
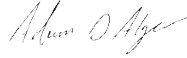



Test Report # TR 3664 A BL653μ V2

| | |
|------------------------------|------------------------------------------------------------------------------------------------|
| Equipment Under Test: | BL653μ |
| Requirement(s): | FCC: 15.247 ICED: RSS-247 |
| Test Date(s): | 3/9/2023, 3/15/2023 – 3/16/2023 |
| Prepared for: | Laird Connectivity, LLC Attn: Jonathan Kaye W66 N220 Commerce Ct. Cedarburg, WI 53012 |

| | | |
|--------------------------------------------------------------|------------------------------------------------------------------------------------------------|------------------|
| Report Issued by: Dylan Rosenfeldt, EMC Engineer | Signature:  | Date: 2/23/2024 |
| Report Reviewed by: Adam Alger, Laboratory Manager | Signature:  | Date: 10/31/2023 |
| Report Constructed by: Dylan Rosenfeldt, EMC Engineer | Signature:  | Date: 2/13/2024 |

This test report may not be reproduced, except in full, without approval of Laird Connectivity LLC

| | | |
|----------------------------------|--------------|----------------------------|
| Company: Laird Connectivity, LLC | Page 1 of 23 | Name: BL653μ |
| Report: TR3664A BL653μ | | Model: BL653μ |
| Quote: NBO-12-2022-005678 | | Serial: Engineering Sample |

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Laird Connectivity Test Services in Review

The Laird Connectivity LLC laboratory located at W66 N220 Commerce Court Cedarburg, Wisconsin, 53012 USA is recognized through the following organizations:



A2LA – American Association for Laboratory Accreditation

Accreditation based on ISO/IEC 17025:2017 with Electrical (EMC) Scope

A2LA Certificate Number: 1255.01

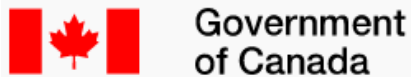
Scope of accreditation includes all test methods listed herein unless otherwise noted



Federal Communications Commission (FCC) – USA

Accredited Test Firm Registration Number: 953492

Recognition of two 3 meter Semi-Anechoic Chambers



Innovation, Science and Economic Development Canada

Accredited U.S. Identification Number: US0218

Recognition of two 3 meter Semi-Anechoic Chambers

| | | |
|----------------------------------|--------------|----------------------------|
| Company: Laird Connectivity, LLC | Page 3 of 23 | Name: BL653μ |
| Report: TR3664A BL653μ | | Model: BL653μ |
| Quote: NBO-12-2022-005678 | | Serial: Engineering Sample |

1 TEST REPORT SUMMARY

During **3/9/2023, 3/15/2023 – 3/16/2023** the Equipment Under Test (EUT), **BL653μ**, as provided by **Laird Connectivity, LLC** was tested to the following requirements for the purpose of a Class 2 Permissive Change to add an antenna:

47 CFR Part 15 & ISED Canada

| Requirements | Description | Specification | Method | Compliant |
|---------------------------------------------|--------------------------------------------------|---------------------------|-------------|-----------|
| FCC: 15.247 (b)(3) ISED: RSS-247 5.4 (d) | Maximum Conducted Output Power | 30 dBm | ANSI C63.10 | Yes |
| FCC: 15.247 (d) ISED: RSS-GEN 8.10 | Spurious Emissions in Restricted Frequency Bands | FCC 15.209 RSS-GEN 8.9 | ANSI C63.10 | Yes |

Notice:

The results relate only to the item tested as configured and described in this report. Any additional configurations, modes of operation, or modifications made to the equipment under test after the specified test date(s) are at the decision of the client and may not apply to the data seen in this test report.

The decision rule for Pass / Fail assessment to the specification or standard listed in this test report has been agreed upon by the client and laboratory to be as follows:

| Measurement Type | Rule |
|-----------------------|--------------------------------|
| Emissions – Amplitude | 1 dB below specified limit |
| Emissions – Frequency | 1% less than the specification |
| Immunity | Tested at specified level |

2 CLIENT INFORMATION

| | |
|-----------------------|---------------------------------------------|
| Company Name | Laird Connectivity, LLC |
| Contact Person | Jonathan Kaye |
| Address | W66N220 Commerce Ct. Cedarburg, WI 53012 |

2.1 Equipment Under Test (EUT) Information

The following information has been supplied by the client

| | |
|----------------------|--------------------|
| Product Name | BL653μ |
| Model Number | BL653μ |
| Serial Number | Engineering Sample |
| FCC ID | SQGBL653U |
| IC ID | 3147A-BL653U |

2.2 Product Description

Bluetooth Low Energy Module operating in the 2.4GHz range

2.3 Modifications Incorporated for Compliance

None noted at time of test.

2.4 Deviations and Exclusions from Test Specifications

None noted at time of test.

2.5 Additional Information

nRF Connect for Desktop v4.0.0 – Direct Test Mode v2.0.4 used to program EUT. Bluetooth LE (Low Energy) 125k, 500k, 1Mbps, 2Mbps. Channels tested: 37 (2402 MHz), 17 (2440 MHz), and 39 (2480 MHz).

2.6 Additional Information

This testing is for a permissive change to add the iFlex-Pifa Antenna, with an antenna gain of 3.1 dBi, to the list of antennas usable by the BL653μ. EUT tested via Cabinet Radiation method.

| | | |
|----------------------------------|--------------|----------------------------|
| Company: Laird Connectivity, LLC | Page 5 of 23 | Name: BL653μ |
| Report: TR3664A BL653μ | | Model: BL653μ |
| Quote: NBO-12-2022-005678 | | Serial: Engineering Sample |

3 REFERENCES

| Publication | Edition | Date | AMD 1 | AMD 2 |
|----------------|---------|------|-------|-------|
| eCFR | - | 2023 | - | - |
| RSS-247 | 3 | 2023 | - | - |
| ANSI C63.10 | - | 2020 | - | - |
| RSS-Gen | 5 | 2018 | 2019 | 2021 |
| KDB 178919 D01 | 6 | 2015 | - | - |

4 UNCERTAINTY SUMMARY

Using the guidance of the following publications the calculated measurement uncertainty represents an expanded uncertainty expressed at approximately the 95 % confidence level, using a coverage factor of $k = 2$.

| References |
|-----------------|
| CISPR 16-4-1 |
| CISPR 16-4-2 |
| CISPR 32 |
| ANSI C63.23 |
| A2LA P103 |
| A2LA P103c |
| ETSI TR 100-028 |

| Measurement Type | Configuration | Uncertainty \pm |
|-----------------------------|-------------------------------|-------------------|
| Radiated Emissions | Biconical Antenna | 5.0 dB |
| Radiated Emissions | Log Periodic Antenna | 5.3 dB |
| Radiated Emissions | Horn Antenna | 4.7 dB |
| AC Line Conducted Emissions | Artificial Mains Network | 3.4 dB |
| Telecom Conducted Emissions | Asymmetric Artificial Network | 4.9 dB |
| Disturbance Power Emissions | Absorbing Clamp | 4.1 dB |
| Radiated Immunity | 3 Volts/meter | 2.2 dB |
| Conducted Immunity | CDN/EM/BCI | 2.4/3.5/3.4 dB |
| EFT Burst/Surge | Peak pulse voltage | 164 volts |
| ESD Immunity | 15 kV level | 1377 Volts |

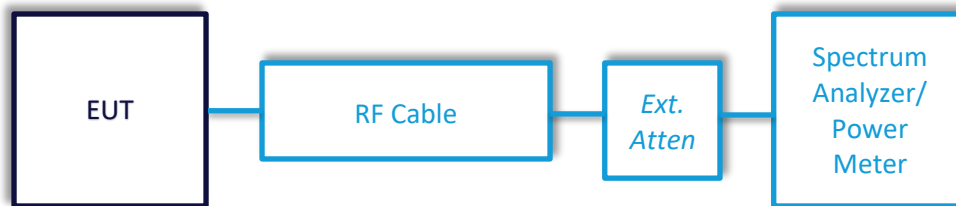
| Parameter | ETSI U.C. \pm | U.C. \pm |
|--------------------------------------------|--------------------|-----------------------|
| Radio Frequency, from F0 | 1×10^{-7} | 0.55×10^{-7} |
| Occupied Channel Bandwidth | 5 % | 2 % |
| RF conducted Power (Power Meter) | 1.5 dB | 1.2 dB |
| RF conducted emissions (Spectrum Analyzer) | 3.0 dB | 1.7 dB |
| All emissions, radiated | 6.0 dB | 5.3 dB |
| Temperature | 1° C | 0.65° C |
| Humidity | 5 % | 2.9 % |
| Supply voltages | 3 % | 1 % |

5 TEST DATA

5.1 Antenna Port Conducted Emissions

| | |
|-----------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Description of Measurement | <p>The direct measurement of emissions at the antenna port of the EUT is achieved by use of a RF connection to a spectrum analyzer or power meter.</p> <p>The cable and attenuator factors are loaded into the analyzer or power meter allowing for direct measurement readings without the need for further corrections.</p> |
| Example Calculations | <p>Measurement (dBm) + Cable factor (dB) + External Attenuator (dB) = Corrected Reading (dBm)</p> <p>Margin (dB) = Limit (dBm) – Corrected Reading (dBm)</p> |

Block Diagram



5.1.1 Antenna Port Conducted Emissions – RF Output Power

| | | | |
|--------------------|------------------------------|-----------------|-----------------|
| Operator | Dylan Rosenfeldt | QA | Anthony Smith |
| Temperature | 20.8°C | R.H. % | 29.4% |
| Test Date | 3/9/2023 | Location | Conducted Bench |
| Requirement | FCC: 15.247 ICES: RSS-247 | Method | ANSI C63.10 |

FCC 15.247 Limits:

| Frequency (MHz) | Limit (dBm) |
|-----------------|-------------|
| 2400 – 2483.5 | 30.0 |

Test Parameters

| | | | |
|--------------------|-----------------|-----------------|-------------------|
| Frequency | 2400 – 2480 MHz | Setup | Conducted RF port |
| RBW | 3MHz | VBW | 50MHz |
| Detector(s) | Peak | Settings | Trace Max Hold |

Instrumentation

| Asset # | Description | Manufacturer | Model # | Serial # | Date | Due Date | Status |
|--------------|-------------------------|--------------------|-----------|------------|-----------|-----------|---------------------|
| EE 960088 | Analyzer - EMI Receiver | Agilent | N9038A | MY51210138 | 4/12/2022 | 4/12/2023 | Active Calibration |
| AA 960173 | Cable | A.H. Systems, Inc. | SAC-26G-1 | 388 | 3/22/2022 | 3/22/2023 | Active Verification |

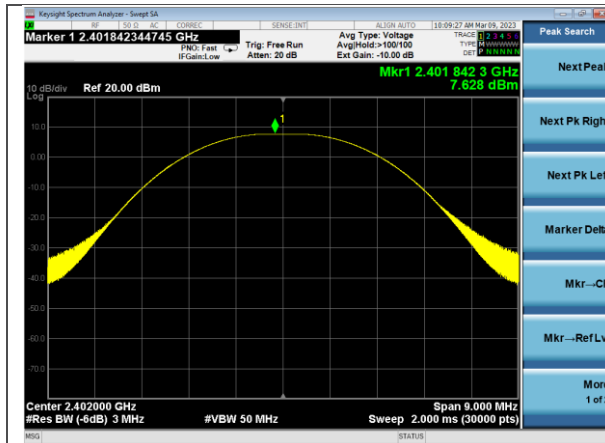
EUT Parameters

| | | | |
|--------------------|----------------------|-----------------|-----------------|
| Input Power | 5V USB | Mode | BLE TX |
| Frequency | 2402, 2440, 2480 MHz | Channels | 37, 17, 39 |
| Data Rates | 125k, 500k, 1M, 2M | Settings | Power setting 8 |

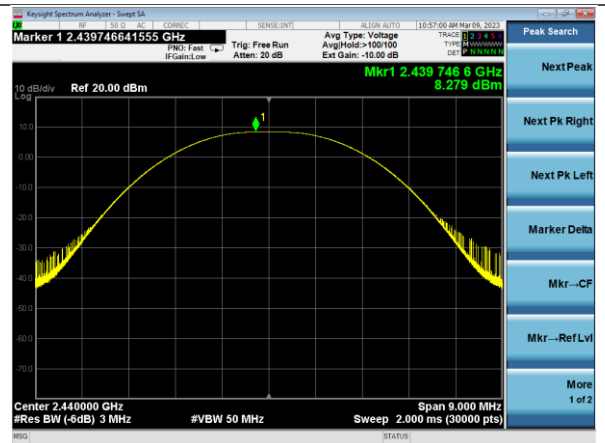
Fundamental Emission Table

| Frequency (MHz) | Data rate | Peak Output Power (dBm) | Peak Output Power Limit (dBm) | Peak Output Power Margin (dB) |
|-----------------|-----------|-------------------------|-------------------------------|-------------------------------|
| 2402 | 125kbps | 8.3 | 30 | 21.7 |
| 2440 | 125kbps | 8.3 | 30 | 21.7 |
| 2480 | 125kbps | 8.3 | 30 | 21.7 |
| 2402 | 500kbps | 8.3 | 30 | 21.7 |
| 2440 | 500kbps | 8.3 | 30 | 21.7 |
| 2480 | 500kbps | 8.3 | 30 | 21.7 |
| 2402 | 1Mbps | 8.3 | 30 | 21.7 |
| 2440 | 1Mbps | 8.3 | 30 | 21.7 |
| 2480 | 1Mbps | 8.4 | 30 | 21.6 |
| 2402 | 2Mbps | 8.3 | 30 | 21.7 |
| 2440 | 2Mbps | 8.3 | 30 | 21.7 |
| 2480 | 2Mbps | 8.4 | 30 | 21.6 |

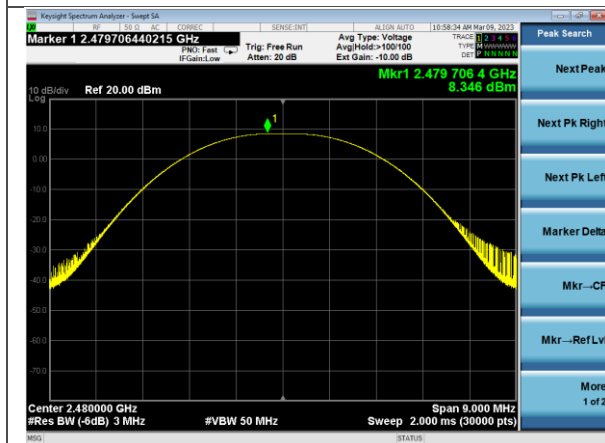
Fundamental Plots



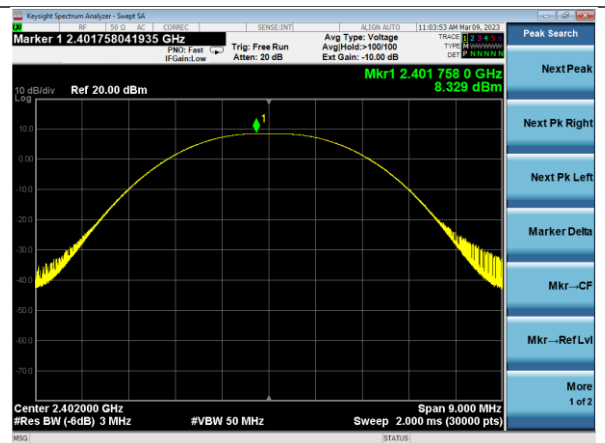
125k, Ch 37



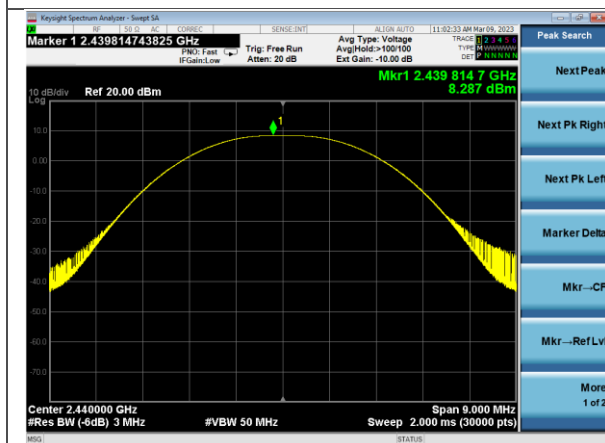
125k, Ch 17



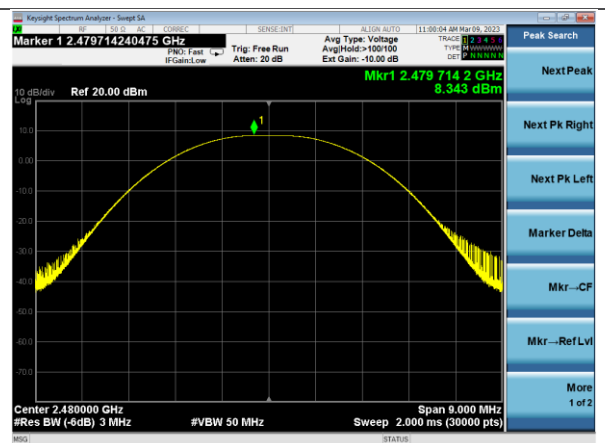
125k, Ch 39



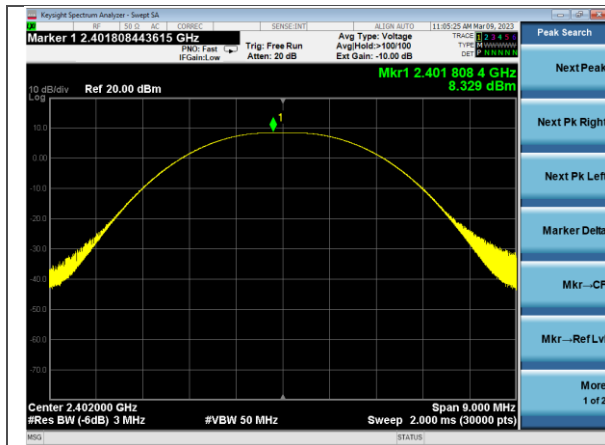
500k, Ch 37



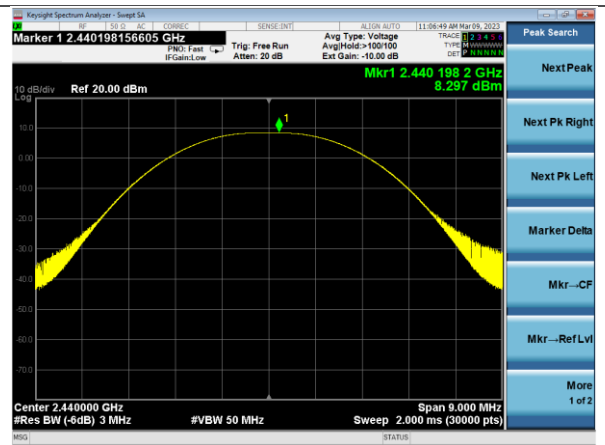
500k, Ch 17



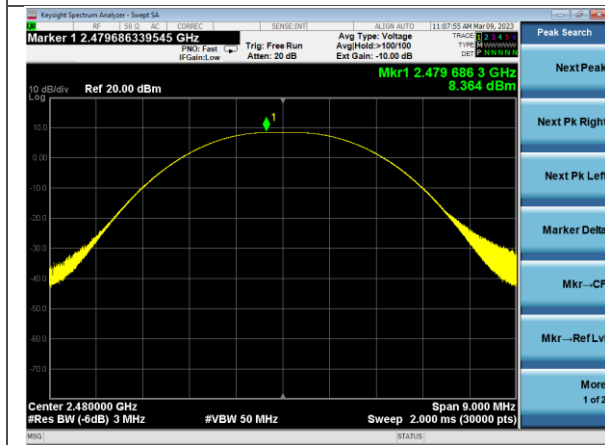
500k, Ch 39



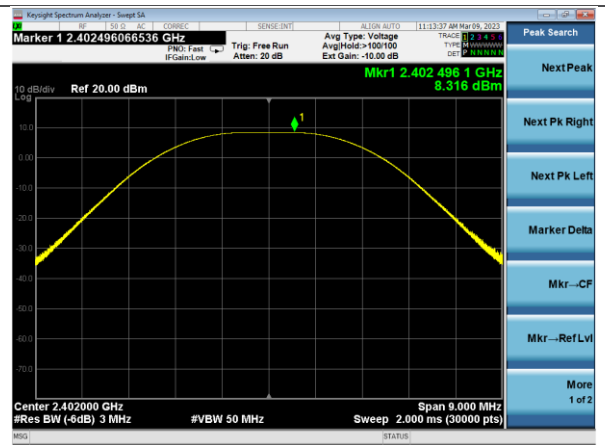
1M, Ch 37



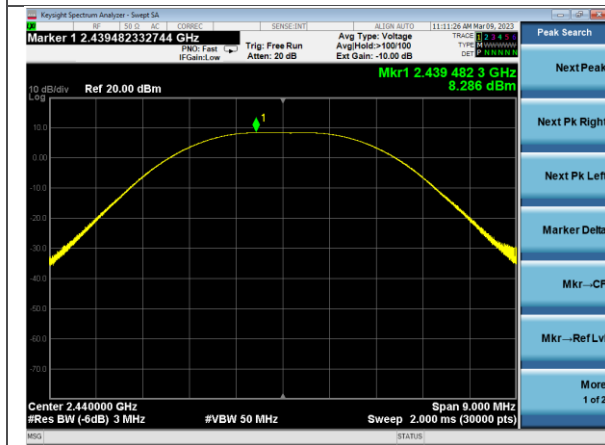
1M, Ch 17



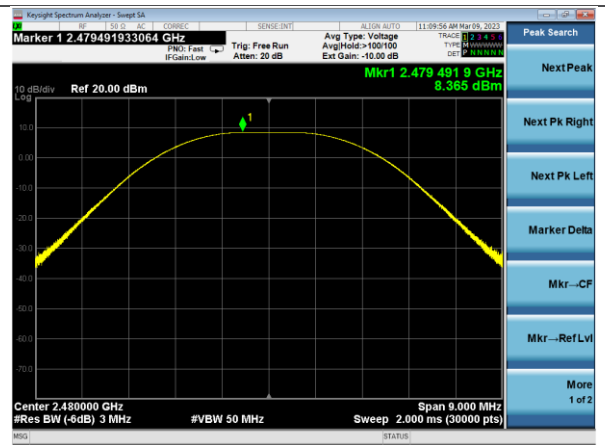
1M, Ch 39



2M, Ch 37



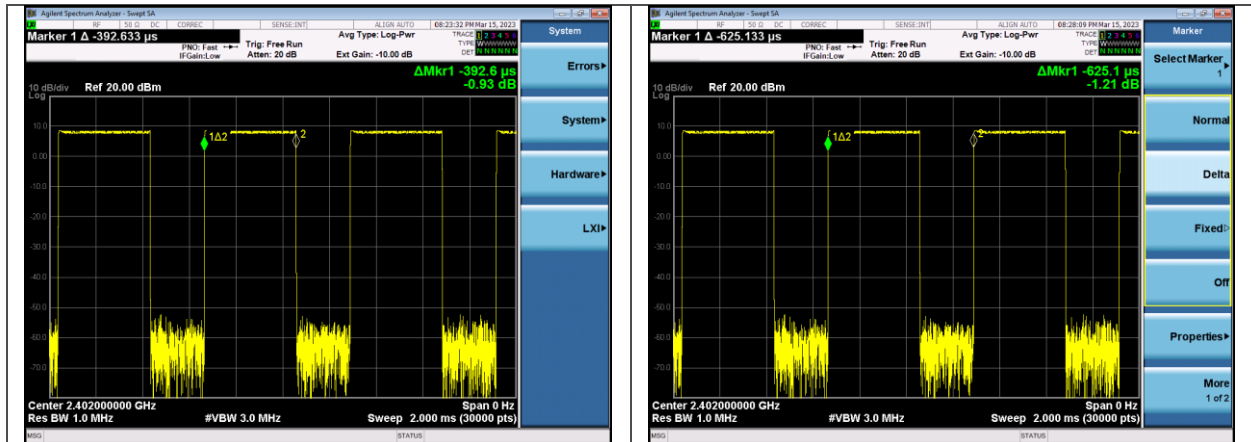
2M, Ch 17



2M, Ch 39

| | | |
|----------------------------------|---------------|----------------------------|
| Company: Laird Connectivity, LLC | Page 12 of 23 | Name: BL653μ |
| Report: TR3664A BL653μ | | Model: BL653μ |
| Quote: NBO-12-2022-005678 | | Serial: Engineering Sample |

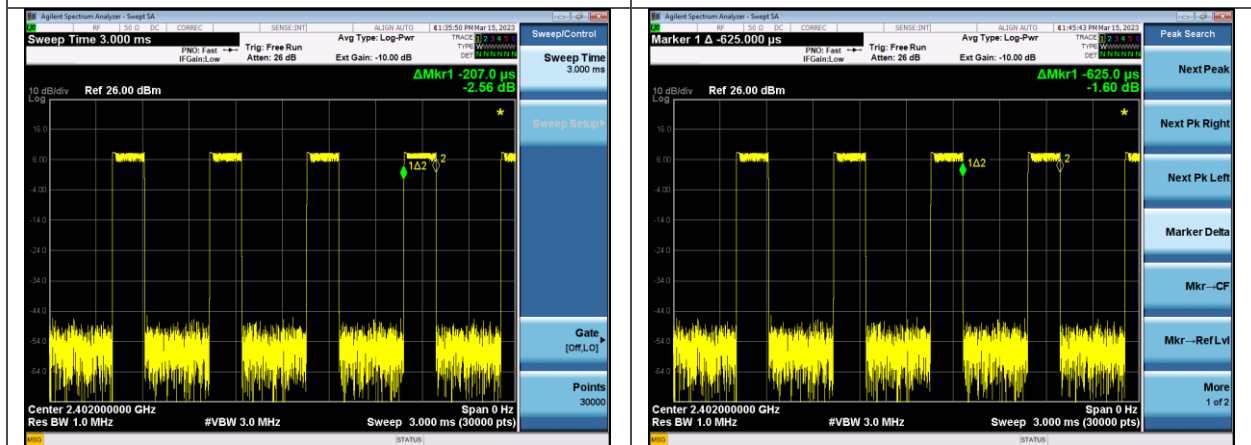
Duty Cycle Plots



1Mbps, on time 392.6μs

1Mbps, period 625.1μs

Minimum VBW used for average is 2.7 kHz, Duty cycle is 62.8%



2Mbps, on time 207.0μs

1Mbps, period 625.0μs

Minimum VBW used for average is 5.1 kHz, Duty cycle is 33.1%

| | | |
|----------------------------------|---------------|----------------------------|
| Company: Laird Connectivity, LLC | Page 13 of 23 | Name: BL653μ |
| Report: TR3664A BL653μ | | Model: BL653μ |
| Quote: NBO-12-2022-005678 | | Serial: Engineering Sample |

5.1.2 Antenna Port Conducted Emissions in Restricted Bands

| | | | |
|--------------------|------------------------------|-----------------|---------------------------|
| Operator | Dylan Rosenfeldt | QA | Adam Alger, Anthony Smith |
| Temperature | 20.8°C | R.H. % | 23.1% |
| Test Date | 3/15/2023 – 3/16/2023 | Location | RF Conducted Bench |
| Requirement | FCC: 15.247 ISED: RSS-247 | Method | ANSI C63.10 |

FCC 15.247 Limits:

| Frequency (MHz) | Quasi-Peak (dBμV/m) | Average (dBμV/m) | Peak (dBμV/m) |
|-----------------|---------------------|------------------|---------------|
| 30 - 88 | 40.0 | - | - |
| 88 - 216 | 43.5 | - | - |
| 216 - 960 | 46.0 | - | - |
| 960 - 1000 | 54.0 | - | - |
| 1000 - 25000 | - | 54.0 | 74.0 |

Test Parameters

| | | | |
|--------------------|-------------------------------------------------------------|----------------------------|------------------------------|
| Frequency | 30 – 25000 MHz | Setup | Conducted RF port |
| RBW | 120kHz (<1GHz), 1MHz (>1GHz) | VBW | 1.2MHz (<1GHz), 3MHz (>1GHz) |
| Detector(s) | Peak – Trace/Final Quasi-Peak – Final Average – Final | Example Calculation | E-Field @ 3m = EIRP + 95.2 |

Instrumentation

| Asset # | Description | Manufacturer | Model # | Serial # | Date | Due Date | Status |
|--------------|-------------------------|--------------------|-----------|------------|-----------|-----------|---------------------|
| EE 960088 | Analyzer - EMI Receiver | Agilent | N9038A | MY51210138 | 4/12/2022 | 4/12/2023 | Active Calibration |
| AA 960173 | Cable | A.H. Systems, Inc. | SAC-26G-1 | 388 | 3/22/2022 | 3/22/2023 | Active Verification |

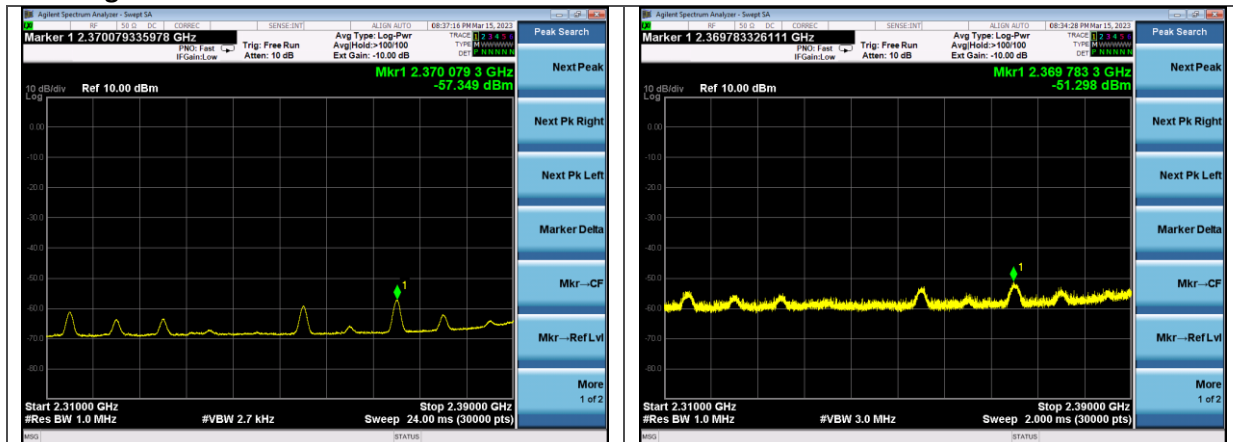
EUT Parameters

| | | | |
|--------------------|--------------------|-----------------|-----------------|
| Input Power | 5V USB | Mode | BLE Tx |
| Frequency | 2400 – 2480 | Channels | 37, 17, 39 |
| Serial | Engineering Sample | Settings | Power setting 8 |

Band Edge Emissions Table

| Channel | Data rate | Freq (MHz) | Measured output power (dBm) | Antenna Gain (dBi) | EIRP (dBm) | E-Field (dBuV/m) | E-Field Limit (dBuV/m) | E-Field Margin (dBuV/m) | Note |
|---------|-----------|------------|-----------------------------|--------------------|------------|------------------|------------------------|-------------------------|------|
| 37 | 1M | 2370.0 | -57.1 | 3.1 | -54.0 | 41.2 | 54.0 | 12.8 | AVE |
| 37 | 1M | 2370.0 | -46.5 | 3.1 | -43.4 | 51.8 | 74.0 | 22.2 | PK |
| 39 | 1M | 2488.0 | -50.8 | 3.1 | -47.7 | 47.5 | 54.0 | 6.5 | AVE |
| 39 | 1M | 2483.5 | -33.9 | 3.1 | -30.8 | 64.4 | 74.0 | 9.6 | PK |
| 37 | 2M | 2370.0 | -58.0 | 3.1 | -54.9 | 40.3 | 54.0 | 13.7 | AVE |
| 37 | 2M | 2386.3 | -47.8 | 3.1 | -44.7 | 50.5 | 74.0 | 23.5 | PK |
| 39 | 2M | 2483.5 | -47.4 | 3.1 | -44.3 | 50.9 | 54.0 | 3.1 | AVE |
| 39 | 2M | 2483.5 | -35.0 | 3.1 | -31.9 | 63.3 | 74.0 | 10.7 | PK |

Band Edge Emission Plots

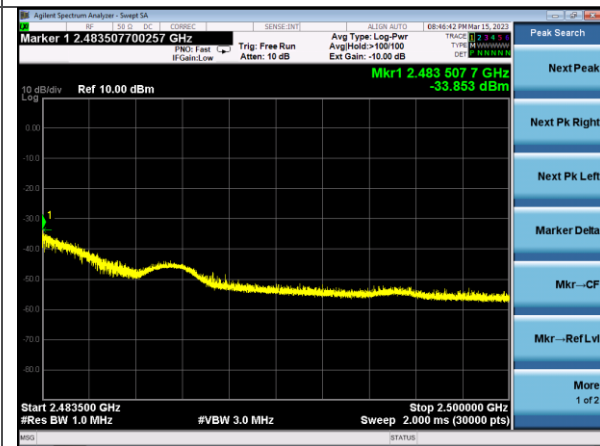


1 Mbps lower band edge, Average

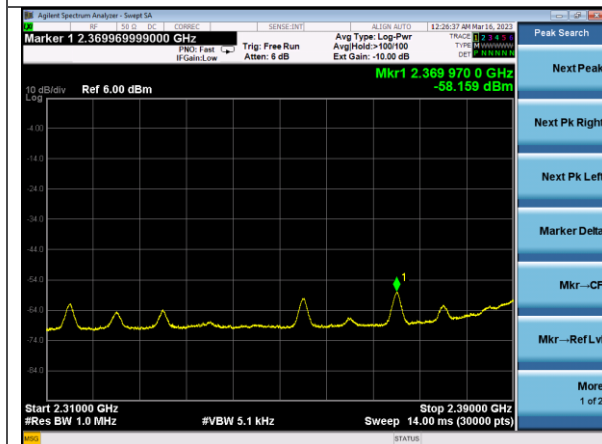
1 Mbps lower band edge, Peak



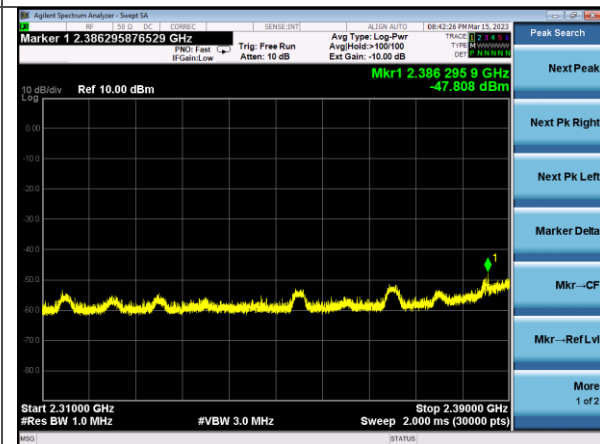
1 Mbps upper band edge, Average



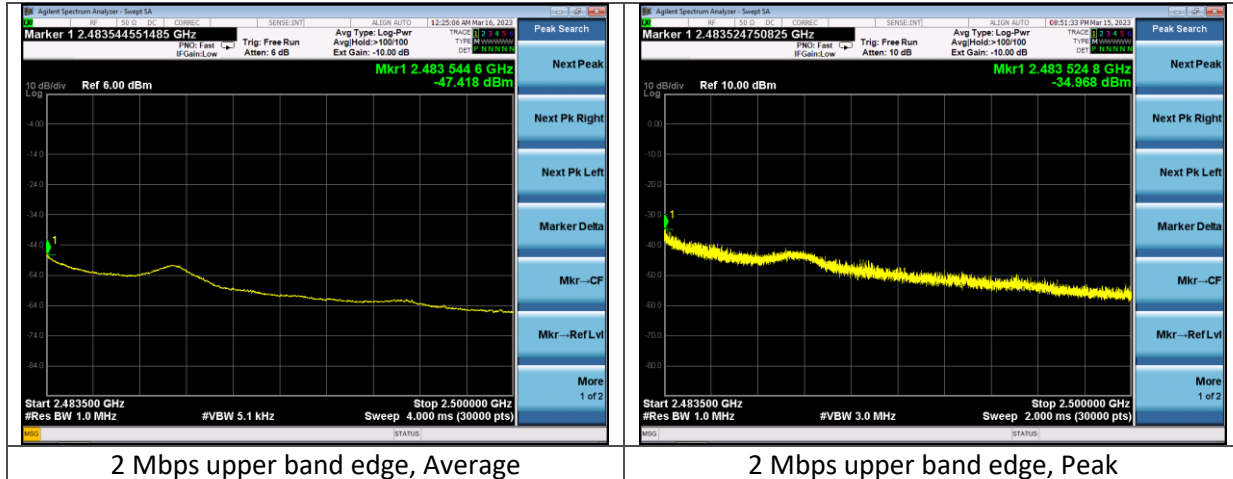
1 Mbps upper band edge, Peak



2 Mbps lower band edge, Average



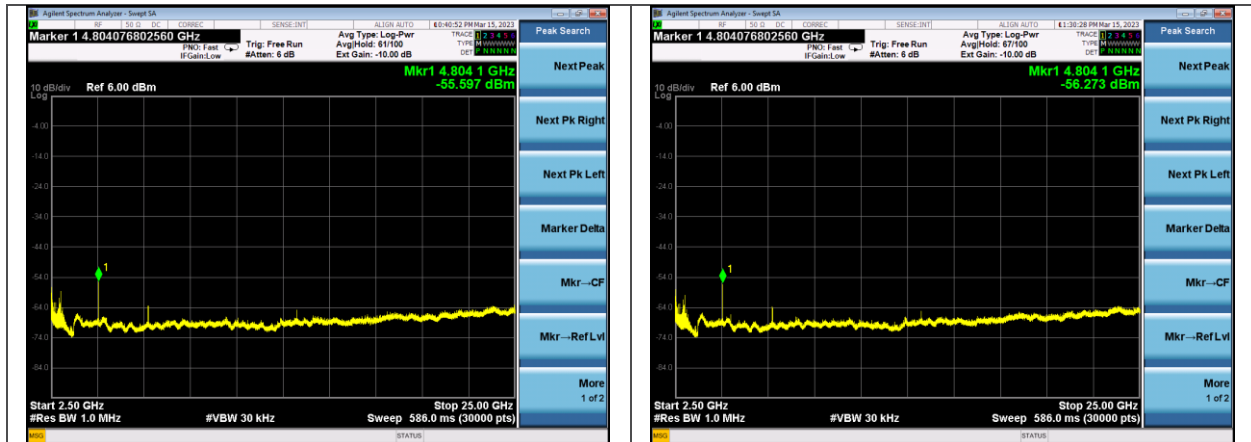
2 Mbps lower band edge, Peak



Channel 37 Spurious Emissions Table

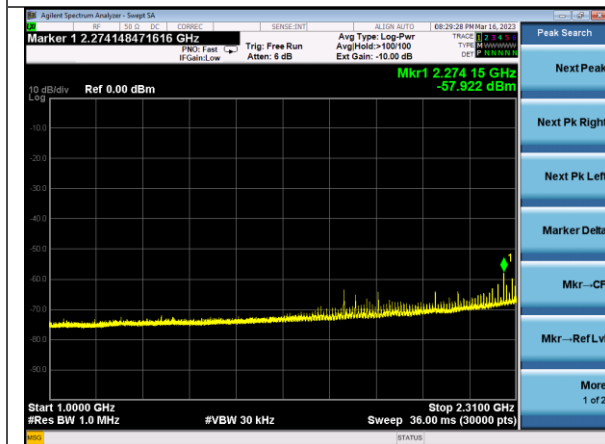
| Data rate | Freq (MHz) | Measured output power (dBm) | Antenna Gain (dBi) | EIRP (dBm) | E-Field (dBuV/m) | E-Field Limit (dBuV/m) | E-Field Margin (dBuV/m) | Note |
|-----------|------------|-----------------------------|--------------------|------------|------------------|------------------------|-------------------------|------|
| 1M | 4803.9 | -57.5 | 3.1 | -54.4 | 40.8 | 54.0 | 13.2 | AVE |
| 1M | 4803.2 | -50.6 | 3.1 | -47.5 | 47.7 | 74.0 | 26.3 | PK |
| 2M | 4803.7 | -61.8 | 3.1 | -58.7 | 36.5 | 54.0 | 17.5 | AVE |
| 2M | 4802.8 | -53.2 | 3.1 | -50.1 | 45.1 | 74.0 | 28.9 | PK |

Plots

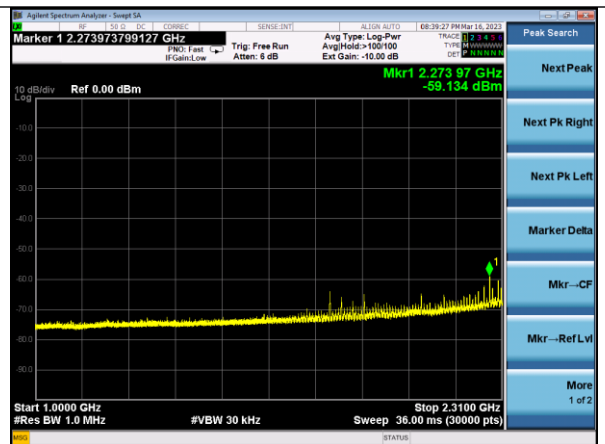


2500 – 25000 MHz, 1Mbps

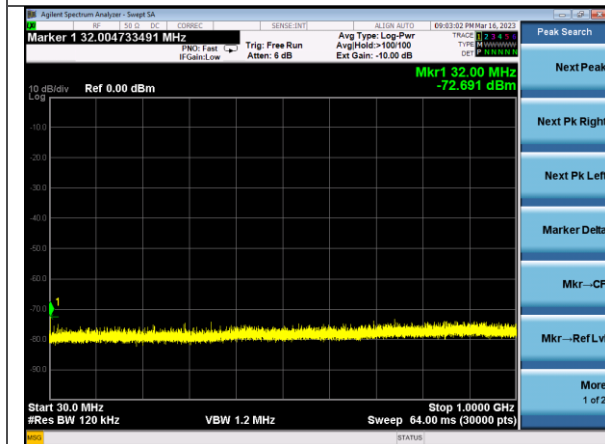
2500 – 25000 MHz, 2Mbps



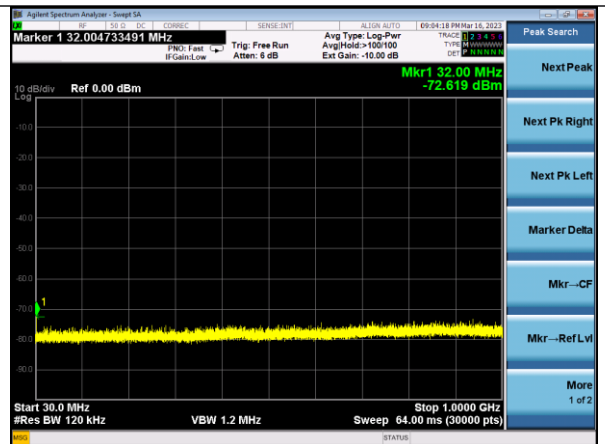
1000 – 2310 MHz, 1Mbps



1000 – 2310 MHz, 2Mbps



30 - 1000 MHz, 1Mbps



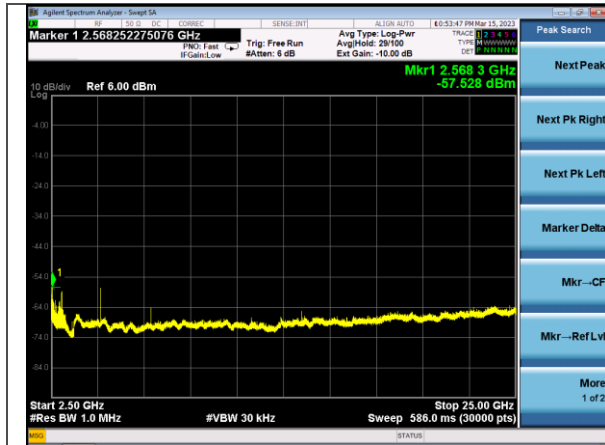
30 - 1000 MHz, 2Mbps

| | | |
|----------------------------------|---------------|----------------------------|
| Company: Laird Connectivity, LLC | Page 18 of 23 | Name: BL653μ |
| Report: TR3664A BL653μ | | Model: BL653μ |
| Quote: NBO-12-2022-005678 | | Serial: Engineering Sample |

Channel 17 Spurious Emissions Table

| Data rate | Freq (MHz) | Measured output power (dBm) | Antenna Gain (dBi) | EIRP (dBm) | E-Field (dBuV/m) | E-Field Limit (dBuV/m) | E-Field Margin (dBuV/m) | Note |
|-----------|------------|-----------------------------|--------------------|------------|------------------|------------------------|-------------------------|------|
| 1M | 4880.0 | -59.9 | 3.1 | -56.8 | 38.4 | 54.0 | 15.6 | AVE |
| 1M | 4880.4 | -54.6 | 3.1 | -51.5 | 43.7 | 74.0 | 30.3 | PK |
| 1M | 7319.7 | -68.0 | 3.1 | -64.9 | 30.3 | 54.0 | 23.7 | AVE |
| 1M | 7320.4 | -57.7 | 3.1 | -54.6 | 40.6 | 74.0 | 33.4 | PK |
| 2M | 4879.6 | -62.7 | 3.1 | -59.6 | 35.6 | 54.0 | 18.4 | AVE |
| 2M | 4879.2 | -55.0 | 3.1 | -51.9 | 43.3 | 74.0 | 30.7 | PK |
| 2M | 7318.6 | -68.4 | 3.1 | -65.3 | 29.9 | 54.0 | 24.1 | AVE |
| 2M | 7318.9 | -58.6 | 3.1 | -55.5 | 39.7 | 74.0 | 34.3 | PK |

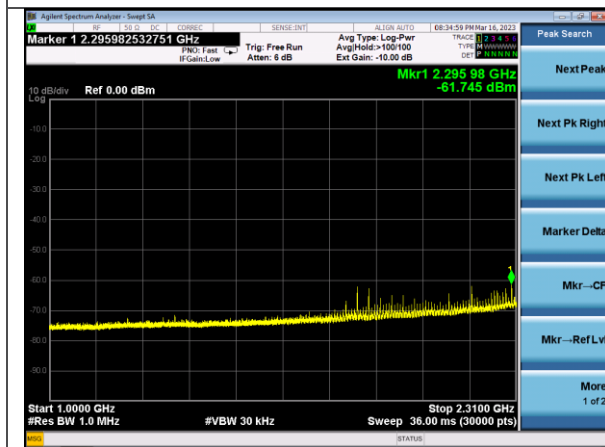
Plots



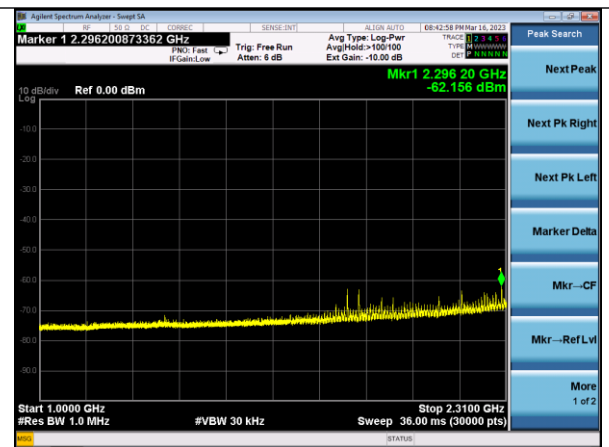
2500 – 25000 MHz, 1Mbps



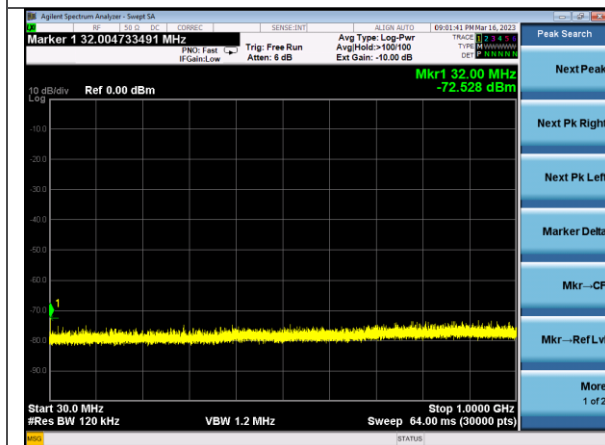
2500 – 25000 MHz, 2Mbps



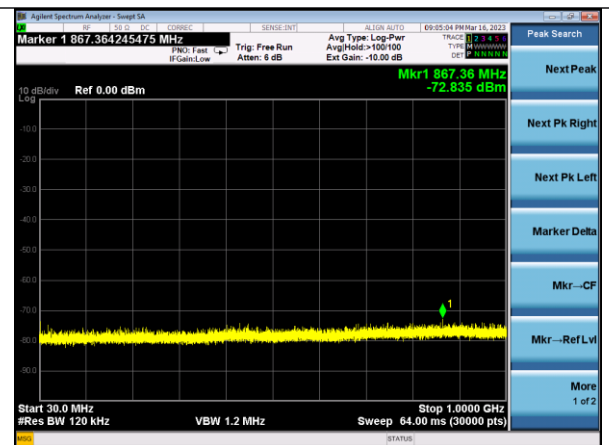
1000 – 2310 MHz, 1Mbps



1000 – 2310 MHz, 2Mbps



30 – 1000 MHz, 1Mbps

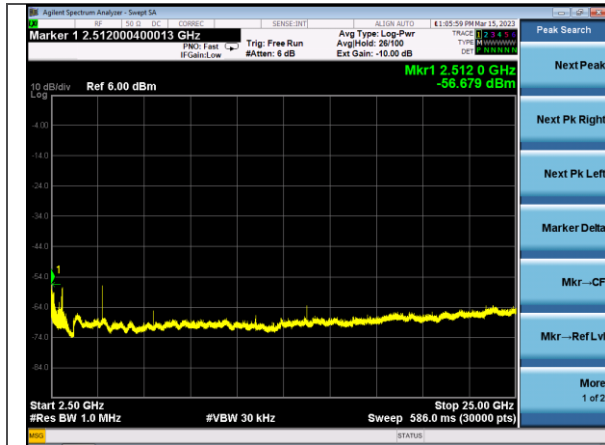


30 – 1000 MHz, 2Mbps

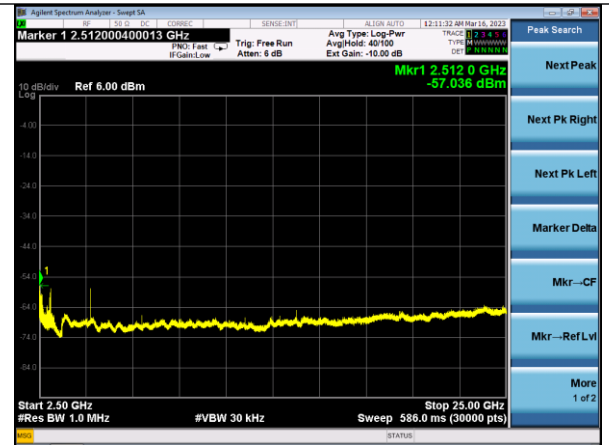
Channel 39 Spurious Emissions Table

| Data rate | Freq (MHz) | Measured output power (dBm) | Antenna Gain (dBi) | EIRP (dBm) | E-Field (dBuV/m) | E-Field Limit (dBuV/m) | E-Field Margin (dBuV/m) | Note |
|-----------|------------|-----------------------------|--------------------|------------|------------------|------------------------|-------------------------|------|
| 1M | 4960.0 | -58.4 | 3.1 | -55.3 | 39.9 | 54.0 | 14.1 | AVE |
| 1M | 4960.5 | -53.5 | 3.1 | -50.4 | 44.8 | 74.0 | 29.2 | PK |
| 1M | 7440.0 | -68.6 | 3.1 | -65.5 | 29.7 | 54.0 | 24.3 | AVE |
| 1M | 7439.4 | -58.8 | 3.1 | -55.7 | 39.5 | 74.0 | 34.5 | PK |
| 2M | 4959.8 | -62.0 | 3.1 | -58.9 | 36.3 | 54.0 | 17.7 | AVE |
| 2M | 4960.8 | -53.9 | 3.1 | -50.8 | 44.4 | 74.0 | 29.6 | PK |
| 2M | 7438.8 | -69.3 | 3.1 | -66.2 | 29.0 | 54.0 | 25.0 | AVE |
| 2M | 7438.3 | -60.0 | 3.1 | -56.9 | 38.3 | 74.0 | 35.7 | PK |

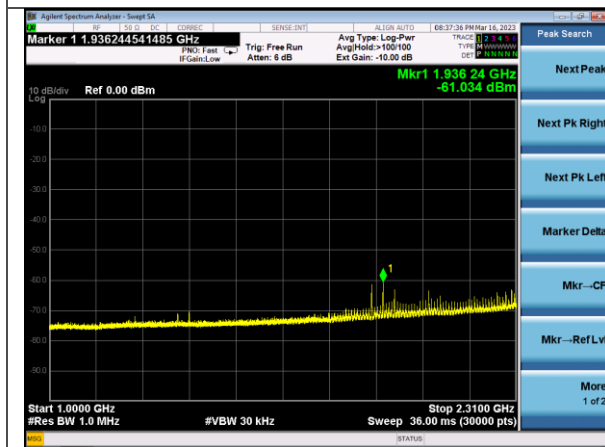
Plots



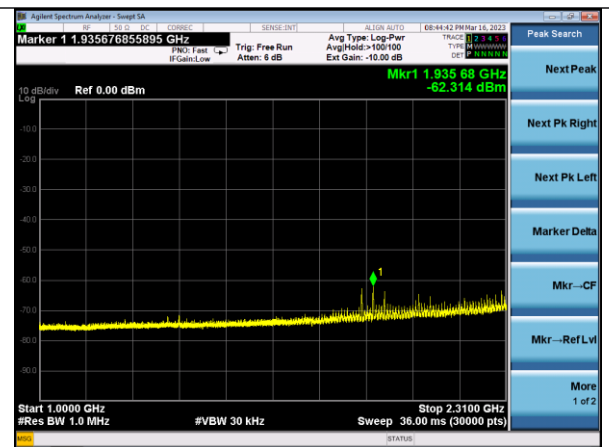
2500 – 25000 MHz, 1Mbps



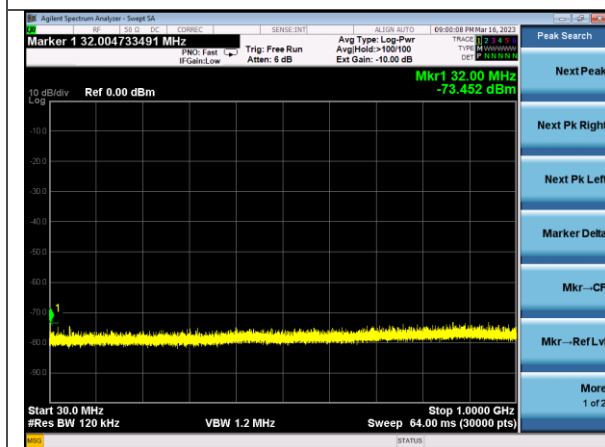
2500 – 25000 MHz, 2Mbps



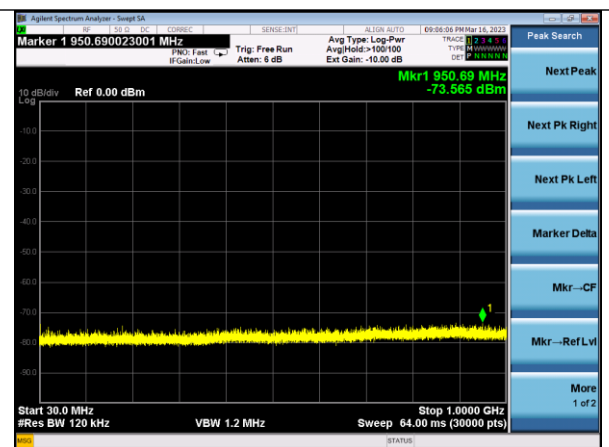
1000 – 2310 MHz, 1Mbps



1000 – 2310 MHz, 2Mbps



30 – 1000 MHz, 1Mbps



30 – 1000 MHz, 2Mbps

6 REVISION HISTORY

| Version | Date | Notes | Person |
|---------|-----------|--------------------|------------------|
| 0 | 3/20/2023 | Initial Draft | Dylan Rosenfeldt |
| 1 | 2/13/2024 | Final Draft | Dylan Rosenfeldt |
| 2 | 2/23/2024 | Updated References | Dylan Rosenfeldt |

END OF REPORT