the Triple DDS Radar Controller board (top face; bottom face not accessible).*

**Proposed FCC ID label and location for Synthesizer-Transmitter Unit, model *MK3-PW-PA-TX.***

## Label




## Label Location



*The device identification label, affixed to the top right of the enclosure door.*

# RF Exposure – Justification for Exemption from Routine Evaluation

The minimum separation distance, R (m), to qualify for exemption from routine evaluation for rf exposure as detailed in 1.1307 Table 1 (version of April 2021) must be at least $\lambda/2\pi$, where $\lambda$ is the free-space operating wavelength in meters.

**TABLE 1 TO §1.1307(b)(3)(i)(C)**

| RF Source frequency (MHz) | Threshold ERP (watts) |
|---|---|
| 0.3-1.34 | 1,920 $R^2$ |
| 1.34-30 | 3,450 $R^2$/f. |
| 30-300 | 3.83 $R^2$ |
| 300-1,500 | 0.0128 $R^2$f |
| 1,500-100,000 | 19.2 $R^2$ |

Using the formulas from table 1 the power thresholds at the separation distances specified for the different operating frequencies for this series of devices are:

| **Calculations to determine ERP thresholds above which routine evaluation for RF exposure would be required.** *Refer to 1.1307 Table 1 for formula.* | | | | | | | |
|---|---|---|---|---|---|---|---|
| f (MHz) | $\lambda/2\pi$ (m) | R = Separation Distance *[1] (m) | ERP Power threshold (W) at distance R (m) | Output Power (dBm) *[2] | Ant Gain + Cable Loss (dBi) *[3] | ERP (W) *[3] | % of Threshold |
| 4.48 | 10.66 | 10.66 | 19525 | 47.5 | -3 | 17.2 | 0% |
| 5.25 | 9.09 | | 14224 | 47.5 | -3 | 17.2 | 0% |
| 13.45 | 3.55 | 3.55 | 240 | 45.5 | -3 | 10.8 | 5% |
| 16.10 | 2.97 | | 168 | 45.5 | -3 | 10.8 | 6% |
| 24.45 | 1.95 | 2.30 | 31 | 45.5 | -3 | 10.8 | 35% |
| 26.20 | 1.82 | | 27 | 45.5 | -3 | 10.8 | 40% |

*[1] The minimum separation distance to qualify for exemption from routine evaluation for rf exposure as detailed in 1.1307 Table 1 must be at least $\lambda/2\pi$, where $\lambda$ is the free-space operating wavelength in meters.

*[2] The declared peak conducted output power at the port for this system is 50 W (47 dBm) for 10 MHz and below, and 30 W (45 dBm) for 10 MHz and above, with production tolerance of +0.5 dB.

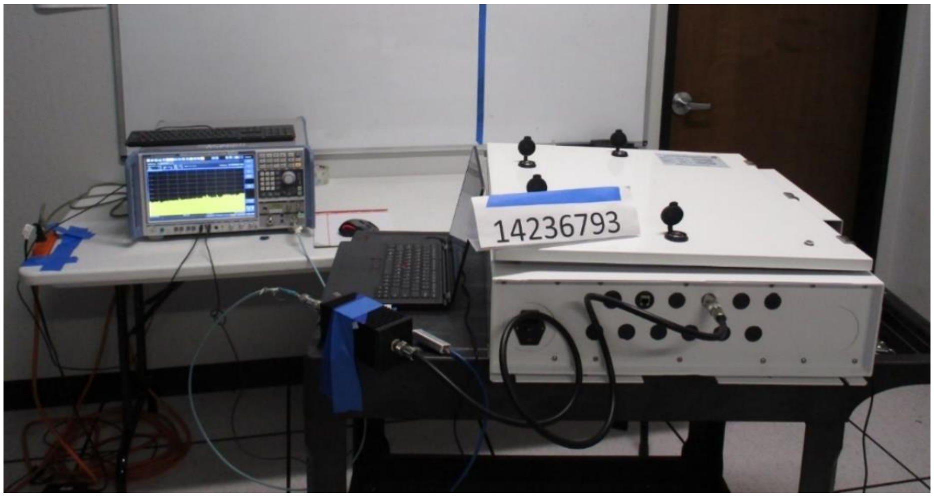
*[3] Declared by manufacturer, a maximum gain of 2 dBi normal-mode helical monopole antenna over finite ground plane and a minimum of 5 dB cable loss of RG213 or RG214 between the RF output and the antenna are used.
EIRP (dBm) = P (dBm) + Ant Gain (dBi) – Cable Loss (dB)
ERP (dBm) = EIRP (dBm) - 2.15 dB

The ERP for all bands is below the threshold that would require routine evaluation and therefore the system is exempt from routine evaluation when installed with the minimum separation distances detailed in the installation instructions.

# 9. SETUP PHOTOS

**RF CONDUCTED MEASUREMENT SETUP**

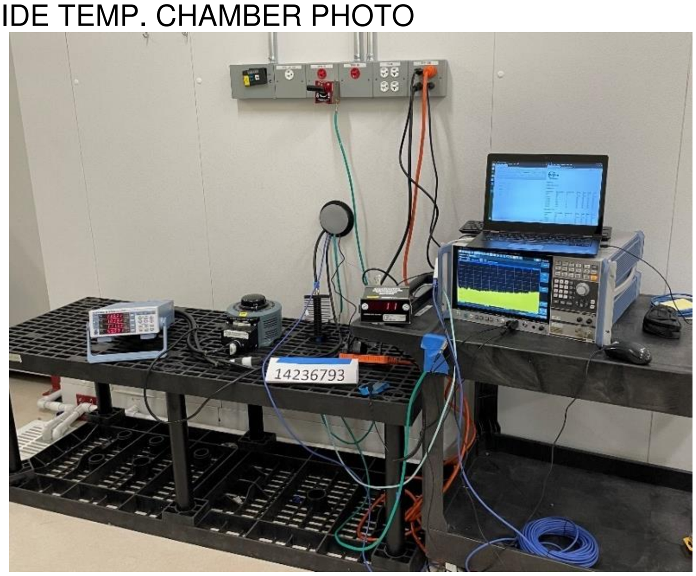
**TX CONDUCTED RF TESTS**



**FREQUENCY STABILITY MEASUREMENT SETUP**

INSIDE TEMP. CHAMBER PHOTO


OUTSIDE TEMP. CHAMBER PHOTO

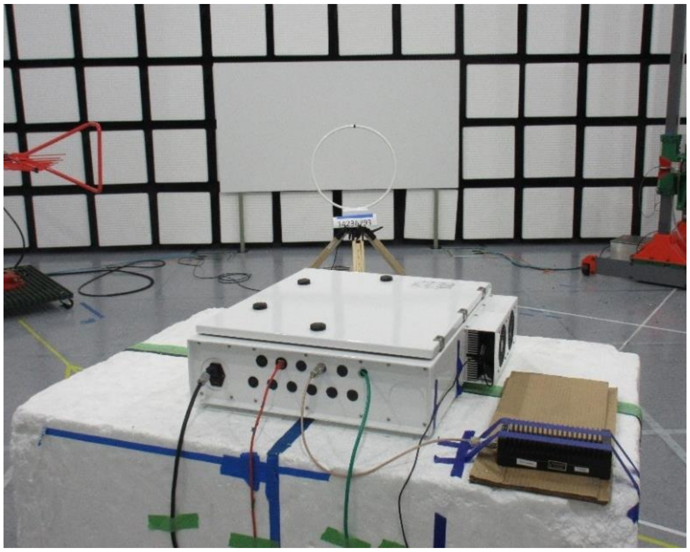




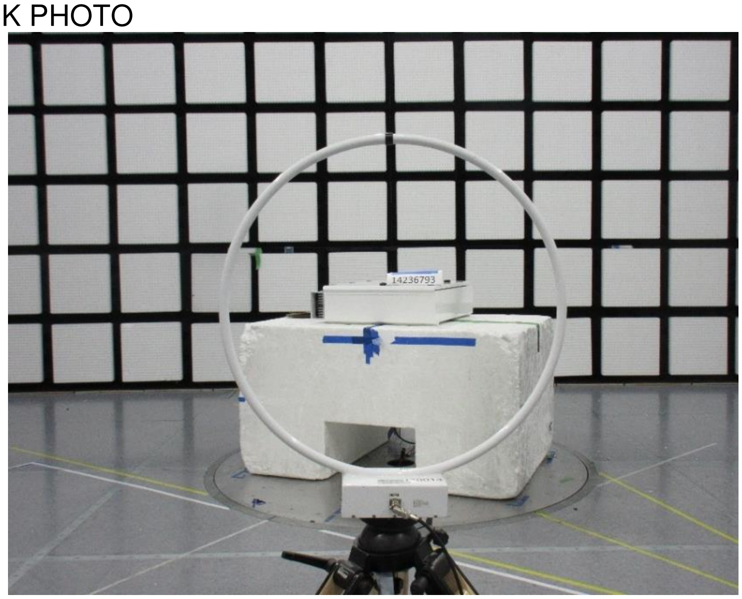

UL VERIFICATION SERVICES INC
47173 BENICIA STREET, FREMONT, CA 94538, USA TEL: (510) 319-4000 FAX: (510) 661-0888

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

FRONT PHOTO



BACK PHOTO





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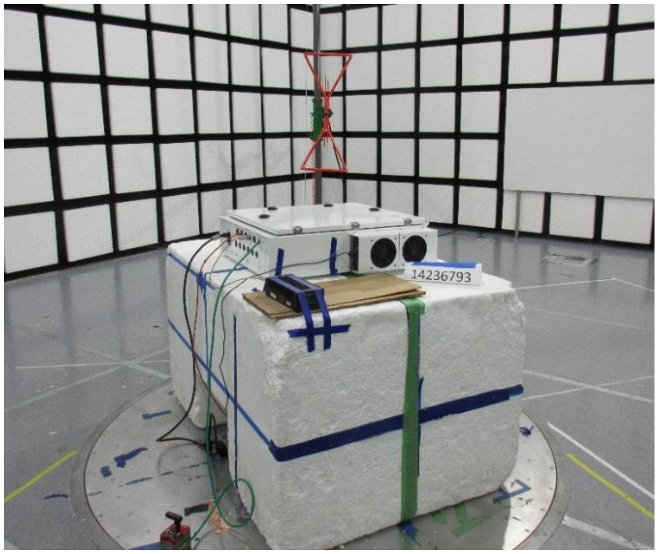
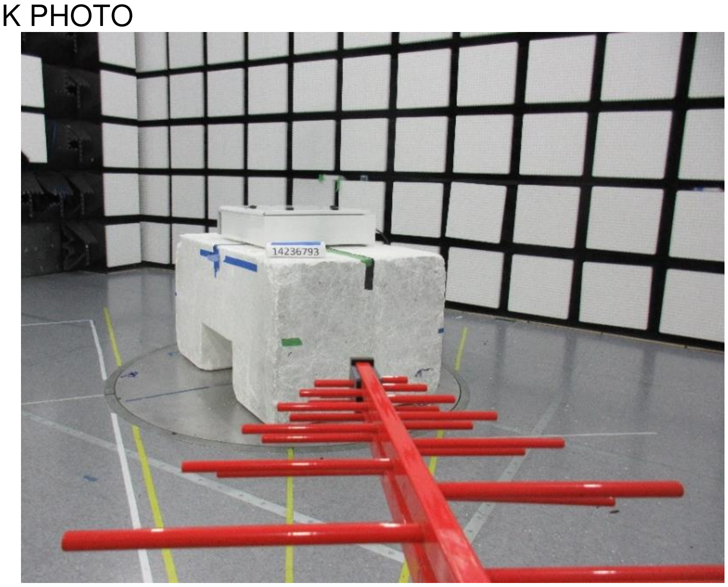
**RF RADIATED MEASUREMENT SETUP, 30 - 1000 MHz**

FRONT PHOTO




BACK PHOTO




# END OF REPORT

# 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
FAX: (510) 661-0888

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 |

# TABLE OF CONTENTS

# 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.



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

# 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 – 26.420 | 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.



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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) |
|---|---|---|---|
| 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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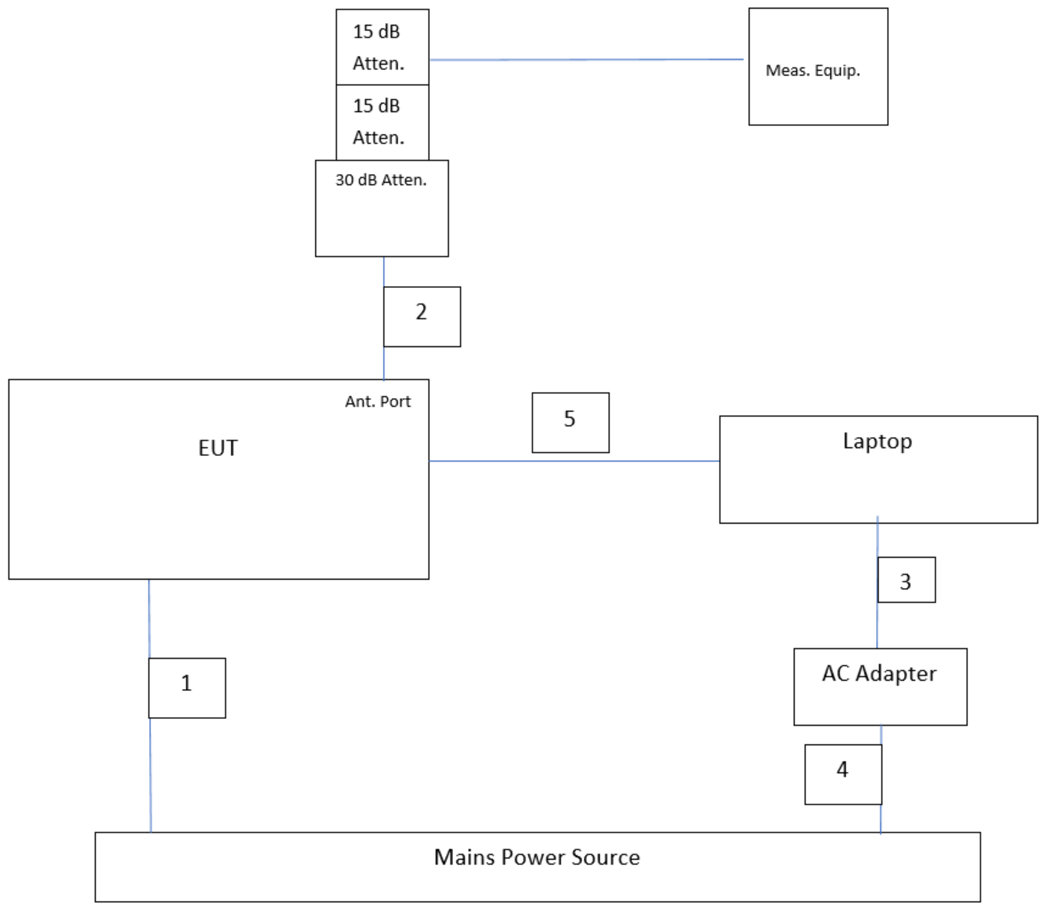
**SETUP DIAGRAMS FOR TESTS**

**TX CONDUCTED RF TESTS**



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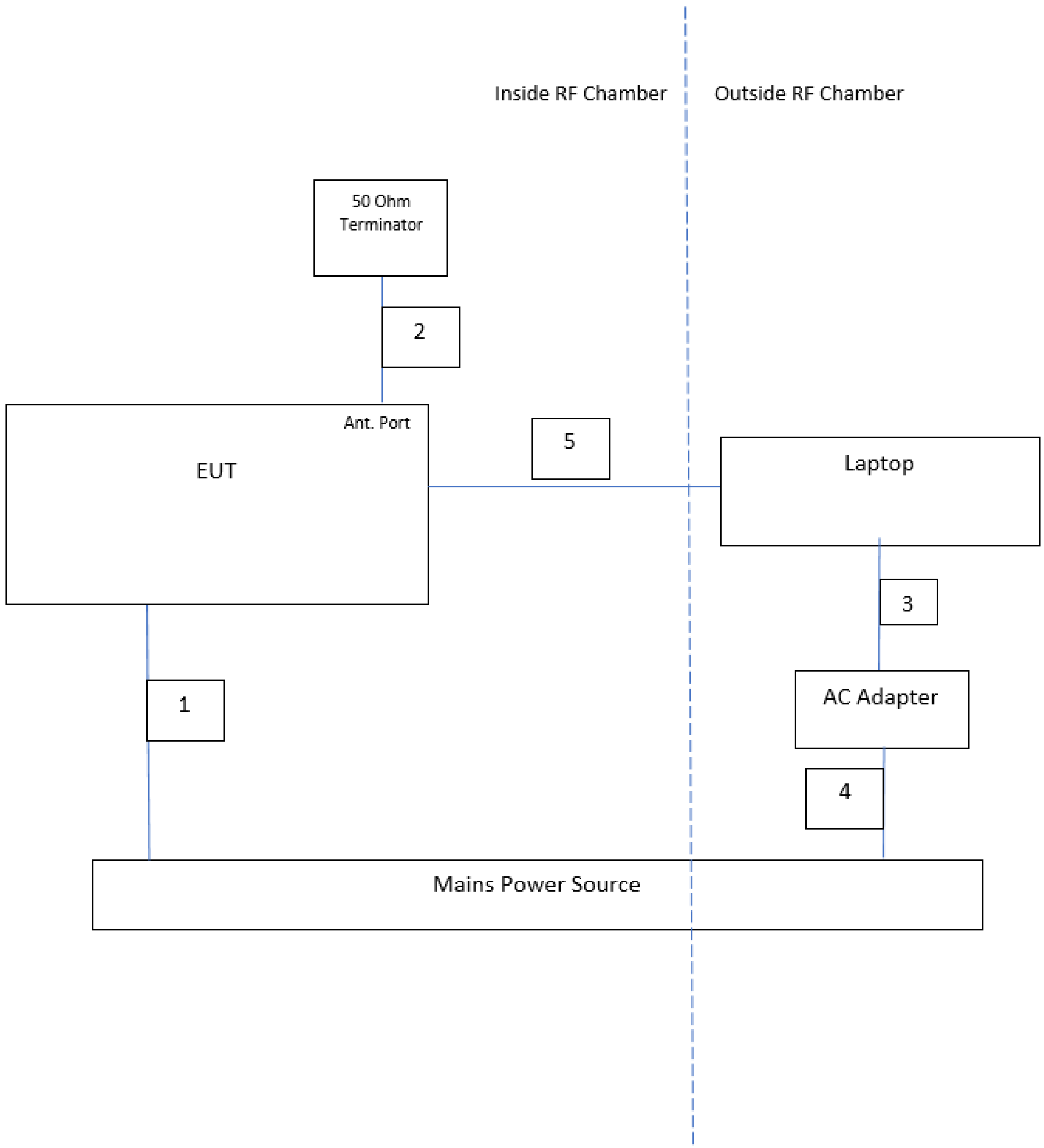
**TX RADIATED RF TESTS**





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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 $F_c$ = 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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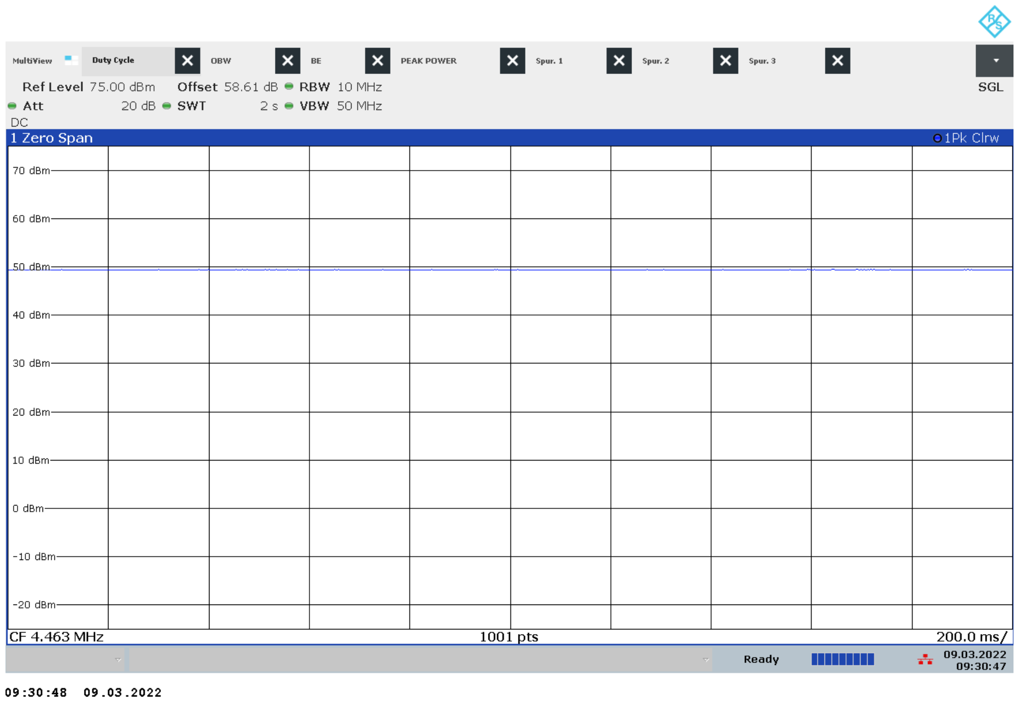
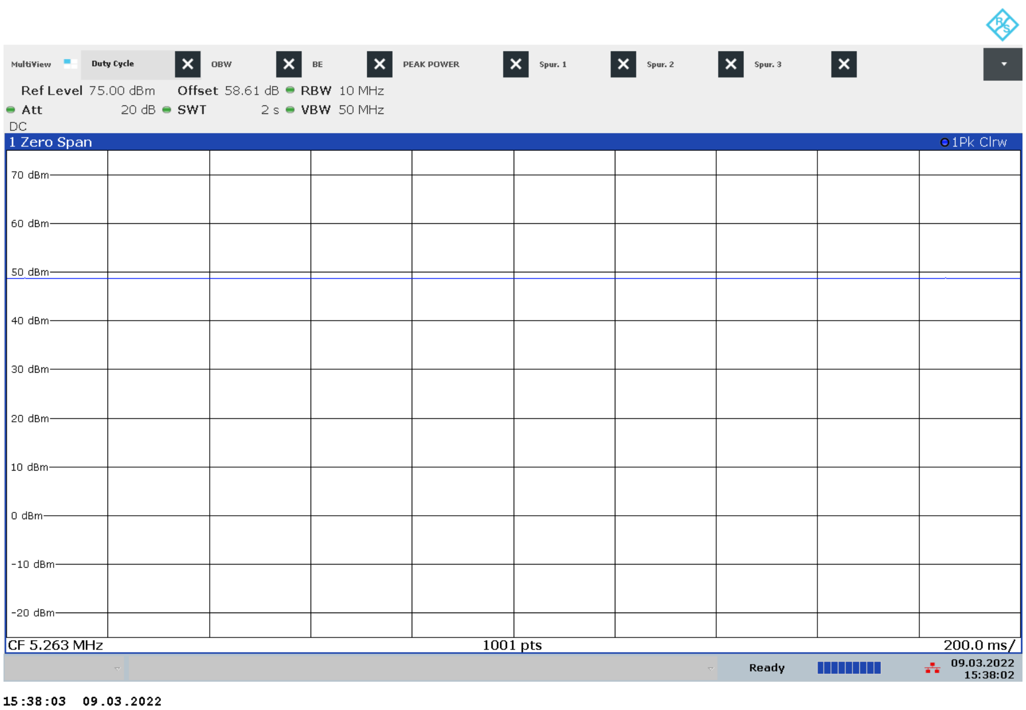
## 4.463 MHz CW Mode




## 5.263 MHz CW Mode





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## 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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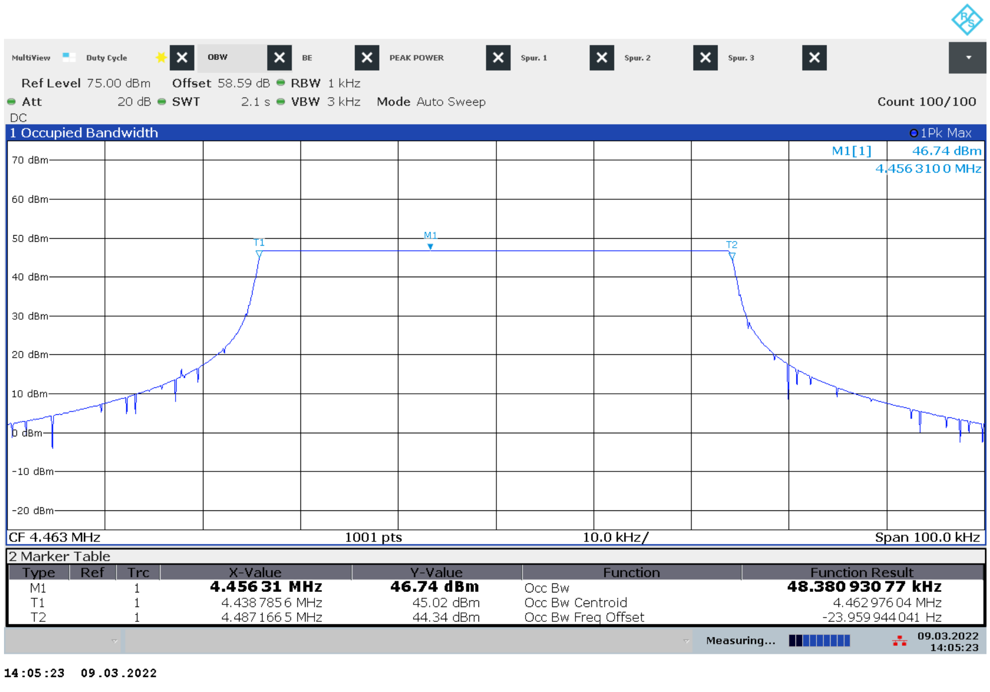
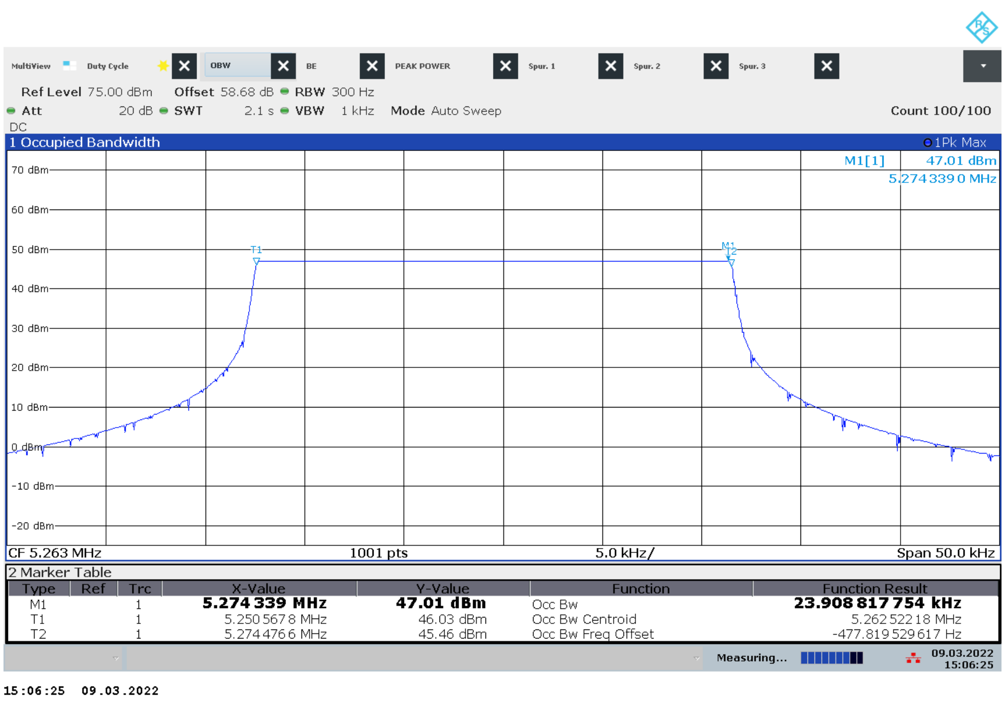
## 4.438 - 4.488 MHz Mode




## 5.250 - 5.275 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 |
|---|---|---|---|---|---|---|---|---|
| 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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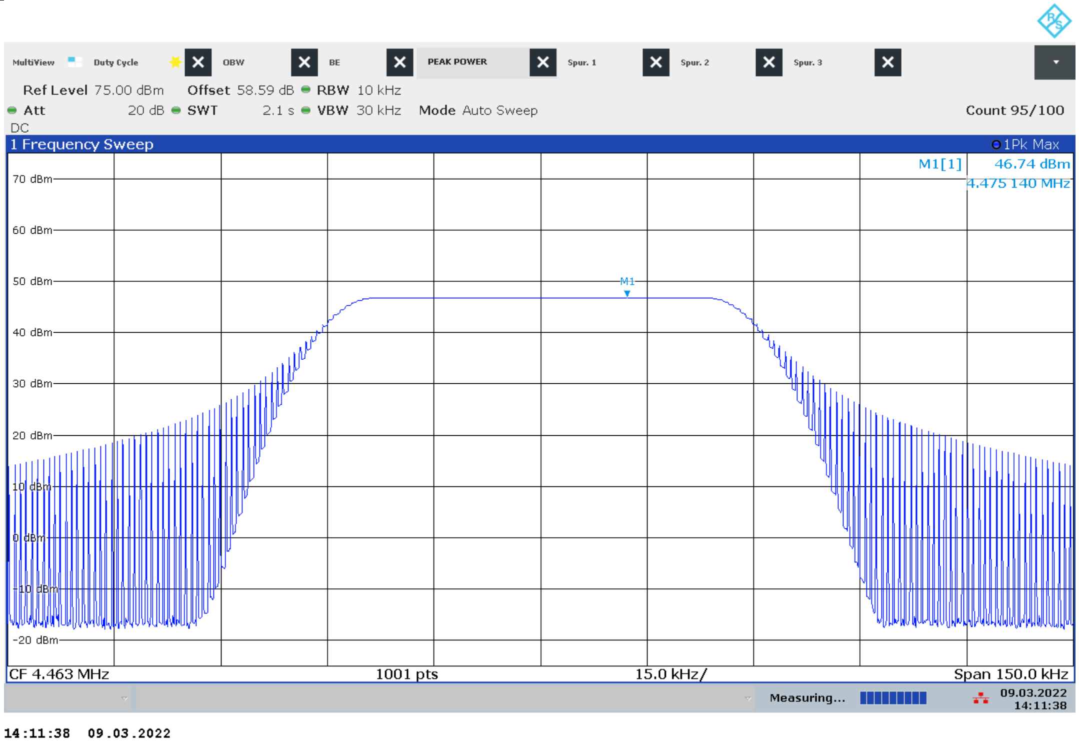
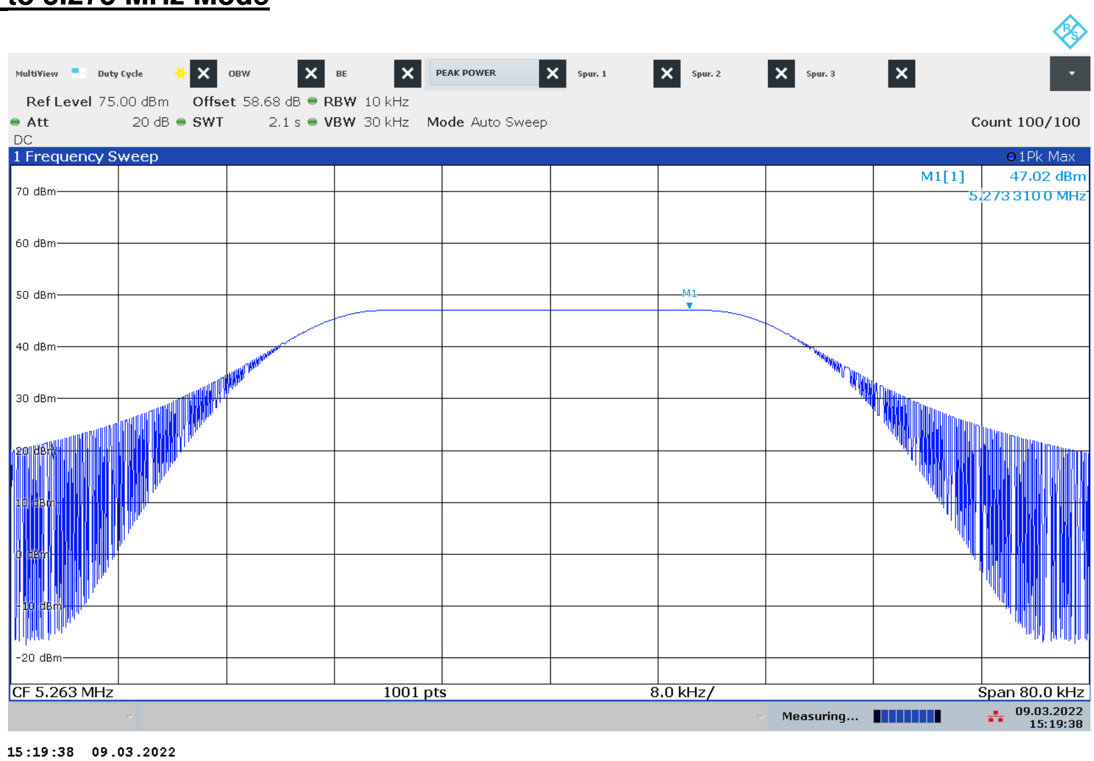
## 4.438 to 4.488 MHz Mode




## 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,

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

$$Applicable\ Peak\ Limit = 44 - (43 + 10log(25)) = 44 - 57 = -13\ dBm$$



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**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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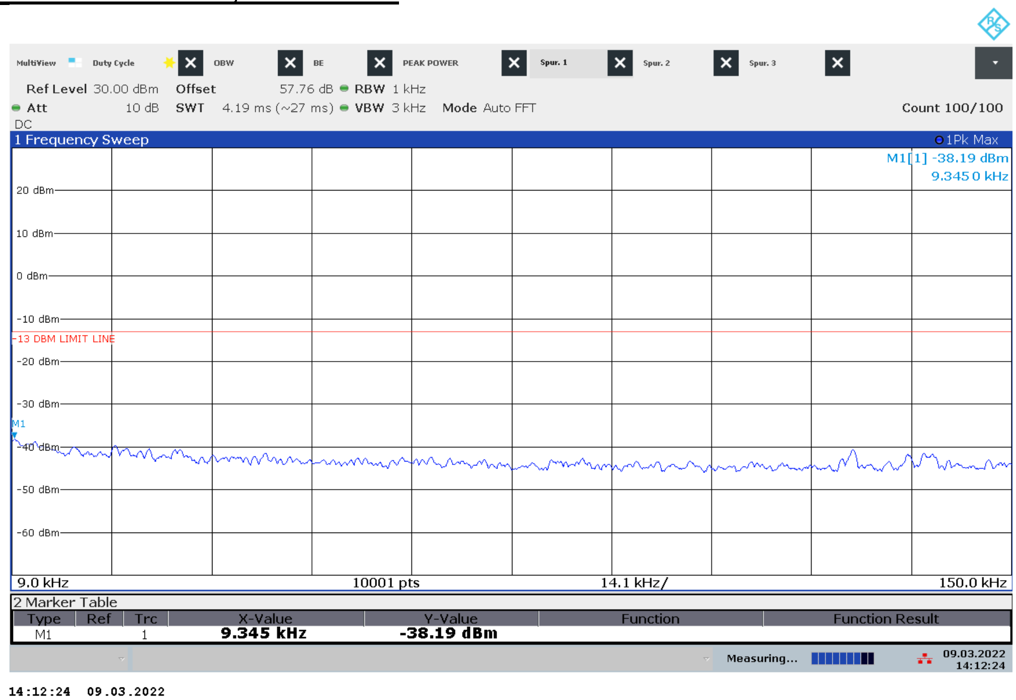
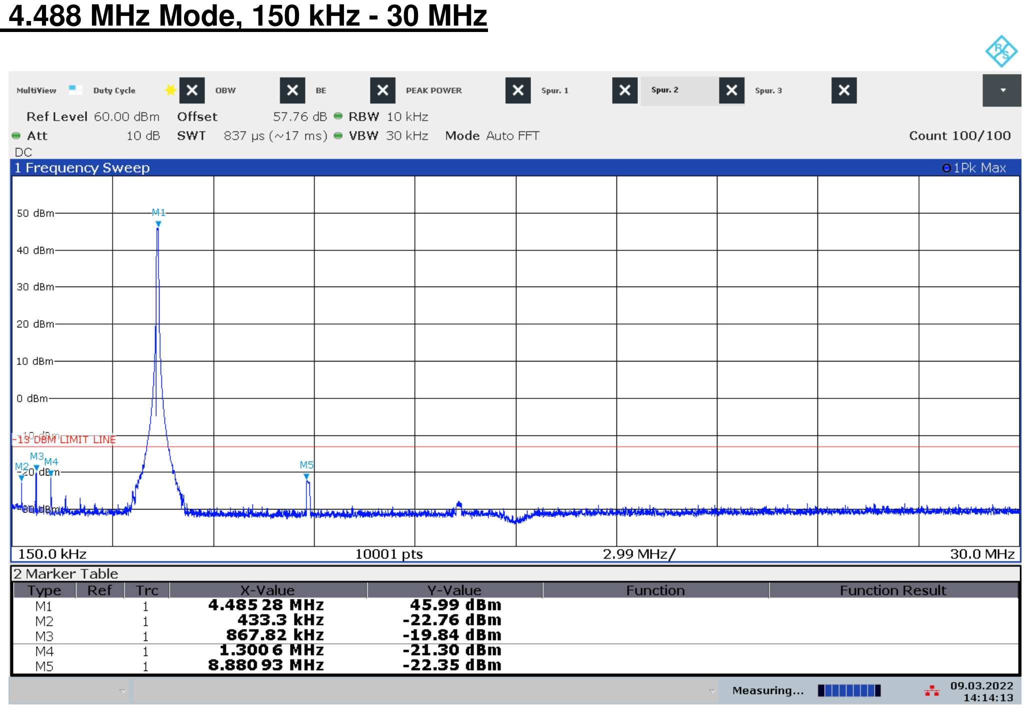
### 8.5.1. SPURIOUS EMISSIONS

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

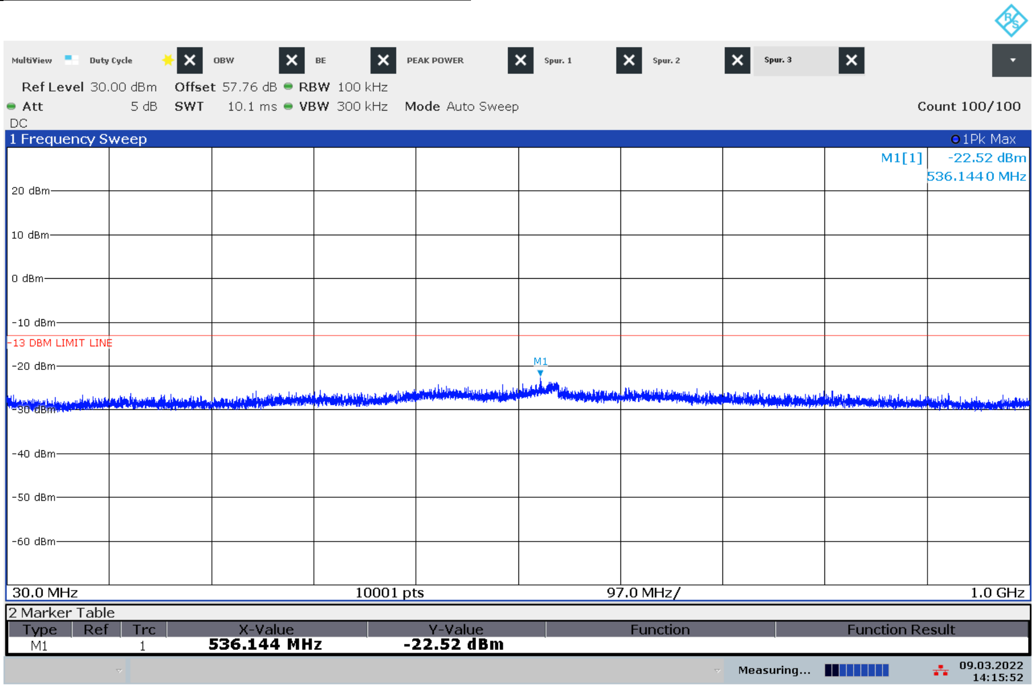



**4.438 to 4.488 MHz Mode, 150 kHz - 30 MHz**




*Marker M1 is the fundamental signal.

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

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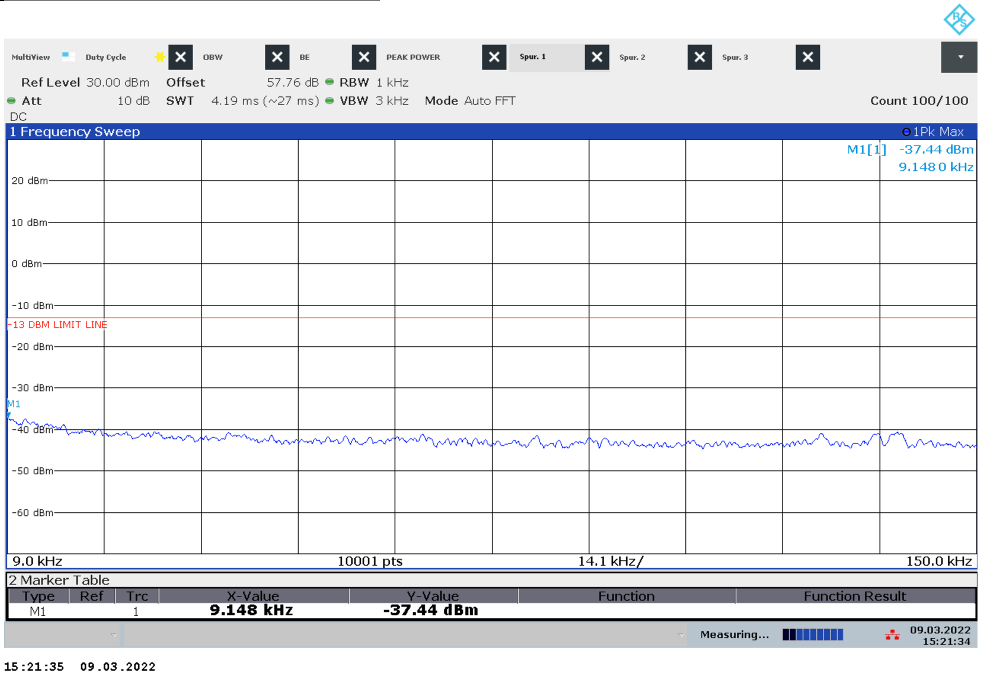
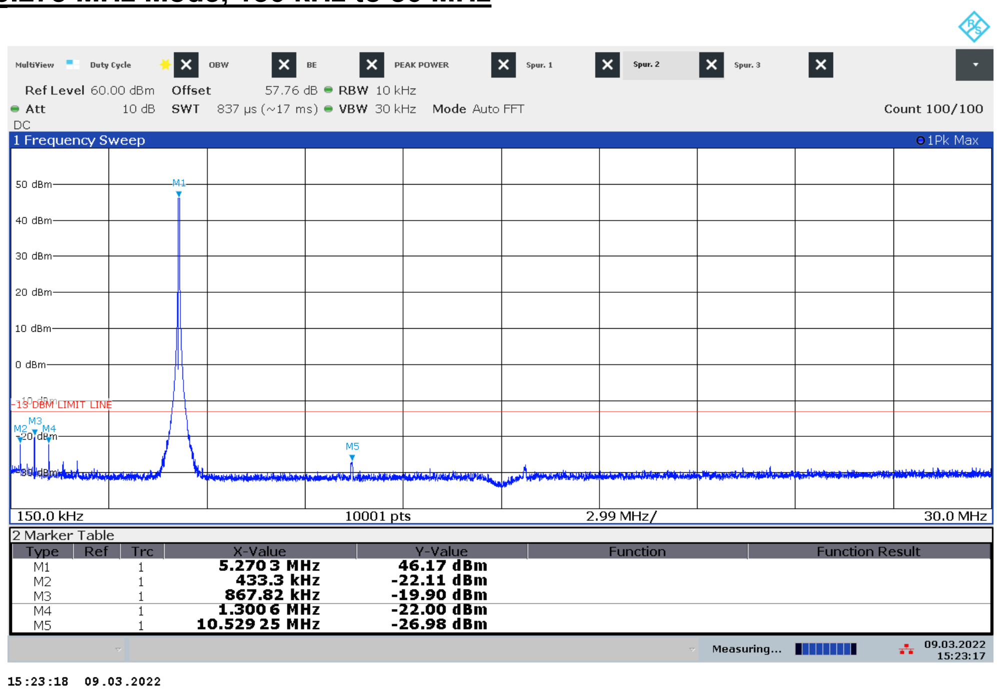
## 5.250 to 5.275 MHz Mode, 9 - 150 kHz




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




*Marker M1 is the fundamental signal.



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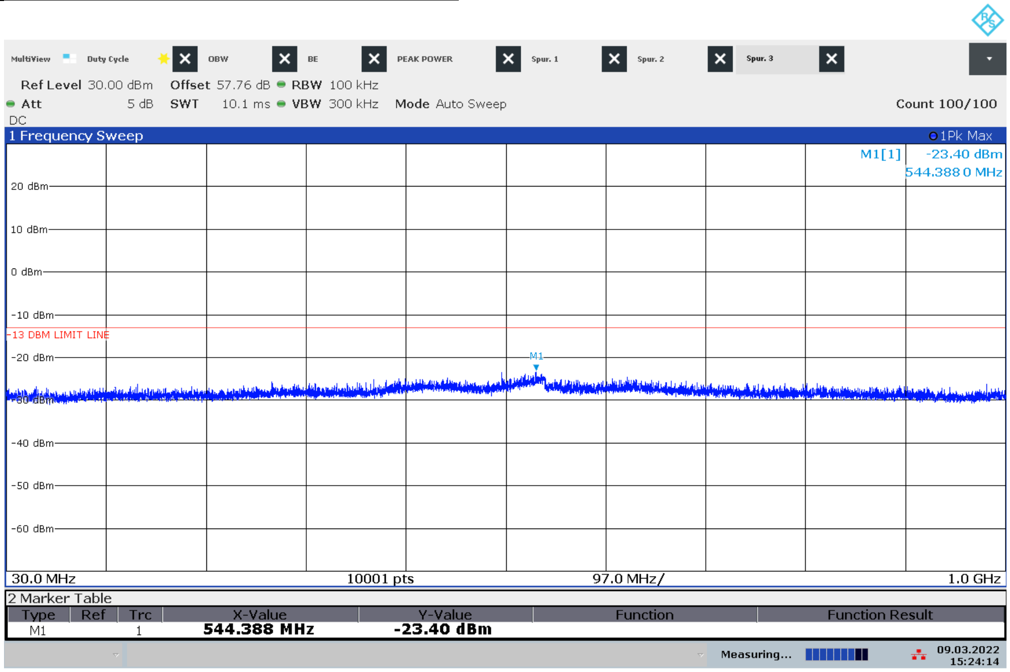
## 5.250 to 5.275 MHz Mode, 30 MHz – 1 GHz

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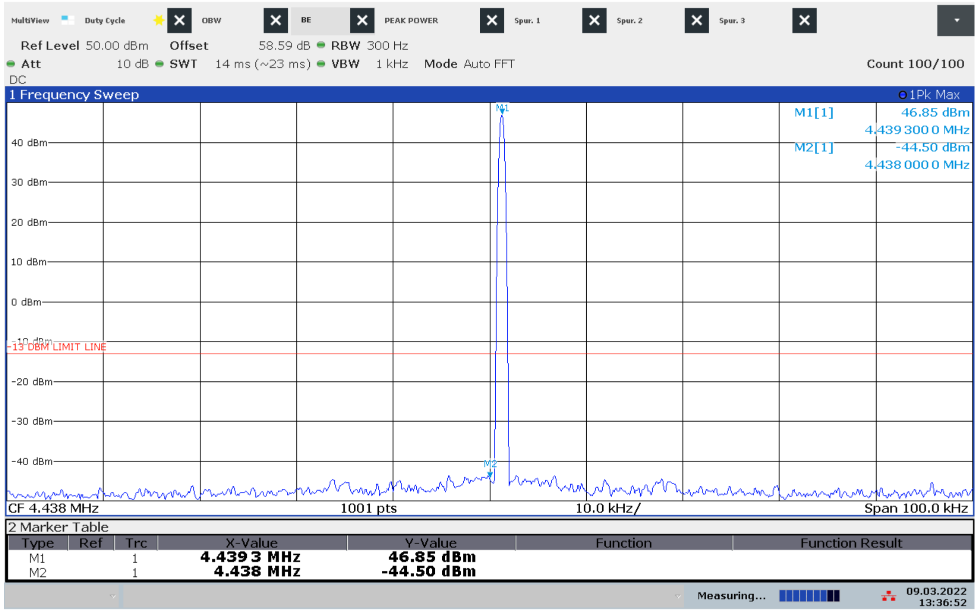
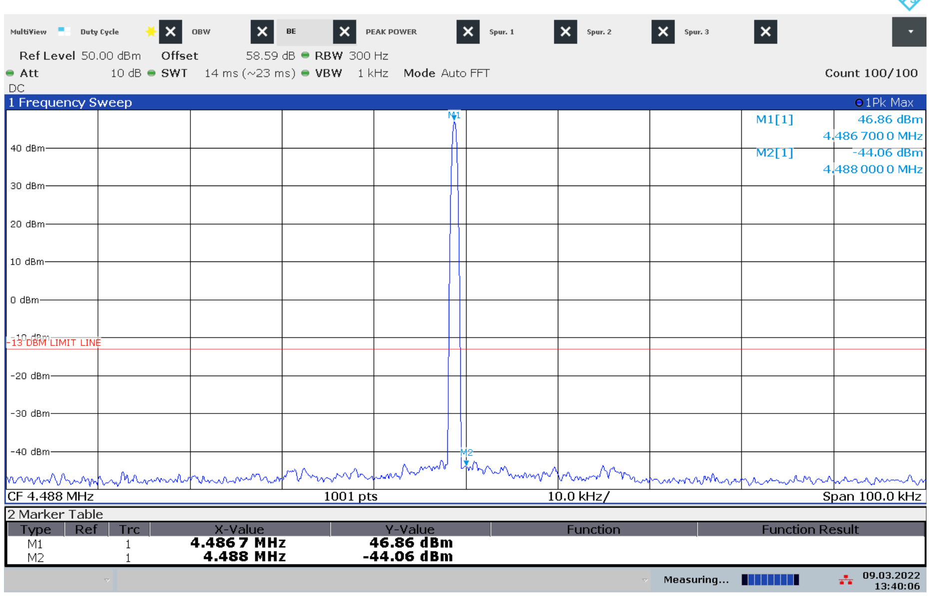
### 8.5.2. BAND EDGE

**4.438 to 4.488 MHz Mode, Low End**



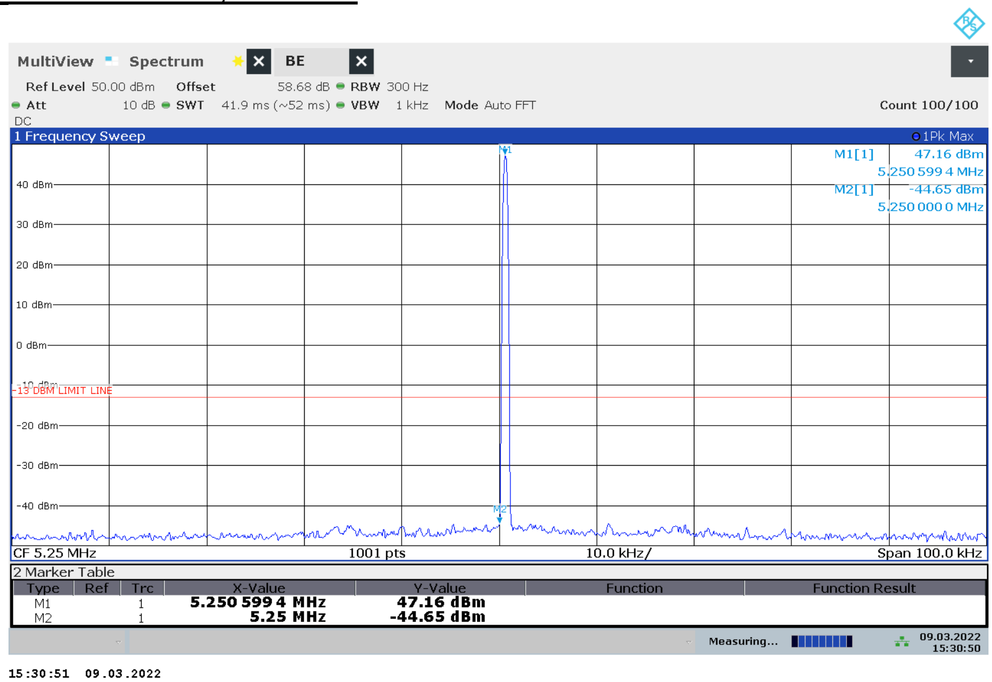

13:36:53 09.03.2022

**4.438 to 4.488 MHz Mode, High End**

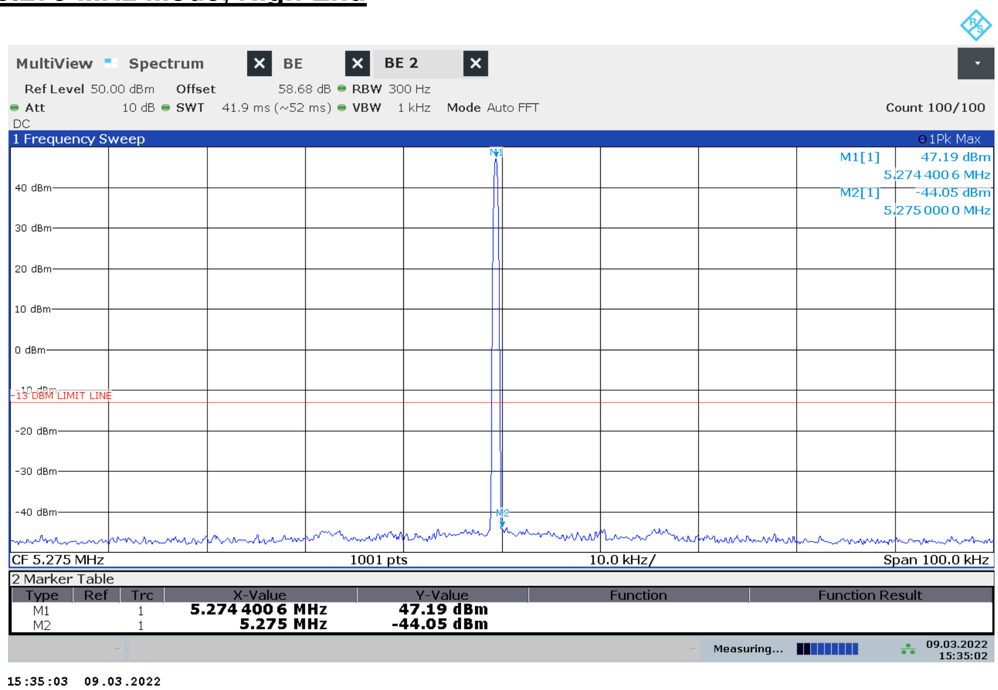



13:40:06 09.03.2022

## 5.250 to 5.275 MHz Mode, Low End




## 5.250 to 5.275 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 = $10 \times (5.275\ MHz) = 52.75\ MHz$
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,

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

$$Applicable\ Peak\ Limit = 44 - \big(43 + 10log(25)\big)$$
$$= 44 - 57$$
$$= -13\ dBm$$



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## 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



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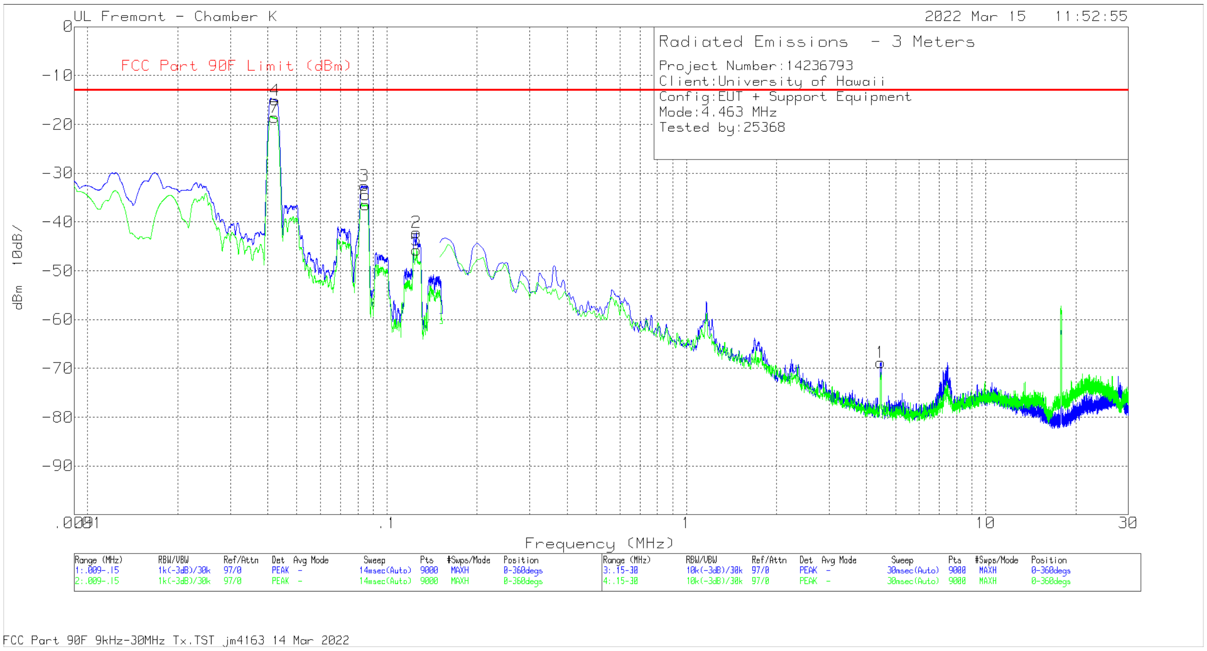
## 4.438 to 4.488 MHz MODE, 9 kHz to 30 MHz




### 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



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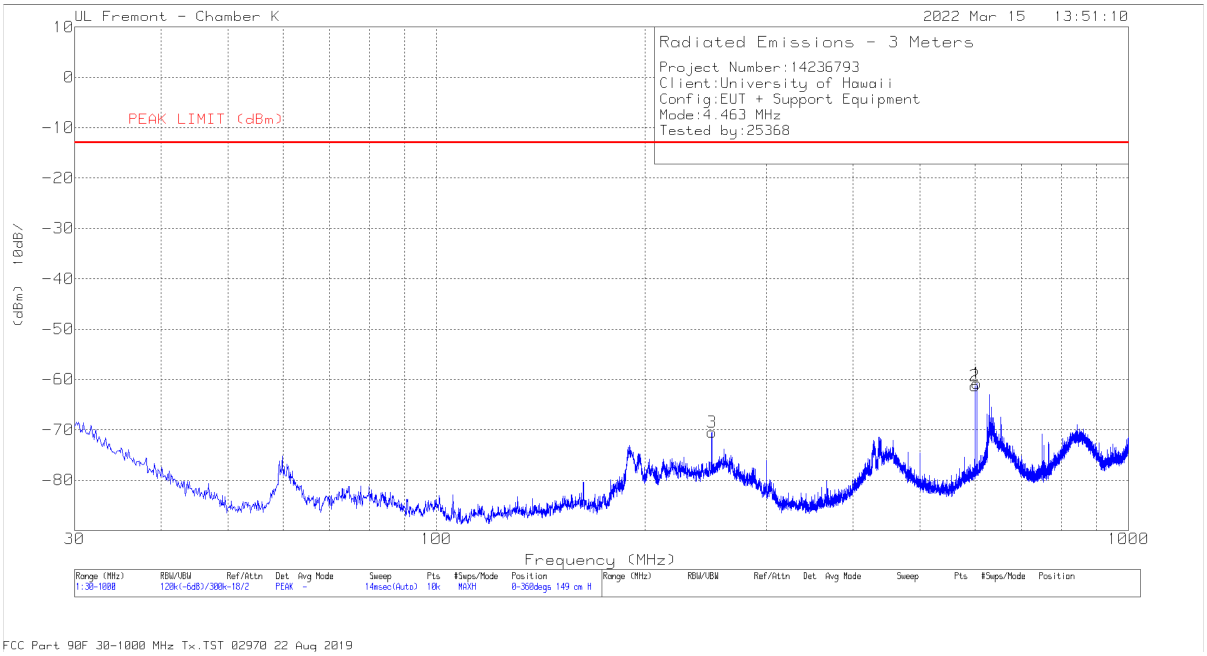
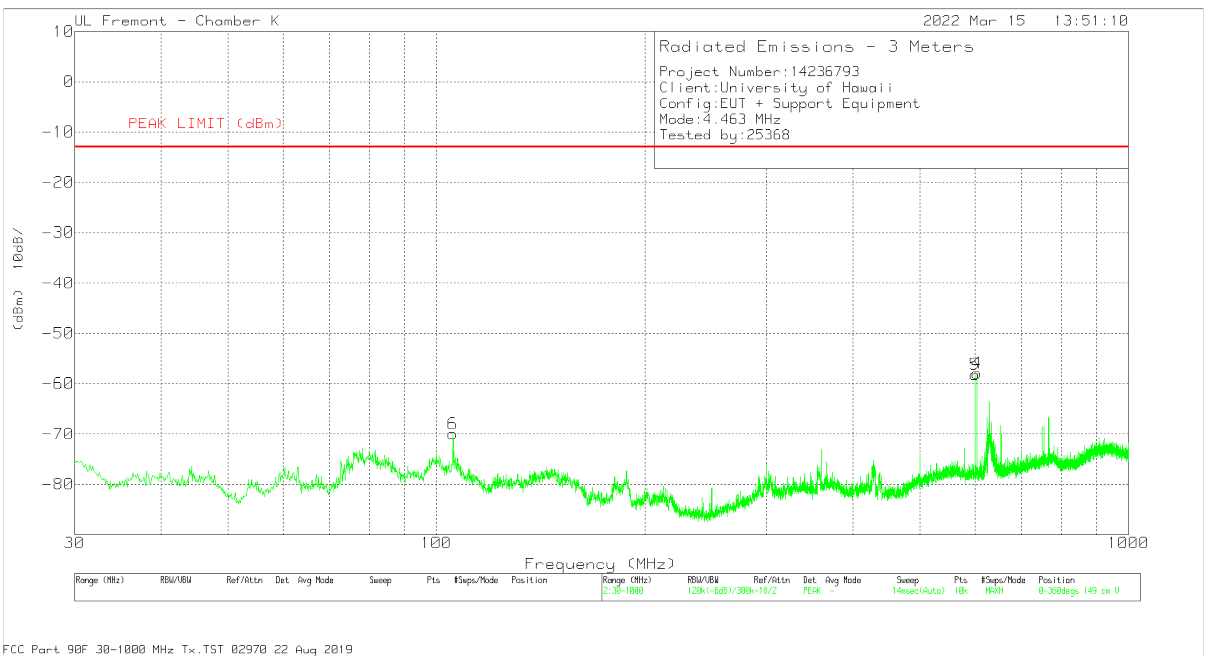
## 4.438 to 4.488 MHz MODE, 30 to 1000 MHz



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## 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



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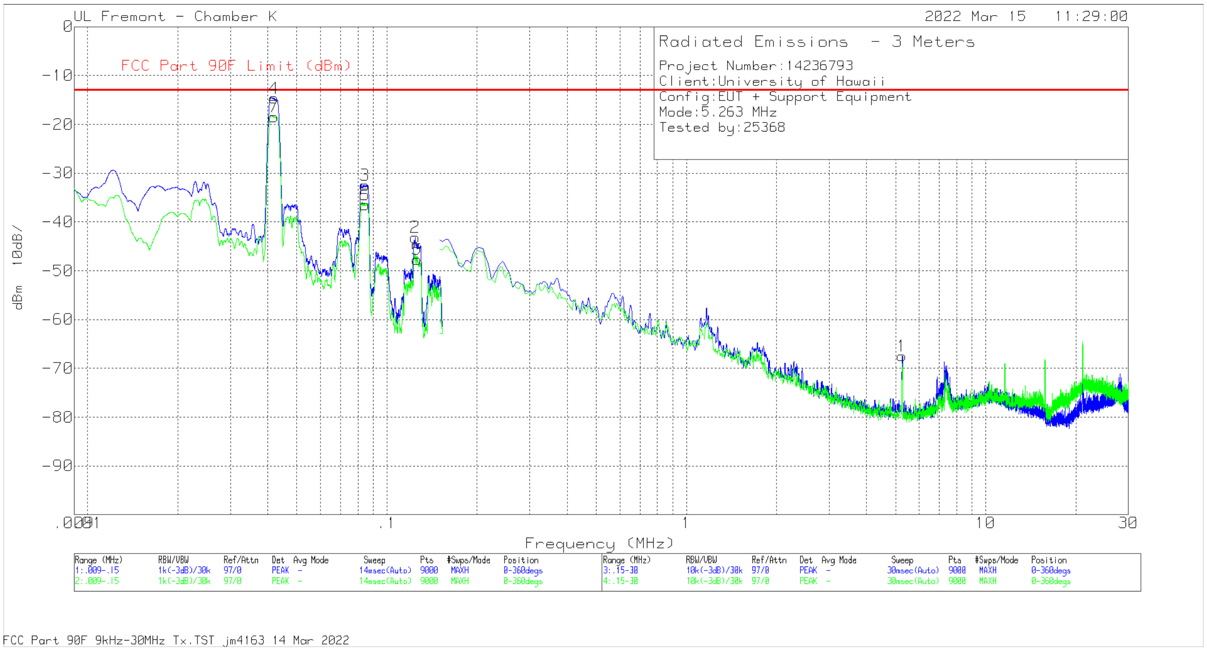
## 5.250 to 5.275 MHz MODE, 9 kHz to 30 MHz




### 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.

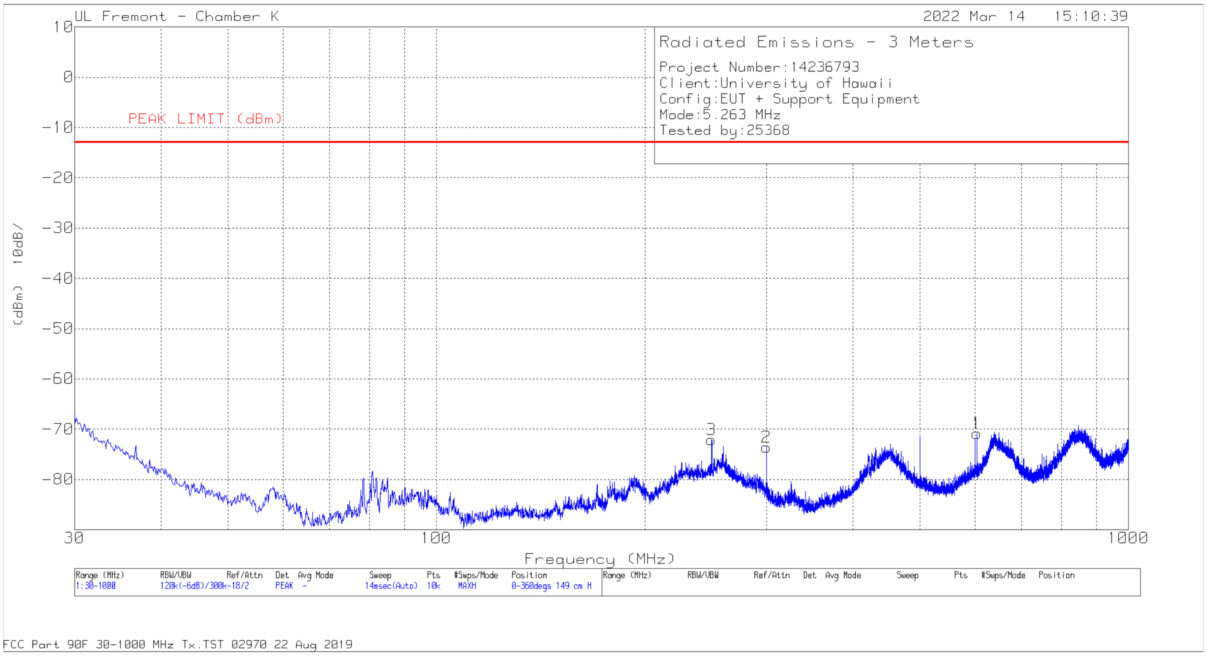
*Marker 1 is the fundamental signal.

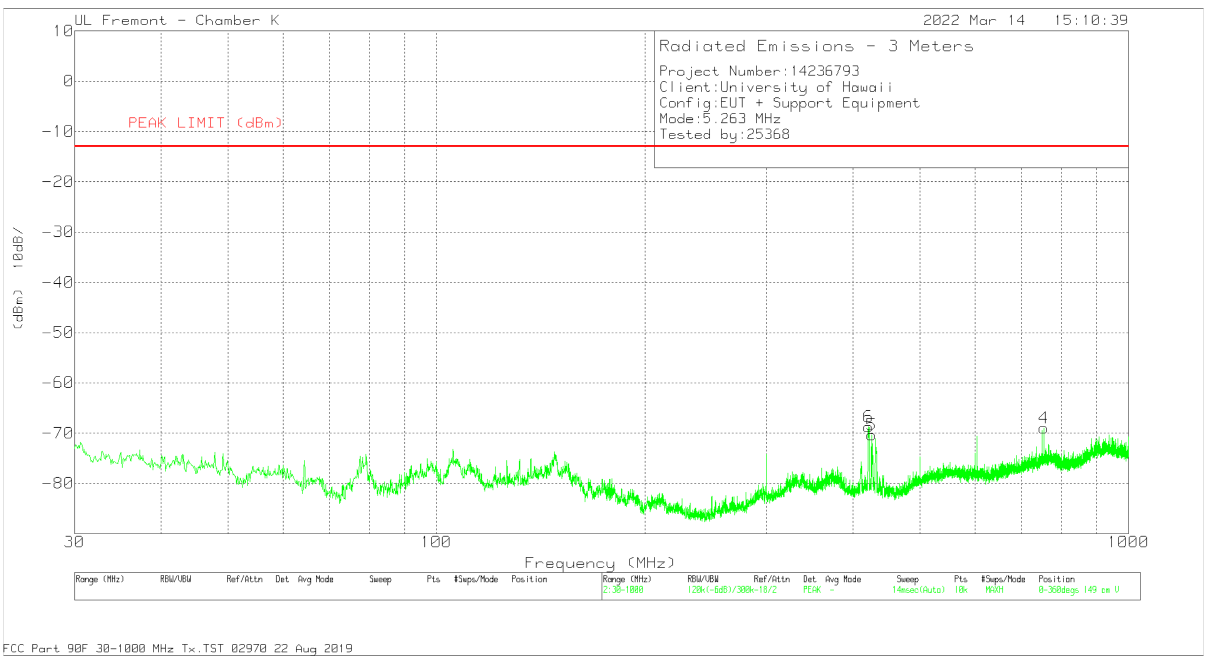
### Radiated Emissions – Final Data

| 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



## 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



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# 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

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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UL VERIFICATION SERVICES INC
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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 $8^{TH}$ - $17^{TH}$, 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 |

# 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,

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



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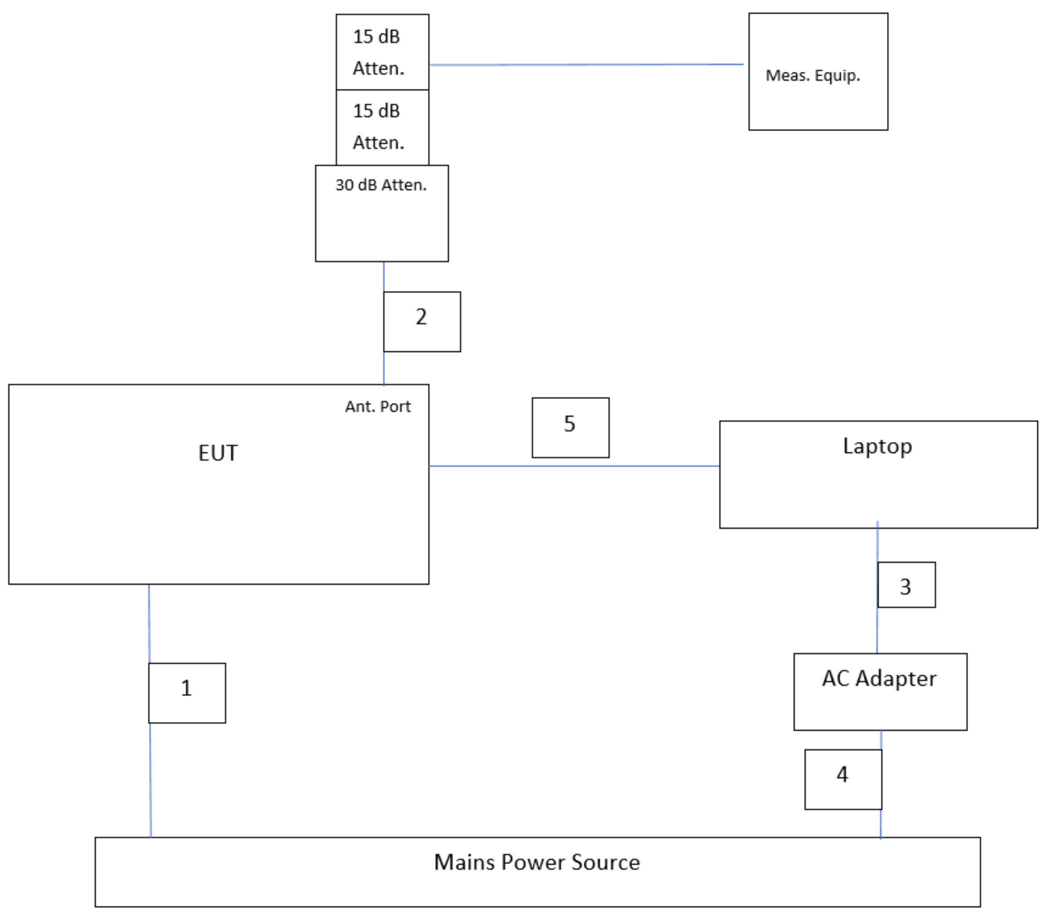
## SETUP DIAGRAMS FOR TESTS

### TX CONDUCTED RF TESTS



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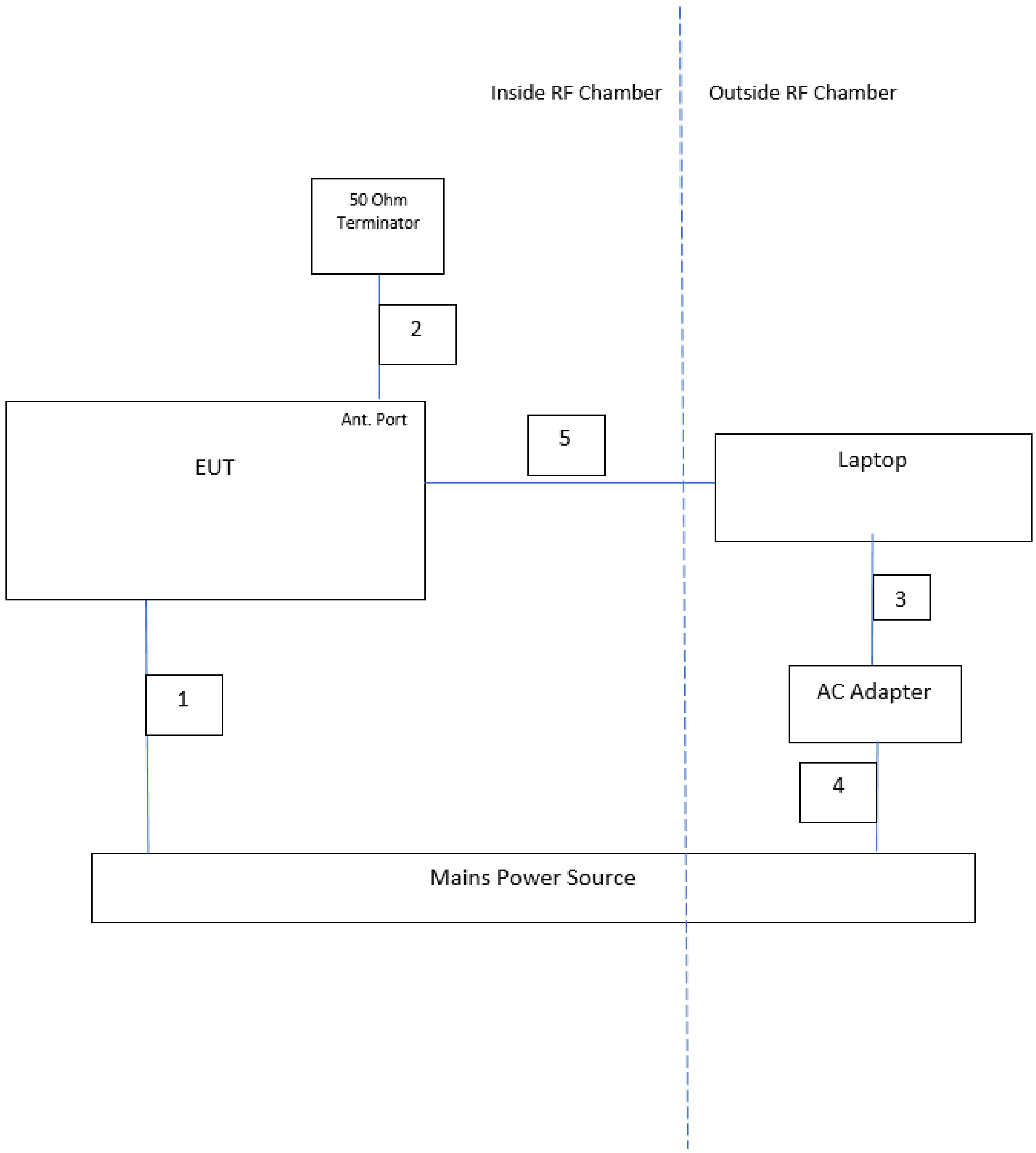
**TX RADIATED RF TESTS**



# 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 $F_c$ = 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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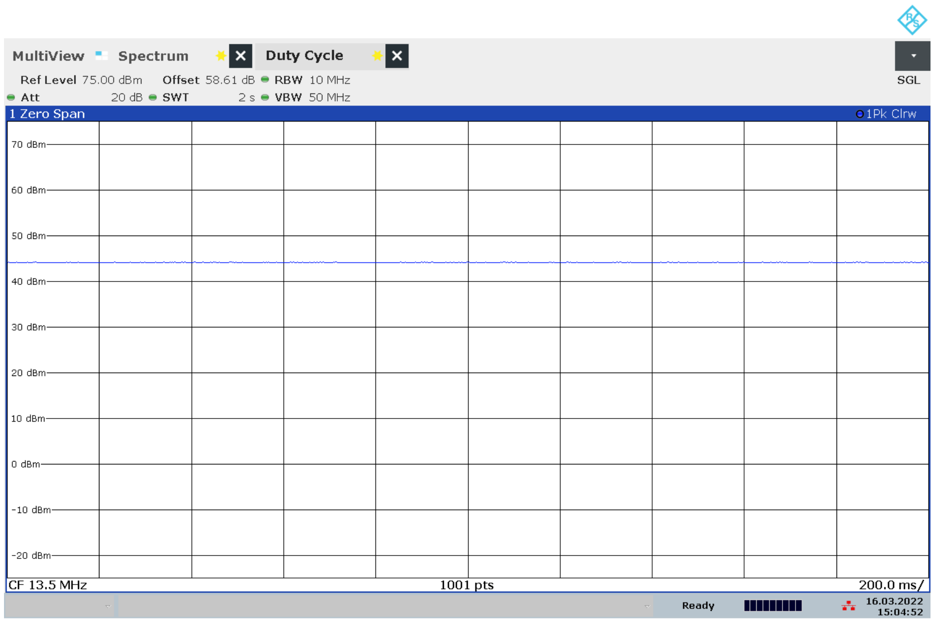
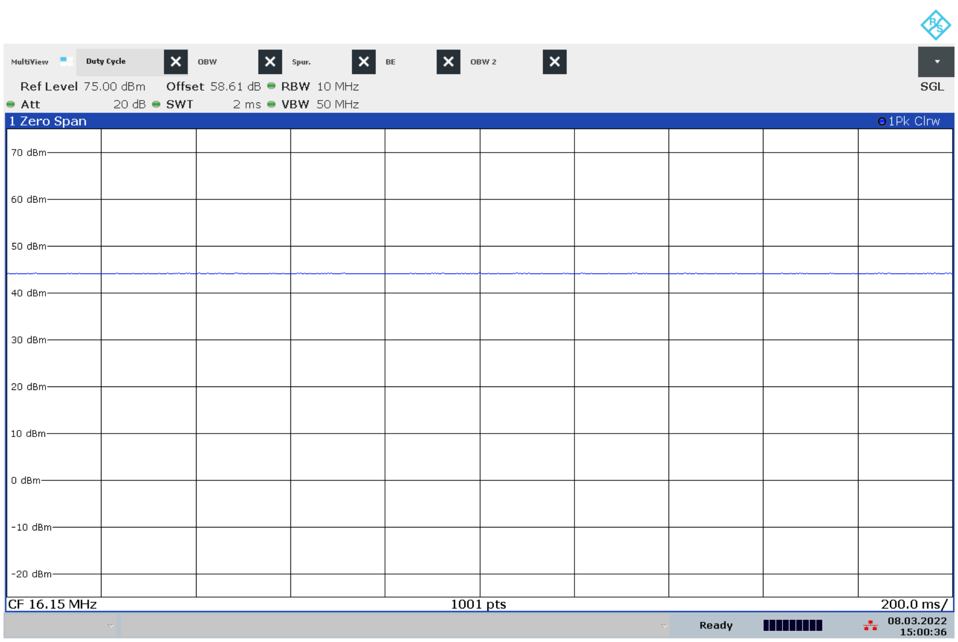
## 13.5 MHz CW Mode




15:04:52 16.03.2022

## 16.15 MHz CW Mode




15:00:37 08.03.2022



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## 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 |



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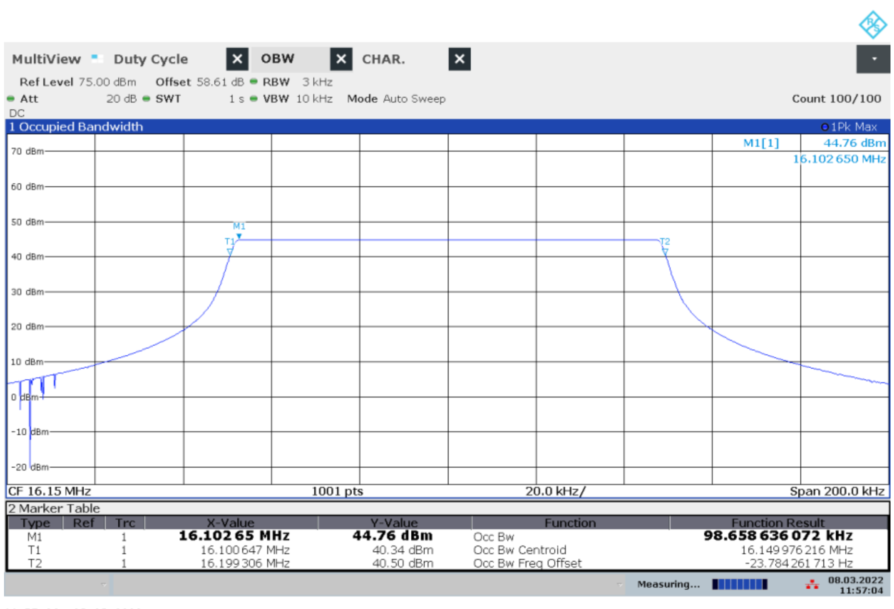
## 13.45 to 13.55 MHz Mode


## 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 | Meas. Peak | Cable Loss | EUT Ant. Gain | Peak EIRP | Peak EIRP | Limit | Pass or |
|---|---|---|---|---|---|---|---|---|
| | (MHz) | (dBm) | (dB) | (dBi) | (dBm) | (W) | (W) | 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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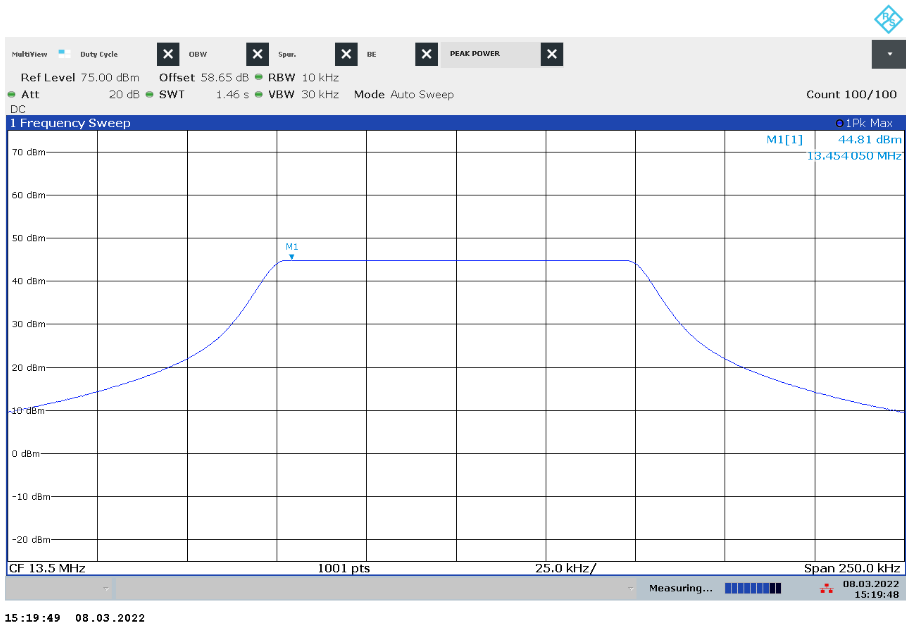
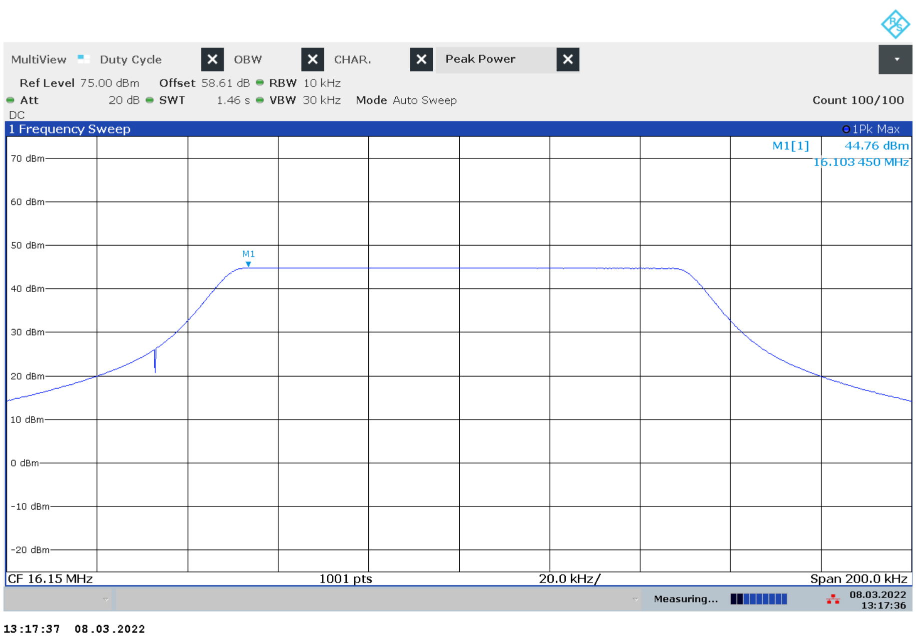
## 13.45 to 13.55 MHz Mode




## 16.10 to 16.20 MHz Mode



## 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,

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

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



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## 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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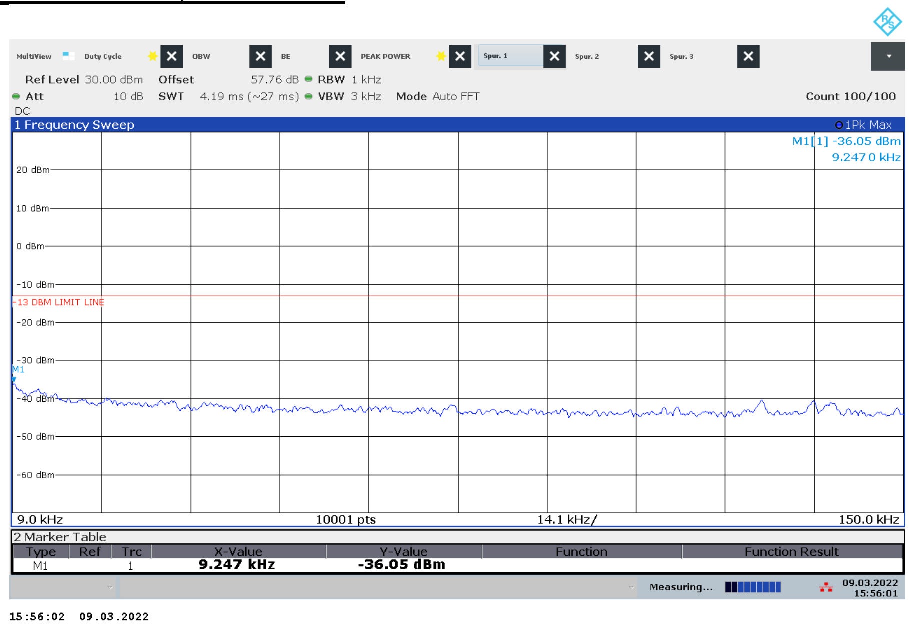
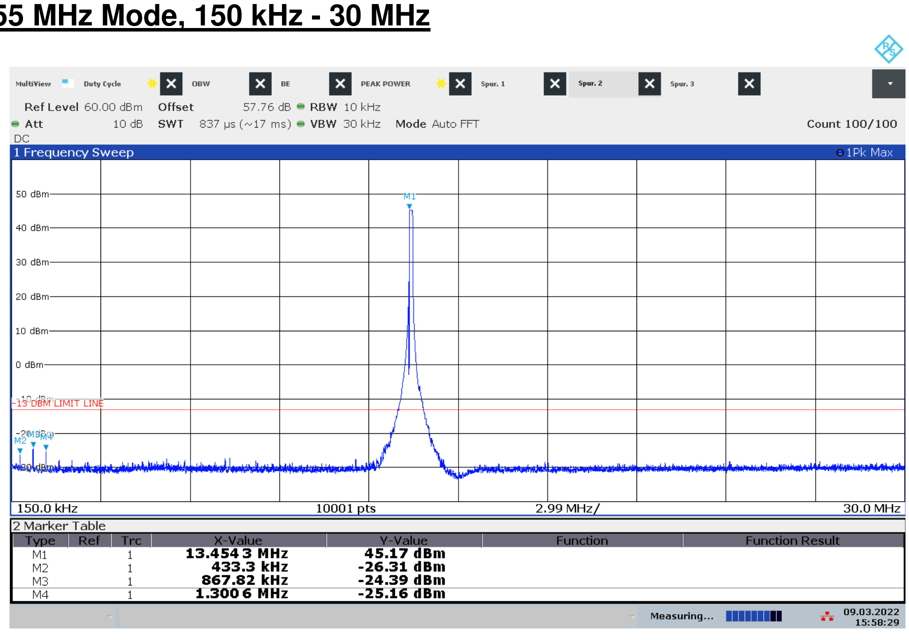
### 8.5.1. SPURIOUS EMISSIONS

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

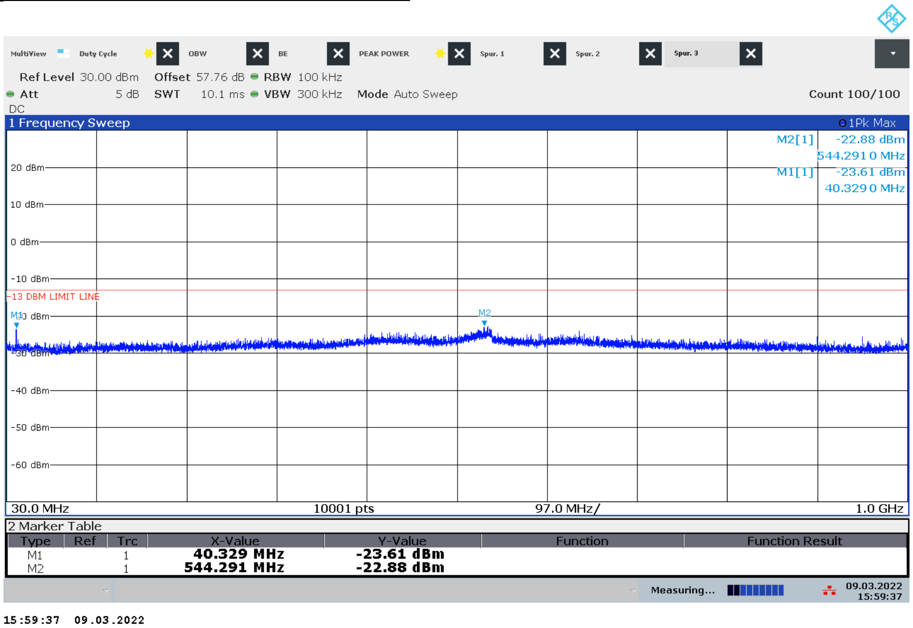



**13.45 to 13.55 MHz Mode, 150 kHz - 30 MHz**



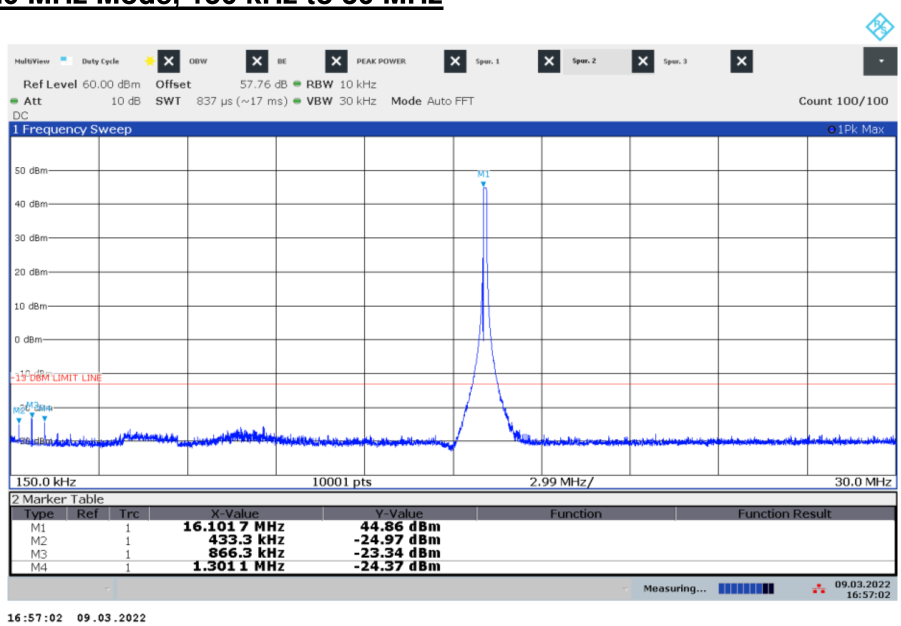

*Marker M1 is the fundamental signal.

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



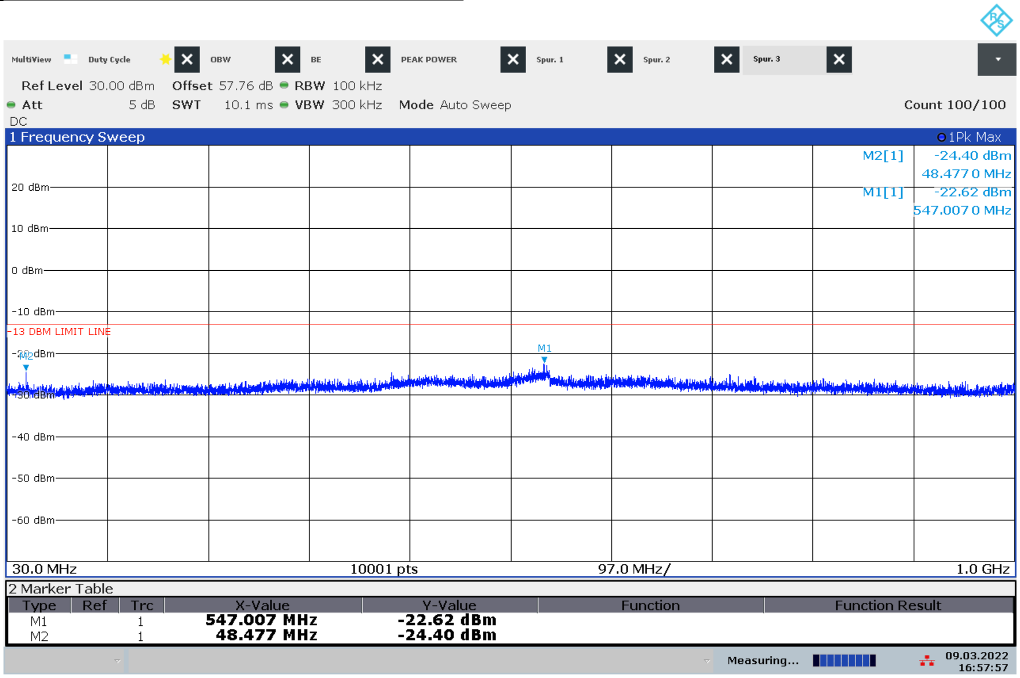
## 16.10 to 16.20 MHz Mode, 9 - 150 kHz


## 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

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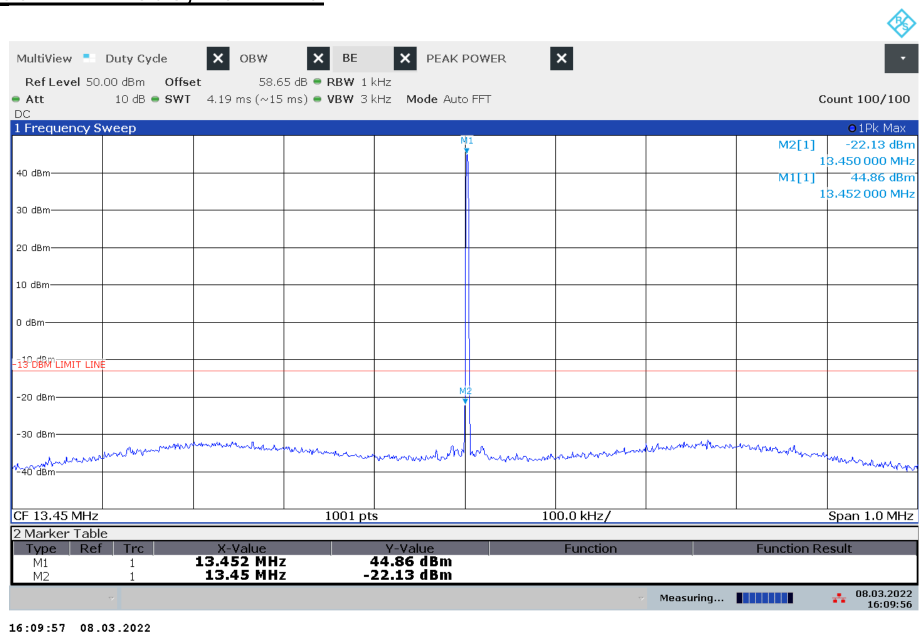
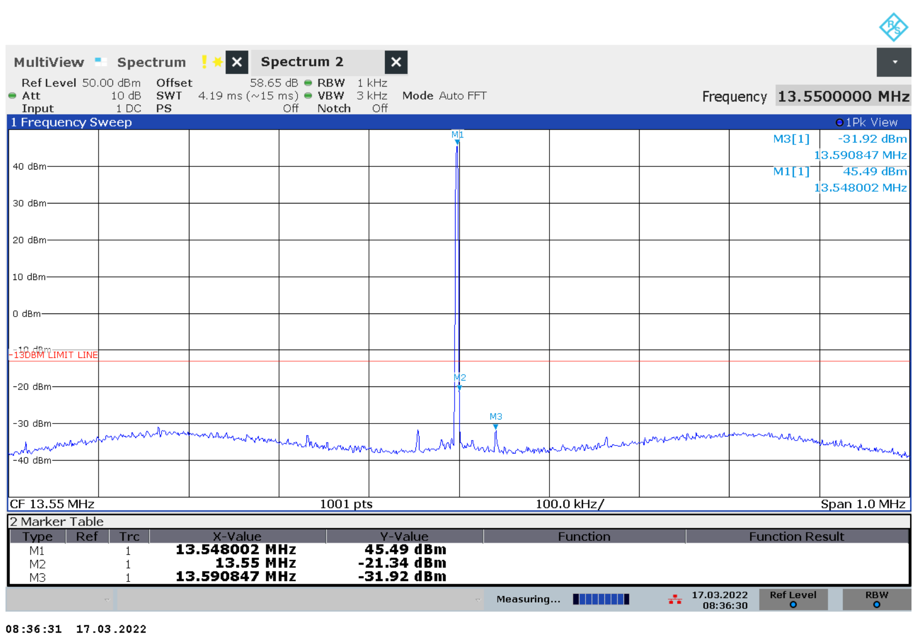
## 8.5.2. BAND EDGE

### 13.45 to 13.55 MHz Mode, Low End




### 13.45 to 13.55 MHz Mode, High End



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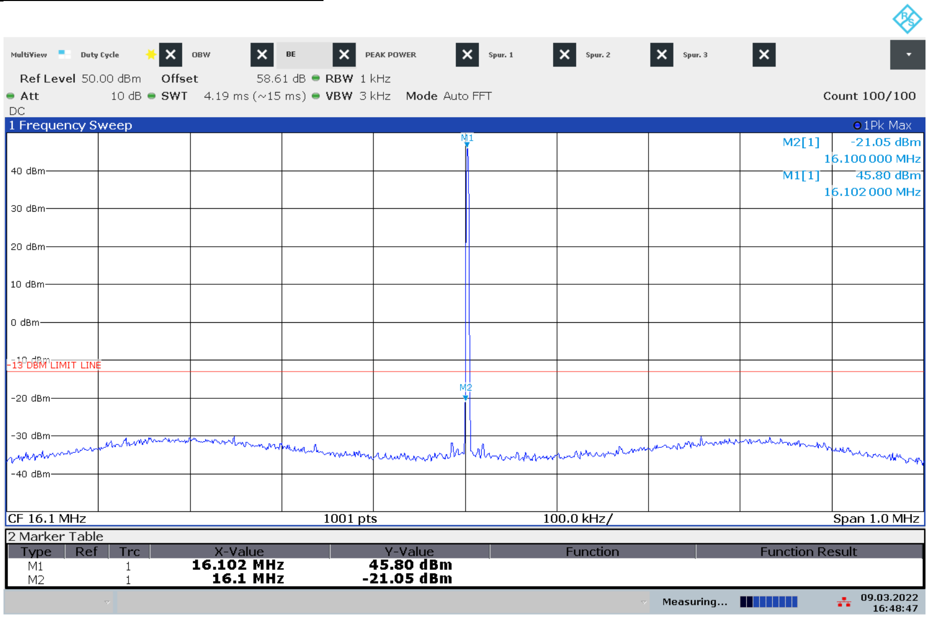
## 16.10 to 16.20 MHz Mode, Low End

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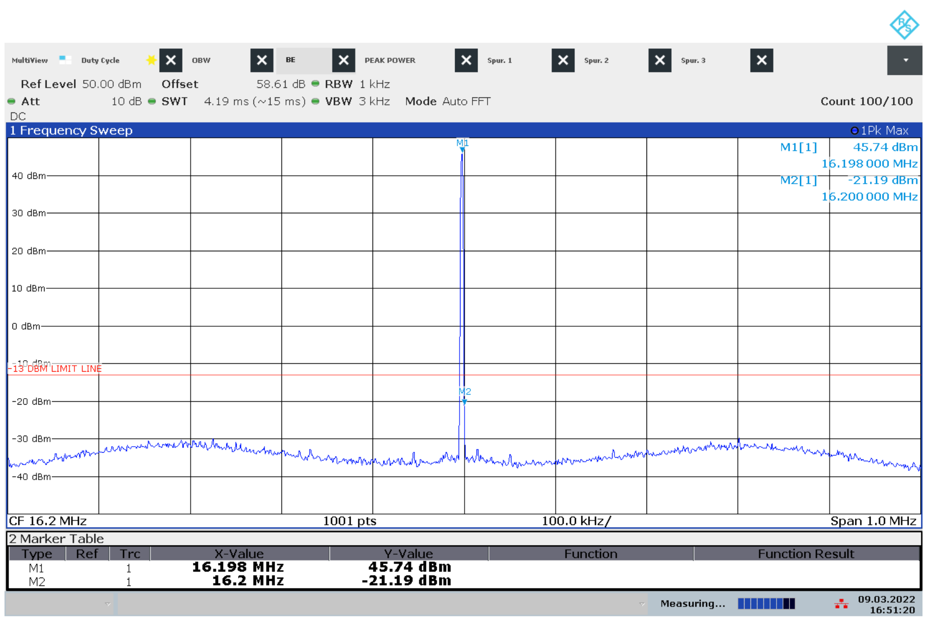
## 16.10 to 16.20 MHz Mode, High End




16:51:20 09.03.2022



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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,

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

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



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**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



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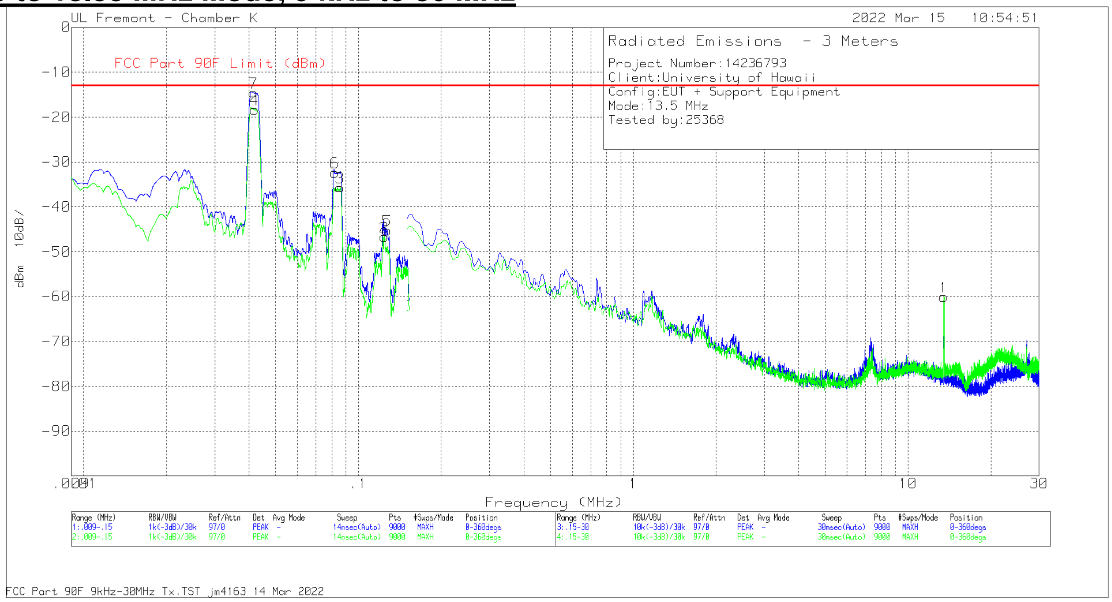
## 13.45 to 13.55 MHz Mode, 9 kHz to 30 MHz




### 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.

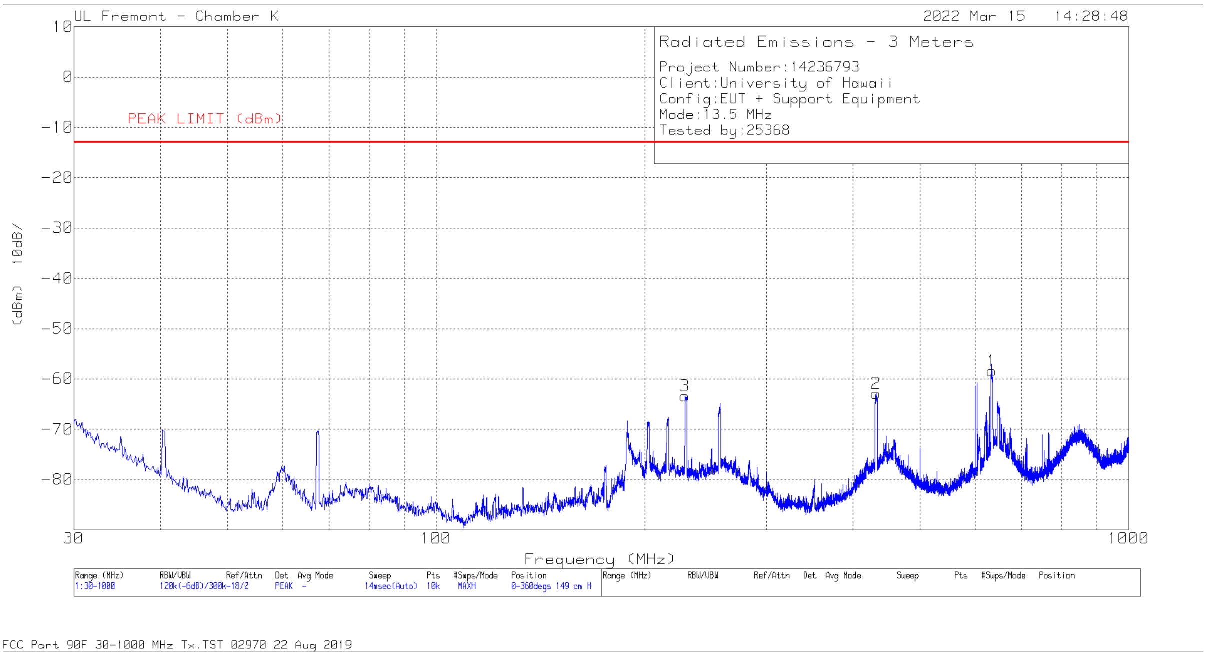
*Marker 1 is the fundamental signal.

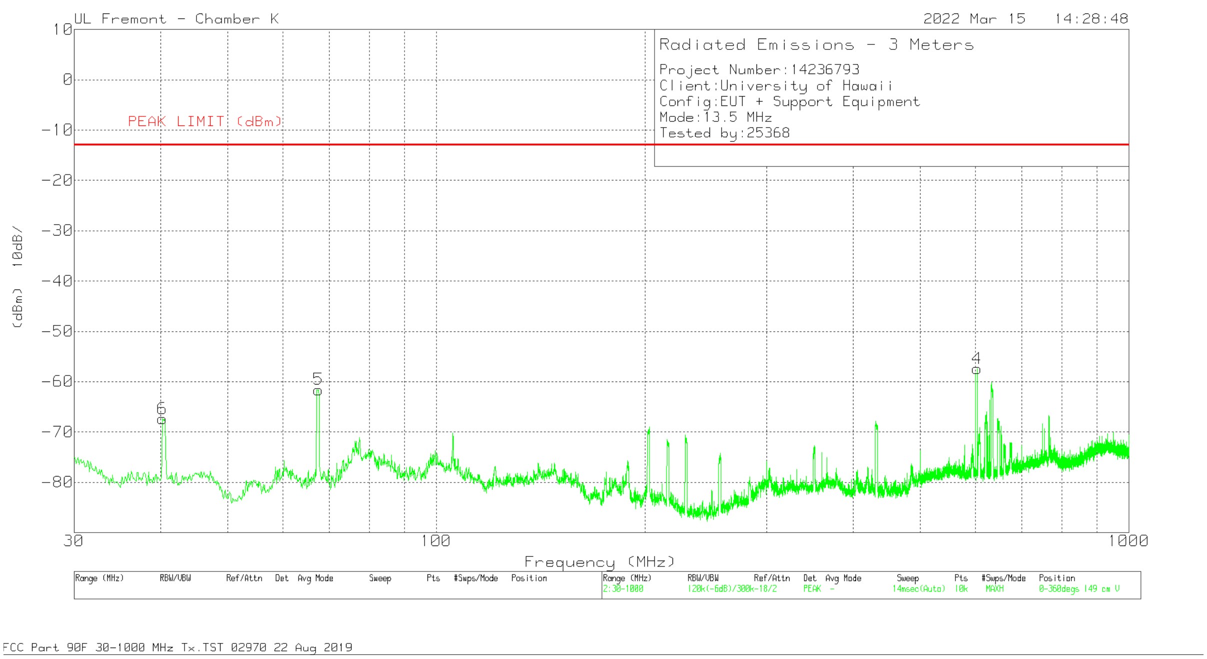
### Radiated Emissions – Final Data

| 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



## 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



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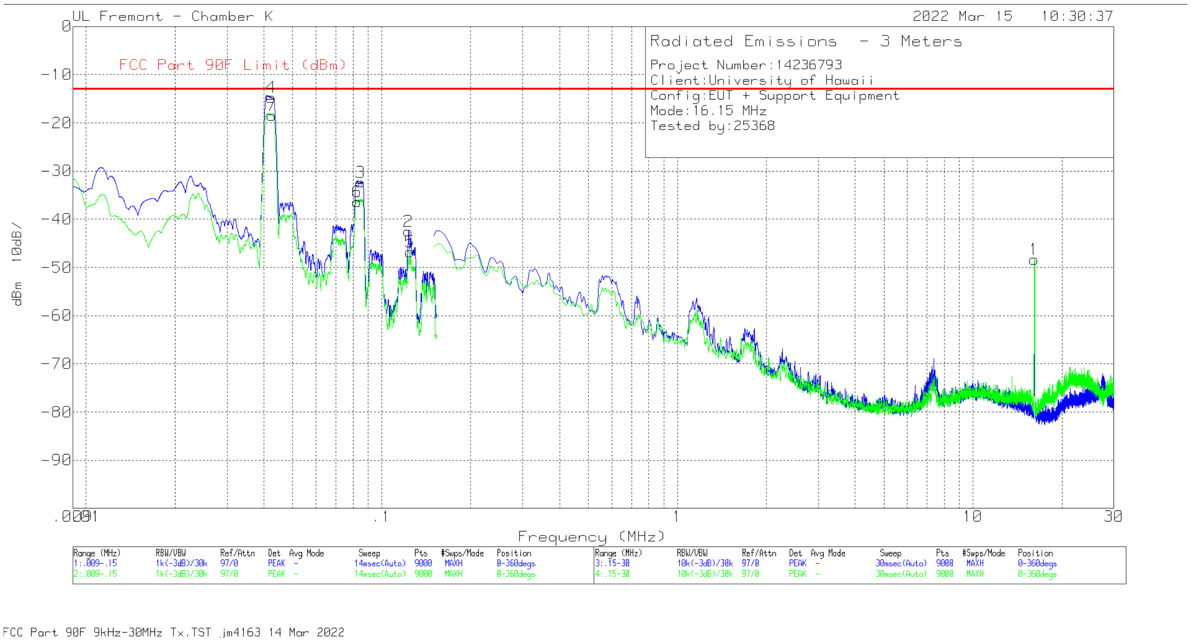
## 16.10 to 16.20 MHz Mode, 9 kHz to 30 MHz




### 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 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



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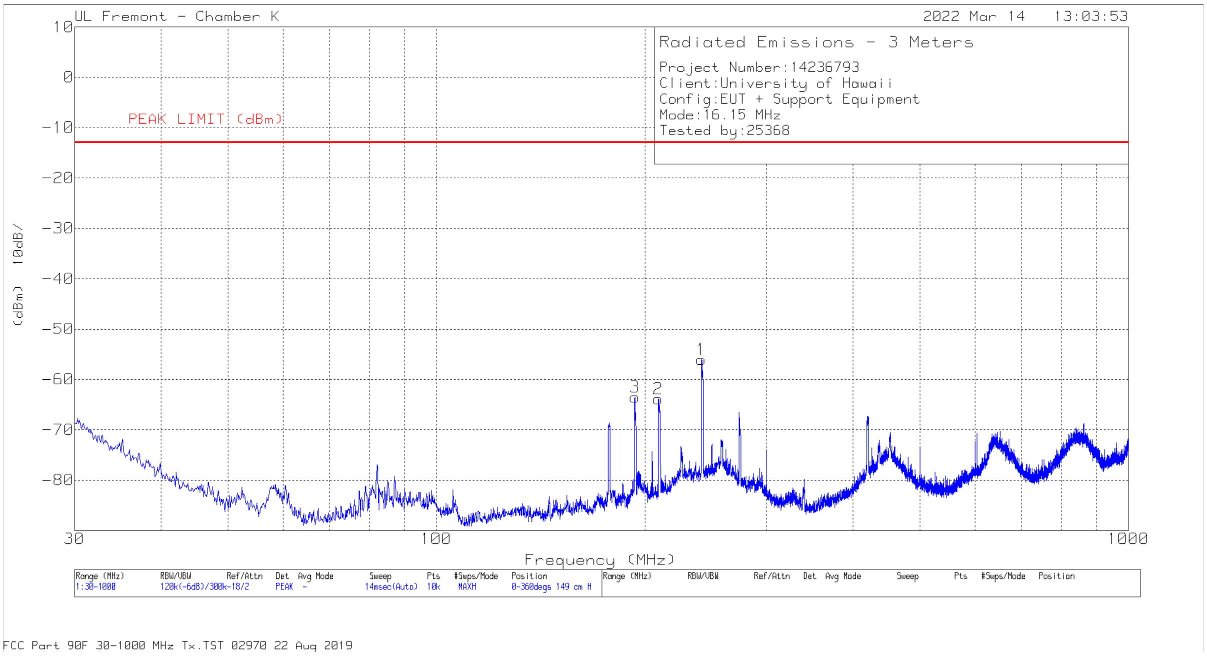
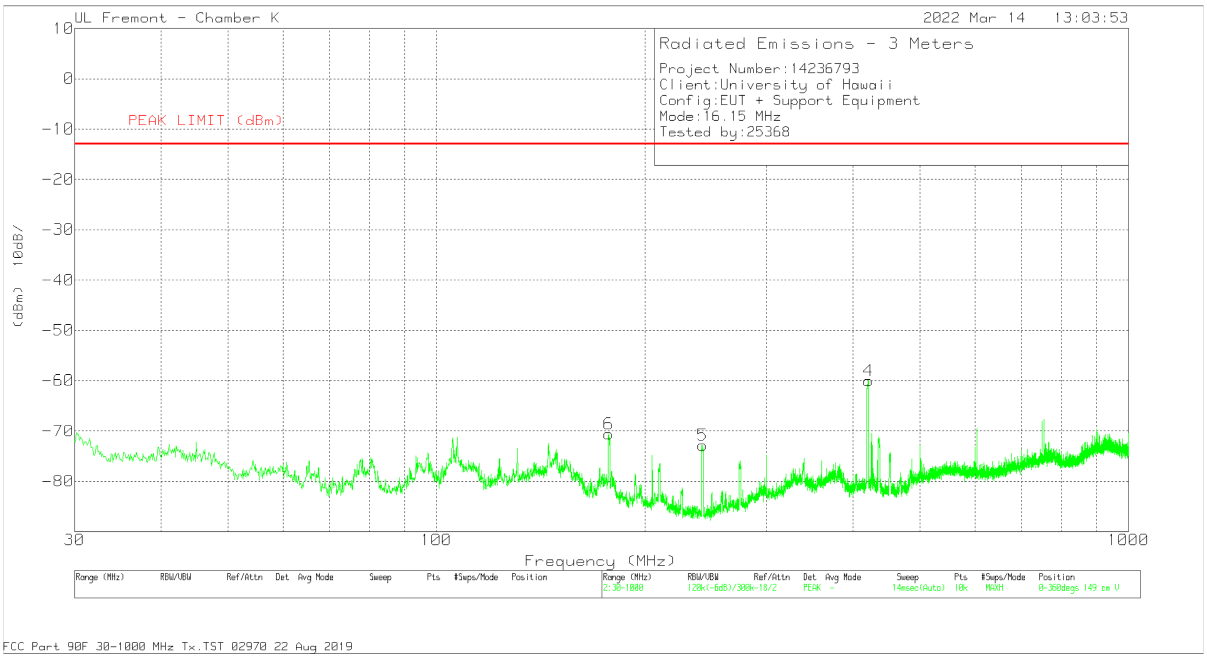
**16.10 to 16.20 MHz Mode, 30 to 1000 MHz**



## 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



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# 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 |



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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 $8^{TH}$ - $15^{TH}$, 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.



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

# 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 |

# 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.



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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) |
|---|---|---|---|
| 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.



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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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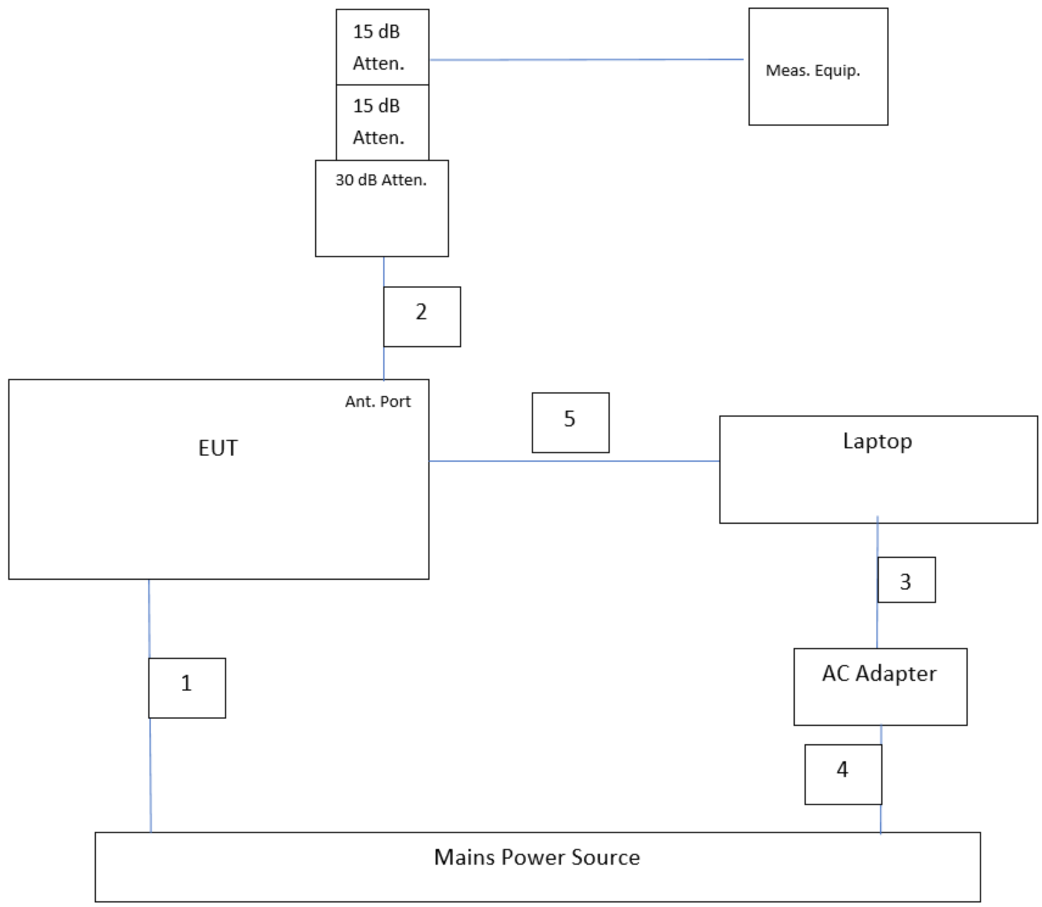
**SETUP DIAGRAMS FOR TESTS**

**TX CONDUCTED RF TESTS**



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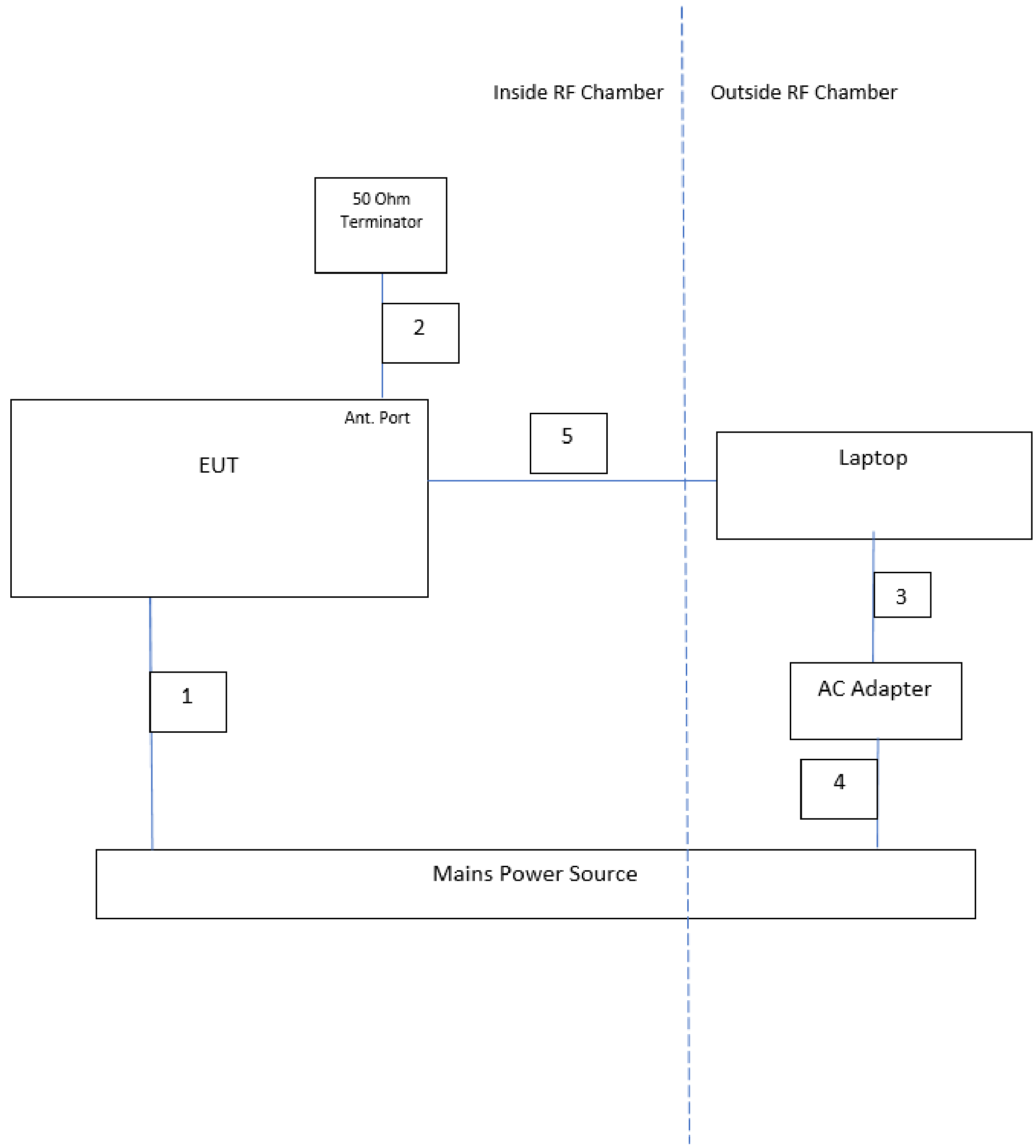
**TX RADIATED RF TESTS**



# 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 $F_c$ = 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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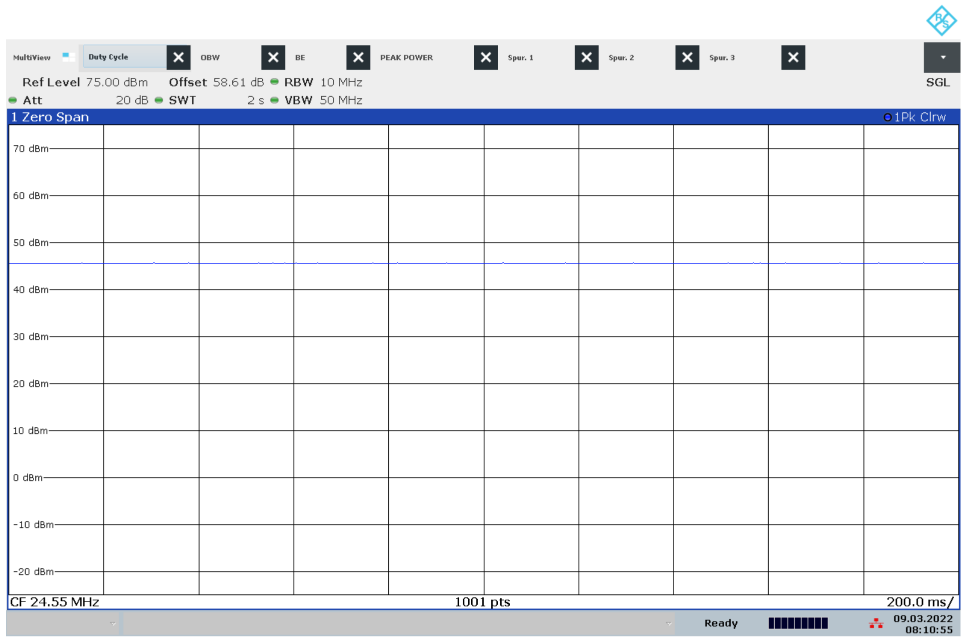
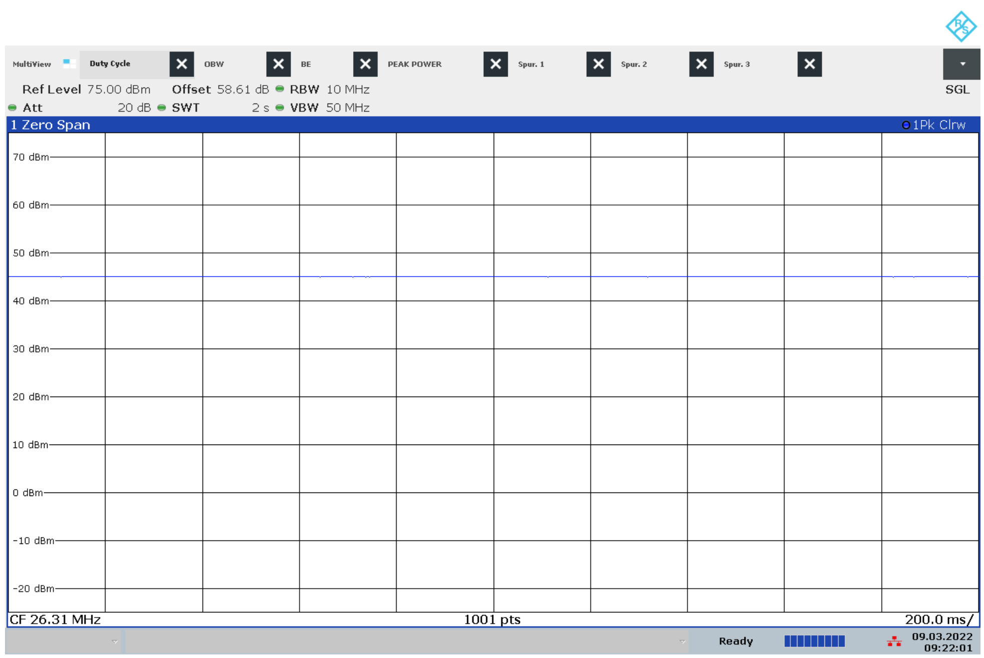
## 24.55 MHz CW Mode




08:10:55 09.03.2022

## 26.31 MHz CW Mode

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## 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 |

## 24.45 – 24.65 MHz Mode


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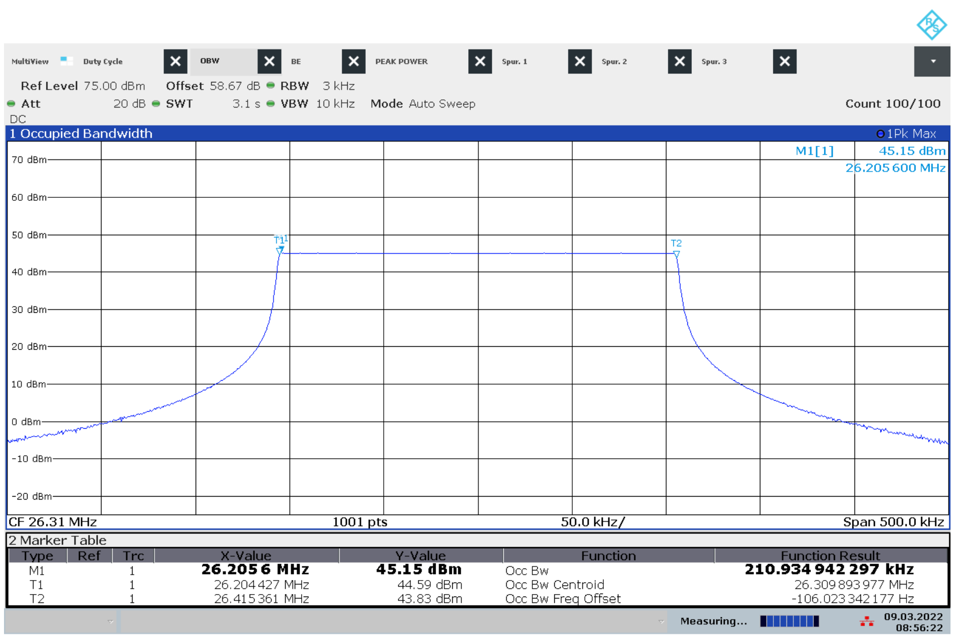
## 26.20 – 26.42 MHz Mode

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## 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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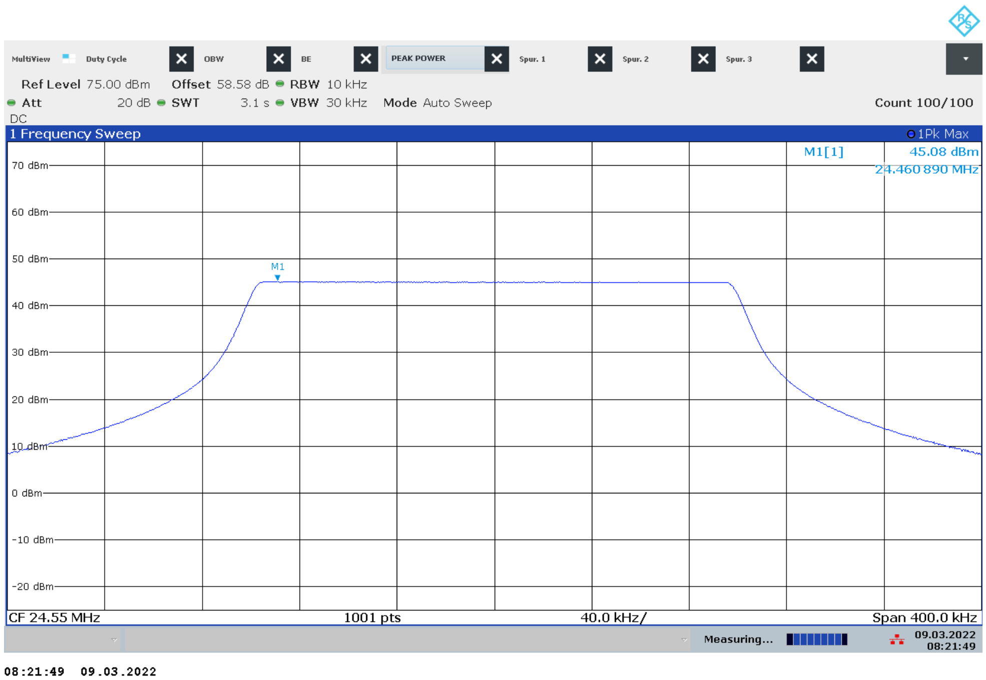
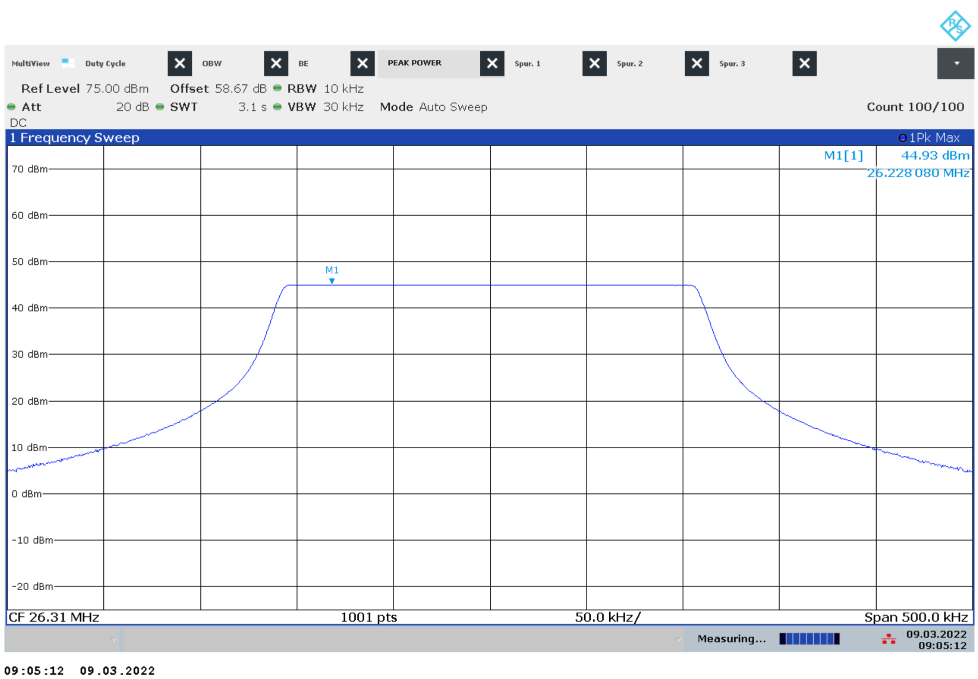
## 24.45 to 24.65 MHz Mode




## 26.20 to 26.42 MHz Mode



## 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.



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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

| 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 |



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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 = $10 \times (26.42\ MHz) = 264.20\ MHz$
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,

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

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



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**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.

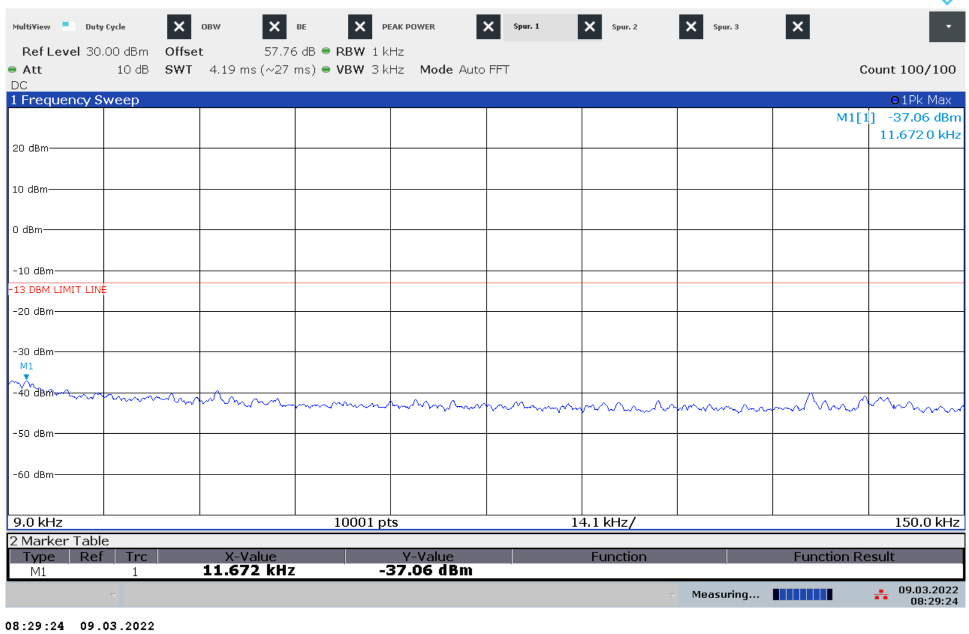
**RESULTS**

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

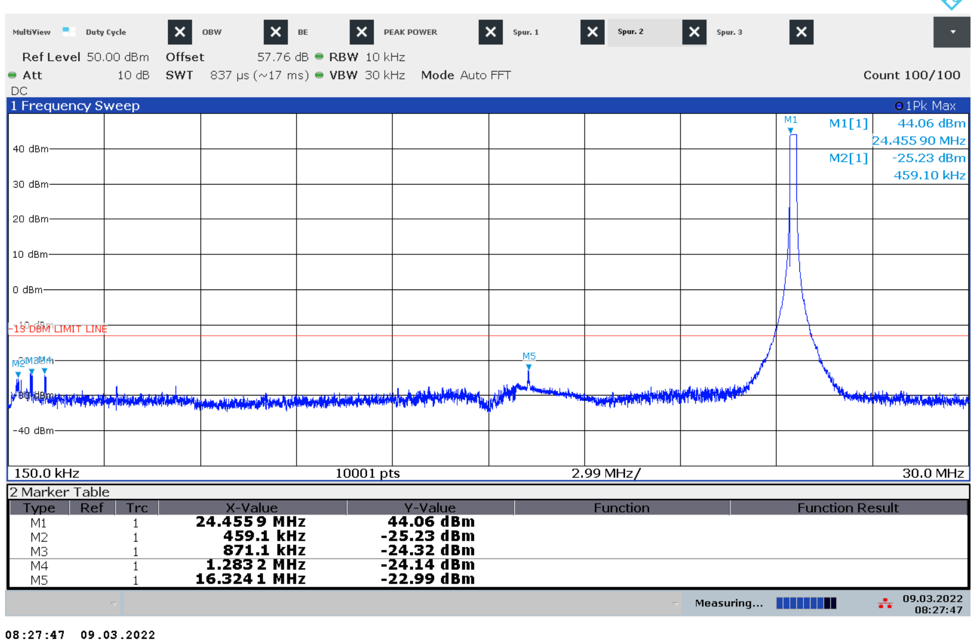
| Mode | 9 - 150 kHz | 150 kHz - 30 MHz | 30 MHz - 1 GHz | Bandedge |
|---|---|---|---|---|
| 24.45 – 24.65 MHz | Pass | Pass | Pass | Pass |
| 26.20 – 26.42 MHz | Pass | Pass | Pass | Pass |

### 8.5.1. SPURIOUS EMISSIONS

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




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




*Marker M1 is the fundamental signal.



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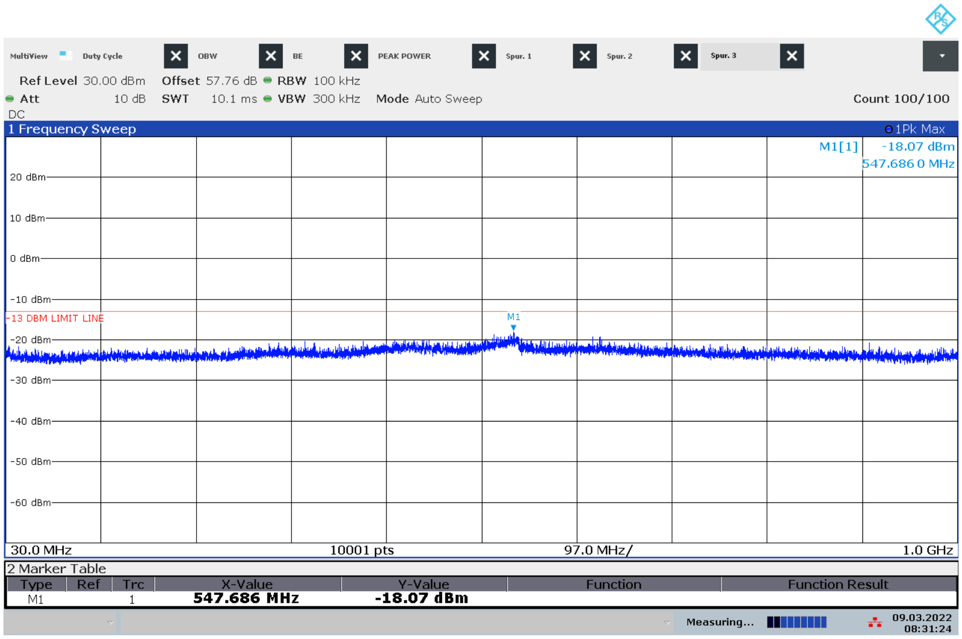
## 24.45 to 24.65 MHz Mode, 30 MHz - 1 GHz

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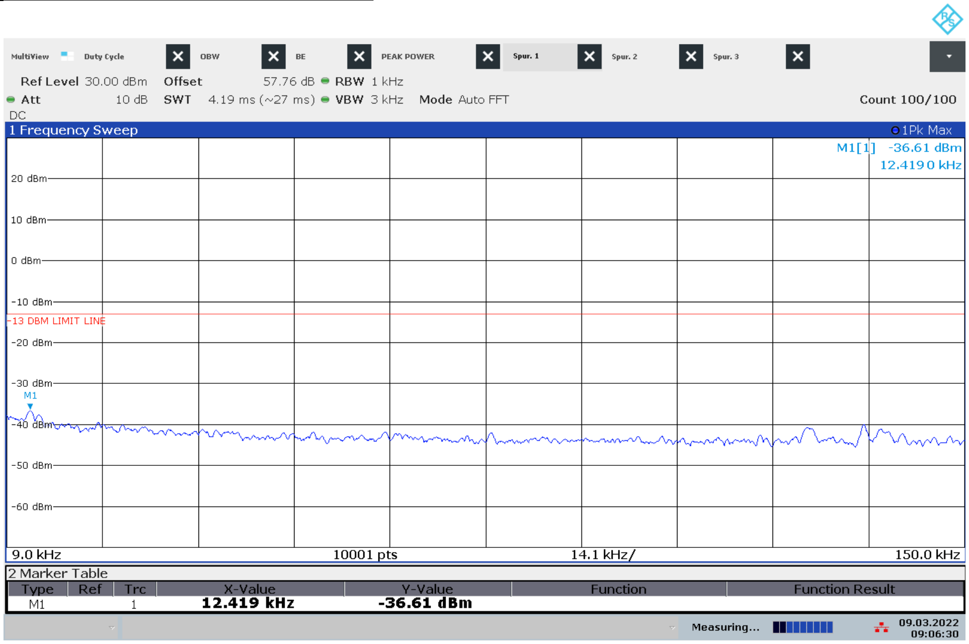
## 26.20 to 26.42 MHz Mode, 9 - 150 kHz

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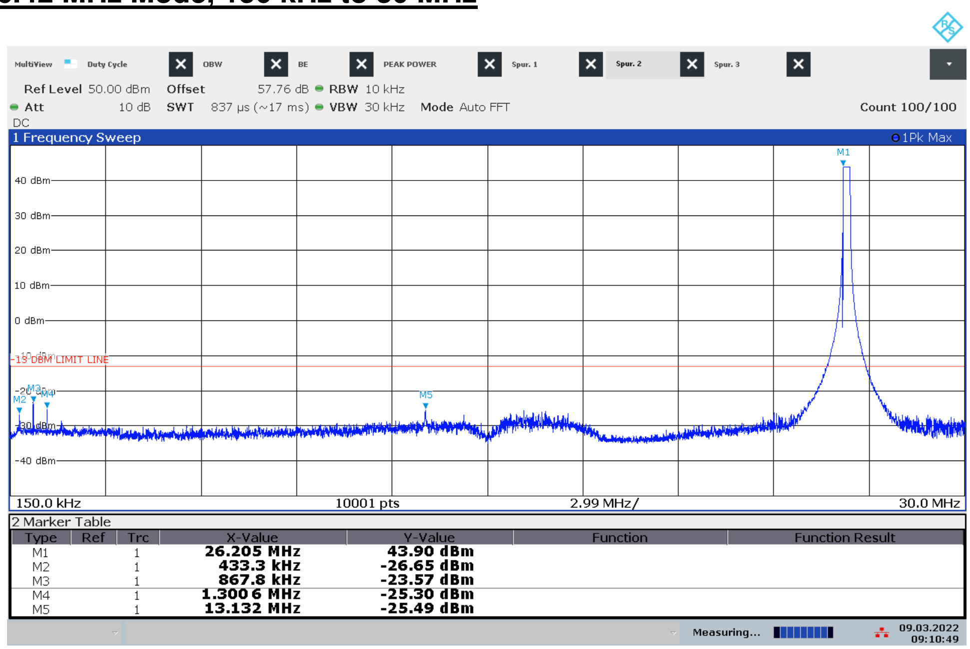
## 26.20 to 26.42 MHz Mode, 150 kHz to 30 MHz

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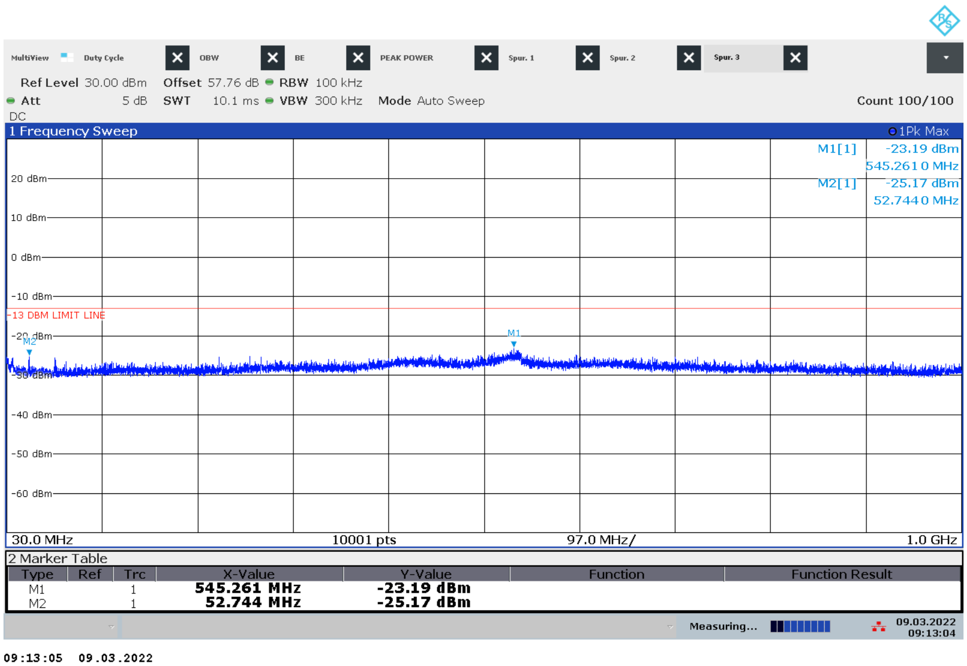
*Marker M1 is the fundamental signal.

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



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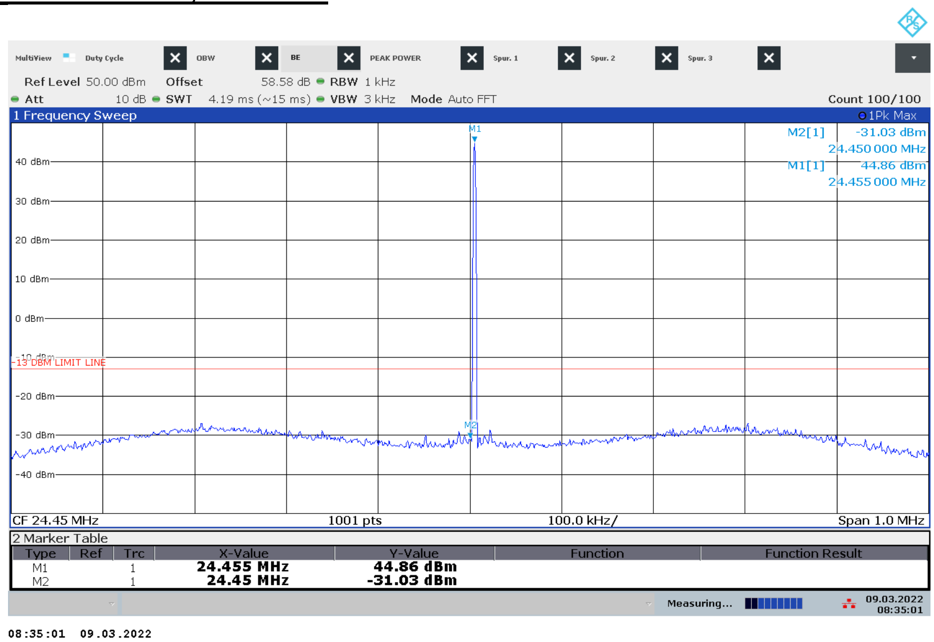
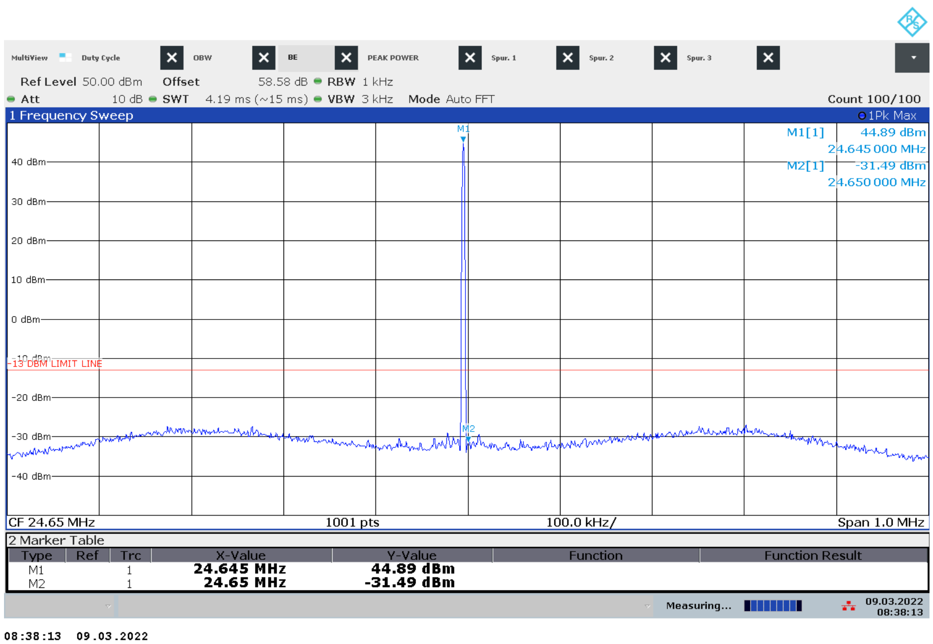
### 8.5.2. BAND EDGE

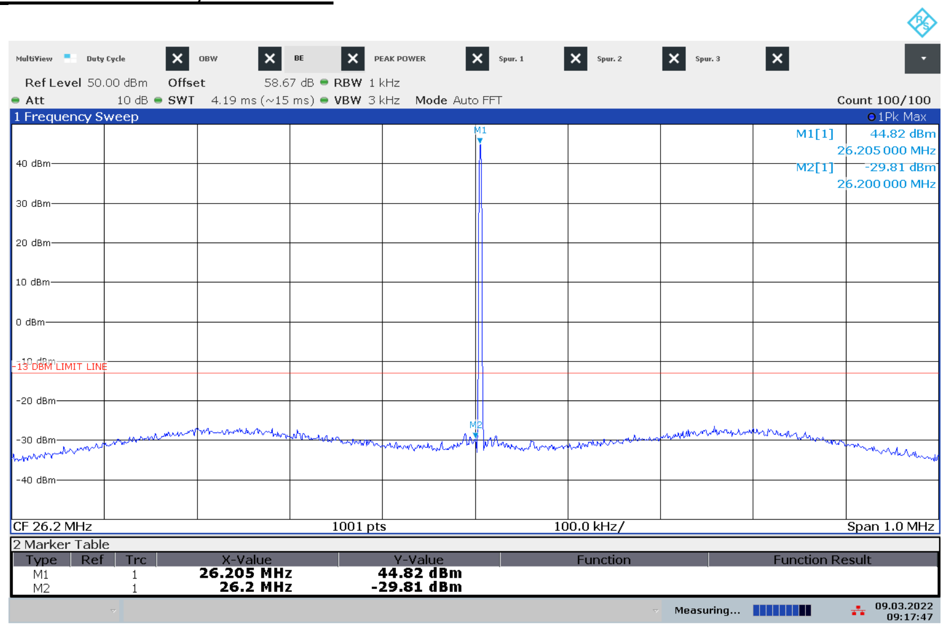
**24.45 to 24.65 MHz Mode, Low End**




**24.45 to 24.65 MHz Mode, High End**



## 26.20 to 26.42 MHz Mode, Low End

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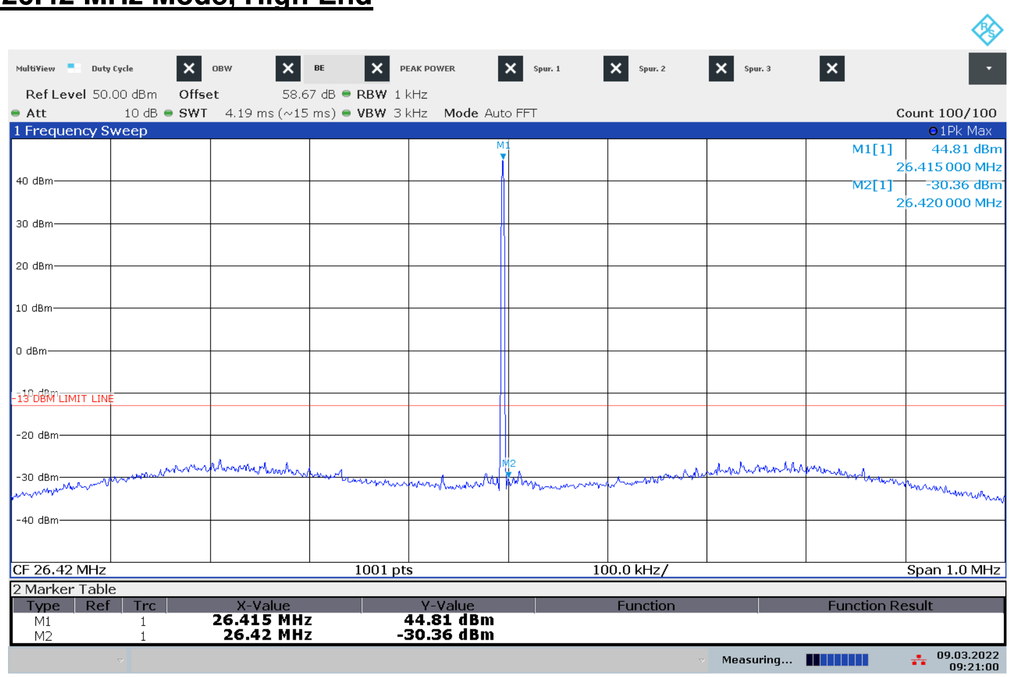
## 26.20 to 26.42 MHz Mode, High End

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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,

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

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



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**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:

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

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

**RESULTS**

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



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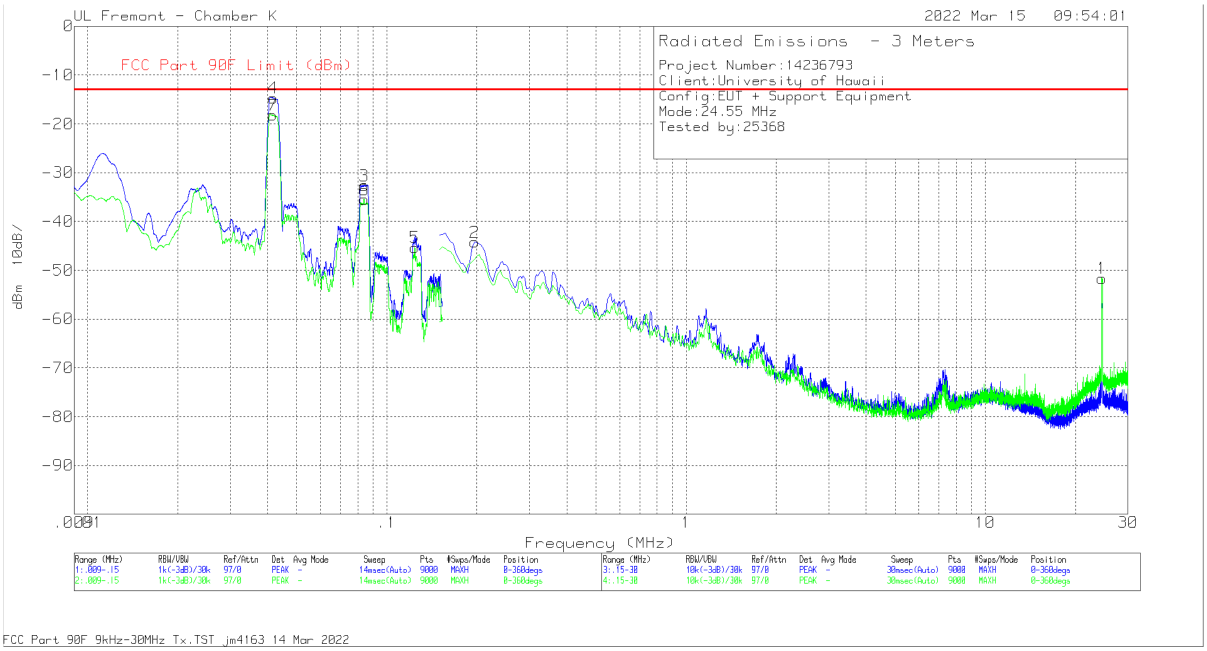
## 24.45 – 24.65 MHz Mode, 9 kHz to 30 MHz




### 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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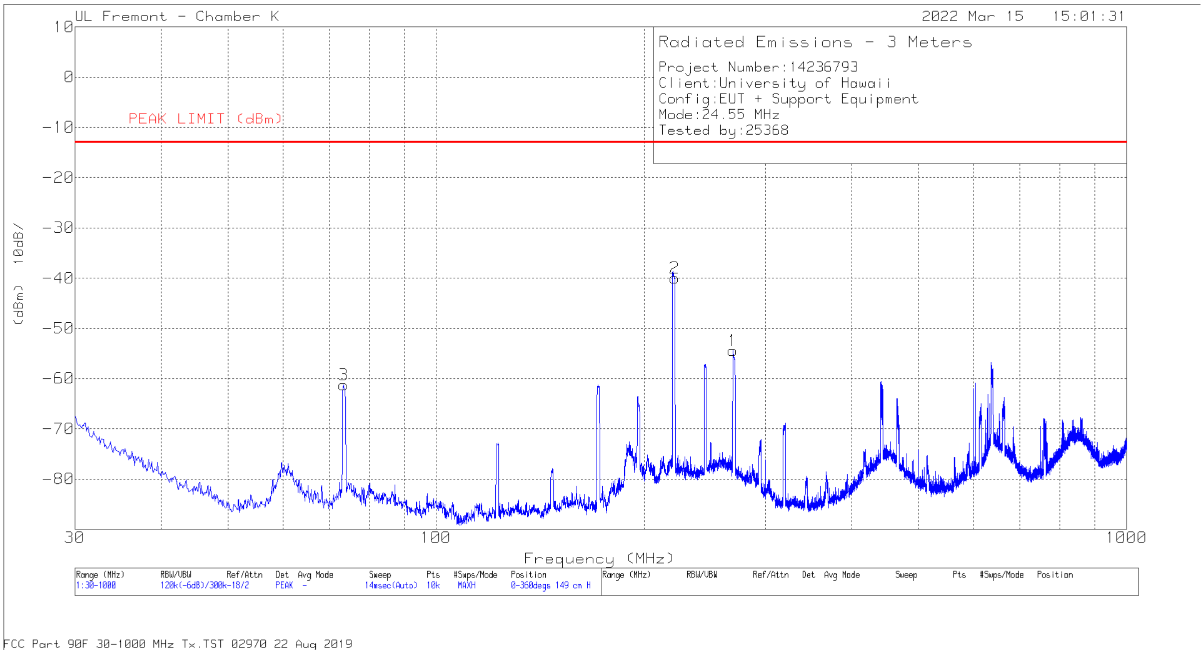
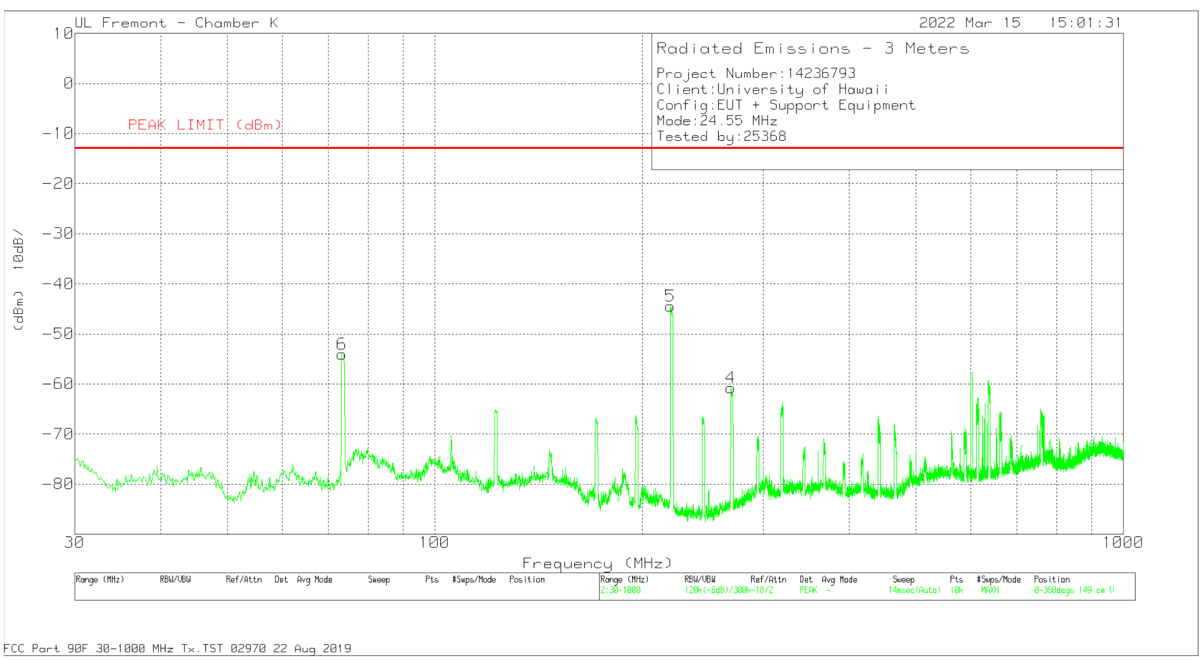
## 24.45 – 24.65 MHz Mode, 30 to 1000 MHz



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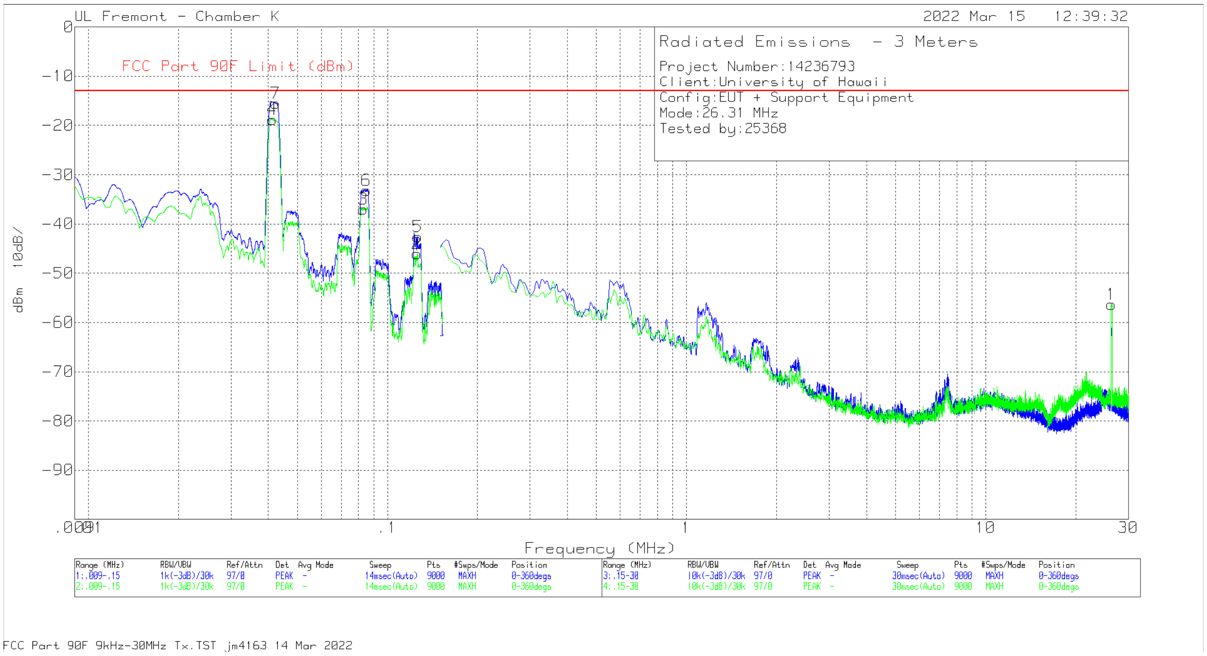
## 26.20 to 26.42 MHz Mode, 9 kHz to 30 MHz




### 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.

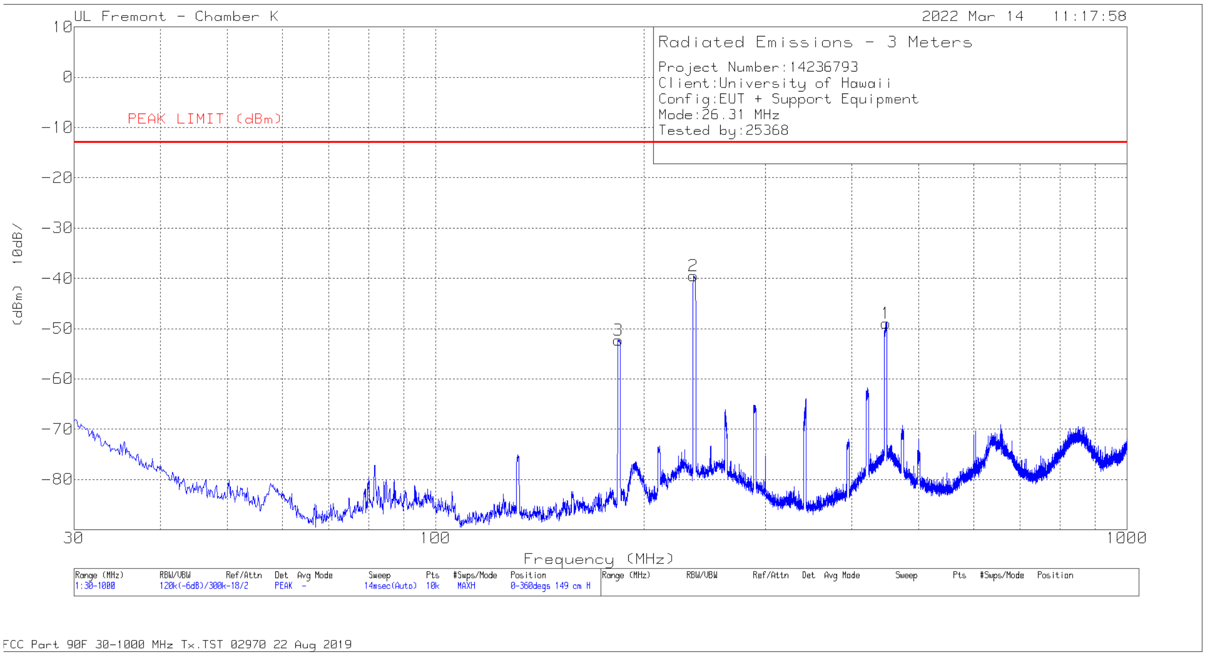
*Marker 1 is the fundamental signal.

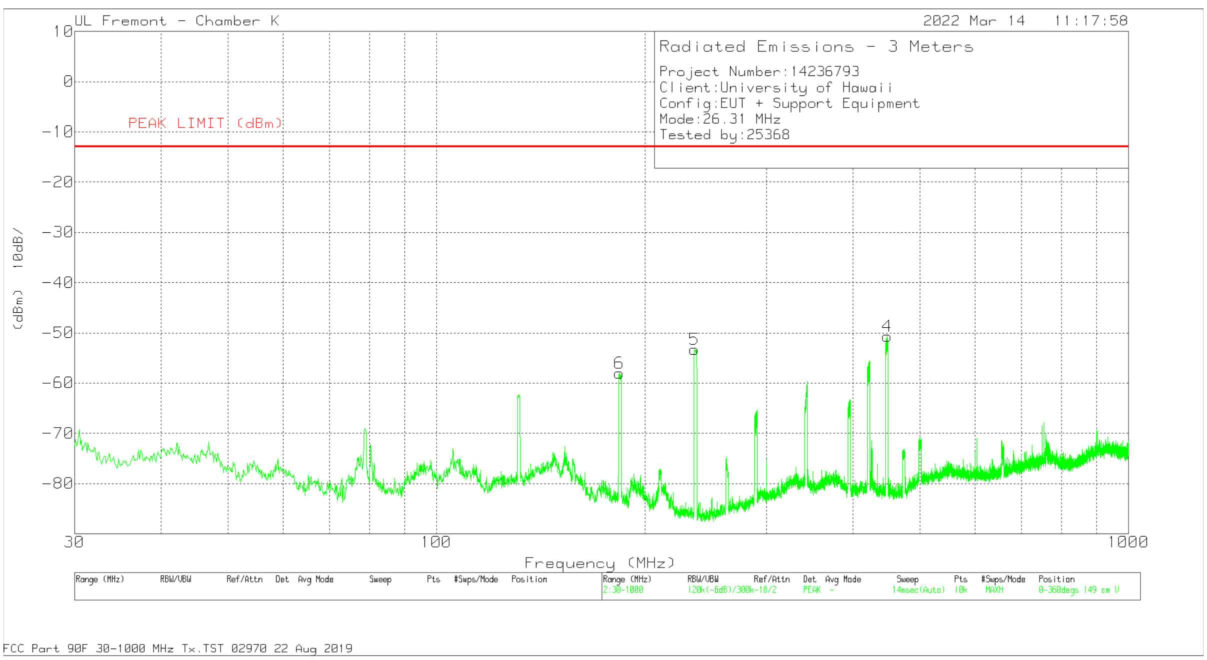
### Radiated Emissions – Final Data

| 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



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## 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


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