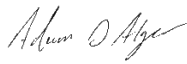


Test Report # TR 3664 A BL653μ V2

Equipment Under Test:	BL653μ
Requirement(s):	FCC: 15.247 ISED: RSS-247 / RSS-GEN
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

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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

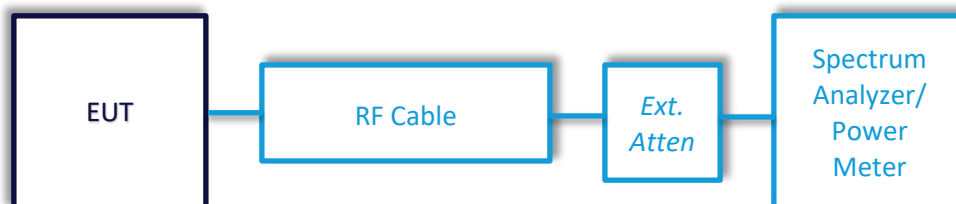
Parameter	ETSI U.C. $\pm$	U.C. $\pm$
Radio Frequency, from F0	1×10^{-7}	0.55×10^{-7}
Occupied Channel Bandwidth	5 %	2 %
RF conducted Power (Power Meter)	1.5 dB	1.2 dB
RF conducted emissions (Spectrum Analyzer)	3.0 dB	1.7 dB
All emissions, radiated	6.0 dB	5.3 dB
Temperature	1° C	0.65° C
Humidity	5 %	2.9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

5 TEST DATA

5.1 Antenna Port Conducted Emissions

Description of Measurement	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. The cable and attenuator factors are loaded into the analyzer or power meter allowing for direct measurement readings without the need for further corrections.
Example Calculations	Measurement (dBm) + Cable factor (dB) + External Attenuator (dB) = Corrected Reading (dBm) Margin (dB) = Limit (dBm) – Corrected Reading (dBm)

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

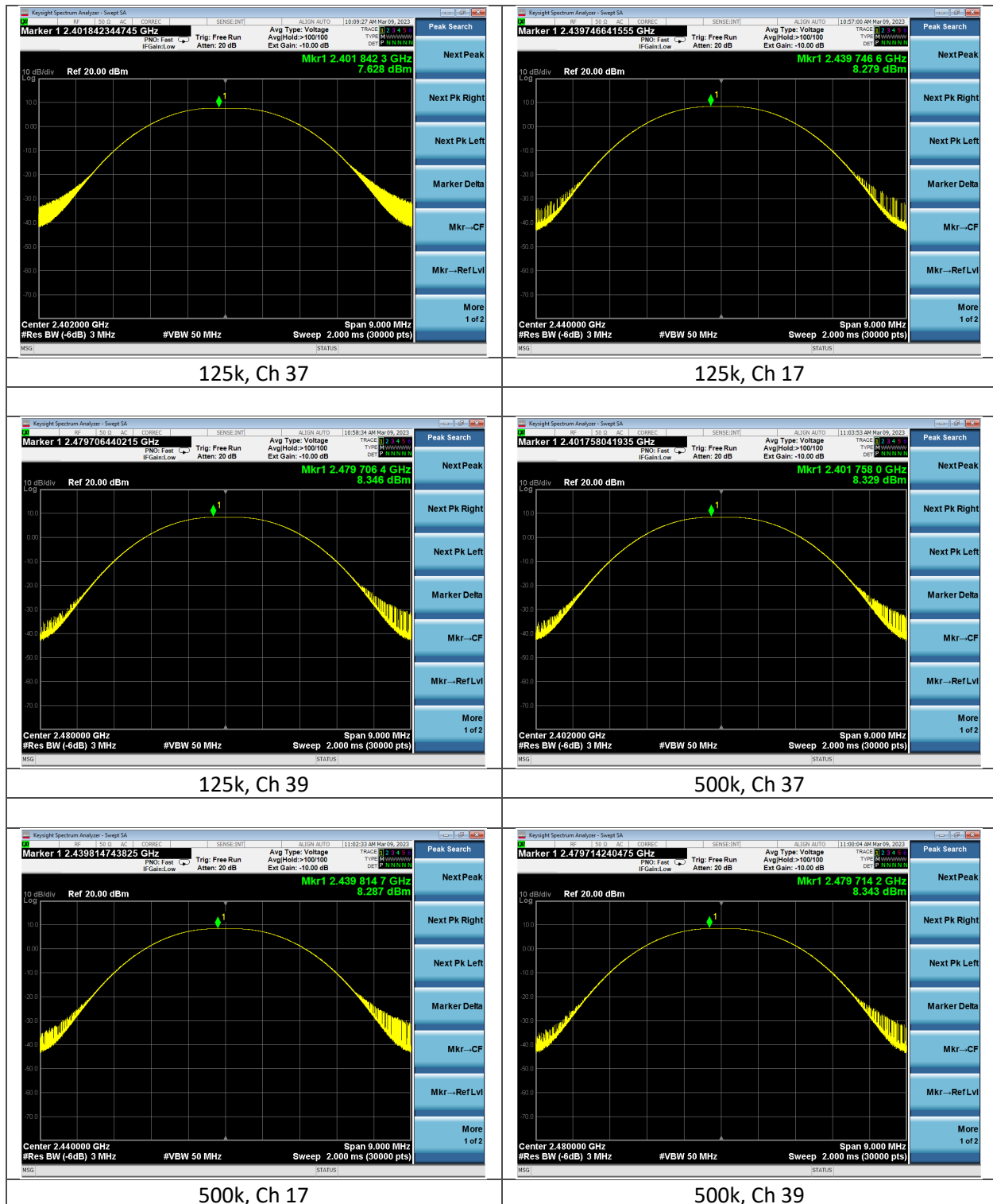
EUT Parameters

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



Company: Laird Connectivity, LLC

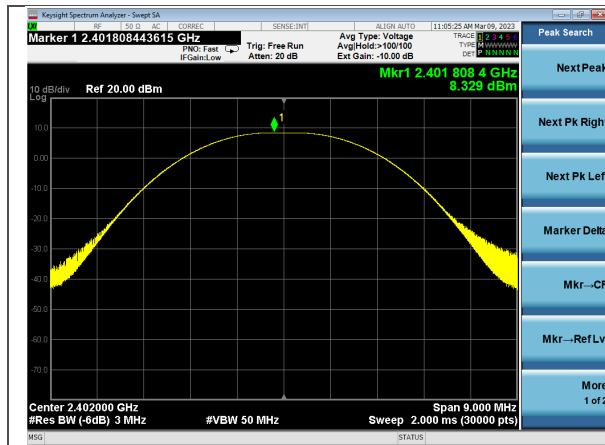
Report: TR3664A BL653μ

Quote: NBO-12-2022-005678

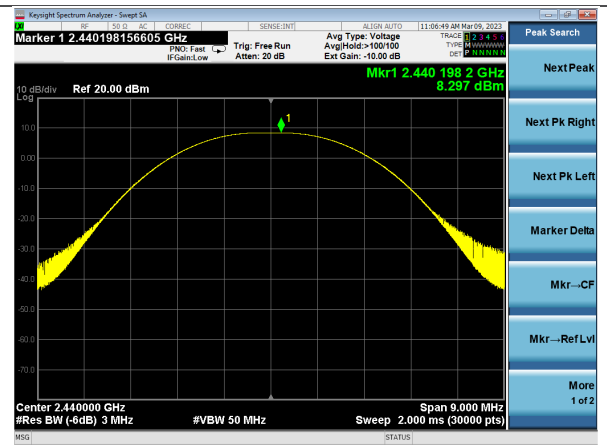
Name: BL653μ

Model: BL653μ

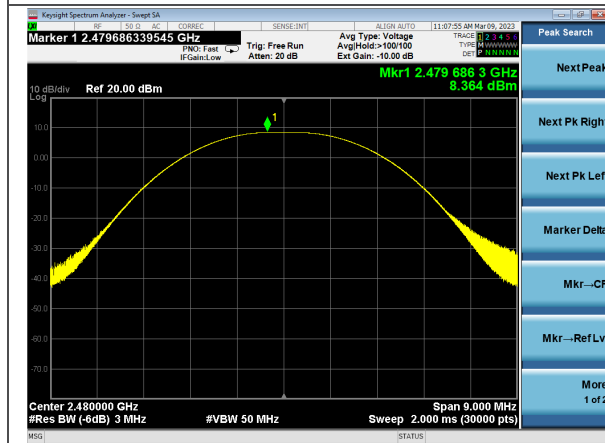
Serial: Engineering Sample



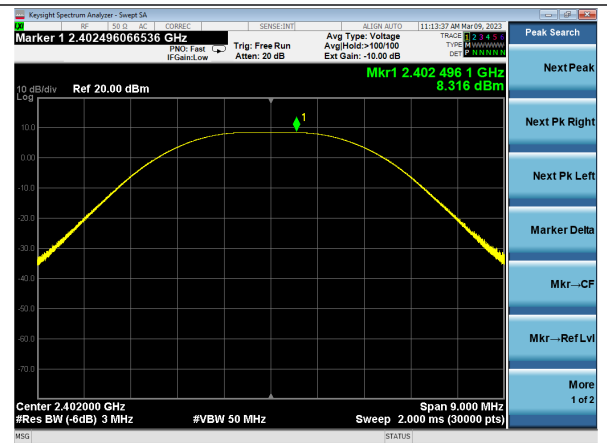
1M, Ch 37



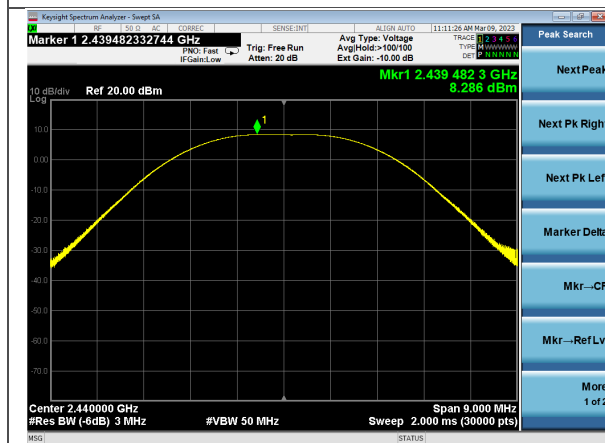
1M, Ch 17



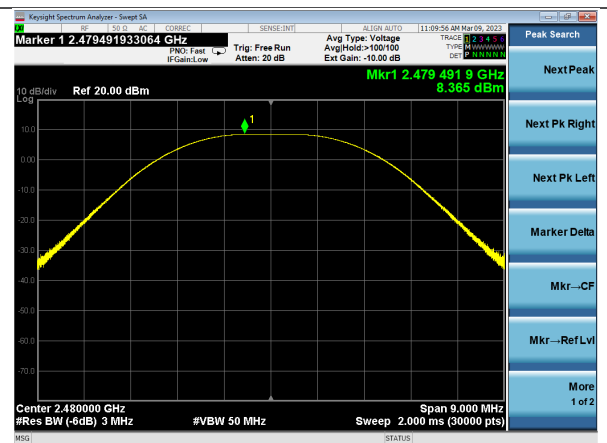
1M, Ch 39



2M, Ch 37

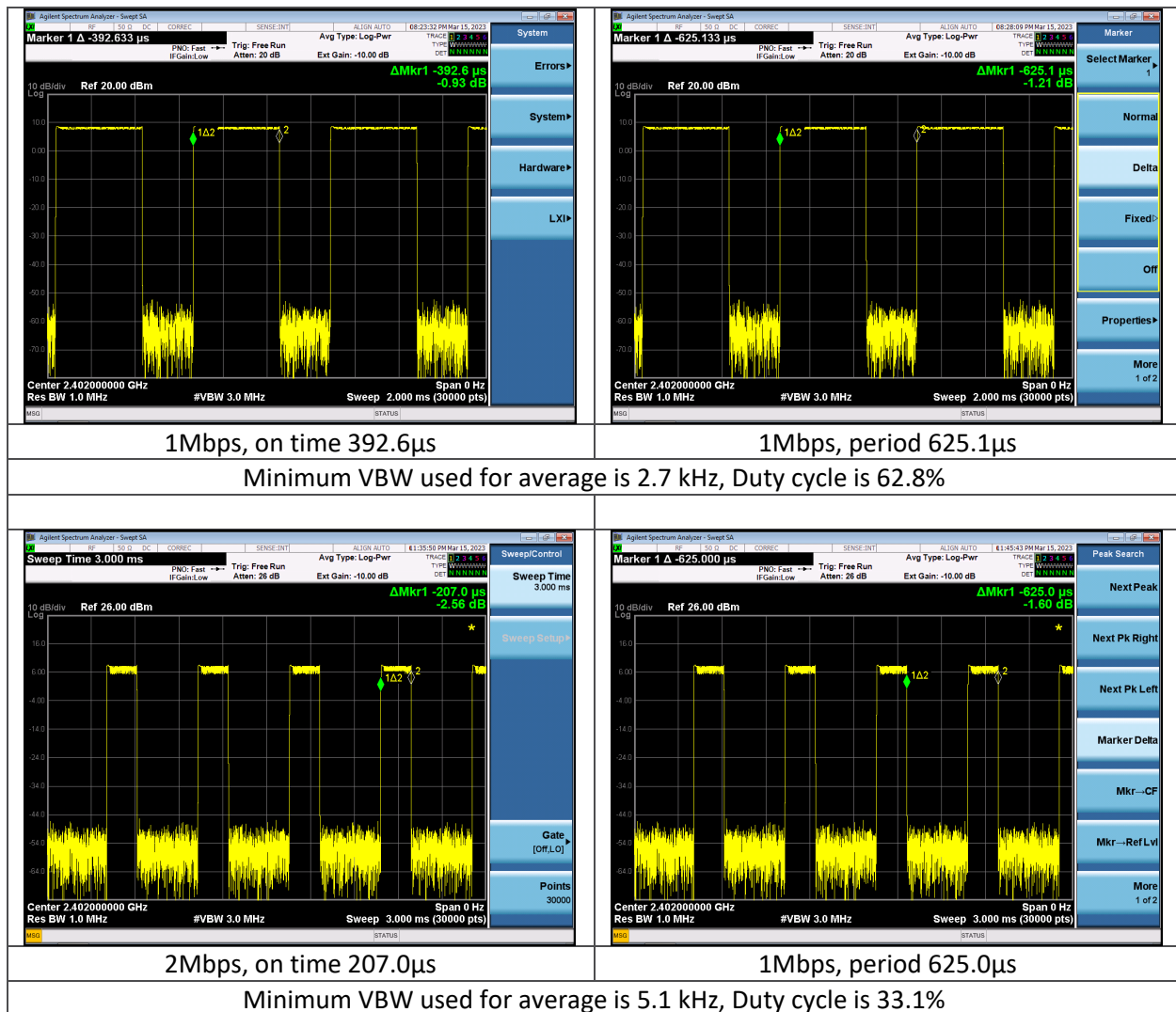


2M, Ch 17



2M, Ch 39

Duty Cycle Plots



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

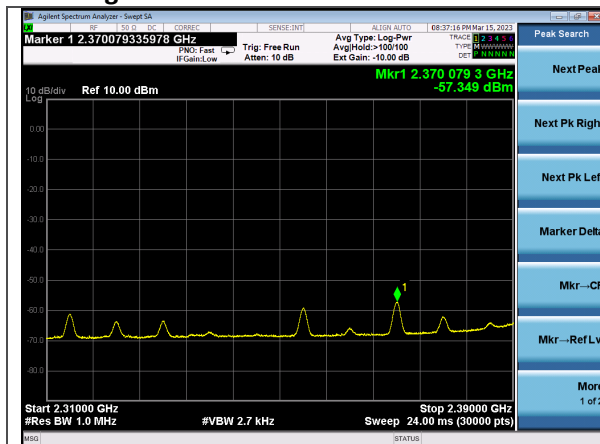
EUT Parameters

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

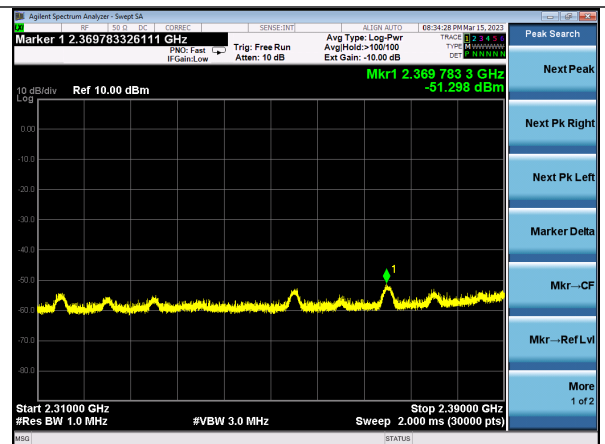
Band Edge Emissions Table

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



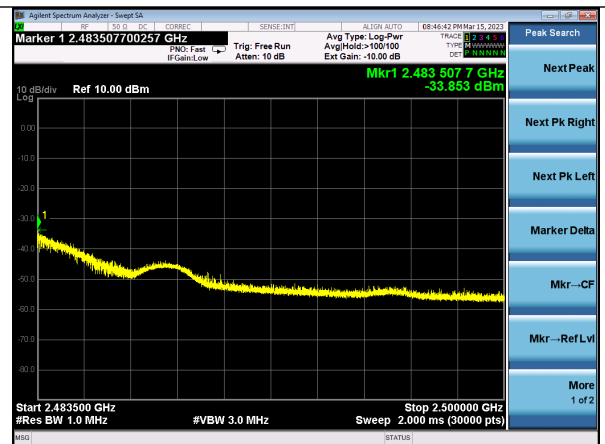
1 Mbps lower band edge, Average



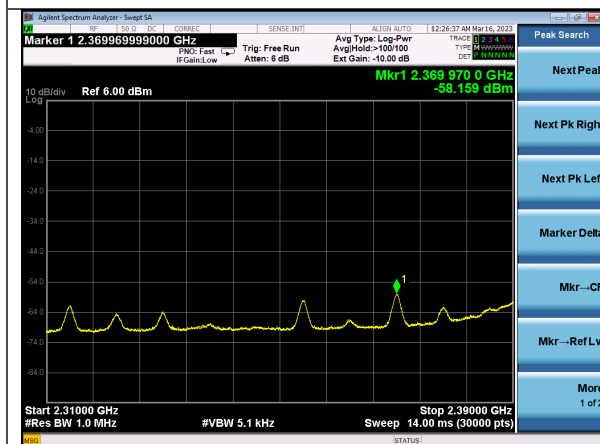
1 Mbps lower band edge, Peak



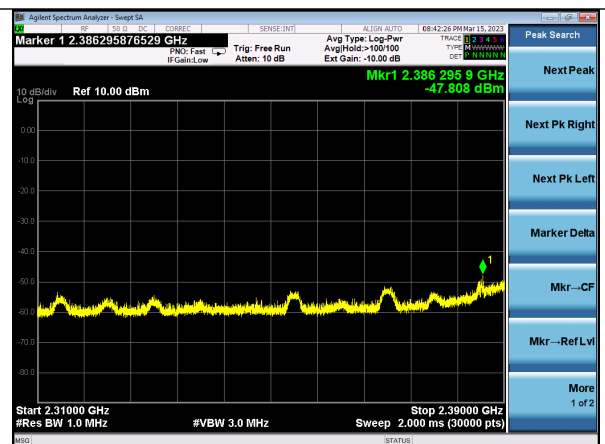
1 Mbps upper band edge, Average



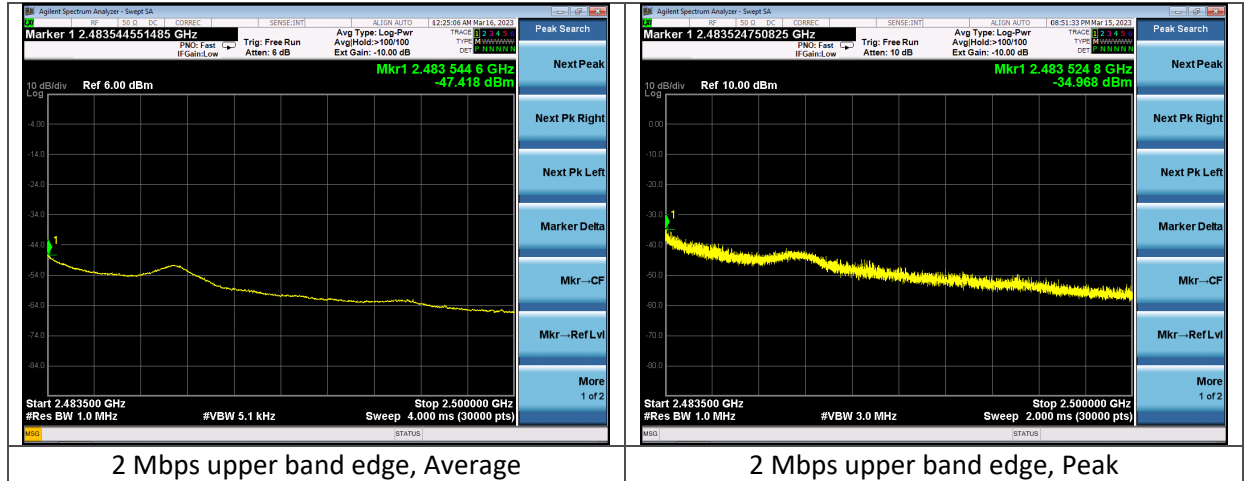
1 Mbps upper band edge, Peak



2 Mbps lower band edge, Average



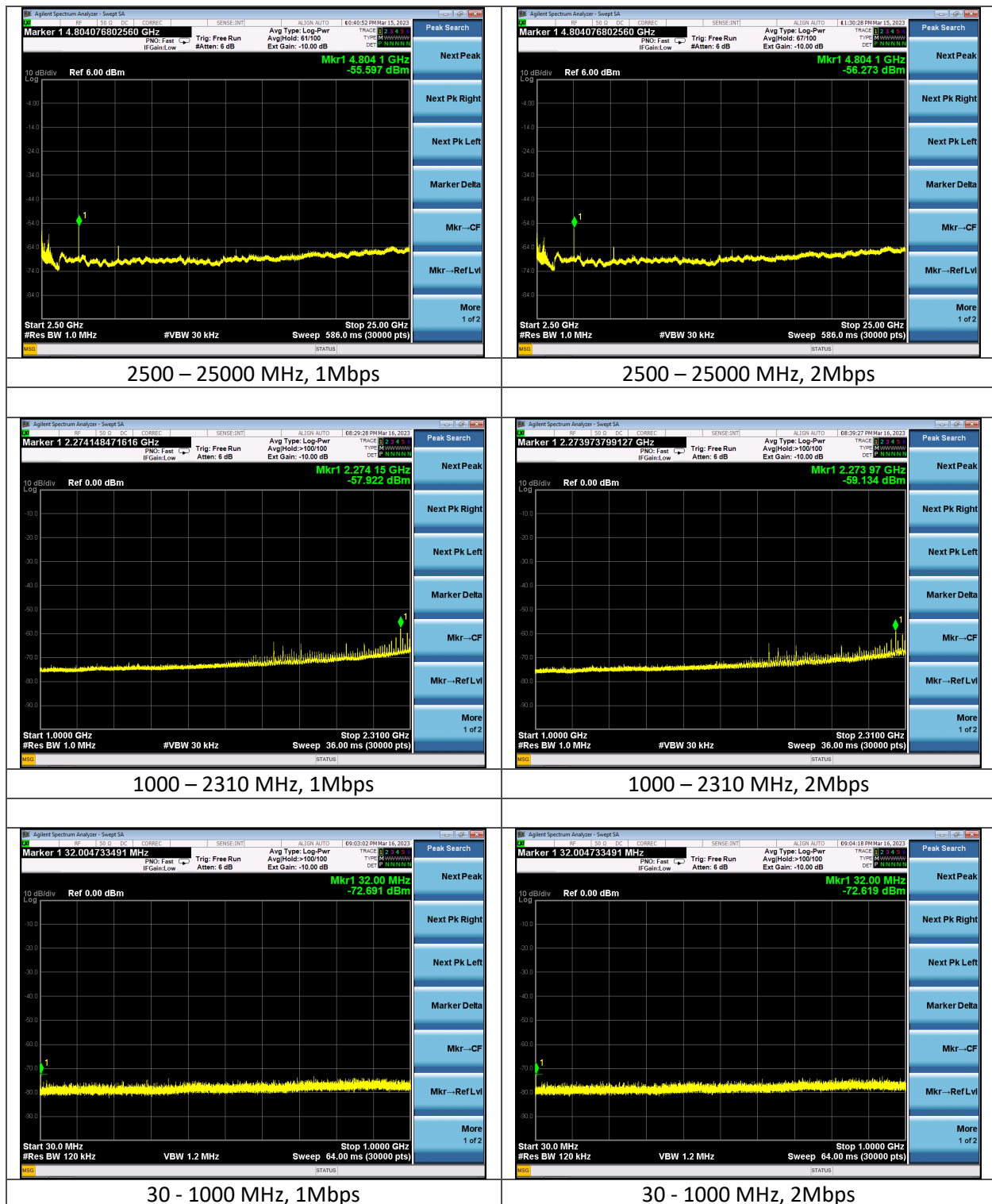
2 Mbps lower band edge, Peak



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

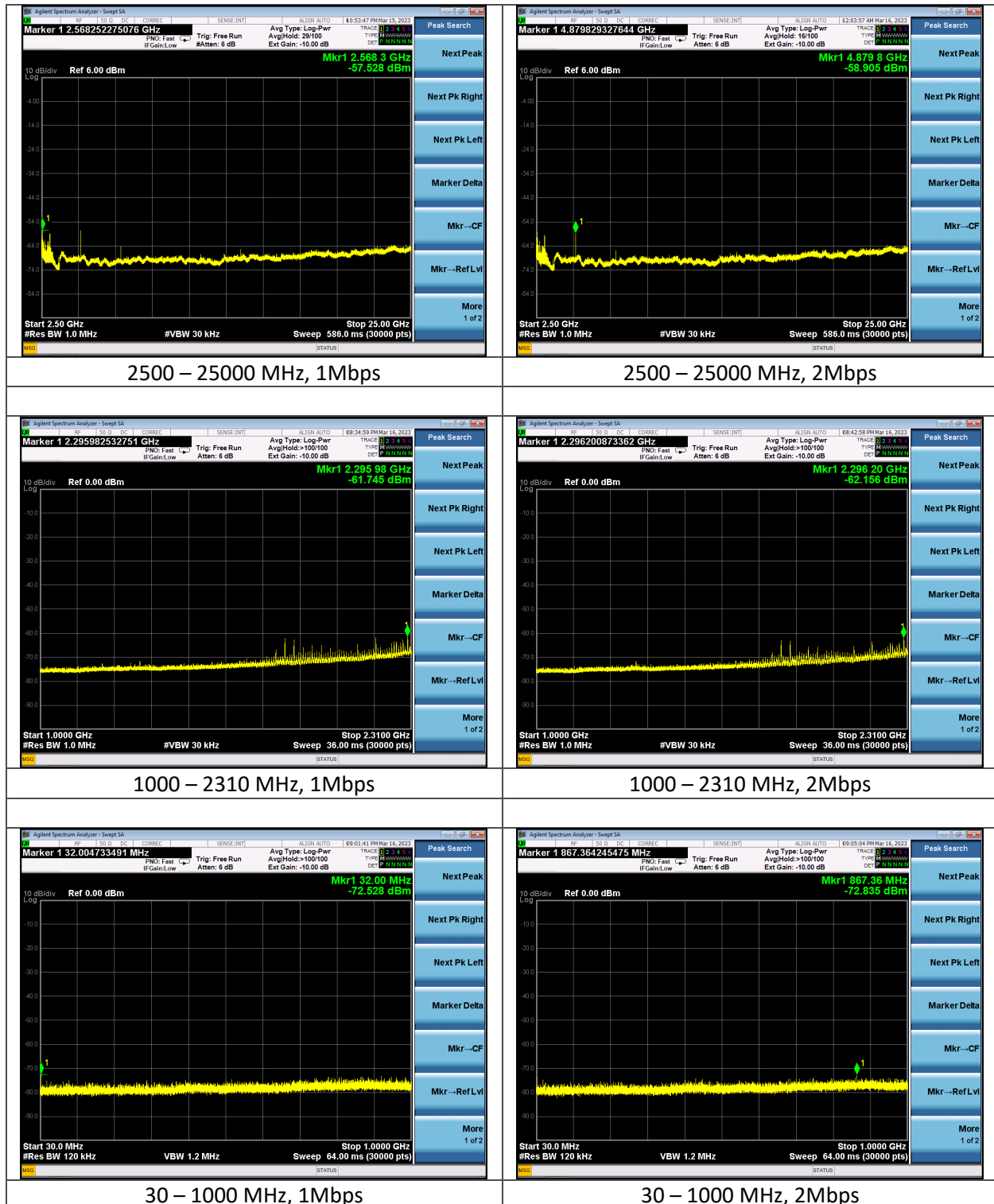
Plots



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

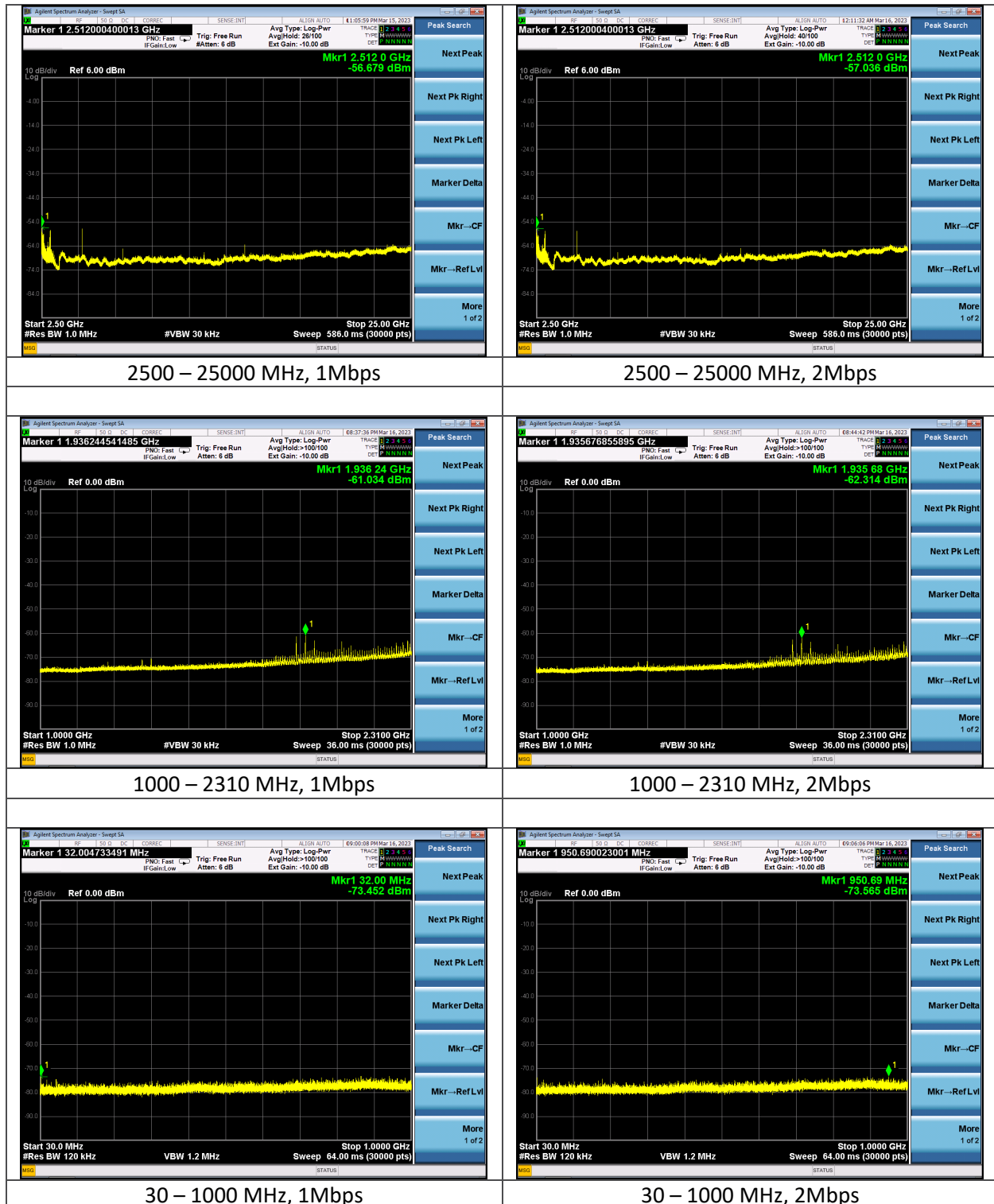
Plots



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



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