**Amber Helm Development L.C.**
92723 Michigan Hwy-152
Sister Lakes, Michigan 49047 USA
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**LB3RFM-WR2325TXAr1**
Issued: **September 8, 2023**

# RF Test Report

regarding

**USA: CFR Title 47, Part 15.249** (Emissions)
**Canada: ISED RSS-210/GENe** (Emissions)

for

# Base3

**Category: Remote Control Gateway**

Judgments:
**Aligns with FCC Part 15.249, ISED RSS-210/GENe**
Testing Completed: September 8, 2023

TESTING
NVLAP LAB CODE 200129-0

Prepared for:

## Lionel, LLC

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Date of Issue: September 8, 2023

## Revision History

| Rev. No. | Date | Details | Revised By |
|---|---|---|---|
| r0 | September 8, 2023 | Initial Release. | J. Nantz |
| r1 | September 29, 2023 | Updated model/misc corrections. | J. Nantz |

## Contents

## List of Tables



## List of Figures

# 1 Test Report Scope and Limitations

## 1.1 Laboratory Authorization

Test Facility description and attenuation characteristics are on file with the FCC Laboratory, Columbia, Maryland (FCC Reg. No: US5348 and US5356) and with ISED Canada, Ottawa, ON (File Ref. No: 3161A and 24249). Amber Helm Development L.C. holds accreditation under NVLAP Lab Code 200129-0.

## 1.2 Report Retention

For equipment verified to comply with the regulations herein, the manufacturer is obliged to retain this report with the product records for the life of the product, and no less than ten years. A copy of this Report will remain on file with this laboratory until October 2033.

## 1.3 Subcontracted Testing

This report does not contain data produced under subcontract.

## 1.4 Test Data

This test report contains data included within the laboratory's scope of accreditation. Any data in this report that is not covered under the laboratory's scope is clearly identified.

## 1.5 Limitation of Results

The test results contained in this report relate only to the item(s) tested. Any electrical or mechanical modification made to the test item subsequent to the test date shall invalidate the data presented in this report. Any electrical or mechanical modification made to the test item subsequent to this test date shall require reevaluation.

## 1.6 Copyright



## 1.7 Endorsements

This report shall not be used to claim product endorsement by any accrediting, regulatory, or governmental agency.

### 1.8 Test Location

The EUT was fully tested by **Amber Helm Development L.C.**, headquartered at 92723 Michigan Hwy-152, Sister Lakes, Michigan 49047 USA. Table 1 lists all sites employed herein. Specific test sites utilized are also listed in the test results sections of this report where needed.

Table 1: Test Site List.

| Description | Location | Quality Num. |
|---|---|---|
| OATS (3 meter) | 3615 E Grand River Rd., Williamston, Michigan 48895 | OATSC |

### 1.9 Traceability and Equipment Used

Pertinent test equipment used for measurements at this facility is listed in Table 2. The quality system employed at Amber Helm Development L.C. has been established to ensure all equipment has a clearly identifiable classification, calibration expiry date, and that all calibrations are traceable to the SI through NIST, other recognized national laboratories, accepted fundamental or natural physical constants, ratio type of calibration, or by comparison to consensus standards.

Table 2: Equipment List.

| Description | Manufacturer/Model | SN | Quality Num. | Cal/Ver By / Date Due |
|---|---|---|---|---|
| Spectrum Analyzer | R & S / FSV30 | 101660 | RSFSV3001 | RS / Apr-2024 |
| EMI Receiver | R & S / ESW26 | 101313 | RSESW2601 | RS / October-2023 |
| Quad Ridge Horn | Singer / A6100 | C35200 | HQR1TO18S01 | Keysight / Aug-2024 |
| Biconical | EMCO / 93110B | 9802-3039 | BICEMCO01 | Keysight / Aug-2025 |
| Log Periodic Antenna | EMCO / 3146 | 9305-3614 | LOGEMCO01 | Keysight / Aug-2025 |
| K-Band Horn | JEF / NRL Std. | 001 | HRNK01 | AHD / Jul-2024 |
| LISN | Solar / 8012-50-R-24-BNC | 970917 | LISNB | AHD / February-2024 |
| BNC-BNC Coax | WRTL / RG58/U | 001 | CAB001-BLACK | AHD / Dec-2023 |
| 3.5-3.5MM Coax | PhaseFlex / PhaseFlex | 001 | CAB015-PURP | AHD / Dec-2023 |

# 2 Test Specifications and Procedures

## 2.1 Test Specification and General Procedures

The goal of Lionel, LLC is to demonstrate that the Equipment Under Test (EUT) complies with the Rules and/or Directives below. Detailed in this report are the results of testing the Lionel, LLC Base3 for compliance to:

| **Country/Region** | **Rules or Directive** | **Referenced Section(s)** |
|---|---|---|
| United States | Code of Federal Regulations | CFR Title 47, Part 15.249 |
| Canada | ISED Canada | ISED RSS-210/GENe |

It has been determined that the equipment under test is subject to the rules and directives above at the date of this testing. In conjunction with these rules and directives, the following specifications and procedures are followed herein to demonstrate compliance (in whole or in part) with these regulations.

| | |
|---|---|
| ANSI C63.4:2014 | "Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz" |
| ANSI C63.10:2013 | "American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices" |
| TP0102RA | "AHD Internal Document TP0102 - Radiated Emissions Test Procedure" |
| ICES-003; Issue 7 (2020) | "Information Technology Equipment (ITE) - Limits and methods of measurement" |

# 3 Configuration and Identification of the Equipment Under Test

## 3.1 Description and Declarations

The equipment under test is an remote control gateway module for controlling multiple train systems containing BLE, Wifi and 2 proprietary 2.4 GHz radios. The EUT is approximately 26 x 13.5 x 5.5 cm (approx.) in dimension, and is depicted in Figure 1. It is powered by 120 VAC mains. In use, this device allows an existing Lionel remote control or smart device to operate all Lionel existing wireless train system architectures, regardless of protocol standard, with a single device controller. Table 3 outlines provider declared EUT specifications.

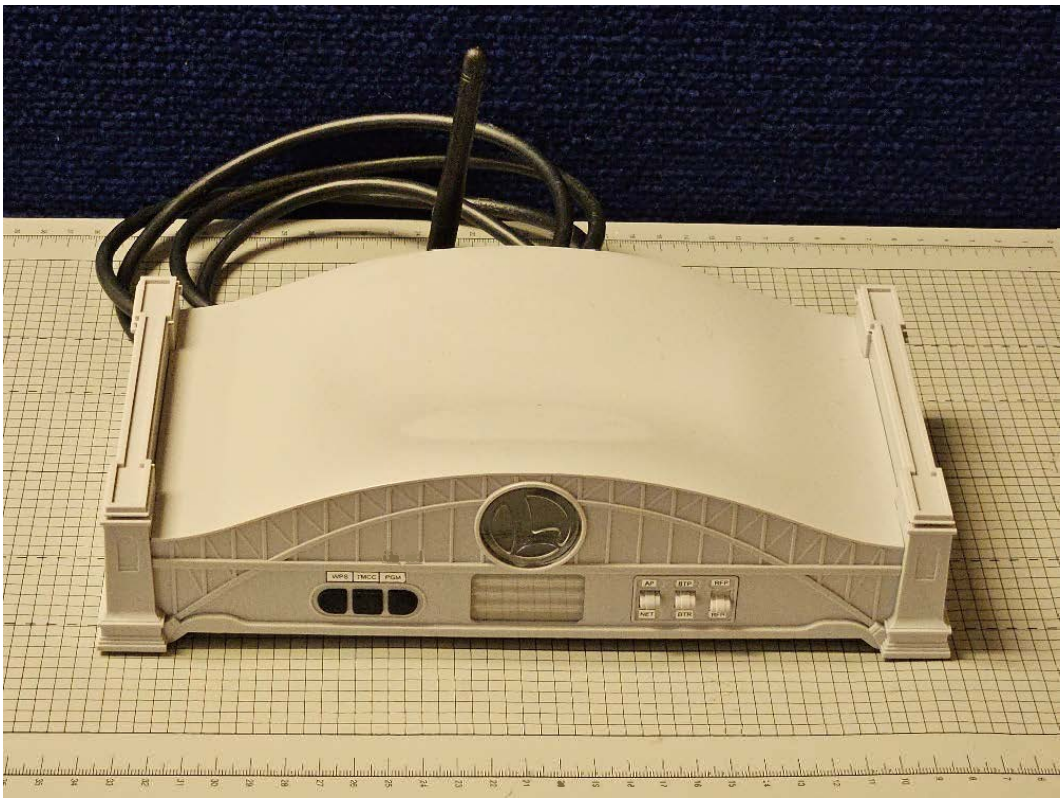



Figure 1: Photos of EUT.

Table 3: EUT Declarations.

| **General Declarations** | |
|---|---|
| **Equipment Type:** | Remote Control Gateway |
| **Country of Origin:** | China |
| **Nominal Supply:** | 120 VAC |
| **Oper. Temp Range:** | Not Declared |
| **Frequency Range:** | 2406 – 2478 MHz |
| **Antenna Dimension:** | 13 mm x 8 mm |
| **Antenna Type:** | PCB Trace |
| **Antenna Gain:** | Not declared, PCB trace |
| **Number of Channels:** | 72 |
| **Channel Spacing:** | 1 MHz |
| **Alignment Range:** | Not Declared |
| **Type of Modulation:** | GFSK |
| | |
| **United States** | |
| **FCC ID Number:** | LIV-BASE3 |
| **Classification:** | DXX |
| | |
| **Canada** | |
| **IC Number:** | 7032A-BASE3 |
| **Classification:** | Remote Control Device, Low Power Device (2400-2483.5 MHz) |

### 3.1.1 EUT Configuration

The EUT is configured for testing as depicted in Figure 2.

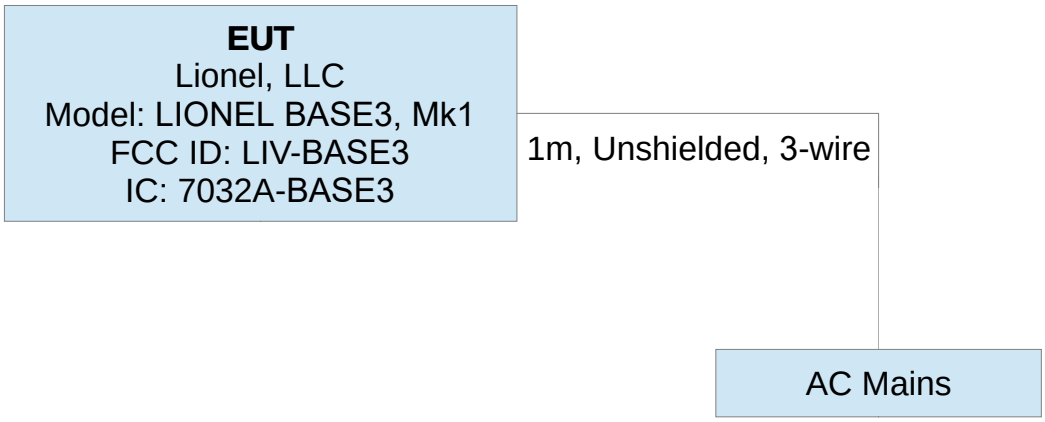



Figure 2: EUT Test Configuration Diagram.

### 3.1.2 Modes of Operation

The EUT employs 4 radios with the following operating modes: BLE, Wifi, RF proprietary 2.4 GHz (RFM75) and an additional RF proprietary 2.4 GHz radio (TICC) for controlling multiple train systems. This report only addresses the RF Proprietary (RFM75) radio, as well as intermodulation measurements made with the other radios active.

### 3.1.3 Variants

There is only a single electrical variant of the EUT.

### 3.1.4 Test Samples

Two samples were provided: One normal operating sample (SN: 27) and one sample (SN: 20) provided with custom software (FW revision "FCC Mode Test") to enable continuous modulated transmission of either low, middle or high channels of every radio. Channel selection was accomplished via a USB connection between the EUT and a manufacturer supplied laptop using the termite terminal application. The manufacturer declares the signals observed for the different radios and channel selections represents the maximum values possible for this EUT.

### 3.1.5 Functional Exerciser

Normal operating EUT functionality was verified by observation of transmitted signal.

### 3.1.6 Modifications Made

There were no modifications made to the EUT by this laboratory. However, the manufacturer did modify the low operating channel up to 2406 MHz to meet spurious limits at the bandedge during pretesting.

### 3.1.7 Production Intent

The EUT appears to be production ready.

### 3.1.8 Declared Exemptions and Additional Product Notes

In addition to the 2406-2478 MHz RFM75 radio tested herein, the EUT employs the following additional radios: Pre-approved BLE modular radio (FCC ID: X8WBM832, IC: 4100A-BM832) to interface with existing BLE train control systems, a pre-approved WiFi modular radio (FCC ID:RI7WE310F5, IC: 5131A-WE310F5) to interface to a phone or other smart device via a manufacturer provided APP, a proprietary radio module (See report no: BASE3 - Exh 06 - AHD LB3TICC-WR2325TXAr1 RF Test Report), and a Carrier Current transmitter operating at 455 kHz. All radios may be active at the same time in this product, and thus are tested for intermodulation products and RF exposure to confirm co-location requirements are met. The Carrier Current transmitter is handled through manufacturer SDoC.

# 4 Emissions

## 4.1 General Test Procedures

### 4.1.1 Radiated Test Setup and Procedures

Radiated electromagnetic emissions from the EUT are first pre-scanned in our screen room. Spectrum and modulation characteristics of all emissions are recorded. Instrumentation, including spectrum analyzers and other test equipment as detailed in Section 1.8 are employed. After pre-scan, emission measurements are made on the test site of record. If the EUT connects to auxiliary equipment and is table or floor standing, the configurations prescribed in relevant test standards are followed. Alternatively, a layout closest to normal use (as declared by the provider) is employed if the resulting emissions appear to be worst-case in such a configuration. See Figure 3. All intentionally radiating elements that are not fixed-mounted in use are placed on the test table lying flat, on their side, and on their end (3-axes) and the resulting worst case emissions are recorded. If the EUT is fixed-mounted in use, measurements are made with the device oriented in the manner consistent with installation and then emissions are recorded. If the EUT exhibits spurious emissions due to internal receiver circuitry, such emissions are measured with an appropriate carrier signal applied.

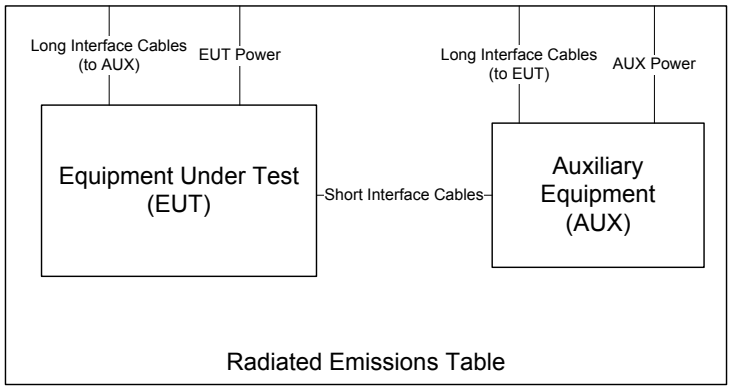



Figure 3: Radiated Emissions Diagram of the EUT.

For devices with intentional emissions below 30 MHz, a shielded loop antenna and/or E-field and H-Field broadband probes are used depending on the regulation. Shielded loops are placed at a 1 meter receive height at the desired measurement distance. For exposure in this band, 10cm diameter single-axis broadband probes meeting the requirements of ISED SPR-002 section 5.2 are employed. Measurements are repeated and summed over three axes, and the entire frequency range is measured with and without the EUT transmitting.

Emissions between 30 MHz and 1 GHz are measured using calibrated broadband antennas. For both horizontal and vertical polarizations, the test antenna is raised and lowered from 1 to 4 m in height until a maximum emission level is detected. The EUT is then rotated through $360^o$ in azimuth until the highest emission is detected. The test antenna is then raised and lowered one last time from 1 to 4 m and the worst case value is recorded. Emissions above 1 GHz are characterized using standard gain or broadband ridge-horn antennas on our OATS with a $4 \times 5$ m rectangle of ECCOSORB absorber covering the OATS ground screen and a 1.5m table height. Care is taken to ensure that test receiver resolution and video bandwidths meet the regulatory requirements, and that the emission bandwidth of the EUT is not reduced. Photographs of the test setup employed are depicted in Figure 4.

Where regulations allow for direct measurement of field strength, power values (dBm) measured on the test receiver / analyzer are converted to dB$\mu$V/m at the regulatory distance, using

$$E_{dist} = 107 + P_R + K_A - K_G + K_E - C_F$$

where $P_R$ is the power recorded on spectrum analyzer, in dBm, $K_A$ is the test antenna factor in dB/m, $K_G$ is the combined pre-amplifier gain and cable loss in dB, $K_E$ is duty correction factor (when applicable) in dB, and $C_F$ is a distance conversion (employed only if limits are specified at alternate distance) in dB. This field strength value is then compared with the regulatory limit. If effective isotropic radiated power (EIRP) is computed, it is computed as

$$EIRP(dBm) = E_{3m}(dB\mu V/m) - 95.2.$$

When presenting data at each frequency, the highest measured emission under all possible EUT orientations (3-axes) is reported.

Figure 4: Radiated Emissions Test Setup Photograph(s).

### 4.1.2 Conducted Emissions Test Setup and Procedures

**AC Port Conducted Spurious** For this device, AC power line conducted emissions are measured in our screen room. If the EUT connects to auxiliary equipment and is table or floor standing, the configurations prescribed in ANSI C63.4 / CISPR 22 are employed. Alternatively, an on-table layout more representative of actual use may be employed if the resulting emissions appear to be worst-case in such a configuration. See Figure 5.

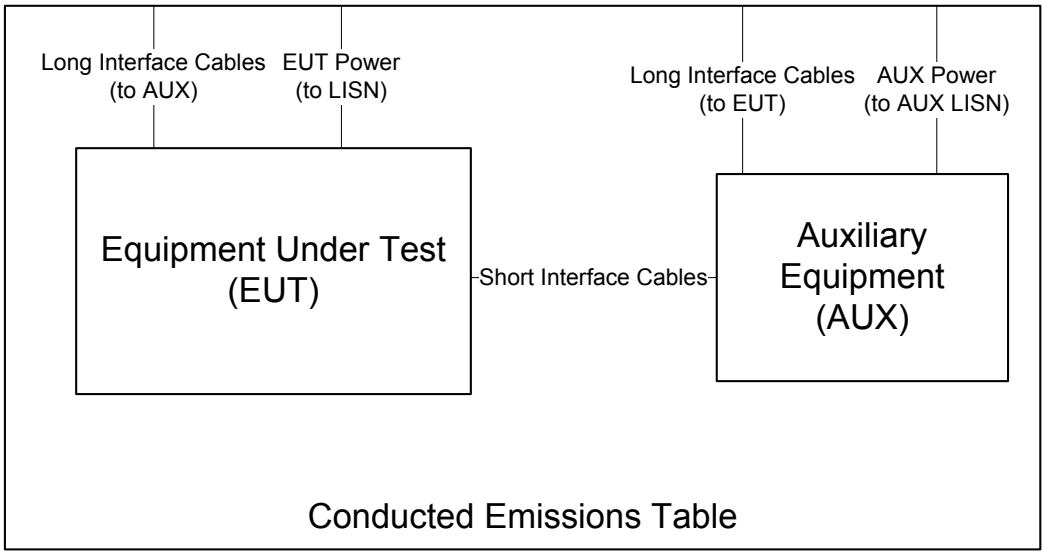



Figure 5: Conducted Emissions Setup Diagram of the EUT.

Conducted emissions are measured and recorded for each AC mains power source over the spectrum 0.15 MHz to 30 MHz for both the ungrounded (HI/PHASE) and grounded (LO/GND) conductors with the EUT placed in its highest current draw operating mode(s). The test receiver is set to peak-hold mode in order to record the peak emissions throughout the course of functional operation. Only if an emission exceeds or is near the limit are quasi-peak and average detection applied. Photographs of the test setup employed are depicted in Figure 6.

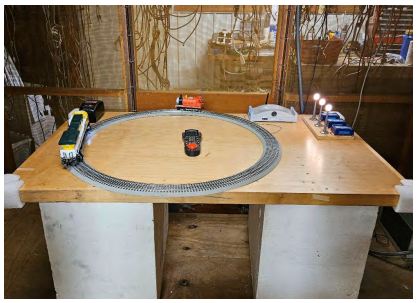


Figure 6: Conducted Emissions Test Setup Photograph(s).

### 4.1.3 Power Supply Variation

Tests at extreme supply voltages are made if required by the procedures specified in the test standard, and results of this testing are detailed in this report.

In the case of this EUT, measurements of the worst-case radiated emissions are performed with the supply voltage varied by no less than 85% and 115% of the nominal rated value for devices connecting to AC power mains.

## 4.2 Intentional Emissions

### 4.2.1 Fundamental Emission Pulsed Operation

**Test Setup & Procedure** The test equipment and facilities were setup in accordance with the standards and procedures listed in Section 2.1. Environmental conditions were set at the appropriate temperature and thermal balance was checked with a thermocouple based probe. Duty cycle is reported for all relevant modes of operation. The test equipment employed includes RSFSV30001, HQR1TO18S01.

**Measurement Results** The details and results of testing the EUT are summarized in Table 4. Plots showing the measurements made to obtain these values are provided in Figure 7.

Table 4: Fundamental Emission Pulsed Operation.

**Test Date:** 5-Sep-23
**Test Engineer:** John Nantz
**EUT** BASE3 - RFM
**Meas. Distance:** 10cm

| | Test Mode Pulsed Operation / Average Measurement Duty Cycle | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| R0 | Mode | Data Rate Mbps | Voltage V | Oper. Freq MHz | Pulse Length (ms) | Pulse Period (ms) | Duty Cycle % | Power Duty Correction dB | Exposure Duty Correction dB |
| R1 | CM | 1.000 | 120.0 | 2434.0 | 0.148 | 10.7 | 1.4 | -20.0 | -18.6 |
| # | C1 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 |

| (ROW) | (COLUMN) | (NOTE) |
|---|---|---|
| R0 | C9 | E-field duty cycle correction (due to burst-modulated carrier) computed as 20*Log(On-Time/Cycle-Time) |
| R0 | C10 | Exposure duty cycle correction (due to burst-modulated carrier) computed as 10*Log(On-Time/Cycle-Time) |

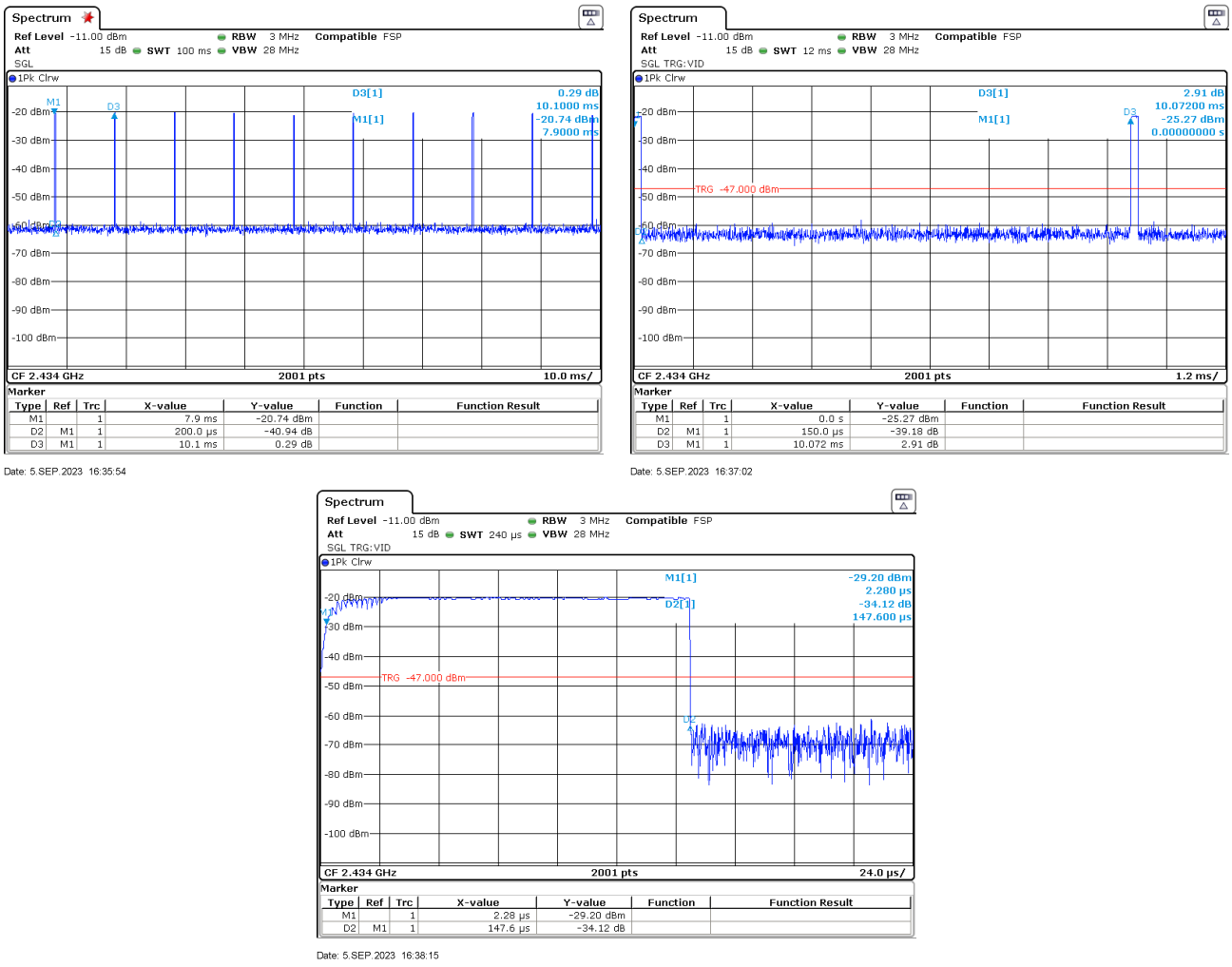



Figure 7: Fundamental Emission Pulsed Operation.

### 4.2.2 Fundamental Emission Bandwidth

**Test Setup & Procedure** The test equipment and facilities were setup in accordance with the standards and procedures listed in Section 2.1. Environmental conditions were set at the appropriate temperature and thermal balance was checked with a thermocouple based probe. Emission bandwidth (EBW) of the EUT is measured with the device placed in the test mode(s) with the shortest available frame length and minimum frame spacing. The 20 dB EBW is measured as the max-held peak-detected signal when the IF bandwidth is greater than or equal to 1% of the receiver span. For complex modulations other than ASK and FSK, the 99% emission bandwidth per IC test procedures has a different result, and is also reported. The test equipment employed includes RSFSV30001, HQR1TO18S01.

**Measurement Results** The details and results of testing the EUT are summarized in Table 5. Plots showing the measurements made to obtain these values are provided in Figure 8.

Table 5: Fundamental Emission Bandwidth.

**Test Date:** 5-Sep-23
**Test Engineer:** John Nantz
**EUT** BASE3 - RFM
**Meas. Distance:** 10cm

| | Occupied Bandwidth | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| R0 | Transmit Mode | Data Rate (Mbps) | Voltage (V) | Oper. Freq (MHz) | 20 dB BW (MHz) | FL (MHz) | FL Limit (MHz) | FH (MHz) | FL Limit (MHz) | Pass/Fail |
| R1 | GFSK | 1.000 | 120.0 | 2406.0 | 3.672 | 2403.9917 | 2400.000 | 2407.664 | 2483.500 | Pass |
| R2 | | | | 2434.0 | 4.173 | 2431.936 | 2400.000 | 2436.109 | 2483.500 | Pass |
| R3 | | | | 2478.0 | 4.360 | 2475.898 | 2400.000 | 2480.259 | 2483.500 | Pass |
| # | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | | C9 |

(ROW) (COLUMN) (NOTE)
R0 C7/C9 Limits according to FCC part 15.215(c)

# Emission Bandwidth

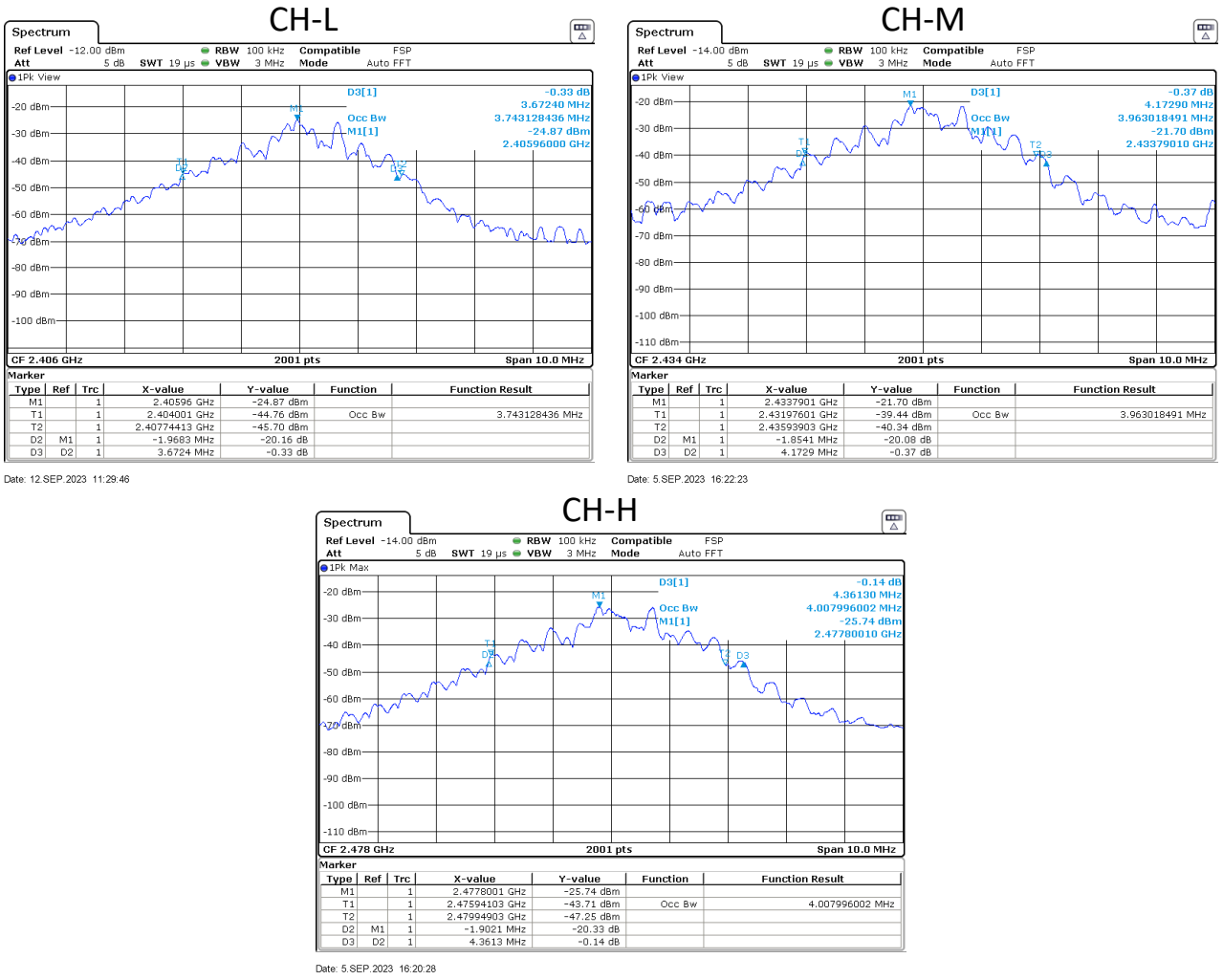



Figure 8: Fundamental Emission Bandwidth.

### 4.2.3 Fundamental Emission Field Strength

**Test Setup & Procedure** The test equipment and facilities were setup in accordance with the standards and procedures listed in Section 2.1. Environmental conditions were set at the appropriate temperature and thermal balance was checked with a thermocouple based probe. Fundamental emissions are measured at the regulatory distance on our OATS. The test equipment employed includes RSFSV30001, HQR1TO18S01.

**Measurement Results** The details and results of testing the EUT are summarized in Table 6.

Table 6: Fundamental Emission Field Strength.

| Frequency Range | Det | IF Bandwidth | Video Bandwidth | | |
|---|---|---|---|---|---|
| 25 MHz ≤ f ≤ 1 000 MHz | Pk/QPk | 120 kHz | 300 kHz | **Test Date:** | 5-Sep-23 |
| f > 1 000 MHz | Pk/Avg | 1 MHz | 3 MHz | **Test Engineer:** | John Nantz |
| | | | | **EUT:** | BASE3 - RFM |
| | | | | **Meas. Distance:** | 10cm |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R0 | Freq. Start MHz | Freq. Stop MHz | Ant. Used | Ant. Pol. | Ka dB/m | Kg dB | Duty Factor dB | E3(Pk) dBµV/m | E3 Pk Lim dBµV/m | E3(Avg) dBµV/m | E3 Avg Lim dBµV/m | Pass dB | Comments |
| R1 | 2406.0 | 2406.0 | HQR1TO18S01 | H/V | 31.4 | -1.1 | -20.0 | 100.4 | 114.0 | 80.4 | 94.0 | 13.6 | Flat |
| R2 | 2434.0 | 2434.0 | HQR1TO18S01 | H/V | 31.5 | -1.1 | -20.0 | 101.8 | 114.0 | 81.8 | 94.0 | **12.2** | End |
| R3 | 2478.0 | 2480.0 | HQR1TO18S01 | H/V | 31.7 | -1.1 | -20.0 | 100.1 | 114.0 | 80.1 | 94.0 | 13.9 | End |
| # | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 | C13 | C14 |

(ROW) (COLUMN) (NOTE)

R0 C10 When E-field or EIRP is reported directly from Spectrum Analyzer, Antenna Factors and Cable losses are included directly in SA settings and Pr is not reported.

R0 C11 Avg computed from Pk measurement by applying duty cycle correction.

## 4.3 Unintentional Emissions

### 4.3.1 Transmit Chain Spurious Emissions

The results for the measurement of transmit chain spurious emissions at the nominal voltage and temperature are provided in Table 7.

Table 7(a): Transmit Chain Spurious Emissions.

| Frequency Range | Det | IF Bandwidth | Video Bandwidth | | |
|---|---|---|---|---|---|
| 30 MHz < f < 1 000 MHz | Pk/Qpk | 100 kHz | 300 kHz | **Test Date:** | 5-Sep-23 |
| f > 1 000 MHz | Pk/Avg | 1 MHz | 3 MHz | **Test Engineer:** | John Nantz |
| | | | | **EUT:** | BASE3 - RFM |
| | | | | **Meas. Distance:** | 10cm |

| | | | | | | | | | | | | | | FCC/IC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Freq. Start | Freq. Stop | Ant. | Ant. | Pr (Pk) | Pr (Avg) | Ka | Kg | E3(Pk) | E3 Pk Lim | E3(Avg) | E3 Avg Lim | Pass | |
| R0 | MHz | MHz | Used | Pol. | dBm | dBm | dB/m | dB | dBµV/m | dBµV/m | dBµV/m | dBµV/m | dB | Comments |
| R1 | Fundamental Restricted Band Edge (Low Side) | | | | | | | | | | | | | |
| R2 | 2400.0 | 2400.0 | HQR1TO18S01 | H/V | | | 31.3 | -1.1 | 68.0 | 74.0 | 27.6 | 54.0 | 6.0 | max all - baud rates/L,M,H channels/noise |
| R3 | Fundamental Restricted Band Edge (High Side) | | | | | | | | | | | | | |
| R4 | 2483.5 | 2483.5 | HQR1TO18S01 | H/V | | | 31.8 | -1.1 | 71.3 | 74.0 | 27.8 | 54.0 | **2.8** | max all - baud rates/L,M,H channels/noise |
| R5 | Harmonic / Spurious Emissions | | | | | | | | | | | | | |
| R6 | 4812.0 | 4812.0 | HQR1TO18S01 | H/V | | | 35.5 | -1.3 | 34.1 | 74.0 | 14.1 | 54.0 | 39.9 | max all - baud rates/L,M,H channels/noise |
| R7 | 4868.0 | 4868.0 | HQR1TO18S01 | H/V | | | 35.2 | -1.3 | 35.5 | 74.0 | 15.5 | 54.0 | 38.5 | max all - baud rates/L,M,H channels/noise |
| R8 | 4956.0 | 4956.0 | HQR1TO18S01 | H/V | | | 34.8 | -1.3 | 37.3 | 74.0 | 17.3 | 54.0 | 36.7 | max all - baud rates/L,M,H channels/noise |
| R9 | 4000.0 | 6000.0 | HQR1TO18S01 | H/V | | | 32.8 | -1.6 | 36.6 | 74.0 | 16.6 | 54.0 | 37.4 | max all - baud rates/L,M,H channels/noise |
| R10 | 7218.0 | 7218.0 | HQR1TO18S01 | H/V | | | 33.3 | -1.7 | 36.3 | 74.0 | 16.3 | 54.0 | 37.7 | max all - baud rates/L,M,H channels/noise |
| R11 | 7302.0 | 7302.0 | HQR1TO18S01 | H/V | | | 33.3 | -1.7 | 36.8 | 74.0 | 16.8 | 54.0 | 37.2 | max all - baud rates/L,M,H channels/noise |
| R12 | 7434.0 | 7434.0 | HQR1TO18S01 | H/V | | | 33.5 | -1.7 | 37.2 | 74.0 | 17.2 | 54.0 | 36.8 | max all - baud rates/L,M,H channels/noise |
| R13 | 6000.0 | 8400.0 | HQR1TO18S01 | H/V | | | 34.3 | -1.8 | 39.3 | 74.0 | 19.3 | 54.0 | 34.7 | max all - baud rates/L,M,H channels/noise |
| R14 | 8400.0 | 12500.0 | HQR1TO18S01 | H/V | | | 35.6 | -2.2 | 43.7 | 74.0 | 23.7 | 54.0 | 30.3 | max all - baud rates/L,M,H channels/noise |
| R15 | 12500.0 | 18000.0 | HQR1TO18S01 | H/V | | | 34.3 | -2.9 | 44.5 | 74.0 | 24.5 | 54.0 | 29.5 | max all - baud rates/L,M,H channels/noise |
| R16 | 18000.0 | 26500.0 | HRNK001 | H/V | | | 33.7 | -3.9 | 45.1 | 74.0 | 25.1 | 54.0 | 28.9 | max all - baud rates/L,M,H channels/noise |
| R17 | | | | | | | | | | | | | | |
| R18 | | | | | | | | | | | | | | |
| R19 | | | | | | | | | | | | | | |
| R20 | | | | | | | | | | | | | | |
| # | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 | C13 | C14 |

| (ROW) | (COLUMN) | NOTE: |
|---|---|---|
| R0 | C5-C6 | When E-field or EIRP is reported directly from Spectrum Analyzer, Antenna Factors and Cable losses are included directly in SA settings and Pr is not reported. |
| R0 | C11 | Avg computed from Pk measurement by applying duty cycle correction factor except for Bandedges where the measurements were made using the average detector of the SA. |

## Table 7(b): Transmit Chain Spurious Emissions.

| Frequency Range | Det | IF Bandwidth | Video Bandwidth | | |
|---|---|---|---|---|---|
| 30 MHz < f < 1 000 MHz | Pk/Qpk | 120 kHz | 300 kHz | **Test Date:** | 3-Sep-23 |
| f > 1 000 MHz | Pk/Avg | 1 MHz | 3 MHz | **Test Engineer:** | J. Brunett |
| | | | | **EUT:** | BASE3 – All Radios |
| | | | | **Meas. Distance:** | 10cm |

| | | | | | | | | | | | | | FCC/IC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R0 | Mode | Freq. Start MHz | Freq. Stop MHz | Ant. Used | Ant. Pol. | Ka dB/m | Kg dB | E3(Pk) dBµV/m | E3 Pk Lim dBµV/m | E3(Avg) dBµV/m | E3 Avg Lim dBµV/m | Pass dB | Comments |
| R1 | Fundamental Restricted Band Edge (Low Side / High Side) | | | | | | | | | | | | |
| R2 | RFM + BLE | 2280.0 | 2400.0 | HQR1TO18S01 | H/V | 31.3 | -1.1 | 68.9 | 74.0 | 27.3 | 54.0 | 5.1 | LMH Channels, Both Radios |
| R3 | RFM + BLE | 2483.5 | 2550.0 | HQR1TO18S01 | H/V | 32.1 | -1.1 | 71.5 | 74.0 | 27.8 | 54.0 | **2.5** | LMH Channels, Both Radios |
| R4 | RFM + WIFIb | 2280.0 | 2400.0 | HQR1TO18S01 | H/V | 31.3 | -1.1 | 69.0 | 74.0 | 27.3 | 54.0 | 5.0 | LMH Channels, Both Radios |
| R5 | RMF + WIFIb | 2483.5 | 2550.0 | HQR1TO18S01 | H/V | 32.1 | -1.1 | 71.3 | 74.0 | 27.6 | 54.0 | **2.7** | LMH Channels, Both Radios |
| R6 | RFM + WIFIg | 2280.0 | 2400.0 | HQR1TO18S01 | H/V | 31.3 | -1.1 | 68.5 | 74.0 | 27.3 | 54.0 | 5.5 | LMH Channels, Both Radios |
| R7 | RFM + WIFIg | 2483.5 | 2550.0 | HQR1TO18S01 | H/V | 32.1 | -1.1 | 71.6 | 74.0 | 27.5 | 54.0 | **2.4** | LMH Channels, Both Radios |
| R8 | RFM + WIFIn | 2280.0 | 2400.0 | HQR1TO18S01 | H/V | 31.3 | -1.1 | 68.8 | 74.0 | 27.4 | 54.0 | 5.2 | LMH Channels, Both Radios |
| R9 | RFM + WIFIn | 2483.5 | 2550.0 | HQR1TO18S01 | H/V | 32.1 | -1.1 | 71.8 | 74.0 | 27.6 | 54.0 | **2.2** | LMH Channels, Both Radios |
| R10 | RFM +TICC | 2280.0 | 2400.0 | HQR1TO18S01 | H/V | 31.3 | -1.1 | 68.3 | 74.0 | 27.4 | 54.0 | 5.7 | LMH Channels, Both Radios |
| R11 | RFM + TICC | 2483.5 | 2550.0 | HQR1TO18S01 | H/V | 32.1 | -1.1 | 72.2 | 74.0 | 27.7 | 54.0 | **1.8** | LMH Channels, Both Radios |
| R12 | RFM + TICC +BLE +WIFIb | 2280.0 | 2400.0 | HQR1TO18S01 | H/V | 31.3 | -1.1 | 68.1 | 74.0 | 27.4 | 54.0 | 5.9 | LMH Channels, ALL Radios |
| R13 | RFM + TICC +BLE +WIFIb | 2483.5 | 2550.0 | HQR1TO18S01 | H/V | 32.1 | -1.1 | 72.1 | 74.0 | 27.6 | 54.0 | **1.9** | LMH Channels, ALL Radios |
| R14 | | | | | | | | | | | | | |
| R15 | | | | | | | | | | | | | |
| R16 | | | | | | | | | | | | | |
| R17 | | | | | | | | | | | | | |
| R18 | | | | | | | | | | | | | |
| R19 | | | | | | | | | | | | | |
| R20 | | | | | | | | | | | | | |
| # | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 | C13 |

| ROW) | (COLUMN) | NOTE: |
|---|---|---|
| R0 | C5-C6 | When E-field or EIRP is reported directly from Spectrum Analyzer, Antenna Factors and Cable losses are included directly in SA settings and Pr is not reported. |
| R0 | C11 | Avg computed from Pk measurement by applying duty cycle correction factor except for Bandedges where the measurements were made using the average detector of the S |

### 4.3.2 General Radiated Spurious

The results for the measurement of general spurious emissions (emissions arising from digital circuitry) at the nominal voltage and temperature are provided in Table 8. Radiation from digital components are measured up to 1000 MHz or to the highest frequency required by the applied standards, whichever is greater.

Table 8: Radiated Spurious Emissions.

| Frequency Range | Det | IF Bandwidth | Video Bandwidth |
|---|---|---|---|
| 25 MHz ≤ f ≤ 1 000 MHz | Pk/QPk | 120 kHz | 300 kHz |
| f > 1 000 MHz | Pk | 1 MHz | 3 MHz |
| f > 1 000 MHz | Avg/RMS | 1 MHz | 3 MHz |

| | |
|---|---|
| **Test Date:** | 24-Aug-23 |
| **Test Engineer:** | J. Nantz |
| **EUT:** | LION BASE3 |
| **EUT Mode:** | All ports exercised |
| **Meas. Distance:** | 3 m |
| **Temperature:** | 27C |
| **Rel. Humidty:** | 78% |

**Digital Spurious Emissions** CISPR 11 / EN 55011

| | Test | Antenna | | | | E-Field @ 3m** | | FCC CLB (QPk/Avg) | | CE CLB (QPk/Avg) | | FCC CLA (QPk/Avg) | | CE CLA (QPk/Avg) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Freq. | QN | Test | Ka | Kg | Pk | Qpk/Avg | E3lim | Pass | E3lim | Pass | E3lim | Pass | E3lim | Pass | |
| R0 | MHz | | Pol. | dB/m | dB | dBµV/m | dBµV/m | dBµV/m | dB | dBµV/m | dB | dBµV/m | dB | dBµV/m | dB | Comments |
| R1 | 48.8 | BICEMCO01 | V | 9.3 | -.4 | 33.6 | 26.5 | 40.0 | 13.5 | 40.5 | 14.0 | 49.5 | 23.0 | 50.5 | 24.0 | |
| R2 | 63.9 | BICEMCO01 | H | 7.8 | -.4 | 42.3 | 39.4 | 40.0 | **0.6** | 40.5 | **1.1** | 49.5 | 10.1 | 50.5 | 11.1 | |
| R3 | 63.9 | BICEMCO01 | V | 7.8 | -.4 | 39.7 | 34.0 | 40.0 | 6.0 | 40.5 | 6.5 | 49.5 | 15.5 | 50.5 | 16.5 | |
| R4 | 71.7 | BICEMCO01 | H | 7.6 | -.4 | 40.0 | 30.6 | 40.0 | 9.4 | 40.5 | 9.9 | 49.5 | 18.9 | 50.5 | 19.9 | |
| R5 | 71.7 | BICEMCO01 | V | 7.6 | -.4 | 37.0 | 30.0 | 40.0 | 10.0 | 40.5 | 10.5 | 49.5 | 19.5 | 50.5 | 20.5 | |
| R6 | 147.5 | BICEMCO01 | H | 12.3 | -.7 | 36.0 | 26.8 | 43.5 | 16.7 | 40.5 | 13.7 | 54.0 | 27.2 | 50.5 | 23.7 | |
| R7 | 158.7 | BICEMCO01 | V | 13.1 | -.7 | 32.5 | 26.8 | 43.5 | 16.7 | 40.5 | 13.7 | 54.0 | 27.2 | 50.5 | 23.7 | |
| R8 | 168.4 | BICEMCO01 | H | 13.6 | -.7 | 31.5 | 24.7 | 43.5 | 18.8 | 40.5 | 15.8 | 54.0 | 29.3 | 50.5 | 25.8 | |
| R9 | 168.4 | BICEMCO01 | V | 13.6 | -.7 | 33.0 | 24.9 | 43.5 | 18.6 | 40.5 | 15.6 | 54.0 | 29.1 | 50.5 | 25.6 | |
| R10 | 244.5 | LOGEMCO01 | H | 12.3 | -1.0 | 34.2 | 27.3 | 46.0 | 18.7 | 47.5 | 20.2 | 56.9 | 29.6 | 57.0 | 29.7 | |
| R11 | 244.5 | LOGEMCO01 | V | 12.3 | -1.0 | 32.1 | 22.6 | 46.0 | 23.4 | 47.5 | 24.9 | 56.9 | 34.3 | 57.0 | 34.4 | |
| R12 | 287.0 | LOGEMCO01 | V | 13.4 | -1.1 | 32.3 | 21.5 | 46.0 | 24.5 | 47.5 | 26.0 | 56.9 | 35.4 | 57.0 | 35.5 | |
| R13 | 298.0 | LOGEMCO01 | H | 13.7 | -1.1 | 34.5 | 28.4 | 46.0 | 17.6 | 47.5 | 19.1 | 56.9 | 28.5 | 57.0 | 28.6 | |
| R14 | 457.7 | LOGEMCO01 | V | 16.7 | -1.6 | 33 | 23.5 | 46.0 | 22.5 | 47.5 | 24.0 | 56.9 | 33.4 | 57.0 | 33.5 | |
| R15 | 772.0 | LOGEMCO01 | H | 21.2 | -2.5 | 34.3 | 28.1 | 46.0 | 17.9 | 47.5 | 19.4 | 56.9 | 28.8 | 57.0 | 28.9 | Background Noise |
| R16 | | | | | | | | | | | | | | | | |
| R17 | | | | | | | | | | | | | | | | |
| R18 | | | | | | | | | | | | | | | | |
| R19 | | | | | | | | | | | | | | | | |
| R20 | | | | | | | | | | | | | | | | |
| R21 | | | | | | | | | | | | | | | | |
| R22 | | | | | | | | | | | | | | | | |
| # | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 | C13 | C14 | C15 | C16 |

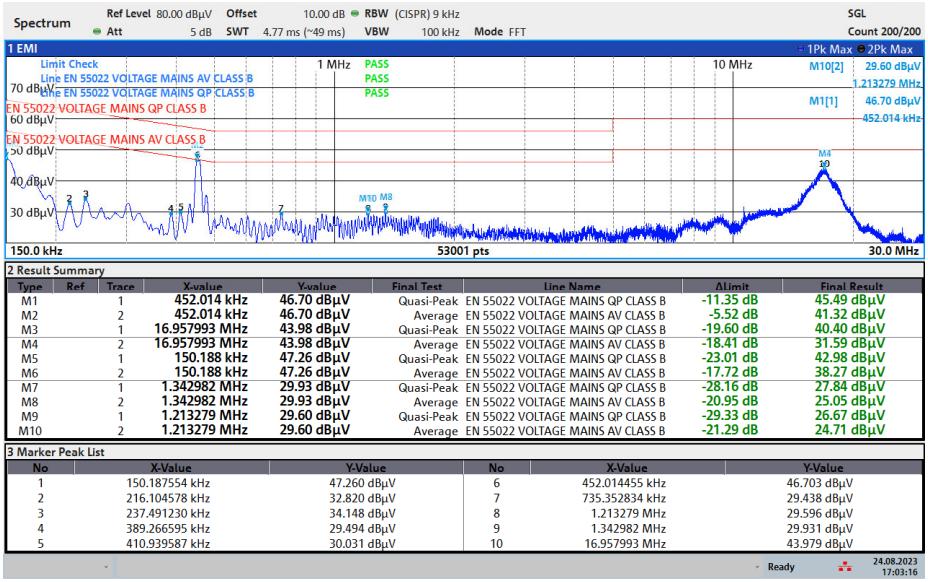
| (ROW) | (COLUMN) | (NOTE) |
|---|---|---|
| R0 | C7 | Pk+Avg detection (narrowband), Pk + QPk detection (wideband) emissions |
| R0 | C7 | When E-field is reported directly from Spectrum Analyzer, Antenna Factors and Cable losses are included directly in SA settings. |
| R0 | C7 | Emissions > 20dB below the limit are not reported. |

### 4.3.3 Conducted Emissions Test Results - AC Power Port(s)

The results of emissions from the EUT's AC mains power port(s) are reported in Table 9.

Table 9: AC Mains Power Conducted Emissions Results.

**CONDUCTED EMISSIONS – AC PORT – L1**




2 Result Summary

| Type | Ref | Trace | X-value | Y-value | Final Test | Line Name | ΔLimit | Final Result |
|---|---|---|---|---|---|---|---|---|
| M1 | | 1 | 452.014 kHz | 46.70 dBµV | Quasi-Peak | EN 55022 VOLTAGE MAINS QP CLASS B | -11.35 dB | 45.49 dBµV |
| M2 | | 2 | 452.014 kHz | 46.70 dBµV | Average | EN 55022 VOLTAGE MAINS AV CLASS B | -5.52 dB | 41.32 dBµV |
| M3 | | 1 | 16.957993 MHz | 43.98 dBµV | Quasi-Peak | EN 55022 VOLTAGE MAINS QP CLASS B | -19.60 dB | 40.40 dBµV |
| M4 | | 2 | 16.957993 MHz | 43.98 dBµV | Average | EN 55022 VOLTAGE MAINS AV CLASS B | -18.41 dB | 31.59 dBµV |
| M5 | | 1 | 150.188 kHz | 47.26 dBµV | Quasi-Peak | EN 55022 VOLTAGE MAINS QP CLASS B | -23.01 dB | 42.98 dBµV |
| M6 | | 2 | 150.188 kHz | 47.26 dBµV | Average | EN 55022 VOLTAGE MAINS AV CLASS B | -17.72 dB | 38.27 dBµV |
| M7 | | 1 | 1.342982 MHz | 29.93 dBµV | Quasi-Peak | EN 55022 VOLTAGE MAINS QP CLASS B | -28.16 dB | 27.84 dBµV |
| M8 | | 2 | 1.342982 MHz | 29.93 dBµV | Average | EN 55022 VOLTAGE MAINS AV CLASS B | -20.95 dB | 25.05 dBµV |
| M9 | | 1 | 1.213279 MHz | 29.60 dBµV | Quasi-Peak | EN 55022 VOLTAGE MAINS QP CLASS B | -29.33 dB | 26.67 dBµV |
| M10 | | 2 | 1.213279 MHz | 29.60 dBµV | Average | EN 55022 VOLTAGE MAINS AV CLASS B | -21.29 dB | 24.71 dBµV |

3 Marker Peak List

| No | X-Value | Y-Value | No | X-Value | Y-Value |
|---|---|---|---|---|---|
| 1 | 150.187554 kHz | 47.260 dBµV | 6 | 452.014455 kHz | 46.703 dBµV |
| 2 | 216.104578 kHz | 32.820 dBµV | 7 | 735.352834 kHz | 29.438 dBµV |
| 3 | 237.491230 kHz | 34.148 dBµV | 8 | 1.213279 MHz | 29.596 dBµV |
| 4 | 389.266595 kHz | 29.494 dBµV | 9 | 1.342982 MHz | 29.931 dBµV |
| 5 | 410.939587 kHz | 30.031 dBµV | 10 | 16.957993 MHz | 43.979 dBµV |

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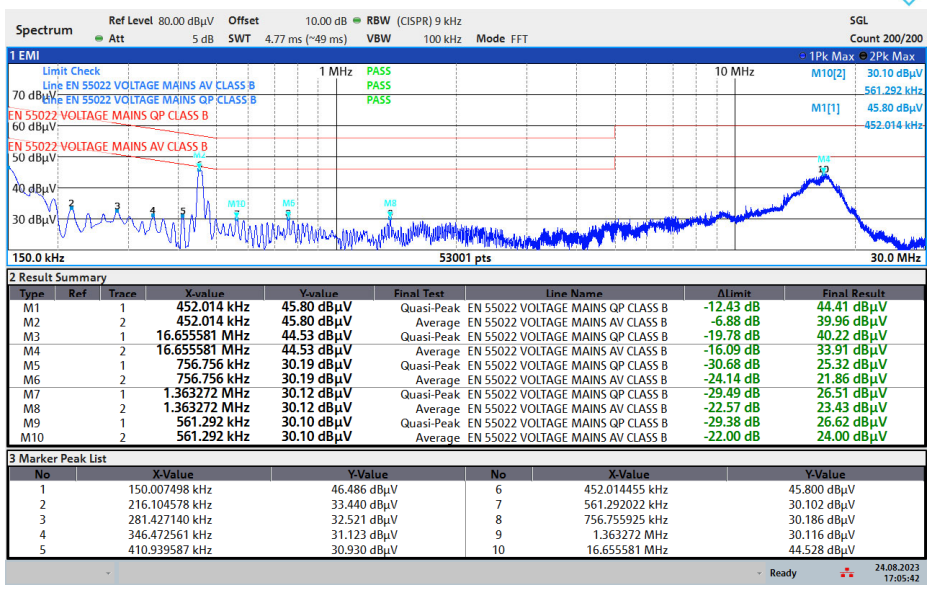
**CONDUCTED EMISSIONS – AC PORT – L2**




2 Result Summary

| Type | Ref | Trace | X-value | Y-value | Final Test | Line Name | ΔLimit | Final Result |
|---|---|---|---|---|---|---|---|---|
| M1 | | 1 | 452.014 kHz | 45.80 dBµV | Quasi-Peak | EN 55022 VOLTAGE MAINS QP CLASS B | -12.43 dB | 44.41 dBµV |
| M2 | | 2 | 452.014 kHz | 45.80 dBµV | Average | EN 55022 VOLTAGE MAINS AV CLASS B | -6.88 dB | 39.96 dBµV |
| M3 | | 1 | 16.655581 MHz | 44.53 dBµV | Quasi-Peak | EN 55022 VOLTAGE MAINS QP CLASS B | -19.78 dB | 40.22 dBµV |
| M4 | | 2 | 16.655581 MHz | 44.53 dBµV | Average | EN 55022 VOLTAGE MAINS AV CLASS B | -16.09 dB | 33.91 dBµV |
| M5 | | 1 | 756.756 kHz | 30.19 dBµV | Quasi-Peak | EN 55022 VOLTAGE MAINS QP CLASS B | -30.68 dB | 25.32 dBµV |
| M6 | | 2 | 756.756 kHz | 30.19 dBµV | Average | EN 55022 VOLTAGE MAINS AV CLASS B | -24.14 dB | 21.86 dBµV |
| M7 | | 1 | 1.363272 MHz | 30.12 dBµV | Quasi-Peak | EN 55022 VOLTAGE MAINS QP CLASS B | -29.49 dB | 26.51 dBµV |
| M8 | | 2 | 1.363272 MHz | 30.12 dBµV | Average | EN 55022 VOLTAGE MAINS AV CLASS B | -22.57 dB | 23.43 dBµV |
| M9 | | 1 | 561.292 kHz | 30.10 dBµV | Quasi-Peak | EN 55022 VOLTAGE MAINS QP CLASS B | -29.38 dB | 26.62 dBµV |
| M10 | | 2 | 561.292 kHz | 30.10 dBµV | Average | EN 55022 VOLTAGE MAINS AV CLASS B | -22.00 dB | 24.00 dBµV |

3 Marker Peak List

| No | X-Value | Y-Value | No | X-Value | Y-Value |
|---|---|---|---|---|---|
| 1 | 150.007498 kHz | 46.486 dBµV | 6 | 452.014455 kHz | 45.800 dBµV |
| 2 | 216.104578 kHz | 33.440 dBµV | 7 | 561.292022 kHz | 30.102 dBµV |
| 3 | 281.427140 kHz | 32.521 dBµV | 8 | 756.755925 kHz | 30.186 dBµV |
| 4 | 346.472561 kHz | 31.123 dBµV | 9 | 1.363272 MHz | 30.116 dBµV |
| 5 | 410.939587 kHz | 30.930 dBµV | 10 | 16.655581 MHz | 44.528 dBµV |

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## 5 Measurement Uncertainty and Accreditation Documents

The maximum values of measurement uncertainty for the laboratory test equipment and facilities associated with each test are given in the table below. This uncertainty is computed for a 95.45% confidence level based on a coverage factor of $k = 2$.

Table 10: Measurement Uncertainty.

| Measured Parameter | Measurement Uncertainty† |
|---|---|
| Radio Frequency | $\pm(f_{Mkr}/10^7 + RBW/10 + (SPN/(PTS-1))/2 + 1\,\text{Hz})$ |
| Conducted Emm. Amplitude | $\pm 1.9\,\text{dB}$ |
| Radiated Emm. Amplitude ($f < 30\,\text{MHz}$) | $\pm 3.1\,\text{dB}$ |
| Radiated Emm. Amplitude ($30 - 200\,\text{MHz}$) | $\pm 4.0\,\text{dB}$ |
| Radiated Emm. Amplitude ($200 - 1000\,\text{MHz}$) | $\pm 5.2\,\text{dB}$ |
| Radiated Emm. Amplitude ($f > 1000\,\text{MHz}$) | $\pm 3.7\,\text{dB}$ |

†Ref: CISPR 16-4-2:2011+A1:2014


United States Department of Commerce
National Institute of Standards and Technology

NVLAP® ilac-MRA

Certificate of Accreditation to ISO/IEC 17025:2017

NVLAP LAB CODE: 200129-0

AHD (Amber Helm Development, L.C.)
Sister Lakes, MI

*is accredited by the National Voluntary Laboratory Accreditation Program for specific services, listed on the Scope of Accreditation, for:*

**Electromagnetic Compatibility & Telecommunications**

*This laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025:2017. This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system (refer to joint ISO-ILAC-IAF Communique dated January 2009).*

2023-06-20 through 2024-06-30
*Effective Dates*

*For the National Voluntary Laboratory Accreditation Program*



Figure 9: Accreditation Documents