# FCC & ISED Canada Certification Test Report

for the

## Guideline Geo AB
## MIRA Compact

## FCC ID: QLA-MIRA500
## IC ID: 25943-MIRA500

## WLL REPORT# 18262-01 REV 1

Prepared for:

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Testing Certificate AT-1448

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July 27, 2023

WLL Report# 18262-01 Rev 1

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# Abstract

This report has been prepared on behalf of Guideline Geo AB to support the attached Application for Equipment Authorization. The test report and application are submitted for an Intentional Radiator under Part 15.509 of the FCC Rules and Regulations current at the time of testing and Innovation, Science and Economic Development (ISED) Canada Spectrum Management and Telecommunications Policy RSS-220, Issue 1 (3/2009). This Certification Test Report documents the test configuration and test results for the Guideline Geo AB Ultra-Wideband (UWB) Transmitter (FCC ID: QLA-MIRA500 // ISED ID: 25943-MIRA500). The information provided on this report is only applicable to device herein documented, as the EUT.

Radiated testing was performed in the Free-space Anechoic Chamber Test-site (FACT) 3m chamber of Washington Laboratories, Ltd., located at 4840 Winchester Boulevard, Suite #5. Frederick, MD 21703. Site description and site attenuation data have been placed on file with the FCC's Sampling and Measurements Branch at the FCC laboratory in Columbia, MD.

Washington Laboratories, Ltd. has been accepted by the FCC and approved by ANAB under Certificate AT-1448 as an independent FCC test laboratory (ISED Canada number 3035A).

The Guideline Geo AB, MIRA Compact complies with the requirements for an Intentional Radiator under FCC Part 15.509 and RSS-220 Issue 1 (3/2009).

| Revision History | Description of Change | Date |
|---|---|---|
| Rev 0 | Initial Release | July 27, 2023 |
| Rev 1 | TCB Comments, Dated: 9/22/2023 | September 25, 2023 |

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# 1 Introduction

## 1.1 Compliance Statement

The Guideline Geo AB, MIRA Compact complies with the requirements for an Intentional Radiator under FCC Part 15.509 and RSS-220 Issue 1 (3/2009).

## 1.2 Test Scope

Tests for radiated emissions were performed. All measurements were performed in accordance with ANSI C63.10. The measurement equipment conforms to ANSI C63.2 Specifications for Electromagnetic Noise and Field Strength Instrumentation.

## 1.3 Contract Information

| | |
|---|---|
| Customer: | Guideline Geo AB |
| Purchase Order Number: | 45066 |
| Quotation Number: | 74062B |

## 1.4 Test and Support Personnel

| | |
|---|---|
| Washington Laboratories, LTD | Ryan Mascaro |
| Customer Representative | Per Westholm and Johan Friborg |

## 1.5 Test Dates

The MIRA Compact, UWB Ground Penetrating Radar (GPR) was tested during the following dates: 7/20/2023 to 7/25/2023.

# 2 Equipment Under Test

## 2.1 EUT Identification and Technical Details

Table 1: Device Summary

| | | |
|---|---|---|
| Manufacturer: | Guideline Geo AB | |
| FCC ID: | QLA-MIRA500 | |
| ISED ID: | 25943-MIRA500 | |
| HVIN: | 21-005995 | |
| Rule Parts: | FCC: §15.509 | ISED: RSS-220 |
| FCC Emission Designator: | 373MDXN | |
| IC Emission Designator: | 643MDXN | |
| UWB Transmit Frequencies (worst-case) | $F_L$ | 34.40 MHz |
| | $F_M$ | 220.46 MHz |
| | $F_H$ | 547.60 MHz |
| Occupied Bandwidth: | 10dB | 373.30 MHz (minimum) |
| | 99% | 642.8 MHz (maximum) |
| Keying: | Automatic | |
| Modulation or Protocol: | Impulse Excitation (UWB) | |
| Type of Information: | Imaging, Radar | |
| 3m Radiated Field Strength: | Peak: 58.55 dBuV/m | |
| 3m EIRP (from FS): | Peak: -36.70 dBm/MHz | |
| Worst-Case Unwanted Emission: | 319.97 MHz, 45.083 dBuV/m Quasi-Peak (0.917 dB under the limit) | |
| Power Density for Canada: | .00000043 W/m$^2$ (calculated) | |
| Antenna Type: | Guideline Geo AB, P/N: 13-002329-1 | |
| Maximum Antenna Gain: | Not Declared by Applicant | |
| Test Software/Firmware: | MIRA Control 1.4.23.609, MCU 0x60000096, FPGA 0x41 (RX) 0x40 | |
| Power Source & Voltage: | Battery Powered, via 14.4VDC Rechargeable Batteries | |

## 2.2 EUT Description

The Guideline Geo AB, QLA-MIRA500 is an Ultra-Wideband Ground Penetrating Radar array system that is used for detailed 3D mapping of the subsurface. Typical application areas include infrastructure and/or archaeology. The EUT is powered by rechargeable batteries. The charging station is coupled to the AC Public Mains Network but cannot power the EUT. The batteries cannot charge and allow the EUT to transmit simultaneously.

## 2.3 Testing Algorithm

The EUT was tested in a powered-on, steady state, with the transmitter enabled as appropriate. Please note that all of the UWB transmitter testing was performed via 3-meter radiated testing. There is not a single azimuth (i.e., turn-table degree) that yields a wort-case fundamental amplitude. Rather, the turntable must be rotated to a variety of degrees (from 0 to 360) to properly characterize the worst-case emissions signature. All of the test data provided in this report represents the absolute worst-case emissions from the EUT. Care was taken to ensure that all of the UWB transmit energy was captured and reported correctly. The EUT was oriented on the testing site in accordance with the use-case positioning.

## 2.4 Testing Configuration

The QLA-MIRA500 was tested in an active measurement/imaging mode. The EUT was controlled via a support laptop. The laptop was used to command the EUT into a transmit enabled state. The laptop was not introduced onto the testing site. For all radiated emissions testing, the alternative test site configuration defined in Section 10.2.2 of ANSI C63.10-2013 was employed.

## 2.5 Test Location

All measurements herein were performed at Washington Laboratories, Ltd. test center in Frederick, MD. Site description and site attenuation data have been placed on file with the FCC's Sampling and Measurements Branch at the FCC laboratory in Columbia, MD. The ISED Canada number for Washington Laboratories, Ltd. is 3035A. Washington Laboratories, Ltd. has been accepted by the FCC and approved by ANAB under Testing Certificate AT-1448 as an independent FCC test laboratory.

Figure 1: EUT Testing Configuration (Example Only)

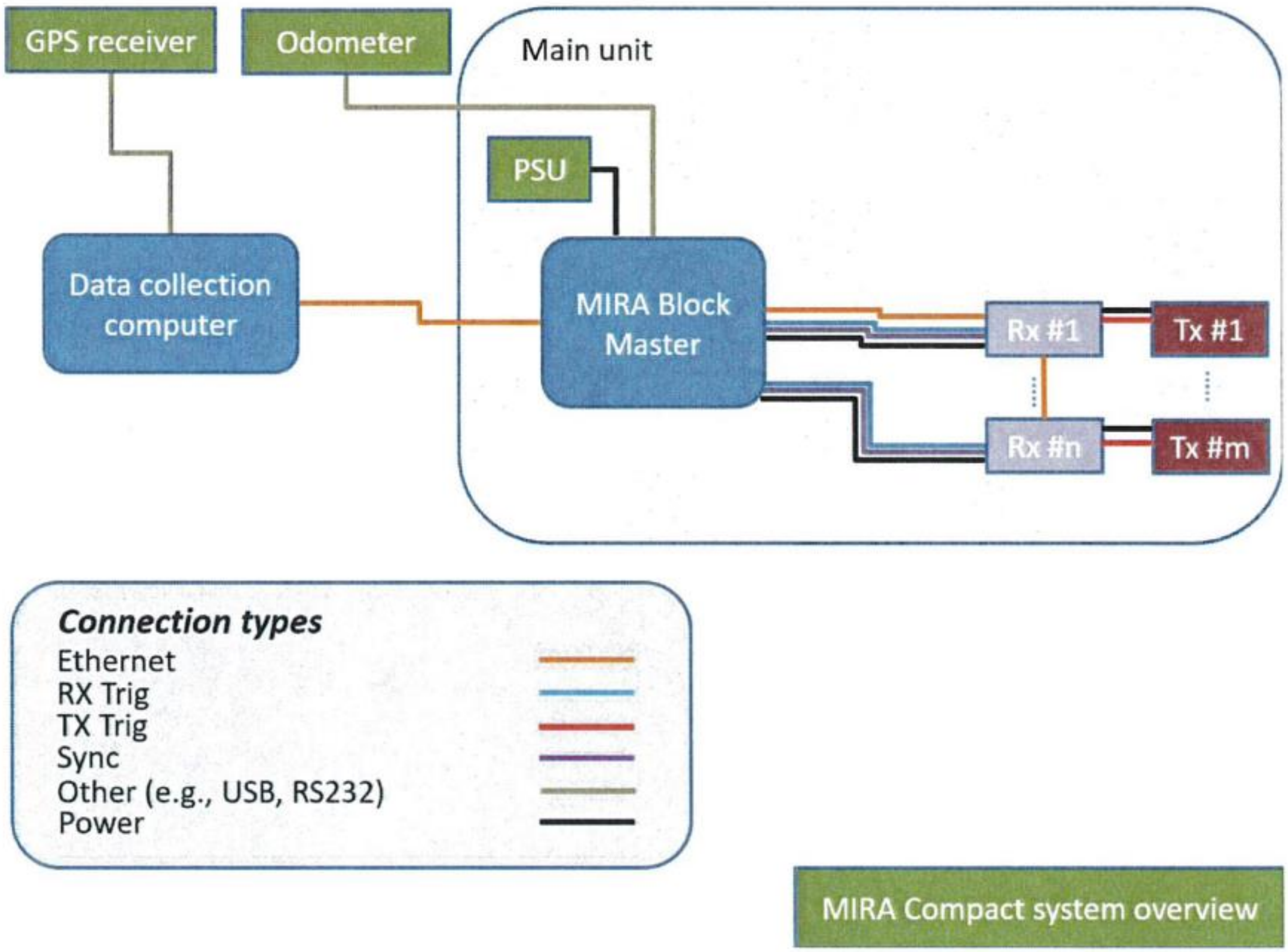


Table 2: System Configuration List

| Name / Description | Model Number | Part Number | Serial Number | Revision |
|---|---|---|---|---|
| MIRA Compact | 21-005992 | N/A | Unit 1 | 1 |
| Li-Ion Batteries | 30-003049 | N/A | N/A | N/A |

Table 3: Support Equipment

| Item | Model/Part Number | Serial Number |
|---|---|---|
| Laptop | Dell, Toughbook | N/A |
| Ethernet Cable | N/A | N/A |

Table 4: Cable Configuration

| Port Identification | Port on EUT | Description | Qty. | Length (meters) | Shielded (Y/N) |
|---|---|---|---|---|---|
| 1 | Encoder | N/A | 1 | N/A | No |
| 2 | Ext. Antenna | N/A | 1 | N/A | No |
| 3 | Power In | N/A | 1 | N/A | No |
| 4 | Power Out | N/A | 1 | N/A | No |
| 5 | Ethernet | Data | 1 | 3 | Yes |

## 2.6 Measurements

### 2.6.1 References

ANSI C63.2 (Jan-2016) Specifications for Electromagnetic Noise and Field Strength Instrumentation

ANSI C63.4 (Jan 2014) American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz

ANSI C63.10 (Jun 2013) American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices

### 2.6.2 Radiated Data Reduction and Reporting

To convert the raw spectrum analyzer radiated data into a form that can be compared with the FCC limits, it is necessary to account for various calibration factors that are supplied with the antennas and other measurement accessories. These factors are included into the antenna factor (AF) column of the table and in the cable factor (CF) column of the table. The AF (in dB/m) and the CF (in dB) is algebraically added to the raw Spectrum Analyzer Voltage in dBµV to obtain the Radiated Electric Field in dBµV/m. This logarithm amplitude is converted to a linear amplitude, then compared to the limit.

Example:

| | |
|---|---|
| Spectrum Analyzer Voltage: | VdBµV (SA) |
| Antenna Correction Factor: | AFdB/m |
| Cable Correction Factor: | CFdB |
| Pre-Amplifier Gain (if applicable): | GdB |
| Electric Field: | EdBµV/m = V dBµV (SA) + AFdB/m + CFdB - GdB |
| To convert to linear units of measure: | Inv Log (EdBµV/m/20) |

## 2.7 Measurement Uncertainty

All results reported herein relate only to the equipment tested. The basis for uncertainty calculation uses ANSI/NCSL Z540-2-1997 (R2002) with a type B evaluation of the standard uncertainty. Elements contributing to the standard uncertainty are combined using the method described in Equation 1 to arrive at the total standard uncertainty. The standard uncertainty is multiplied by the coverage factor to determine the expanded uncertainty which is generally accepted for use in commercial, industrial, and regulatory applications and when health and safety are concerned (see Equation 2). A coverage factor was selected to yield a 95% confidence in the uncertainty estimation

Equation 1: Standard Uncertainty

$$u_c = \pm\sqrt{\frac{a^2}{div_a{}^2} + \frac{b^2}{div_b{}^2} + \frac{c^2}{div_c{}^2} + \ldots\ldots}$$

where:

| | |
|---|---|
| uc | = standard uncertainty |
| a, b, c,.. | = individual uncertainty elements |
| Diva, b, c | = the individual uncertainty element divisor based on the probability distribution |
| Divisor | = 1.732 for rectangular distribution |
| Divisor | = 2 for normal distribution |
| Divisor | = 1.414 for trapezoid distribution |

Equation 2: Expanded Uncertainty

$$U = ku_c$$

where:

| | |
|---|---|
| U | = expanded uncertainty |
| k | = coverage factor |
| k | ≤ 2 for 95% coverage (ANSI/NCSL Z540-2 Annex G) |
| uc | = standard uncertainty |

The measurement uncertainty complies with the maximum allowed uncertainty from CISPR 16-4-2. Measurement uncertainty is not used to adjust the measurements to determine compliance. The expanded uncertainty values for the various scopes in the WLL accreditation are provided in Table 5 below.

Table 5: Expanded Uncertainty List

| Scope | Standard(s) | Expanded Uncertainty |
|---|---|---|
| Conducted Emissions | CISPR11, CISPR22, CISPR32, CISPR14, FCC Part 15 | ± 2.63 dB |
| Radiated Emissions | CISPR11, CISPR22, CISPR32, CISPR14, FCC Part 15 | ± 4.55 dB |

# 3 Test Sequence and Results Summary

Table 6: Transmitter Testing Summary

| FCC Rule Part | ISED Rule Part | Summary Description | Result |
|---|---|---|---|
| §15.509(a) | RSS-220, 6.2.1(a) | GRP Operates Below 10.6 GHz, and is Wholly Contained Below 960 MHz | Pass |
| §15.509(a)<br>§2.1049 | RSS-220, 6.2.1<br>RSS-220, Annex(2) | 10dB Occupied Bandwidth ≥ 500 MHz or the Fractional Bandwidth is ≥ 0.2 | Pass |
| §15.509(b)(1) | N/A | Parties Operating this Equipment Must be Eligible for Licensing Under the Provisions of FCC Part §90 | Managed by Applicant |
| §15.509(b)(2) | N/A | Operation of Imaging Systems Under this Section Requires Coordination, as detailed in FCC Part §15.525 | Pass |
| §15.509(c) | RSS-220, 6.2.1(b) | Handheld GPRs: Cessation of Operation, 10-seconds | N/A |
| §15.509(d)<br>§15.209 | RSS-220, 6.2.1(c)<br>RSS-GEN | Radiated Emissions and EIRP Requirements < 960 MHz | Pass |
| §15.509(d)<br>§15.209 | RSS-220, 6.2.1(d)<br>RSS-GEN | Radiated Emissions and EIRP Requirements > 960 MHz | Pass |
| §15.509(e) | RSS-220, 6.2.1(e) | Radiated Emissions with the GNSS Bands | Pass |
| §15.509(f) | N/A | Fundamental Transmitters Above 960 MHz | N/A |
| N/A | RSS-220, 6.2.1(g)<br>RSS-220, Annex(4) | GPR Transmissions, Peak $EIRP_{dBm/50MHz}$ Requirements | Pass |
| §15.107(a) | RSS-GEN | AC Powerline Conducted Emissions | Pass |

# 4 Test Results

## 4.1 §15.509(a) and RSS-220, 6.2.1(a) – UWB GRP Operates Below 10.6 GHz

Under this provision, the UWB shall operate below 10.6 GHz and the 10dB OBW shall be wholly contained below 960 MHz. The EUT fundamental UWB transmit signal was evaluated for compliance under this rule part. The testing site and measurement method were maintained in accordance with ANSI C63.10-2013, Section 10.

The test results are provided below.

Vertical Testing Summary:

$f_L$ 34.40 MHz

$f_C$ 291.00 MHz

$f_M$ 222.74 MHz

$f_H$ 547.60 MHz

Horizontal Testing Summary:

$f_L$ 75.50 MHz

$f_C$ 262.15 MHz

$f_M$ 220.46 MHz

$f_H$ 448.80 MHz

where:

$f_M$ is the frequency of maximum UWB transmission

$f_H$ is the highest frequency at which the power spectral density of the UWB transmission is -10 dB relative to $f_M$

$f_L$ is the lowest frequency at which the power spectral density of the UWB transmission is -10 dB relative to $f_M$

$f_C$ $= (f_H + f_L) \div 2$ is the center frequency of the -10 dB bandwidth.

Figure 2: UWB Transmitter Emissions – Vertical

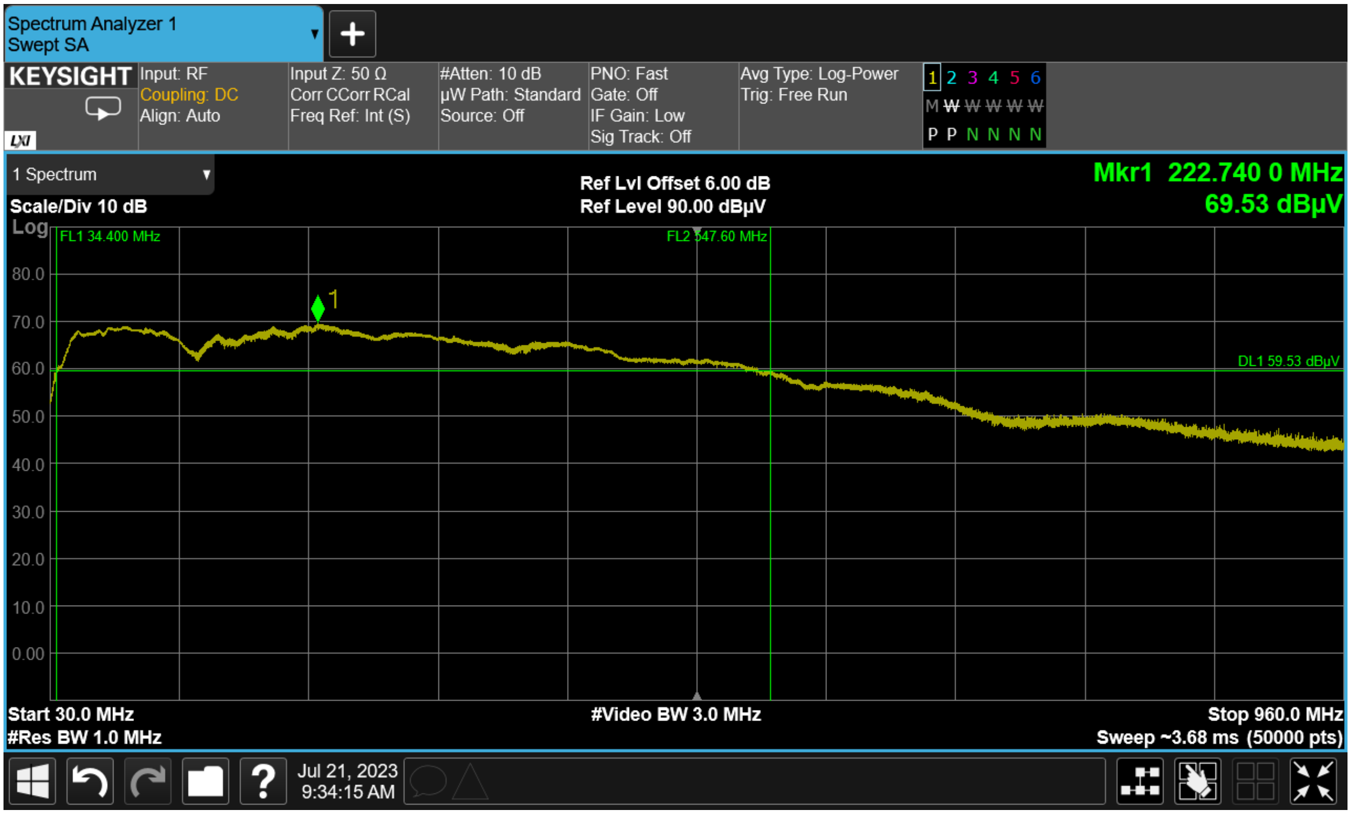


Figure 3: UWB Transmitter Emissions – Horizontal

## 4.2 §15.509(a), §2.1049, and RSS-220, 6.2.1(a) – Occupied Bandwidth

According to the rules for UWB devices, outlined in FCC Rule Part §15F, RSS-220, Section 2, and as defined in ANSI C63.10-2013, Section 10.1 – a UWB transmitter is defined as "an intentional radiator that, at any point in time, has a fractional bandwidth equal to or greater than 0.20 or has a UWB bandwidth equal to or great than 500 MHz, regardless of the fractional bandwidth.

The -10dB Occupied Bandwidth (OBW) was evaluated in accordance with the following method:

The frequency at which the maximum power level is measured with the peak detector is designated $f_M$. The peak power measurements shall be made using a spectrum analyzer or EMI receiver with a 1 MHz resolution bandwidth and a video bandwidth of 1 MHz or greater. The instrument shall be set to peak detection using the maximum-hold trace mode. The outermost 1 MHz segments above and below $f_M$, where the peak power falls by 10 dB relative to the level at $f_M$, are designated as $f_H$ and $f_L$, respectively:

a) For the lowest frequency bound $f_L$, the emission is searched from a frequency lower than $f_M$ that has, by inspection, a peak power much lower than 10 dB less than the power at $f_M$ and increased toward $f_M$ until the peak power indicates 10 dB less than the power at $f_M$. The frequency of that segment is recorded.

b) This process is repeated for the highest frequency bound $f_H$, beginning at a frequency higher than $f_M$ that has, by inspection, a peak power much lower than 10 dB below the power at $f_M$. The frequency of that segment is recorded.

c) The two recorded frequencies represent the highest $f_H$ and lowest $f_L$ bounds of the UWB transmission, and the −10 dB bandwidth ($B - 10$) is defined as ($f_H - f_L$).[82] The center frequency ($f_c$) is mathematically determined from ($f_H - f_L$) / 2.

d) The fractional bandwidth is defined as $2(f_H - f_L) / (f_H + f_L)$.

e) Determine whether the −10 dB bandwidth ($f_H - f_L$) is ≥500 MHz, or whether the fractional bandwidth $2(f_H - f_L) / (f_H + f_L)$ is ≥0.2.

The final OBW test results are provided below.

Under the provisions of RSS-GEN, Section 6.7, the 99% bandwidth was also recorded.

Table 7: Occupied Bandwidth Test Results (Worst-Case)

| Receive Antenna | -10dB Bandwidth | Required OBW (Minimum) | Results |
|---|---|---|---|
| Vertical | 513.20 MHz | 500 MHz | Pass |
| Horizontal | 373.30 MHz | 500 MHz | Pass * |

* When the EUT is evaluated with the testing antenna in a Horizontal polarity, the 10dB OBW of the UWB transmitter is less than 500 MHz. As such, the Fractional Bandwidth must be calculated to demonstrate compliance.

Fractional BW $= 2(f_H - f_L) \div (f_H + f_L)$

where

$f_L$ = 75.50 MHz

$f_H$ = 448.80 MHz

therefore

Fractional BW $= 2(448.8 - 75.5) \div (448.8 + 75.5)$

$= 2(373.3) \div (524.3)$

= 1.424 is the Fractional BW

finally

Because 1.42 is $\geq$ 0.2, the EUT meets the requirements of this section.

Figure 4: 10dB Occupied Bandwidth – Vertical

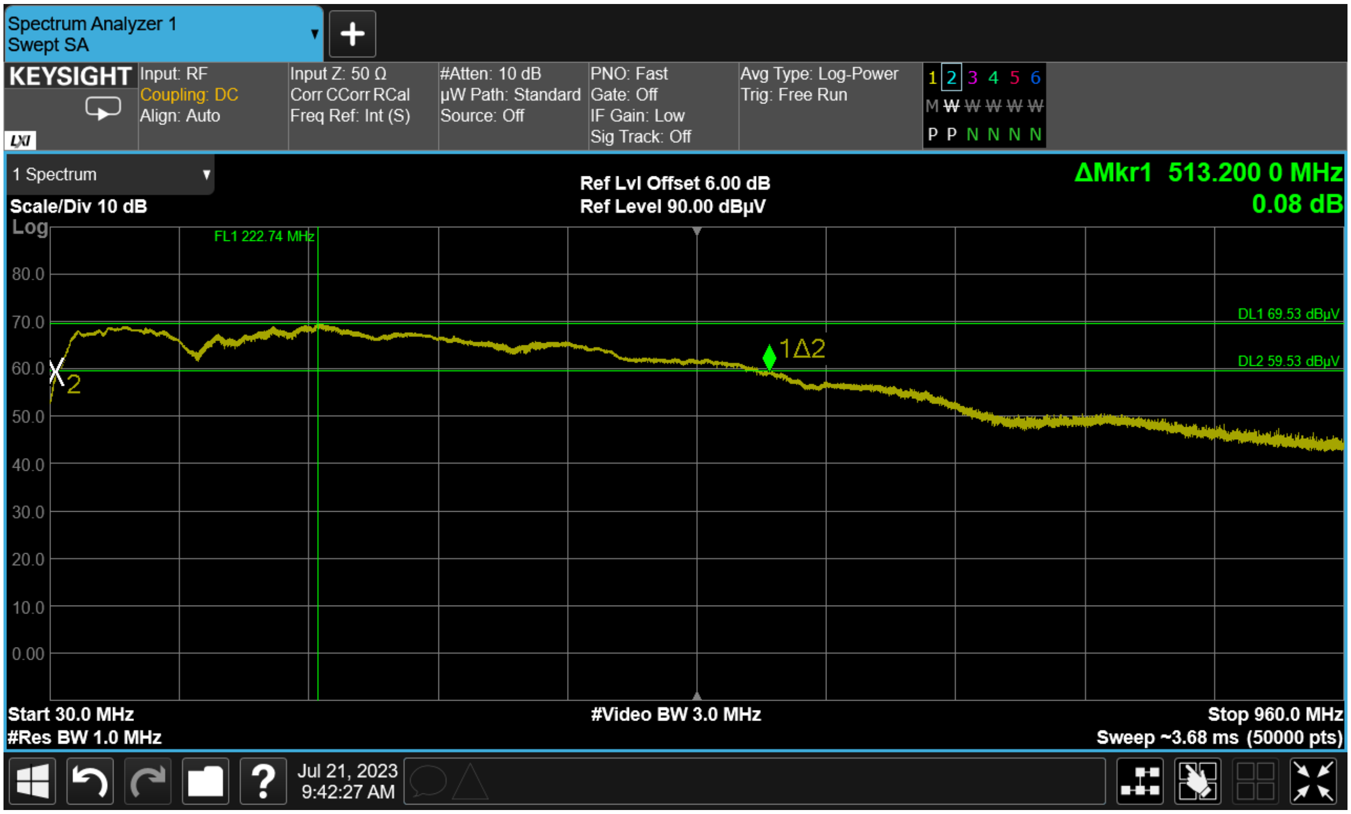


Figure 5: 10dB Occupied Bandwidth – Horizontal

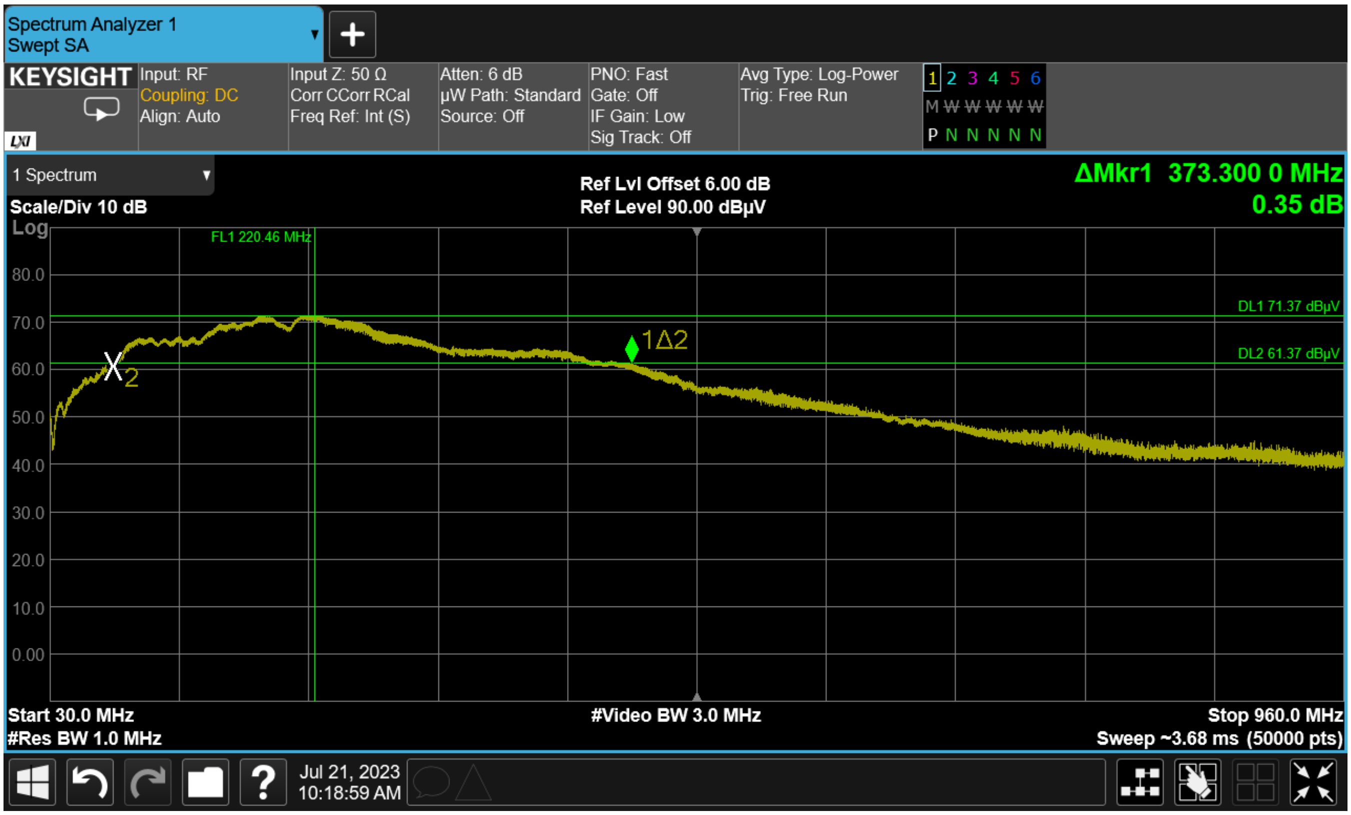
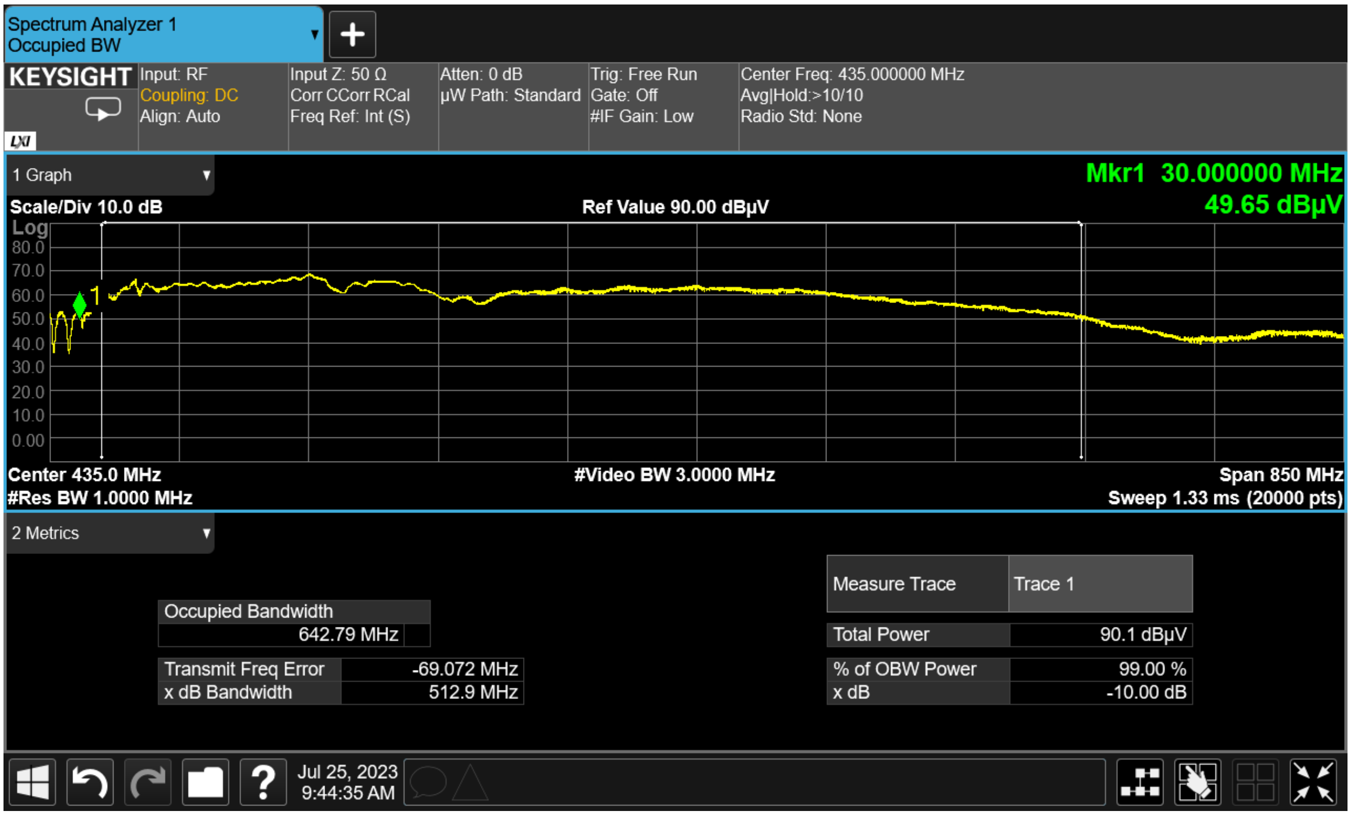


Figure 6: Worst-Case 99% Occupied Bandwidth




For the 99% bandwidth, the UWB transmitter emissions were maximized until the -10dB metric aligned with the measurement provided in Table 7 of this report. That is, when the -10dB bandwidth is equal to 513 MHz (as noted above) the 99% bandwidth shall be recorded.

In this case, the worst-case 99% bandwidth is 642.8 MHz. (radiated at 3-meters)

This plot is not a corrected representation of amplitude.

## 4.3 §15.509(b) and RSS-220, 6.2 – Standard Specifications

Under this provision, UWB GPRs shall be operated for purposes associated with law enforcement, firefighting, emergency rescue, scientific research, commercial mining, or construction.

The EUT complies with this requirement, as the applicant has declared that the MIRA Comact GPR array system shall be used for infrastructure/construction and archaeology research.

Additionally, under the provisions of §15.509(b)(1) and §15.509(b)(2) the applicant shall ensure that parties operating this equipment are eligible for licensing under the provisions of FCC Rule Part §90, and that the coordination requirements of §15.252 are satisfied.

## 4.4 §15.509(d) and RSS-220, 6.2.1(c) and 6.2.1(d) – Radiated Emissions

The radiated emissions at, or below, 960 MHz from a device operating under the provisions of this section shall not exceed the emission limits in FCC Rule Part §15.209, nor shall they exceed the emission limits of RSS-220 Section 3.4.

| FCC Rule Part §15.209 | | | |
|---|---|---|---|
| **Frequency (MHz)** | **Field Strength Limit (uV/m)** | **Measurement Distance (meters)** | **EIRP Limit (dBmW)** |
| 30 – 88 | 100 | 3 | N/A |
| 88 – 216 | 150 | 3 | N/A |
| 216 – 960 | 200 | 3 | N/A |
| > 960 | 500 | 3 | N/A |

| ISED Canada, RSS-220 Section 3.4 | | | |
|---|---|---|---|
| **Frequency (MHz)** | **Field Strength Limit (uV/m)** | **Measurement Distance (meters)** | **EIRP Limit (dBmW)** |
| .009 – .490 | $2400/F_{kHz}$ | 300 | $10LOG(17.28/F_{kHz}^2)$ |
| .490 – 1.705 | $24,000/F_{kHz}$ | 30 | $10LOG(17.28/F_{kHz}^2)$ |
| 1.705 – 30 | 30 | 30 | -45.7 |
| 30 – 80 | 100 | 3 | -55.2 |
| 88 – 216 | 150 | 3 | -51.7 |
| 216 – 960 | 200 | 3 | -49.2 |

Additionally, the radiated emissions above 960 MHz from a device operating under the provisions of this section shall not exceed the following Average EIRP limits, when measured using a RBW of 1 MHz.

| Frequency (MHz) | EIRP Limit (dBm) |
|---|---|
| 960 – 1610 | -65.3 |
| 1610 – 1990 | -53.3 |
| 1990 – 3100 | -51.3 |
| 3100 – 10600 | -41.3 |
| > 10600 | -51.3 |

The above noted EIRP limits shall be converted to Field Strength via the following:

$FS_{dBuV/m}$ = $EIRP_{dBm}$ – 20LOG($D_m$) + 104.8 *(reference: ANSI C63.26-2015, Section 5.2.7)*

where $D_m$ is the measurement distance in meters

therefore $FS_{dBuV/m}$ = $EIRP_{dBm}$ – 20LOG(3) + 104.8

$FS_{dBuV/m}$ = -65.3 – 20LOG(3) + 104.8

$FS_{dBuV/m}$ = 29.95 Average Limit (shall be rounded to 30 dBuV/m)

### 4.4.1 Test Procedure Summary

The requirements of this test call for the EUT to be placed on an 80cm high, 1m X 1.5m non-conductive motorized turntable for radiated testing of frequencies at, or below, 960 MHz. For radiated testing of frequencies above 960 MHz, the height of the EUT shall be raised to 150cm. All radiated emissions measured during this testing, were performed at a distance of 3-meters. The conditions of the testing site were maintained in accordance with ANSI C63.10-2013, Section 10.2.2 and RSS-220, Section 7.

An initial pre-scan of the EUT was performed to identify any emissions that exceed, or come within 6dB of, the applicable limit. This pre-scan was performed a with the employment of a spectrum analyzer peak detector function. The highest amplitude (worst-case) emissions noted during the pre-scan were selected for final compliance measurements.

The emissions from the EUT were measured continuously at every azimuth by rotating the turntable. Broadband log periodic and double-ridged horn antennas were mounted on an antenna mast to determine the height of maximum emissions. The height of the antenna was varied between 1 and 4 meters. The output of the antenna was connected to the input of the spectrum analyzer and the emissions in the frequency range of 30 MHz to 18 GHz were measured. The EUT peripherals were placed on the table in accordance with ANSI C63.4. Cables were varied in position to produce maximum emissions. Both the horizontal and vertical field components were measured. The detector function was set to quasi-peak for measurements below 1 GHz. The measurement bandwidth of the spectrum analyzer system was set to at least 120 kHz, with all post-detector filtering no less than 10 times the measurement bandwidth. For measurements above 1 GHz, the average levels are recorded, using a measurement bandwidth of 1 MHz with a video bandwidth setting of 10 Hz, in the case of video averaging. Otherwise, an AVG RMS detector shall be employed.

Environmental Conditions During Radiated Emissions Testing

| | |
|---|---|
| Ambient Temperature: | 19 °C |
| Relative Humidity: | 44 % |

### 4.4.2 Radiated Data Reduction and Reporting

To convert the raw spectrum analyzer radiated data into a form that can be compared with the FCC limits, it is necessary to account for various calibration factors that are supplied with the antenna(s) and other measurement equipment. These factors include the antenna factor ((AF)(in dB/m)), cable loss factors ((CF)(in dB)), and the pre-amplifier gain [if applicable] ((G)(in dB)). These correction values are algebraically added to the raw Spectrum Analyzer Voltage (in dBµV) to obtain the corrected radiated electric field, which shall be the final corrected logarithm amplitude ((Corr. Meas.)(in dBµV/m)). This logarithm amplitude is then compared to the FCC limit, which has been converted to a unit of log in dBµV/m.

<u>Example:</u>

| | |
|---|---|
| Spectrum Analyzer Voltage: | VdBµV (SA) |
| Antenna Correction Factor: | AFdB/m |
| Cable Correction Factor: | CFdB |
| Pre-Amplifier Gain (if applicable): | GdB |
| Electric Field: | EdBµV/m = V dBµV (SA) + AFdB/m + CFdB - GdB |
| To convert from linear units of measure: | dBuV/m = 20LOG(uV/m) |

### 4.4.3 Test Data

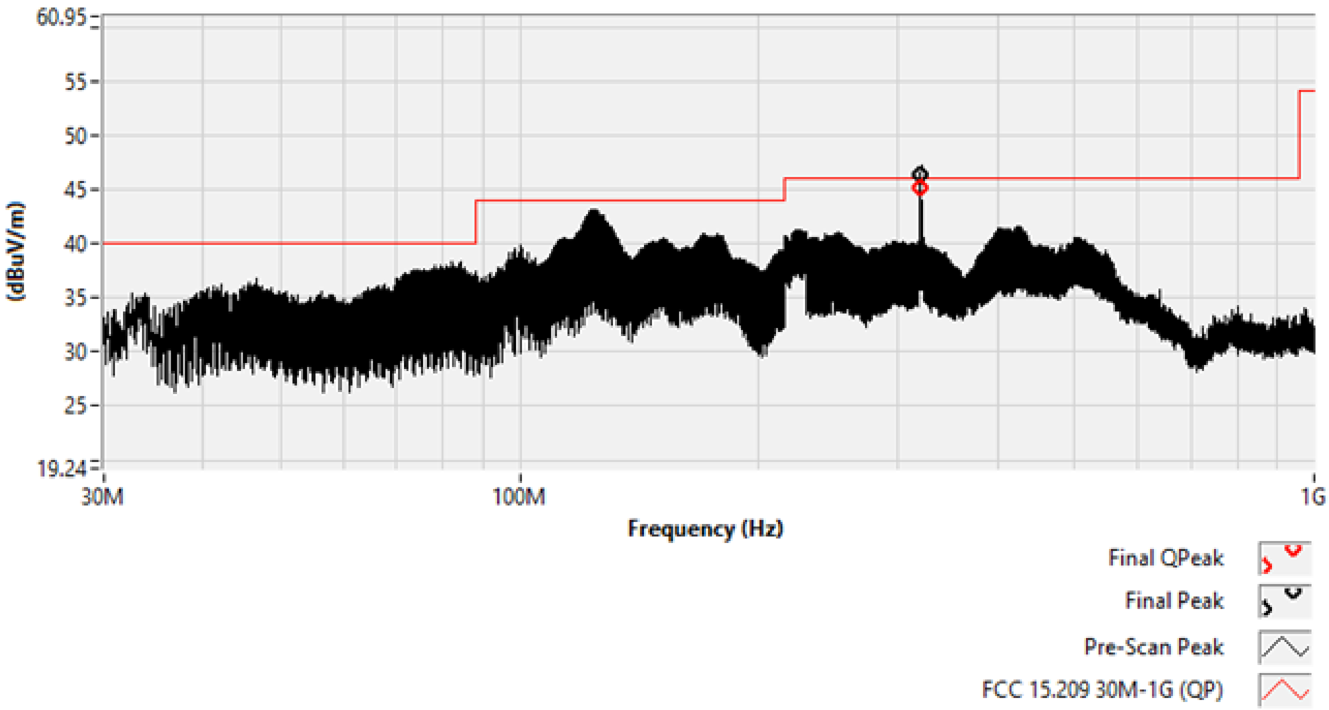
The EUT complies with the Radiated Emissions requirements. The EUT was scanned from 30 MHz to 18 GHz. The worst-case emissions are reported.

| 3-meter Radiated Emissions < 960 MHz (120kHz RBW) | | | | | | |
|---|---|---|---|---|---|---|
| **Frequency (MHz)** | **Detector** | **Corr. Meas. (dBuV/m)** | **Limit (dBuV/m)** | **Delta (dB)** | **Turn Table (deg)** | **Antenna (cm)** |
| 180.00 | Peak | 43.979 | -- | -- | 280 | Horiz, 110 |
| | QP | 42.741 | 44 | -1.259 | 280 | Horiz, 110 |
| † 319.97 | Peak | 46.420 | -- | -- | 200 | Vert, 100 |
| | QP | 45.083 | 46 | -0.917 | 200 | Vert, 100 |

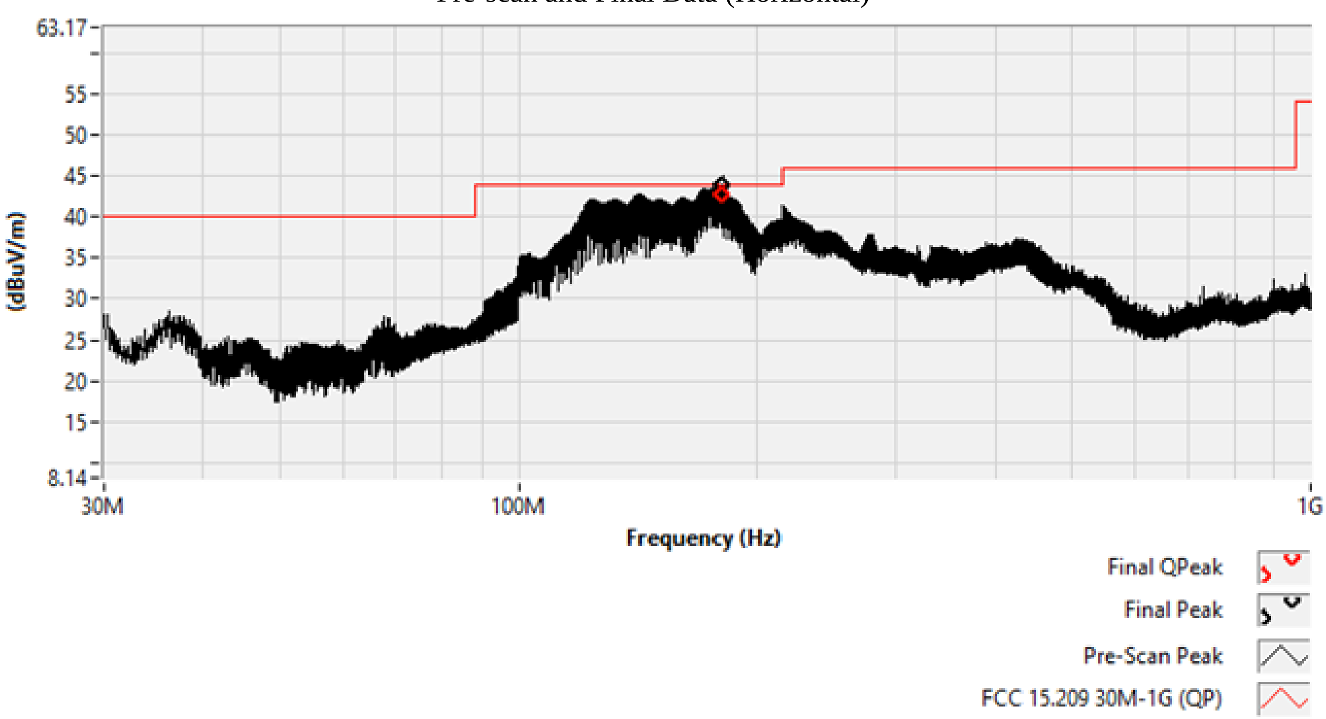
† please note that the emission marked at 319.97 MHz is a [discrete] ambient condition that inadvertently coupled to the pre-amp portion of the measurement system. This signal was marked for compliance to ensure that it passed the Class B limits, because at the time of testing it was unclear whether the emission was a product of the EUT. However, further investigation revealed that the spur at 319.97 MHz is an ambient condition, and not from the EUT. Please see Figure 9 of this test report for clarification. It can be seen that this emission is not part of the EUT Transmitter waveform signature.

| 3-meter Radiated Emissions > 960 MHz (1MHz RBW) | | | | | | |
|---|---|---|---|---|---|---|
| **Frequency (GHz)** | **Detector** | **Corr. Meas. (dBuV/m)** | **Limit (dBuV/m)** | **Delta (dB)** | **Turn Table (deg)** | **Antenna (cm)** |
| 1.010 | Peak | 39.273 | 50 | -10.727 | 220 | Horiz, 155 |
| | AVG | 22.850 | 30 | -7.150 | 220 | Horiz, 155 |
| 1.336 | Peak | 47.253 | 50 | -2.747 | 265 | Horiz, 165 |
| | AVG | 25.176 | 30 | -4.824 | 260 | Horiz, 170 |
| ‡ 3.096 | Peak | 44.632 | 64 | -19.368 | 260 | Horiz, 140 |
| | AVG | 30.291 | 44 | -13.709 | 265 | Horiz, 165 |
| ‡ 6.961 | Peak | 55.492 | 74 | -18.508 | 260 | Vert, 160 |
| | AVG | 41.646 | 54 | -12.354 | 260 | Vert, 165 |
| ‡ 7.302 | Peak | 57.383 | 74 | -16.617 | 265 | Horiz, 155 |
| | AVG | 41.561 | 54 | -12.439 | 260 | Horiz, 170 |
| ‡ the measurement was made at the noise-floor (ambient) | | | | | | |

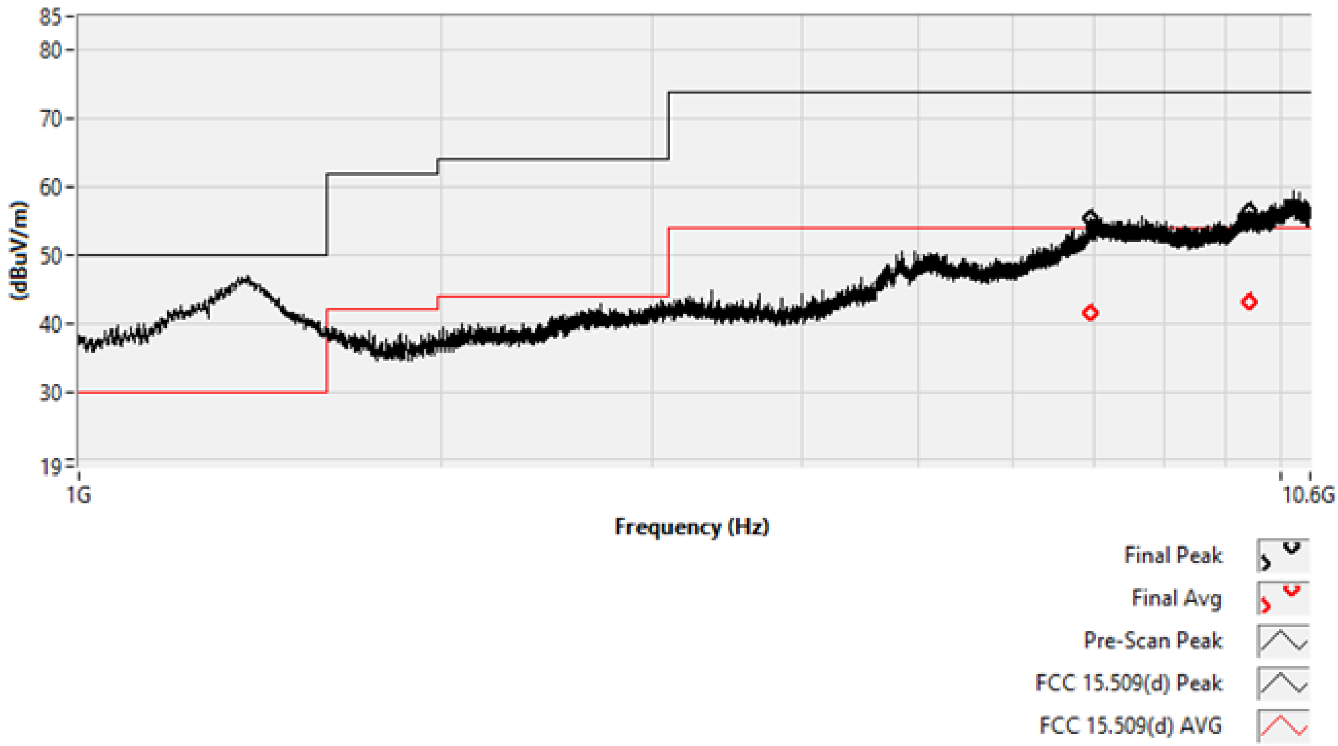
Pre-scan and Final Data (Vertical)




Pre-scan and Final Data (Horizontal)



Pre-scan and Final Data (Vertical)




Pre-scan and Final Data (Horizontal)

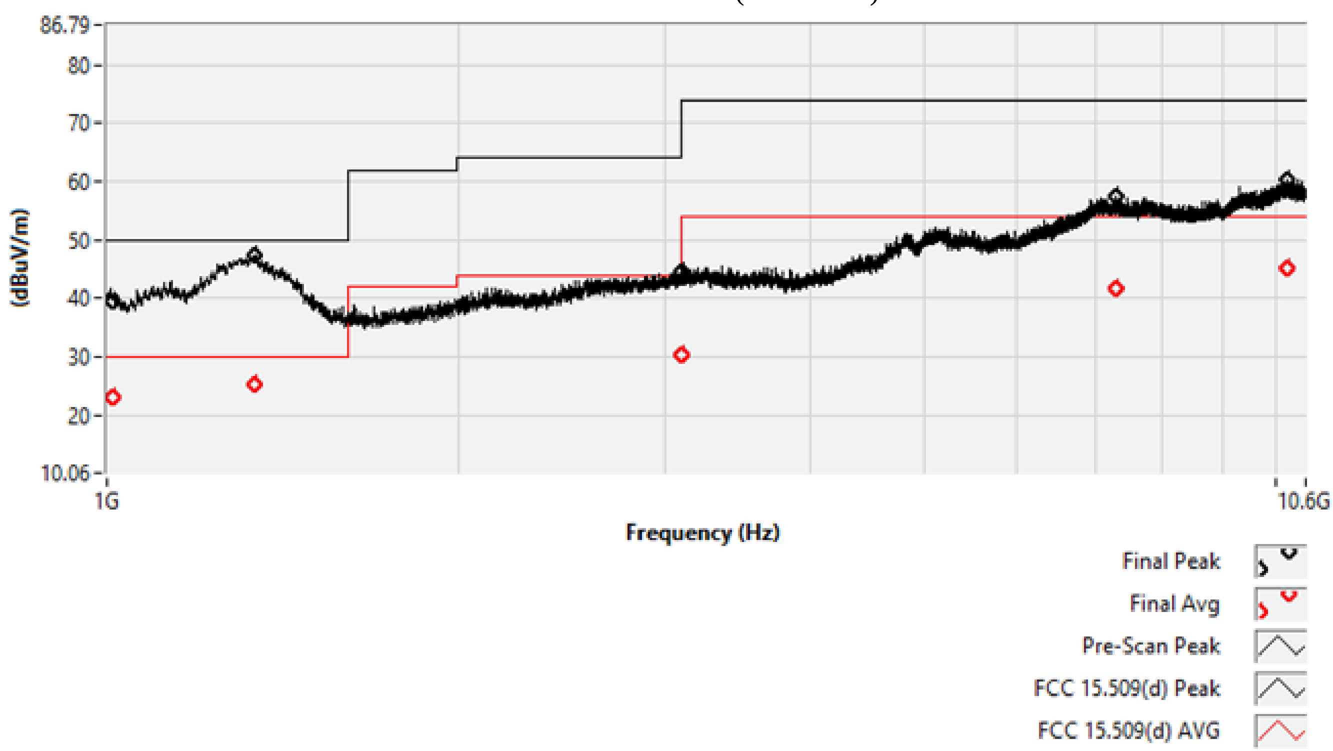
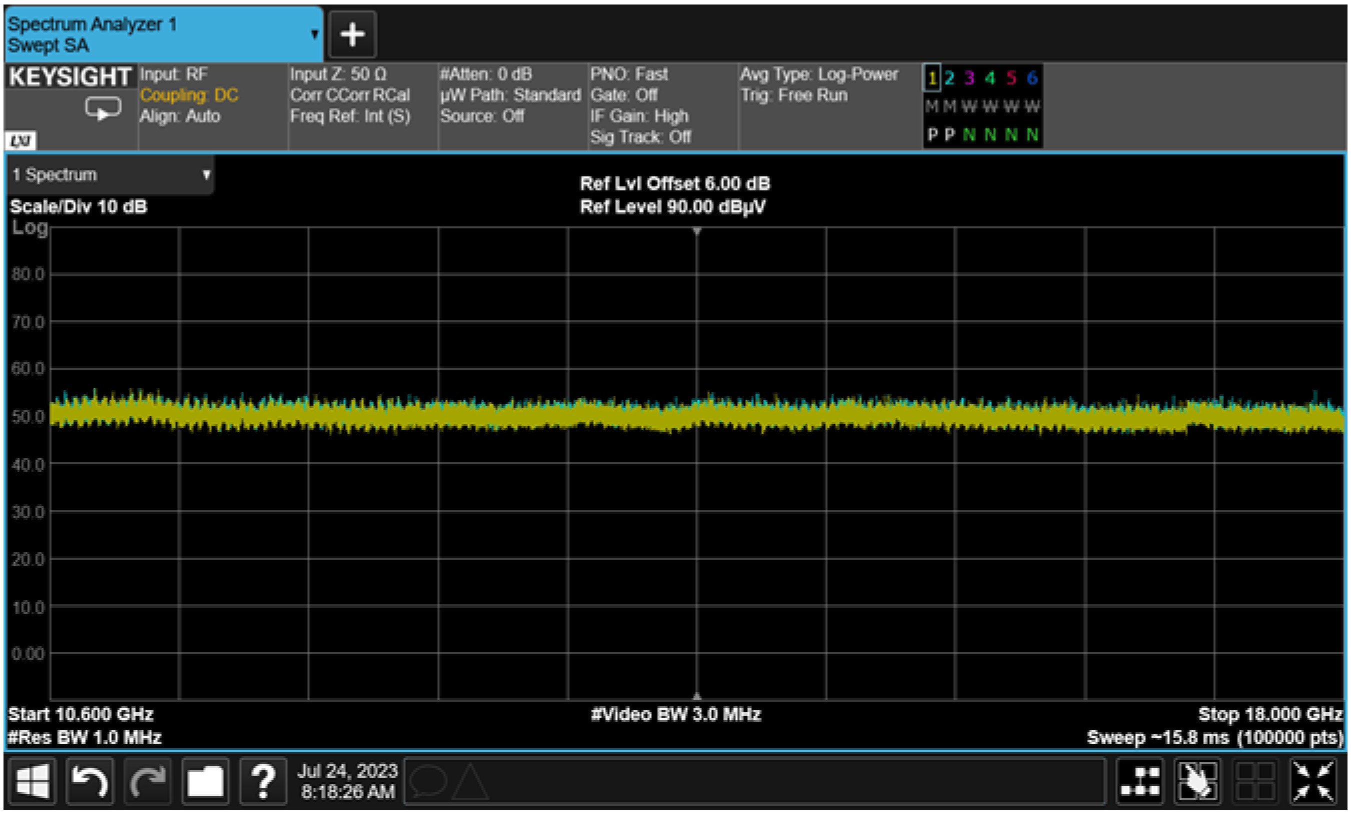


Figure 7: Radiated Emissions Test Data, 10.6 GHz to 18 GHz




* No Emissions from the EUT were Detected.

Trace 1 = Ambient

Trace 2 = EUT Transmitting

## 4.5 §15.509(e) and RSS-220, 6.2.1(e) – Radiated Emissions, GNSS Bands

Under this provision, radiated emissions shall not exceed the following Average limits when measured using a resolution bandwidth of no less than 1 kHz. The measurements shall demonstrate compliance with the stated limits at whatever resolution bandwidth is used.

| **Frequency (MHz)** | **EIRP Limit (dBm)** |
|---|---|
| 1164 – 1240 | -75.3 |
| 1559 – 1610 | -75.3 |

The above noted EIRP limits shall be converted to Field Strength via the following:

$FS_{dBuV/m}$ = $EIRP_{dBm}$ – 20LOG($D_m$) + 104.8 *(reference: ANSI C63.26-2015, Section 5.2.7)*

where $D_m$ is the measurement distance in meters

therefore $FS_{dBuV/m}$ = $EIRP_{dBm}$ – 20LOG(3) + 104.8

$FS_{dBuV/m}$ = -75.3 – 20LOG(3) + 104.8

$FS_{dBuV/m}$ = 19.95 Average Limit (shall be rounded to 20 dBuV/m)

### 4.5.1 Test Procedure Summary

The requirements of this test call for the EUT to be placed on an 150cm high, 1m X 1.5m non-conductive motorized turntable. All radiated emissions measured during this testing, were performed at a distance of 3-meters. The conditions of the testing site were maintained in accordance with ANSI C63.10-2013, Section 10.2.2 and RSS-220, Section 7.

An initial pre-scan of the EUT was performed to identify any emissions that exceed, or come within 6dB of, the applicable limit. This pre-scan was performed a with the employment of a spectrum analyzer peak detector function. The highest amplitude (worst-case) emissions noted during the pre-scan were selected for final compliance measurements.

The emissions from the EUT were measured continuously at every azimuth by rotating the turntable. A broadband double-ridged horn antenna was mounted on an antenna mast to determine the height of maximum emissions. The height of the antenna was varied between 1 and 4 meters. The output of the antenna was connected to the input of the spectrum analyzer and the emissions in the frequency range of 1164 MHz to 1610 MHz were measured. The EUT peripherals were placed on the table in accordance with ANSI C63.4. Cables were varied in position to produce maximum emissions. Both the horizontal and vertical field components were measured.

For the initial pre-scan and final Peak measurements, a RBW setting of 9 kHz was employed. This is a worst-case scenario as the requirements call for a 1 kHz RBW. That is, the Peak energy captured in any 9 kHz, complies with the $EIRP_{dBm}$/1kHz limitations.

For the final Average compliance measurements, a RBW setting of 1 kHz and a detector function of AVG RMS was employed.

### 4.5.2 Test Data

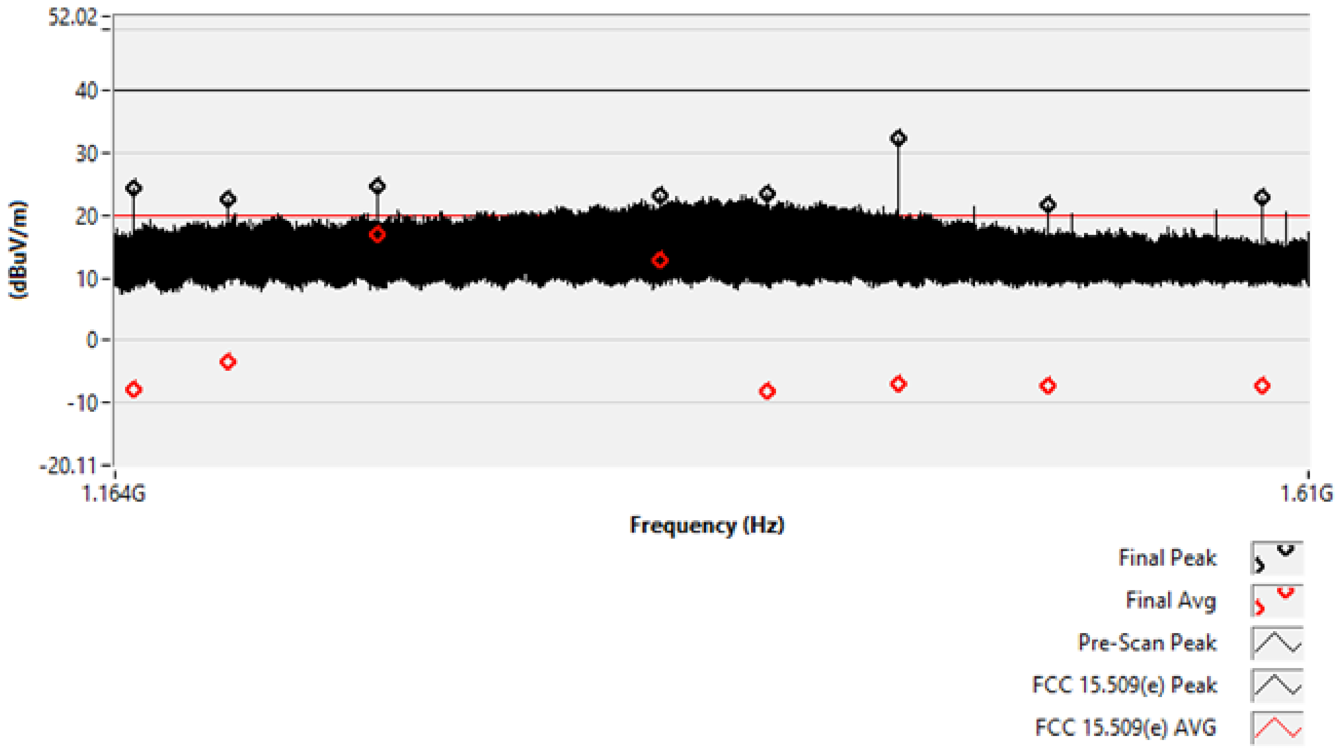
The EUT complies with the Radiated Emissions requirements.

The EUT was scanned from 1164 MHz to 1610 MHz.

The worst-case emissions are reported below.

| 3-meter Radiated Emissions (GNSS Band) – 15.509(e) | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Frequency (MHz)** | **Detector** | **RBW (kHz)** | **Corr. Meas. (dBuV/m)** | **Limit (dBuV/m)** | **Delta (dB)** | **Turn Table (deg)** | **Antenna (cm)** |
| 1100.00 | Peak | 9 | 24.536 | 40 | -15.464 | 260 | Vert, 160 |
| | AVG | 1 | -8.051 | 20 | -28.051 | 260 | Vert, 160 |
| 1200.00 | Peak | 9 | 22.562 | 40 | -17.438 | 220 | Vert, 155 |
| | AVG | 1 | -3.499 | 20 | -23.499 | 22 | Vert, 155 |
| 1230.00 | Peak | 9 | 20.522 | 40 | -19.478 | 225 | Horiz, 170 |
| | AVG | 1 | -6.862 | 20 | -26.862 | 225 | Horiz, 170 |
| 1250.00 | Peak | 9 | 24.769 | 40 | -15.231 | 260 | Vert, 160 |
| | AVG | 1 | 17.107 | 20 | -2.893 | 260 | Vert, 160 |
| 1270.00 | Peak | 9 | 25.618 | 40 | -14.382 | 220 | Horiz, 155 |
| | AVG | 1 | 18.256 | 20 | -1.744 | 220 | Horiz, 155 |
| 1350.00 | Peak | 9 | 23.124 | 40 | -16.876 | 260 | Vert, 160 |
| | AVG | 1 | 12.72 | 20 | -7.280 | 260 | Vert, 160 |
| 1370.00 | Peak | 9 | 25.195 | 40 | -14.805 | 225 | Horiz, 170 |
| | AVG | 1 | 12.371 | 20 | -7.629 | 225 | Horiz, 170 |
| 1390.00 | Peak | 9 | 23.389 | 40 | -16.611 | 260 | Vert, 160 |
| | AVG | 1 | -8.094 | 20 | -28.094 | 260 | Vert, 160 |
| 1440.00 | Peak | 9 | 32.51 | 40 | -7.490 | 260 | Vert, 170 |
| | AVG | 1 | -6.927 | 20 | -26.927 | 260 | Vert, 170 |
| 1450.00 | Peak | 9 | 23.329 | 40 | -16.671 | 225 | Horiz, 170 |
| | AVG | 1 | -7.224 | 20 | -27.224 | 225 | Horiz, 170 |
| 1470.00 | Peak | 9 | 23.876 | 40 | -16.124 | 225 | Horiz, 170 |
| | AVG | 1 | -7.134 | 20 | -27.134 | 225 | Horiz, 170 |
| 1500.00 | Peak | 9 | 21.808 | 40 | -18.192 | 260 | Vert, 160 |
| | AVG | 1 | -7.312 | 20 | -27.312 | 260 | Vert, 160 |
| 1590.00 | Peak | 9 | 22.938 | 40 | -17.062 | 260 | Vert, 155 |
| | AVG | 1 | -7.402 | 20 | -27.402 | 260 | Vert, 155 |

Pre-scan and Final Data (Vertical)




Pre-scan and Final Data (Horizontal)

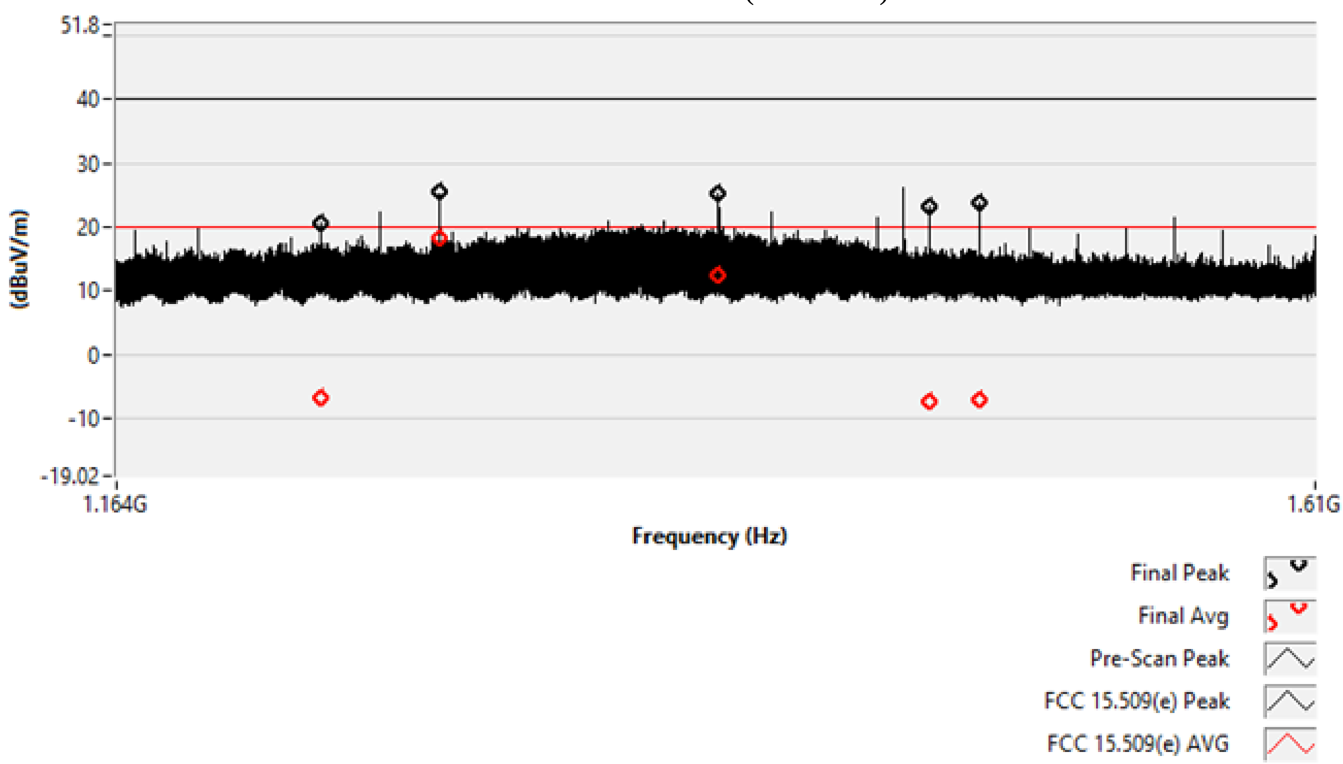
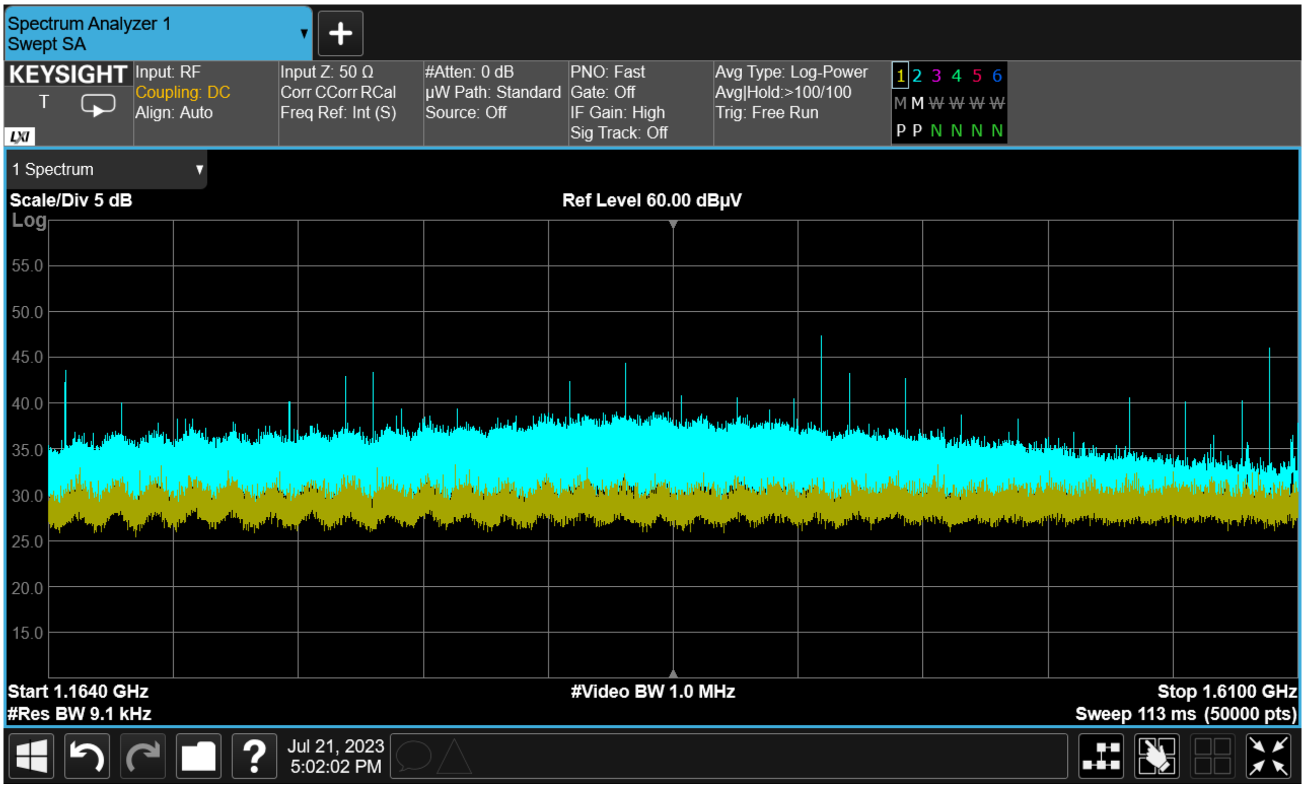


Figure 8: Investigation of EUT Emissions within the GNSS Band




* this plot is provided for reference only, the levels are uncorrected

Trace 1 = Ambient

Trace 2 = EUT Transmitting

## 4.6 RSS-210, 6.2.1(g) – Peak EIRP Transmitter Requirements

### 4.6.1 Requirements

Under this provision, Peak measurements shall be made in addition to average measurements. Only the 50 MHz bandwidth, centered on the frequency $f_M$ where the highest power occurs, needs to be measured to satisfy the peak requirements for all frequencies. The Peak level of the UWB transmissions shall not exceed the Peak equivalent of the average limit contained within any 50 MHz bandwidth, as defined in Section 4(c) of the Annex, contained within RSS-220.

Peak UWB transmissions shall not exceed 0 dBm EIRP in any 50 MHz bandwidth, when the Average limit is -41.3 dBm/MHz. This is the equivalent peak limit as calculated by combining the 6 dB peak-to-average conversion with a resolution bandwidth (RBW) scaling factor of 20LOG(1MHz/50MHz).

A different resolution bandwidth and a correspondingly different peak limit may also be used, in which case the RBW may be set anywhere between 1 MHz and 50 MHz.

The different peak EIRP limit is then calculated from:

Peak Limit in $EIRP_{dBm}$ = 20LOG(RBW/50)

where RBW is the setting employed during the measurement in MHz

### 4.6.2 Testing Procedure Summary

The requirements of this test call for the EUT to be placed on an 80cm high, 1m X 1.5m non-conductive motorized turntable. All radiated emissions measured during this testing, were performed at a distance of 3-meters. The conditions of the testing site were maintained in accordance with ANSI C63.10-2013, Section 10.2.2 and RSS-220, Section 7. The emissions from the EUT were measured continuously at every azimuth by rotating the turntable. A broadband log-periodic antenna was mounted on an antenna mast to determine the height of maximum emissions. The height of the antenna was varied between 1 and 4 meters. The output of the antenna was connected to the input of the spectrum analyzer and the emissions from the EUT were measured. The EUT peripherals were placed on the table in accordance with ANSI C63.4. Cables were varied in position to produce maximum emissions. Both the horizontal and vertical field components were measured. There is not a single azimuth (i.e., turn-table degree) that yields a worst-case fundamental signature. Rather, the turn-table must be rotated to a variety of degrees (from 0 to 360) to properly characterize the worst-case emissions.

### 4.6.3 Test Data

The UWB GPR transmit signal was measured using a RBW setting of 1 MHz. The worst-case transmit signal was identified to be 220.46 MHz, measuring 71.37 dBuV. This level is an uncorrected level. The following table provides the necessary correction factors and compliance comparison.

| Frequency (MHz) | SA Level (dBuV) | Corr. Factors (dB/m) | Corr. Level (dBuV/m) | EIRP (dBm/MHz) | Peak Limit (dBm/MHz) | Delta (dB) | Result |
|---|---|---|---|---|---|---|---|
| 220.46 | 71.37 | -12.82 | 58.55 | -36.70 | -34.00 | -2.70 | Pass |

Please note the following calculations, used to demonstrate compliance.

dBuV/m = dBuV + $AF_{dB/m}$ + $CL_{dB}$ – $PG_{dB}$

$EIRP_{dBm}$ = dBuV/m + 20LOG($D_m$) – 104.8

where $D_m$ is the measurement distance in meters

therefore

$EIRP_{dBm}$ = 58.55 + 20LOG(3) – 104.8

$EIRP_{dBm}$ = -36.70

Peak Limit = 20LOG(RBW/50)

Peak Limit = 20LOG(1/50)

Peak Limit = -33.97 (shall be rounded to -34 dBm)

Figure 9: Peak Field Strength – Vertical (Uncorrected)

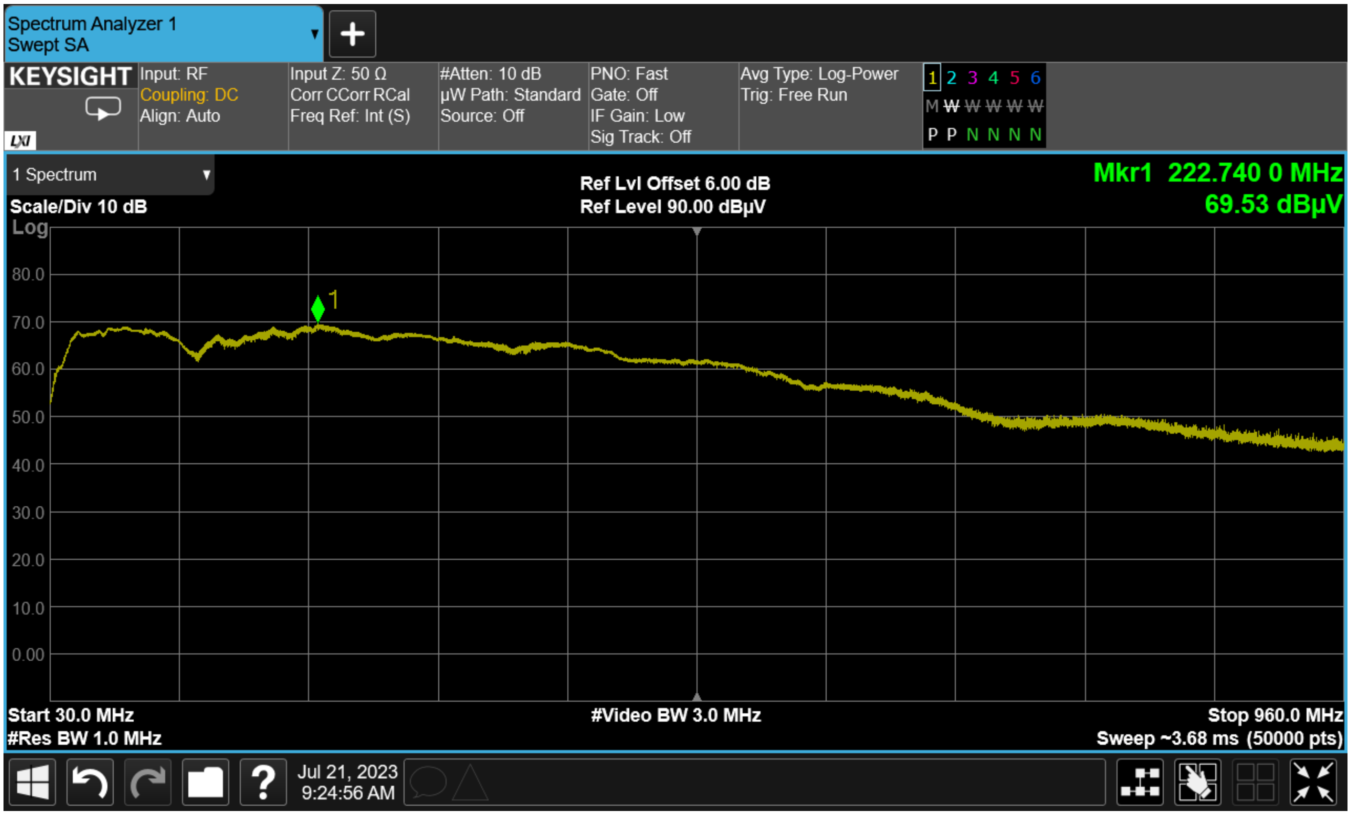
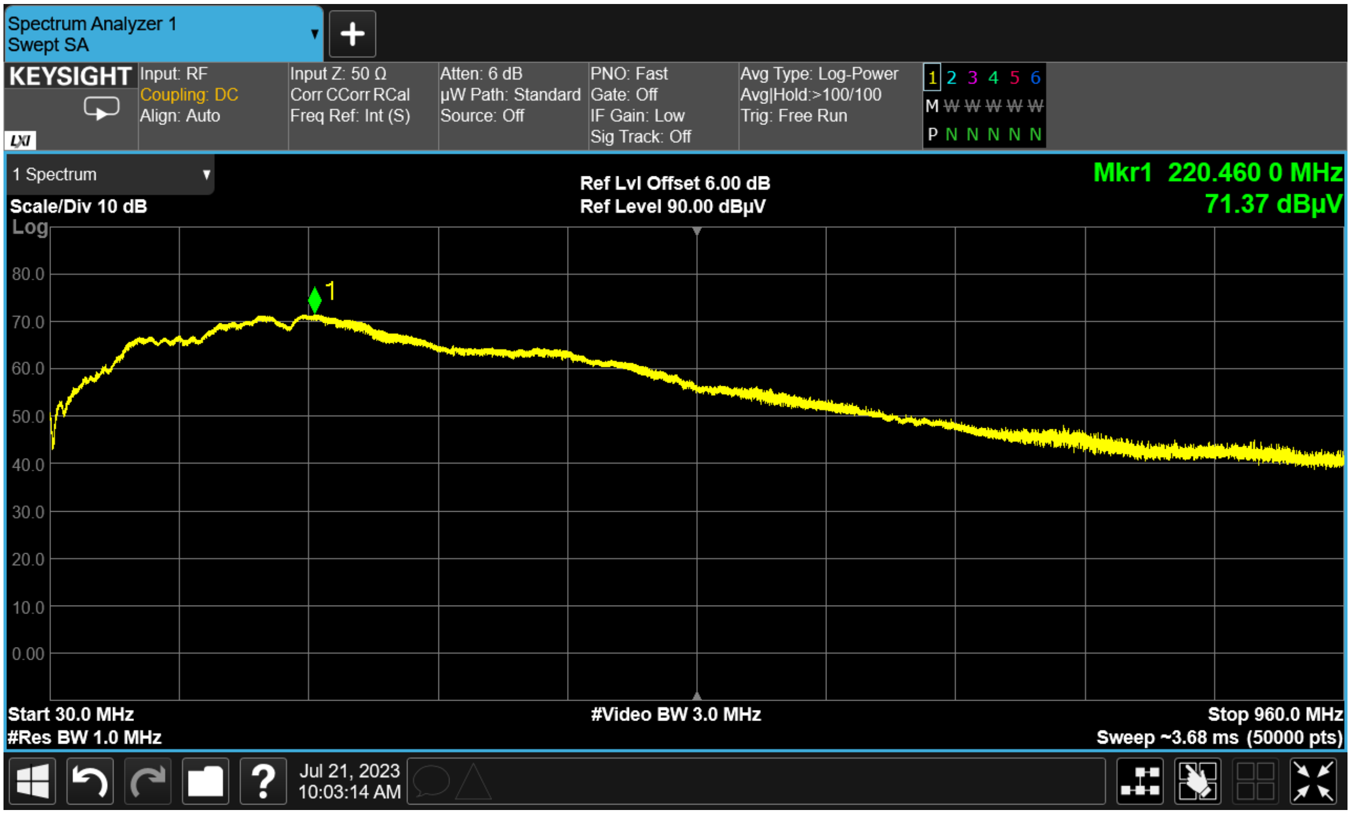


Figure 10: Peak Field Strength – Horizontal (Uncorrected)



# 4.7 AC Powerline Conducted Emissions

## 4.7.1 Requirements

Compliance Standard: FCC Part 15.107, Class B

| Powerline Emissions Compliance Limits | | |
|---|---|---|
| Frequency Range | Class B Digital Device | |
| | Quasi-peak | Average |
| 0.15 – 0.5 MHz | 66 to 56 dBµV | 56 to 46 dBµV |
| 0.5 – 5 MHz | 56 dBµV | 46 dBµV |
| 0.5 – 30 MHz | 60 dBµV | 50 dBµV |

## 4.7.2 AC Powerline Emissions Summary

Please note that the EUT cannot transmit while its batteries are charging. As such, the digital portion is covered by a Supplier's Declaration of Conformity (DOC).

Please see WLL Test Report # 18264-01 for the FCC 15B test results.

# 5 Test Equipment

Table 8 shows a list of the test equipment used for measurements along with the calibration information.

Table 8: Test Equipment List

| Test Name: | **Radiated Emissions** | Test Date: 7/20/2023 to 7/25/2023 | |
|---|---|---|---|
| **Asset #** | **Manufacturer/Model** | **Description** | **Cal. Due** |
| 00644 | SUNOL SCIENCES CORP. JB1 | BICONALOG ANTENNA | 11/7/2024 |
| 00626 | ARA DRG-118/A | ANTENNA HORN | 6/19/2024 |
| 00977 | JUNKOSHA MWX322-06000 | ARMORED COAXIAL CABLE | 12/28/2023 |
| 00806 | MINI-CIRCUITS CBL-6FT | SMA COAXIAL CABLE | 12/28/2023 |
| 00834 | ULTIFLEX UFA 2108-0-360 | SMA COAXIAL CABLE 90CM | 12/28/2023 |
| 00823 | AGILENT/KEYSIGHT | SPECTRUM ANALYZER | 6/7/2024 |
| 00065 | HP 8447D | RF PRE-AMPLIFIER | 5/9/2024 |
| 00066 | BZ-01002650-401545-282525 | HF PRE-AMPLIFIER 1-26.5GHZ | 5/24/2024 |
| 00742 | PENN ENGINEERING WR284 | 2.2-4.15GHZ BANDPASS FILTER | 6/27/2025 |
| 00280 | ITC 21C-3A1 | WAVEGUIDE FILTER | 6/27/2025 |
| 00281 | ITC 21A-3A1 | WAVEGUIDE FILTER 4.51-10.0GHZ | 6/27/2025 |
| 00282 | ITC 21X-3A1 | WAVEGUIDE FILTER 6.8-15GHZ | 6/27/2025 |