# ENGINEERING TEST REPORT

**LS4550 Combi Master**
**Model: LS4550**
**FCC ID: PQG-LS4550**

*Applicant:*

**Lyngsoe Systems Ltd.**
101 Simona Dr., Unit 2
Bolton, Ontario
Canada L7E 4E8

**In Accordance With**
**Federal Communications Commission (FCC)**
**Part 15, Subpart C, Sections 15.209 & 15.231(e)**
**Low Power Transmitter & Momentarily Operation (125 kHz & 433.92 MHz)**

**UltraTech's File No.: 19LYI172_FCC15C231E**

| | |
|---|---|
| This Test report is Issued under the Authority of<br>Tri M. Luu<br>Vice President of Engineering<br>UltraTech Group of Labs<br><br>Date: February 20, 2019 | |
| Report Prepared by: Dan Huynh<br><br>Issued Date: February 20, 2019 | Tested by: Hung Trinh<br><br>Test Dates:<br>March 16 - 26, 2018<br>February 7, 2019 |

- *The results in this Test Report apply only to the sample(s) tested, and the sample tested is randomly selected.*
- *This report must not be used by the client to claim product endorsement by any agency of the US Government.*
- *This test report shall not be reproduced, except in full, without a written approval from UltraTech*

## TABLE OF CONTENTS

**EXHIBIT 1. INTRODUCTION ..... 1**

1.1. SCOPE ..... 1
1.2. RELATED SUBMITTAL(S)/GRANT(S) ..... 1
1.3. NORMATIVE REFERENCES ..... 1

**EXHIBIT 2. PERFORMANCE ASSESSMENT ..... 2**

2.1. CLIENT INFORMATION ..... 2
2.2. EQUIPMENT UNDER TEST (EUT) INFORMATION ..... 2
2.3. EUT'S TECHNICAL SPECIFICATIONS ..... 3
2.4. ASSOCIATED ANTENNA DESCRIPTIONS ..... 4
2.5. LIST OF EUT'S PORTS ..... 4
2.6. ANCILLARY EQUIPMENT ..... 4
2.7. TEST SETUP BLOCK DIAGRAM ..... 5

**EXHIBIT 3. EUT OPERATING CONDITIONS AND CONFIGURATIONS DURING TESTS ..... 6**

3.1. CLIMATE TEST CONDITIONS ..... 6
3.2. OPERATIONAL TEST CONDITIONS & ARRANGEMENT FOR TESTS ..... 6

**EXHIBIT 4. SUMMARY OF TEST RESULTS ..... 7**

4.1. LOCATION OF TESTS ..... 7
4.2. APPLICABILITY & SUMMARY OF EMC EMISSION TEST RESULTS ..... 7
4.3. MODIFICATIONS INCORPORATED IN THE EUT FOR COMPLIANCE PURPOSES ..... 7

**EXHIBIT 5. TEST DATA ..... 8**

5.1. POWER LINE CONDUCTED EMISSIONS [§15.207(a)] ..... 8
5.2. TRANSMITTER RADIATED EMISSIONS [47 CFR §§ 15.231(e), 15.209 & 15.205] ..... 11
5.3. 20 dB BANDWIDTH [47 CFR §§ 15.215(c) & 15.231(c)] ..... 18
5.4. RF EXPOSURE REQUIRMENTS [§§ 15.247(i), 1.1310 & 2.1091] ..... 21
5.5. TEST EQUIPMENT LIST ..... 23

**EXHIBIT 6. MEASUREMENT UNCERTAINTY ..... 24**

6.1. LINE CONDUCTED EMISSION MEASUREMENT UNCERTAINTY ..... 24
6.2. RADIATED EMISSION MEASUREMENT UNCERTAINTY ..... 24

# EXHIBIT 1. INTRODUCTION

## 1.1. SCOPE

| | |
|---|---|
| **Reference:** | FCC Part 15, Subpart C, Sections 15.209 and 15.231 |
| **Title:** | Code of Federal Regulations (CFR), Title 47, Telecommunication - Part 15 |
| **Purpose of Test:** | Equipment Certification for FCC Parts 15C and 15.231(e) |
| **Test Procedures:** | ▪ ANSI C63.4<br>▪ ANSI C63.10 |
| **Environmental Classification:** | Commercial, industrial or business environment |

## 1.2. RELATED SUBMITTAL(S)/GRANT(S)

None.

## 1.3. NORMATIVE REFERENCES

| Publication | Year | Title |
|---|---|---|
| FCC 47 CFR 15 | 2018 | Code of Federal Regulations, Title 47 – Telecommunication, Part 15 - Radio Frequency Devices |
| ANSI C63.4 | 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 | 2013 | American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices |

# EXHIBIT 2. PERFORMANCE ASSESSMENT

## 2.1. CLIENT INFORMATION

| Applicant | |
|---|---|
| **Name:** | Lyngsoe Systems Ltd. |
| **Address:** | 101 Simona Dr., Unit 2<br>Bolton, Ontario<br>Canada L7E 4E8 |
| **Contact Person:** | Donald Ferguson<br>Phone #: 905-501-1533<br>Fax #: 905-501-1538<br>Email Address: dfe@lyngsoesystems.com |

| Manufacturer | |
|---|---|
| **Name:** | Lyngsoe Systems Ltd. |
| **Address:** | 101 Simona Dr., Unit 2<br>Bolton, Ontario<br>Canada L7E 4E8 |
| **Contact Person:** | Donald Ferguson<br>Phone #: 905-501-1533<br>Fax #: 905-501-1538<br>Email Address: dfe@lyngsoesystems.com |

## 2.2. EQUIPMENT UNDER TEST (EUT) INFORMATION

The following information (with the exception of the Date of Receipt) has been supplied by the applicant.

| | |
|---|---|
| **Brand Name:** | Lyngsoe Systems Ltd. |
| **Product Name:** | LS4550 Combi Master |
| **Model Name or Number:** | LS4550 |
| **Serial Number:** | Test sample |
| **Type of Equipment:** | RFID Device |
| **Input Power Supply Type:** | 24V DC, from external certified AC adapter |
| **Primary User Functions of EUT:** | Fully automated RFID data collection, no user interaction after installation. Automatic tracking of active and passive RFID transponders. |

## 2.3. EUT'S TECHNICAL SPECIFICATIONS

| Transmitter (Exciter Board EXB45) | |
|---|---|
| **Equipment Type:** | Base station |
| **Intended Operating Environment:** | Commercial, light industry & heavy industry |
| **Power Supply Requirement:** | 24V DC, from external certified AC adapter |
| **RF Output Power Rating:** | 125 kHz Tx: 98.31 dBµV/m peak (98.24dBµV/m average) at 10m distance<br>433.92 MHz Tx: 89.44 dBµV/m peak (70.54 dBµV/m average) at 3m distance |
| **Operating Frequency Range:** | 125 kHz & 433.92 MHz<br>Note: other non-LS transmitters are:<br>Digi CC IMX6UL 2.4 and 5.4GHz (FCC ID: MCQ-CCIMX6UL IC: 1846A-CCIMX6UL);<br>Impinj R420 915MHz (FCC ID: TWYIPJREV and IC:6324A-IPJREV) |
| **Duty Cycle:** | 9.50 % (for 433.92 MHz transmitter) |
| **Modulation Type:** | OOK (LF) & FSK (UHF) |
| **Oscillator Frequencies:** | LS board with transmitters:<br>EXB45 clocks 13.56MHz & 20MHz;<br>Other LS boards (no transmitters):<br>RDB45 clocks 32.768kHz, 4.9152MHz, 25MHz<br>SUP45 clock 16MHz |
| **Antenna Connector Type:** | Integral |
| **Antenna Description:** | Manufacturer: Lyngsoe Systems<br>Type: Two loops 40 x 40cm, 16 turns each for 125 kHz;<br>PCB loop Antenna for 433.92 MHz<br>Model: N/A<br>Frequency Range: 125 kHz; 433.92 MHz<br>Gain: Not applicable for near field operation @ 125 kHz;<br>-17.2 dBi @ 433.92 MHz |
| **Receiver (Reader Board RDB45)** | |
| **Equipment Type:** | Base Station (fixed use) |
| **Power Supply Requirement:** | 24V DC, from external certified AC adapter |
| **Operating Frequency Range:** | 433.92 MHz |
| **RF Output Impedance:** | 50 Ω |
| **Antenna Connector Type:** | MCX |

## 2.4. ASSOCIATED ANTENNA DESCRIPTIONS

| Manufacturer | Antenna Type | Model | Frequency Range | Maximum Gain |
|---|---|---|---|---|
| Lyngsoe | Inductive Loops – two pcs, used for the EXB45 transmitter | 500439Rev0-0, 500804Rev0-0 | 125kHz | N/A |
| Lyngsoe | PCB Antenna – on the EXB45 transmitter | N/A | 434MHz | -17.2 dBi |
| Linx Technologies Inc. | Whip, Center-Fed Double – two pcs, used for the RDB45 receiver | ANT433OEMLNG001v2 | 434MHz | 1.2 dBi |
| Laird | Patches, left and right polarization – two pcs, used for the Impinj passive reader | S9028PCLJ36RTNB, S9028PCRJ36RTNB | 902-928MHz | 9 dBic |
| Ethertronics/AVX | PCB Antenna – used for the Digi computer with dual band wifi modem | 1001932PT-AA10L0100 | 2.400–2.485GHz & 5.150–5.825 GHz | 2.5 dBi & 4.4 dBi |

## 2.5. LIST OF EUT'S PORTS

| Port Number | EUT's Port Description | Number of Identical Ports | Connector Type | Cable Type (Shielded/Non-shielded) |
|---|---|---|---|---|
| 1 | Power Input 24Vdc | 2 | Molex 3 pins | Included in the external AC adapter, shielded |
| 2 | LF Sync IN/OUT | 2 | RJ45 | Patch cable, shielded, max 100m |

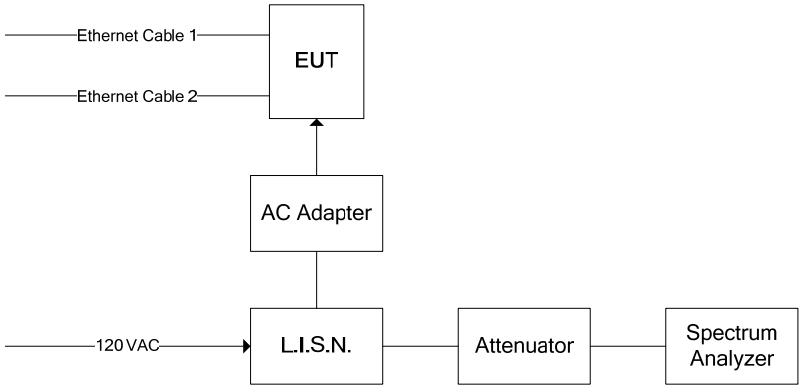
## 2.6. ANCILLARY EQUIPMENT

The EUT was tested while connected to the following representative configuration of ancillary equipment necessary to exercise the ports during tests:

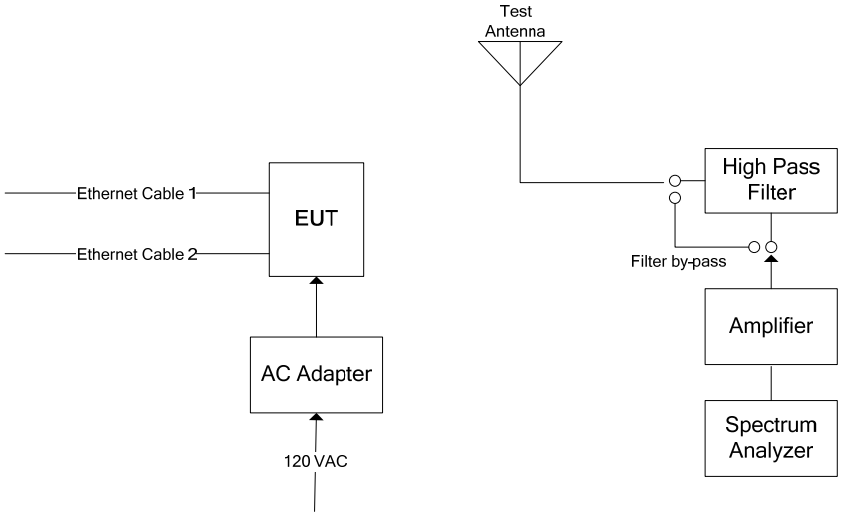
| Ancillary Equipment # 1 | |
|---|---|
| Description: | AC/DC Adapter |
| Brand name: | XP Power |
| Model Name or Number: | VEC50US24 |
| Serial Number: | N/A |
| Connected to EUT's Port: | Power Input |

## 2.7. TEST SETUP BLOCK DIAGRAM

### AC Power-line Conducted Emissions




### Radiated Emissions



# EXHIBIT 3. EUT OPERATING CONDITIONS AND CONFIGURATIONS DURING TESTS

## 3.1. CLIMATE TEST CONDITIONS

The climate conditions of the test environment are as follows:

| | |
|---|---|
| Temperature: | 21 to 23 °C |
| Humidity: | 45 to 58% |
| Pressure: | 102 kPa |
| Power input source: | 24V DC, from external certified AC adapter |

## 3.2. OPERATIONAL TEST CONDITIONS & ARRANGEMENT FOR TESTS

| | |
|---|---|
| **Operating Modes:** | Each channel frequency transmits continuously for emissions measurements. |
| **Special Test Software:** | Special software provided by the Applicant to operate the EUT at each channel frequency continuously and in the range of typical modes of operation. |
| **Special Hardware Used:** | N/A |
| **Transmitter Test Antenna:** | Tx antenna is integral, Rx antenna connector terminated to 50 Ω load as described with the test results. |

| **Transmitter Test Signals** | |
|---|---|
| **Frequency Band(s):** | 125 kHz and 433.92 MHz |
| **Test Frequency(ies):** | 125 kHz and 433.92 MHz |
| **RF Power Output:** | 125 kHz Tx: 98.31 dBµV/m peak (98.24dBµV/m average) at 10m distance<br>433.92 MHz Tx: 89.44 dBµV/m peak (70.54 dBµV/m average) at 3m distance |
| **Normal Test Modulation:** | OOK and FSK |
| **Modulating Signal Source:** | Internal |

# EXHIBIT 4. SUMMARY OF TEST RESULTS

## 4.1. LOCATION OF TESTS

All of the measurements described in this report were performed at Ultratech Group of Labs located in the city of Oakville, Province of Ontario, Canada.

- AC Power Line Conducted Emissions were performed in UltraTech's shielded room, 24'(L) by 16'(W) by 8'(H).
- Radiated Emissions were performed at the Ultratech's 3-10 TDK Semi-Anechoic Chamber situated in the Town of Oakville, province of Ontario. This test site been calibrated in accordance with ANSI C63.4, and found to be in compliance with the requirements of Sec. 2.948 of the FCC Rules. The descriptions and site measurement data of the Oakville 3-10 TDK Semi-Anechoic Chamber has been filed with ANAB File No.: AT-1945.

## 4.2. APPLICABILITY & SUMMARY OF EMC EMISSION TEST RESULTS

| FCC Section(s) | Test Requirements | Compliance (Yes/No) |
|---|---|---|
| 15.203 | Antenna Requirement | Yes* |
| 15.207(a) | AC Powerline Conducted Emissions | Yes |
| 15.231(e)<br>15.209 | Transmitter Radiated Emissions - Fundamental, Harmonic and Spurious Emissions | Yes |
| 15.231(c) | 20 dB Bandwidth | Yes |
| 15.231(d) | Frequency Tolerance for Devices Operating within the Frequency Band 40.66-40.70 MHz | N/A |

* The EUT complies with the requirement; it employs integral antenna.

## 4.3. MODIFICATIONS INCORPORATED IN THE EUT FOR COMPLIANCE PURPOSES

None.

# EXHIBIT 5. TEST DATA

## 5.1. POWER LINE CONDUCTED EMISSIONS [§15.207(a)]

### 5.1.1. Limit(s)

The equipment shall meet the limits of the following table:

| Frequency of emission (MHz) | Conducted Limits (dBμV) | |
|---|---|---|
| | Quasi-peak | Average |
| 0.15–0.5 .....…….. | 66 to 56* ..... | 56 to 46* |
| 0.5–5 .....…….. | 56 ..... | 46 |
| 5-30 …….. | 60 ...…….. | 50 |

*Decreases linearly with the logarithm of the frequency

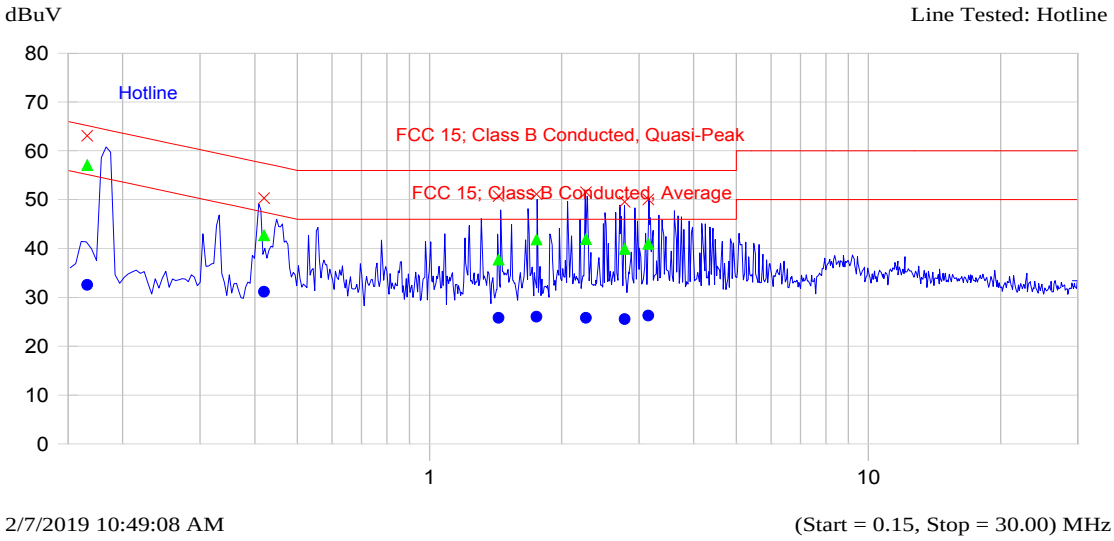
### 5.1.2. Method of Measurements

ANSI C63.4

### 5.1.3. Test Data

**Plot 5.1.3.1.** Power Line Conducted Emissions
Line Voltage: 120 VAC 60 Hz; Line Tested: Hot

**Current Graph**

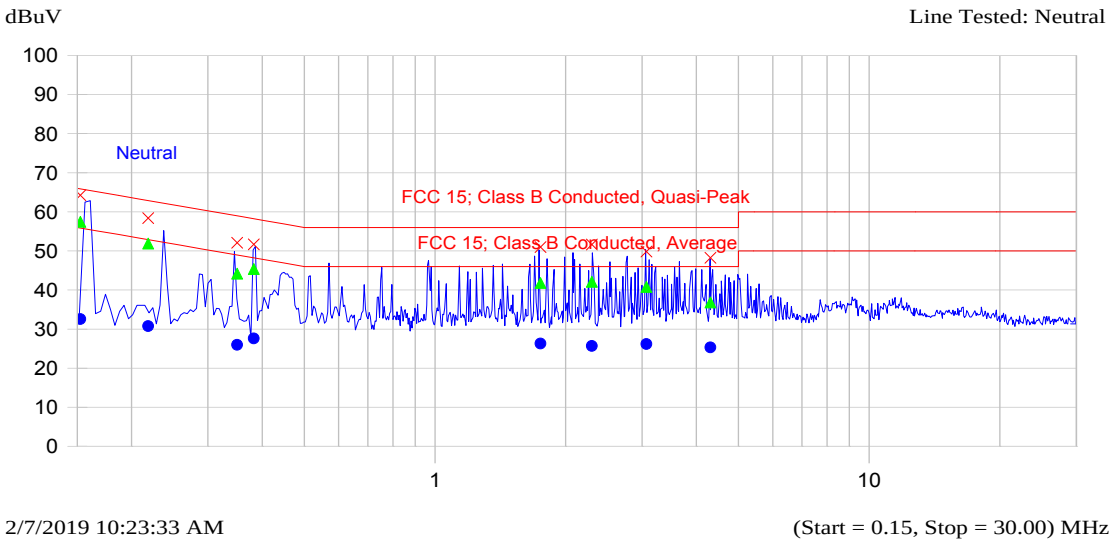



**Current List**

| Frequency MHz | Peak dBuV | QP dBuV | QP-QP Limit dB | Avg dBuV | Avg-Avg Limit dB | Trace Name |
|---|---|---|---|---|---|---|
| 0.166 | 63.1 | 57.1 | -8.1 | 32.6 | -22.6 | Hotline |
| 0.420 | 50.3 | 42.7 | -14.7 | 31.2 | -16.3 | Hotline |
| 1.437 | 50.7 | 37.7 | -18.3 | 25.8 | -20.2 | Hotline |
| 1.753 | 51.1 | 41.8 | -14.2 | 26.0 | -20.0 | Hotline |
| 2.272 | 51.5 | 41.9 | -14.1 | 25.8 | -20.2 | Hotline |
| 2.783 | 49.6 | 39.9 | -16.1 | 25.5 | -20.5 | Hotline |
| 3.153 | 50.0 | 41.0 | -15.0 | 26.3 | -19.7 | Hotline |

**Plot 5.1.3.2.** Power Line Conducted Emissions
Line Voltage: 120 VAC 60 Hz; Line Tested: Neutral

## Current Graph




## Current List

| Frequency MHz | Peak dBuV | QP dBuV | QP-QP Limit dB | Avg dBuV | Avg-Avg Limit dB | Trace Name |
|---|---|---|---|---|---|---|
| 0.153 | 64.3 | 57.4 | -8.4 | 32.6 | -23.3 | Neutral |
| 0.219 | 58.4 | 51.9 | -11.0 | 30.7 | -22.1 | Neutral |
| 0.350 | 52.1 | 44.2 | -14.8 | 26.0 | -23.0 | Neutral |
| 0.383 | 51.7 | 45.3 | -12.9 | 27.6 | -20.6 | Neutral |
| 1.750 | 51.0 | 41.8 | -14.2 | 26.3 | -19.7 | Neutral |
| 2.298 | 51.6 | 42.1 | -13.9 | 25.7 | -20.3 | Neutral |
| 3.068 | 49.8 | 40.8 | -15.2 | 26.2 | -19.8 | Neutral |
| 4.306 | 48.3 | 36.8 | -19.2 | 25.3 | -20.7 | Neutral |

## 5.2. TRANSMITTER RADIATED EMISSIONS [47 CFR §§ 15.231(e), 15.209 & 15.205]

### 5.2.1. Limit(s)

**47 CFR 15.231**

(e) Intentional radiators may operate at a periodic rate exceeding that specified in paragraph (a) of this section and may be employed for any type of operation, including operation prohibited in paragraph (a) of this section, provided the intentional radiator complies with the provisions of paragraphs (b) through (d) of this section, except the field strength table in paragraph (b) of this section is replaced by the following:

| Fundamental frequency (MHz) | Field strength of fundamental (microvolts/meter) | Field strength of spurious emission (microvolts/meter) |
|---|---|---|
| 40.66-40.70 | 1,000 | 100 |
| 70-130 | 500 | 50 |
| 130-174 | 500 to 1,500[1] | 50 to 150[1] |
| 174-260 | 1,500 | 150 |
| 260-470 | 1,500 to 5,000[1] | 150 to 500[1] |
| Above 470 | 5,000 | 500 |

[1]Linear interpolations.

(b)(1) The above field strength limits are specified at a distance of 3 meters. The tighter limits apply at the band edges.

(b)(2) Intentional radiators operating under the provisions of this Section shall demonstrate compliance with the limits on the field strength of emissions, as shown in the above table, based on the average value of the measured emissions. As an alternative, compliance with the limits in the above table may be based on the use of measurement instrumentation with a CISPR quasi-peak detector. The specific method of measurement employed shall be specified in the application for equipment authorization. If average emission measurements are employed, the provisions in Section 15.35 for averaging pulsed emissions and for limiting peak emissions apply. Further, compliance with the provisions of Section 15.205 shall be demonstrated using the measurement instrumentation specified in that section.

(b)(3) The limits on the field strength of the spurious emissions in the above table are based on the fundamental frequency of the intentional radiator. Spurious emissions shall be attenuated to the average (or, alternatively, CISPR quasi-peak) limits shown in this table or to the general limits shown in Section 15.209, whichever limit permits a higher field strength.

**47 CFR 15.205(a) Restricted Bands of Operation**

| MHz | MHz | MHz | GHz |
|---|---|---|---|
| 0.090–0.110 | 16.42–16.423 | 399.9–410 | 4.5–5.15 |
| [1] 0.495–0.505 | 16.69475–16.69525 | 608–614 | 5.35–5.46 |
| 2.1735–2.1905 | 16.80425–16.80475 | 960–1240 | 7.25–7.75 |
| 4.125–4.128 | 25.5–25.67 | 1300–1427 | 8.025–8.5 |
| 4.17725–4.17775 | 37.5–38.25 | 1435–1626.5 | 9.0–9.2 |
| 4.20725–4.20775 | 73–74.6 | 1645.5–1646.5 | 9.3–9.5 |
| 6.215–6.218 | 74.8–75.2 | 1660–1710 | 10.6–12.7 |
| 6.26775–6.26825 | 108–121.94 | 1718.8–1722.2 | 13.25–13.4 |
| 6.31175–6.31225 | 123–138 | 2200–2300 | 14.47–14.5 |
| 8.291–8.294 | 149.9–150.05 | 2310–2390 | 15.35–16.2 |
| 8.362–8.366 | 156.52475–156.52525 | 2483.5–2500 | 17.7–21.4 |
| 8.37625–8.38675 | 156.7–156.9 | 2690–2900 | 22.01–23.12 |
| 8.41425–8.41475 | 162.0125–167.17 | 3260–3267 | 23.6–24.0 |
| 12.29–12.293 | 167.72–173.2 | 3332–3339 | 31.2–31.8 |
| 12.51975–12.52025 | 240–285 | 3345.8–3358 | 36.43–36.5 |
| 12.57675–12.57725 | 322–335.4 | 3600–4400 | ([2]) |
| 13.36–13.41. | | | |

[1] Until February 1, 1999, this restricted band shall be 0.490–0.510 MHz.
[2] Above 38.6

**47 CFR 15.209(a) General Field Strength Limits**

| Frequency (MHz) | Field strength (microvolts/meter) | Measurement distance (meters) |
|---|---|---|
| 0.009–0.490 | 2400/F(kHz) | 300 |
| 0.490–1.705 | 24000/F(kHz) | 30 |
| 1.705–30.0 | 30 | 30 |
| 30–88 | 100 ** | 3 |
| 88–216 | 150 ** | 3 |
| 216–960 | 200 ** | 3 |
| Above 960 | 500 | 3 |
| ** Except as provided in paragraph (g), fundamental emissions from intentional radiators operating under this section shall not be located in the frequency bands 54–72 MHz, 76– 88 MHz, 174–216 MHz or 470–806 MHz. However, operation within these frequency bands is permitted under other sections of this part, e.g., §§ 15.231 and 15.241. | | |

### 5.2.2. Method of Measurements

ANSI C63.4 and/or ANSI C63.10

### 5.2.3. Test Data

#### 5.2.3.1. 125 kHz Transmitter

**Remarks:**

- The measuring receiver shall be tuned over the frequency range 10 kHz to 30 MHz
- Test distance: 0.010 to 30MHz: 10m
- All spurious emissions that are in excess of 20 dB below the specified limit shall be recorded.
- The value measured at 10m shall be extrapolated as applicable to compare with limit and measurement distance specified in section 15.209(a).
- Measurements were performed at 100m and 30m distances to determine the proper extrapolation factor.

Maximum field strength level at 100m distance: 40.53 dBµV/m
Maximum field strength level at 30m distance: 68.15 dBµV/m

Extrapolation factor:
Difference of measurement between 100 m & 30 m: $\Delta E$ = 68.15 – 40.53 = 27.62 dB
$\Delta E = 20 * \log(100/30)^x = 27.62$ dB or x = 27.62 / (20*log(100/30)) = 2.64 ➔ (52.8 dB/decade)

- Field strength limit of the fundamental 125 kHz at 300m distance is 20*log(2400/125) = 25.7 dBµV/m
- For frequency 125 kHz, the measured E-Field at 10m (column 3) will be extrapolated to 300m E-Field Level (column 4) using the extrapolation factor of 52.8*log(10/300) = -77.99 dB

| Frequency (MHz) | RF Peak Level @ 10m (dBµV/m) | RF Average Level @ 10m (dBµV/m) | Extrapolated RF Level (dBµV/m) | Antenna Plane (H/V) | § 15.209 (a) Limits (dBµV/m) | Margin (dB) |
|---|---|---|---|---|---|---|
| **Fundamental Emissions** | | | | | | |
| 0.125 | 98.31 | 98.24 | 20.25 | V | 25.7 | -5.45 |
| 0.125 | 89.76 | 89.71 | 11.72 | H | 25.7 | -13.98 |
| **Harmonic/Spurious Emissions** | | | | | | |
| 0.010 - 0.490 | * | * | * | H / V | * | * |
| 0.490 - 1.705 | * | * | * | H / V | * | * |
| 1.705 - 30.0 | * | * | * | H / V | * | * |

* No emissions component detected.

### 5.2.3.2. 433.92 MHz Transmitter

**Remarks:**

- The measuring receiver shall be tuned over the frequency range of 30 MHz to the 10th harmonic of the highest fundamental frequency.
- All spurious emissions that are in excess of 20 dB below the specified limit shall be recorded.
- In the restricted band per §15.205: 15.209 (a) limits applied
- Outside the restricted band per § 15.205: § 15.231 (e) limits or § 15.209 (a) applied, whichever allows higher field strength emission.
- Section 15.231(e) field strength limit of the fundamental at 433.92 MHz = 20 log [(16.67 x 433.92) – 2833.33] = 72.9 dBµV/m
- Spurious emissions limit is 20 dB below fundamental limit.
- Duty Cycle: measured maximum duty cycle is 9.50 %.
- The peak-average correction factor = -20.45 dB. See Section 5.2.3.3 for details.

| Frequency (MHz) | Peak E-Field @ 3m (dBµV/m) | Average E-Field @ 3m (dBµV/m) | Antenna Plane (H/V) | § 15.231 (e) Limits @ 3m (dBµV/m) | § 15.209 (a) Limits @ 3m (dBµV/m) | Margin (dB) | Pass/Fail |
|---|---|---|---|---|---|---|---|
| **Field strength of fundamental** | | | | | | | |
| 433.92 | 83.19 | 62.74 | V | 72.9 | -- | -10.13 | PASS |
| 433.92 | 89.44 | 68.99 | H | 72.9 | -- | -3.88 | PASS |
| **Field strength of spurious emission** | | | | | | | |
| 867.84 | 57.04 | 36.59 | V | 52.9 | 46.0 | -16.28 | PASS |
| 867.84 | 62.09 | 41.64 | H | 52.9 | 46.0 | -11.23 | PASS |
| 3471.36 | 54.58 | 34.13 | V | 52.9 | 54.0 | -19.87 | PASS |
| 3471.36 | 56.11 | 35.66 | H | 52.9 | 54.0 | -18.34 | PASS |
| 3905.28 | 65.09 | 44.64 | V | 52.9 | 54.0 | -9.36 | PASS |
| 3905.28 | 63.95 | 43.50 | H | 52.9 | 54.0 | -10.50 | PASS |
| 4339.20 | 56.49 | 36.04 | H | 52.9 | 54.0 | -17.96 | PASS |

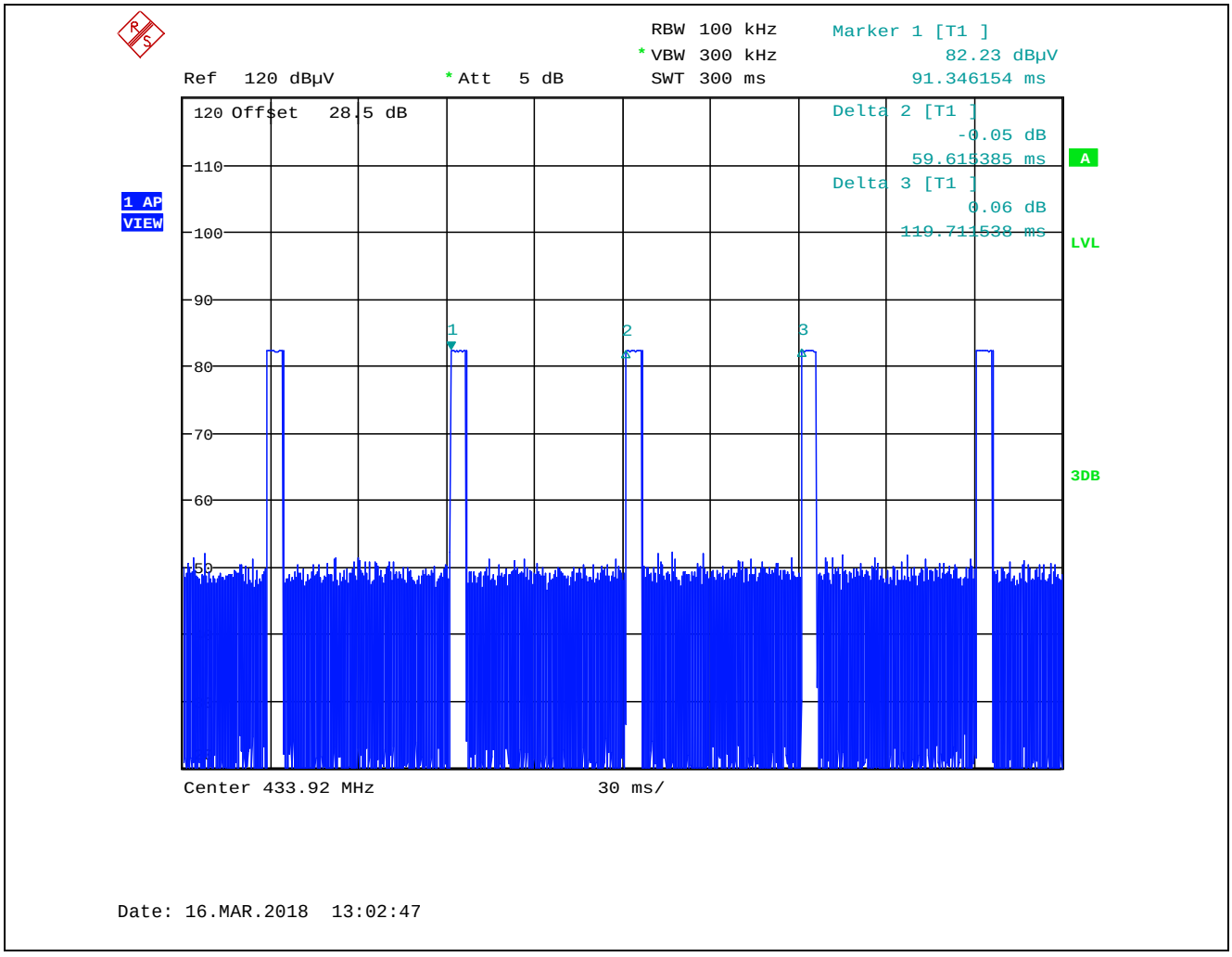
### 5.2.3.3. Duty-Cycle Correction Factor

The duty cycle correction factor is the total “on time” divided by the period of the pulse train (or 100 ms).

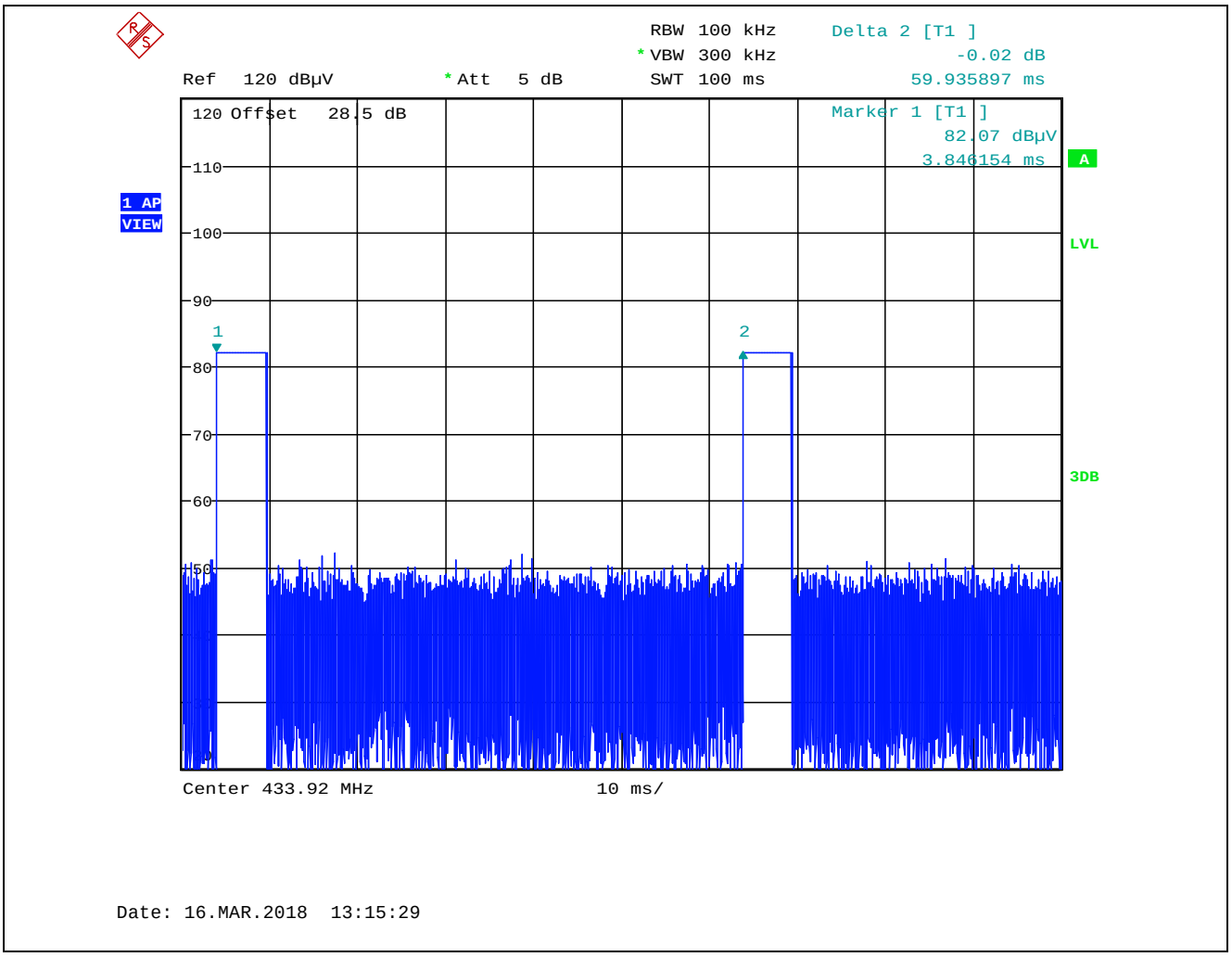
**Computation of duty-cycle correction factor**

| Sub-Pulse | Duration (ms) | Number of pulses | Sub-Pulse “On Time” (ms) |
|---|---|---|---|
| 1 | 5.673 | 1 | 5.673 |
| | | TOTAL ON TIME: | 5.673 |
| Duty cycle correction factor: | 20*log ($T_{ON}$/Period) = 20*log (5.673ms/ 59.936 ms) = -20.45 dB | | |

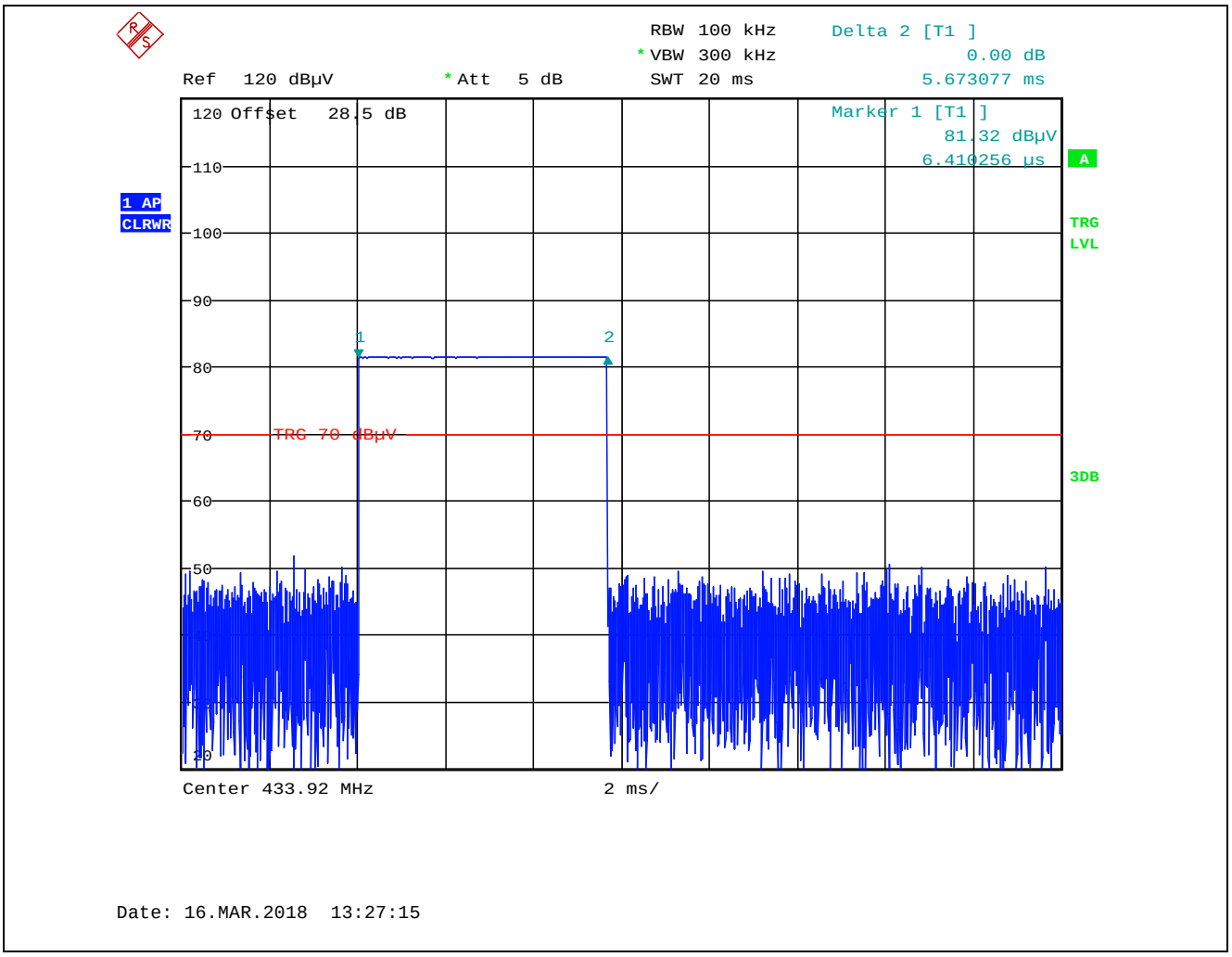
**Plot 5.2.3.3.1. Duty Cycle (Pulse Train)**



**Plot 5.2.3.3.2. Duty Cycle (Period)**



**Plot 5.2.3.3.3. Duty Cycle (Pulse)**



## 5.3. 20 dB BANDWIDTH [47 CFR §§ 15.215(c) & 15.231(c)]

### 5.3.1. Limit(s)

**15.215(c)** Emission bandwidth shall not be located in the restricted bands in 15.205 and the frequency bands 54-72 MHz, 76-88 MHz, 174-216 MHz or 470-806 MHz.

**15.231 (c)** The bandwidth of the emission shall be no wider than 0.25% of the center frequency for devices operating above 70 MHz and below 900 MHz. For devices operating above 900 MHz, the emission shall be no wider than 0.5% of the center frequency. Bandwidth is determined at the points 20 dB down from the modulated carrier.

### 5.3.2. Method of Measurements

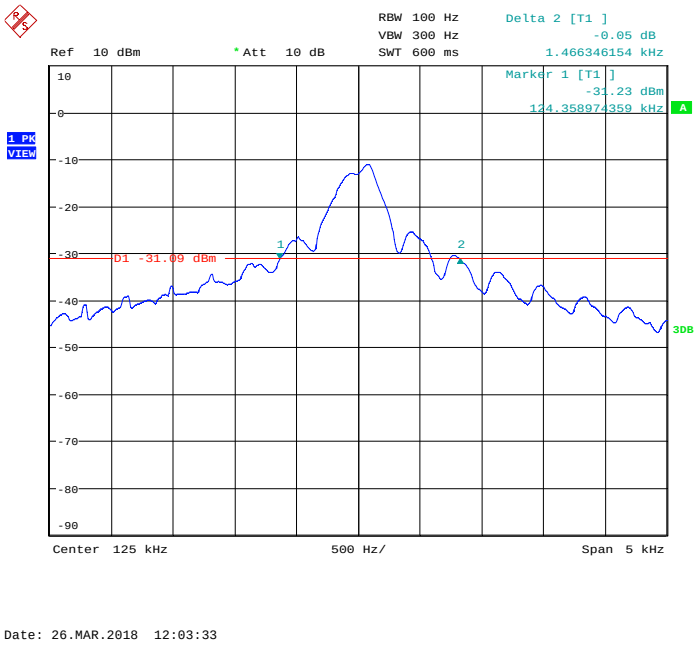
The measurements were performed in accordance with Ultratech Test Procedures, File # ULTR P001-2004 and ANSI C63.4

### 5.3.3. Test Data

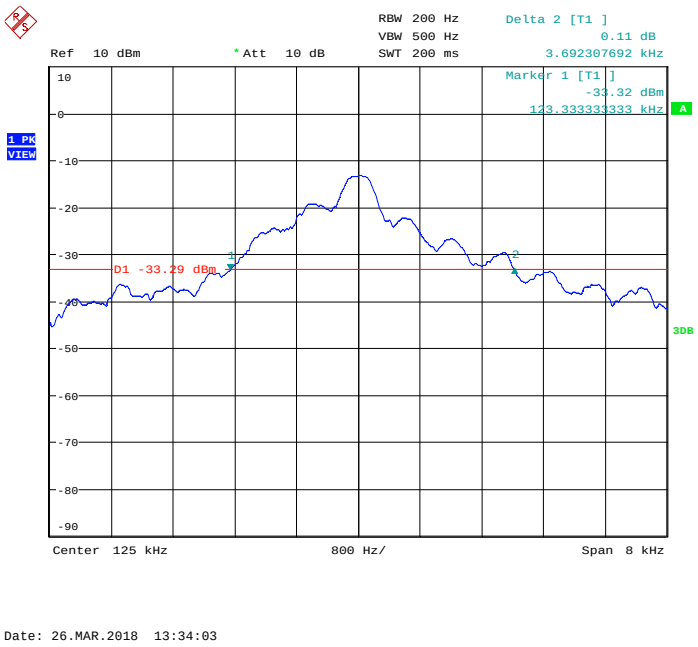
| Channel Frequency | Modulation | 20 dB Bandwidth (kHz) | Limit (kHz) |
|---|---|---|---|
| 125 kHz | Command SM1, Modulation Constant to "1" | 1.466 | -- |
| | Command SM2, OOK Modulation with 600 Hz | 3.692 | -- |
| 433.92 MHz | FSK modulated with programmed messages | 42.788 | $\leq$ 1084.8 |
| | FSK modulated with a signal 101010…, 1 b/s | 26.058 | $\leq$ 1084.8 |

See the following plots for detail.

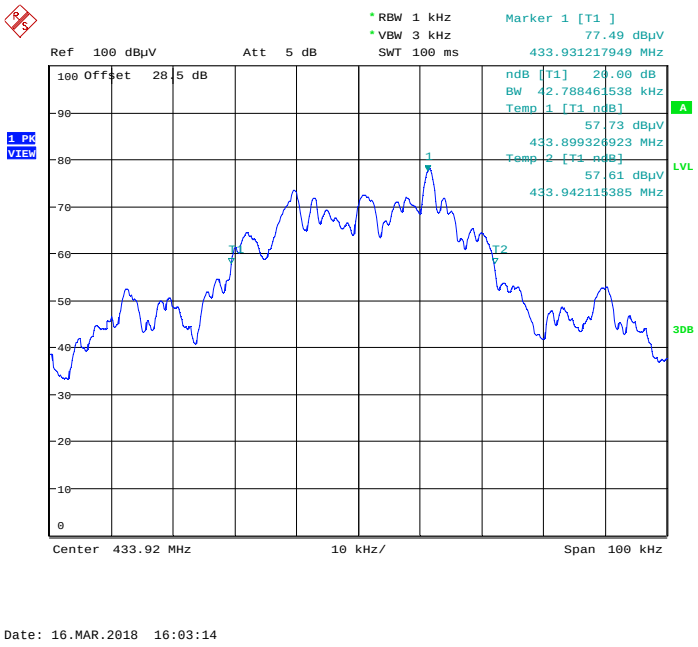
**Plot 5.3.3.1.** 20 dB Bandwidth, Fc: 125 kHz
Command SM1, Modulation Constant to "1"



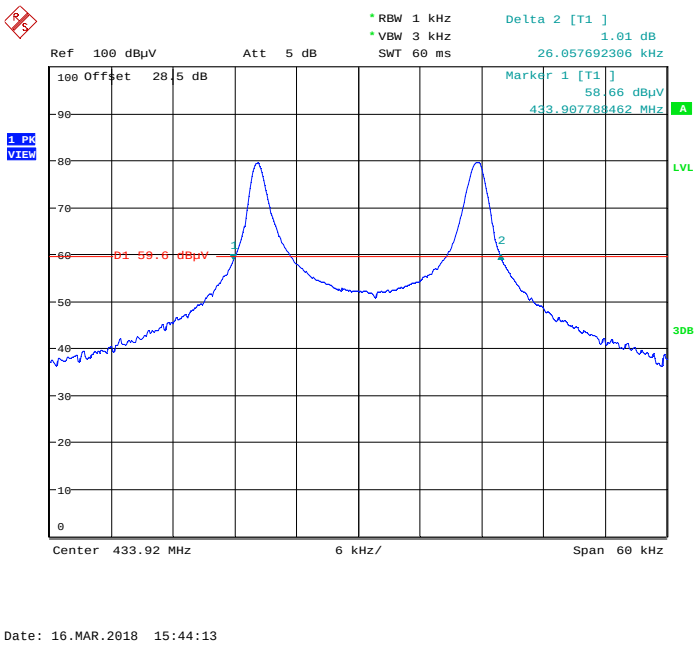

**Plot 5.3.3.2.** 20 dB Bandwidth, Fc: 125 kHz
Command SM2, OOK Modulation with 600 Hz



**Plot 5.3.3.3.** 20 dB Bandwidth, Fc: 433.92 MHz
FSK modulated with programmed messages




**Plot 5.3.3.4.** 20 dB Bandwidth, Fc: 433.92 MHz
FSK modulated with a signal 101010…, 1 b/s



## 5.4. RF EXPOSURE REQUIRMENTS [§§ 15.247(i), 1.1310 & 2.1091]

§ **1.1310:** The criteria listed in the following table shall be used to evaluate the environmental impact of human exposure to radio-frequency (RF) radiation as specified in 1.1307(b).

**Limits for Maximum Permissible Exposure (MPE)**

| Frequency range (MHz) | Electric field strength (V/m) | Magnetic field strength (A/m) | Power density ($mW/cm^2$) | Averaging time (minutes) |
|---|---|---|---|---|
| **(A) Limits for Occupational/Controlled Exposures** | | | | |
| 0.3-3.0 | 614 | 1.63 | *(100) | 6 |
| 3.0-30 | 1842/f | 4.89/f | *($900/f^2$) | 6 |
| 30-300 | 61.4 | 0.163 | 1.0 | 6 |
| 300-1500 | | | f/300 | 6 |
| 1500-100,000 | | | 5 | 6 |
| **(B) Limits for General Population/Uncontrolled Exposure** | | | | |
| 0.3-1.34 | 614 | 1.63 | *(100) | 30 |
| 1.34-30 | 824/f | 2.19/f | *($180/f^2$) | 30 |
| 30-300 | 27.5 | 0.073 | 0.2 | 30 |
| 300-1500 | | | f/1500 | 30 |
| 1500-100,000 | | | 1.0 | 30 |

f = frequency in MHz
* = Plane-wave equivalent power density

Note 1: Occupational/controlled limits apply in situations in which persons are exposed as a consequence of their employment provided those persons are fully aware of the potential for exposure and can exercise control over their exposure. Limits for occupational/controlled exposure also apply in situations when an individual is transient through a location where occupational/controlled limits apply provided he or she is made aware of the potential for exposure.

Note 2: General population/uncontrolled exposures apply in situations in which the general public may be exposed, or in which persons that are exposed as a consequence of their employment may not be fully aware of the potential for exposure or can not exercise control over their exposure.

### 5.4.1. Method of Measurements

Calculation Method of Power Density/RF Safety Distance:

$$S = \frac{PG}{4\pi \cdot r^2} = \frac{EIRP}{4\pi \cdot r^2}$$

Where, P: power input to the antenna in mW
EIRP: Equivalent (effective) isotropic radiated power.
S: power density $mW/cm^2$
G: numeric gain of antenna relative to isotropic radiator
r: distance to centre of radiation in cm

### 5.4.2. RF Evaluation

Pursuant to KDB 447498 D01 General RF Exposure Guidance v06, Section 7.2:

*Simultaneous transmission MPE test exclusion applies when the sum of the MPE ratios for all simultaneously transmitting antennas incorporated in a host device is ≤ 1.0, according to calculated/estimated, numerically modeled, or measured field strengths or power density.*

The following table addresses the co-location of all simultaneous transmitters within the EUT at a minimum separation distance 35 cm

| **Transmitters** | Frequency (MHz) | EUT EIRP (dBm) | EUT EIRP (mW) | Evaluation Distance (cm) | Power Density ($mW/cm^2$) | FCC MPE Limit ($mW/cm^2$) | MPE Ratio |
|---|---|---|---|---|---|---|---|
| Transmitters on EXB45 within EUT | 0.125 | -- | -- | 35 | -- | -- | -- |
| | 433.92 | -5.79 | 0.264 | 35 | 0.00002 | 0.289 | **0.00007** |
| | | | | | | | |
| Impinj, Inc. Speedway Revolution UHF RFID Reader FCC ID: TWYIPJREV IC: 6324A-IPJREV | 902.0 | -- | 4000 | 35 | 0.260 | 0.601 | **0.432** |
| | | | | | | | |
| Digi International Inc ConnectCore for i.MX6UL FCC ID: MCQ-CCIMX6UL IC: 1846A-CCIMX6UL | 2402 | 10.6 | 11.482 | 35 | 0.001 | 1.000 | **0.001** |
| | 2412 | 22.6 | 181.97 | 35 | 0.012 | 1.000 | **0.012** |
| | 5180 | 16.1 | 40.738 | 35 | 0.003 | 1.000 | 0.003 |
| Sum of the MPE ratios for all simultaneously transmitting antennas incorporated within the EUT | | | | | | | **0.445** |

Note: The worst-case configuration (maximum MPE ratio) for each radio module derived from the original radio MPE report was used in the computation. Refer to these reports for detail.

Conclusion: The sum of the MPE ratios is 0.445 ≤ 1.0, thus the EUT is in compliance with the RF exposure requirements

## 5.5. TEST EQUIPMENT LIST

| Test Instruments | Manufacturer | Model No. | Serial No. | Frequency Range | Cal. Due Date |
|---|---|---|---|---|---|
| Semi-Anechoic Chamber | TDK | IC: 2049A-3 | -- | -- | 03 Mar 2020 |
| EMI Receiver | Rohde & Schwarz | ESU40 | 100037 | 20Hz–40 GHz | 09 May 2018* |
| Loop Antenna | EMCO | 6502 | 9104-2611 | 10 kHz – 30 MHz | 15 Dec 2019 |
| Biconilog | EMCO | 3142 | 9601-1005 | 26-2000 MHz | 12 May 2018* |
| RF Amplifier | Com-Power | PAM-0118A | 551052 | 0.5 – 18 GHz | 17 Jul 2018* |
| Horn Antenna | EMCO | 3155 | 9701-5061 | 1 – 18 GHz | 30 Apr 2020 |
| High Pass Filter | Mini-Circuits | SHP-800 | 10425 | Cut off 400 MHz | See Note 1 |
| Spectrum Analyzer | Hewlett Packard | HP 8593EM | 3710A00223 | 9kHz - 22GHz | 22 May 2019 |
| Attenuator | Pasternack | PE7010-20 | 9 | DC TO 2 GHz | 13 Mar 2019 |
| LISN | Schwarzbeck | NSLK 8127 | 8127276 | 10kHz-30MHz | 11 Dec 2019 |
| Note 1: Internal verification/calibration check | | | | | |

*Equipment used before calibration due date

# EXHIBIT 6. MEASUREMENT UNCERTAINTY

The measurement uncertainties stated were calculated in accordance with the requirements of CISPR 16-4-2 @ IEC:2003 and JCGM 100:2008 (GUM 1995) – Guide to the Expression of Uncertainty in Measurement.

## 6.1. LINE CONDUCTED EMISSION MEASUREMENT UNCERTAINTY

| | **Line Conducted Emission Measurement Uncertainty (9 kHz – 30 MHz):** | **Measured** | **Limit** |
|---|---|---|---|
| **$u_c$** | **Combined standard uncertainty:** $u_c(y) = \sqrt{\sum_{i=1}^{m} u_i^2(y)}$ | **± 1.44** | **± 1.8** |
| **U** | **Expanded uncertainty U:** $U = 2u_c(y)$ | **± 2.89** | **± 3.6** |

## 6.2. RADIATED EMISSION MEASUREMENT UNCERTAINTY

| | **Radiated Emission Measurement Uncertainty (10 kHz – 30 MHz):** | **Measured** | **Limit** |
|---|---|---|---|
| **$u_c$** | **Combined standard uncertainty:** $u_c(y) = \sqrt{\sum_{i=1}^{m} u_i^2(y)}$ | **± 1.30** | **± 2.6** |
| **U** | **Expanded uncertainty U:** $U = 2u_c(y)$ | **± 2.60** | **± 5.2** |

| | **Radiated Emission Measurement Uncertainty @ 3m, Horizontal (30-1000 MHz):** | **Measured (dB)** | **Limit (dB)** |
|---|---|---|---|
| **$u_c$** | **Combined standard uncertainty:** $u_c(y) = \sqrt{\sum_{i=1}^{m} u_i^2(y)}$ | **± 2.15** | **± 2.6** |
| **U** | **Expanded uncertainty U:** $U = 2u_c(y)$ | **± 4.30** | **± 5.2** |

| | **Radiated Emission Measurement Uncertainty @ 3m, Vertical (30-1000 MHz):** | **Measured (dB)** | **Limit (dB)** |
|---|---|---|---|
| **$u_c$** | **Combined standard uncertainty:** $u_c(y) = \sqrt{\sum_{i=1}^{m} u_i^2(y)}$ | **± 2.14** | **± 2.6** |
| **U** | **Expanded uncertainty U:** $U = 2u_c(y)$ | **± 4.29** | **± 5.2** |

| | **Radiated Emission Measurement Uncertainty @ 3 m, Horizontal & Vertical (1 – 18 GHz):** | **Measured (dB)** | **Limit (dB)** |
|---|---|---|---|
| **$u_c$** | **Combined standard uncertainty:** $u_c(y) = \sqrt{\sum_{i=1}^{m} u_i^2(y)}$ | **± 1.52** | **Under consideration** |
| **U** | **Expanded uncertainty U:** $U = 2u_c(y)$ | **± 3.04** | **Under consideration** |