

Test Report TR3664A BL654

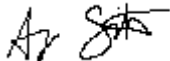
Equipment Under Test: BL654 - BLE

Requirement(s): FCC 15.247
RSS-247

Test Date(s): 3/9/2023 – 3/20/2023

Prepared for: Laird Connectivity
Attn: Jonathan Kaye
W66 N220 Commerce Ct.
Cedarburg, WI 53012

Report Issued by: Anthony Smith, EMC Engineering Specialist

Signature: 

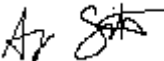
Date: 02/29/2024

Report Reviewed by: Adam Alger, Laboratory Manager

Signature: 

Date: 02/29/2024

Report Constructed by: Anthony Smith, EMC Engineering Specialist

Signature: 

Date: 12/8/2023

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Company: Laird Connectivity	Page 1 of 27	Name: BL654
Report: TR3664A BL654		Model: BL654
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

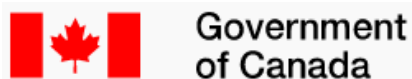
Scope of accreditation includes all test methods listed herein unless otherwise noted



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

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1 TEST REPORT SUMMARY

During **March 9th, 2023 to March 20th, 2023** the Equipment Under Test (EUT), **BL654**, as provided by **Laird Connectivity** was tested to the following requirements:

FCC 15.247 / RSS-247

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-GEN8.9	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
Contact Person	Jonathan Kaye
Address	W66N220 Commerce Court Cedarburg, WI, 53012

2.1 Equipment Under Test (EUT) Information

The following information has been supplied by the client

Product Name	BL654
Model Number	BL654
Serial Number	Engineering Sample
FCC ID	SQGBL654
IC ID	3147A-BL654

2.2 Product Description

Bluetooth 5.0 BLE Data Module

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, 1M, 2M Data Rates. Channels tested: 37 (2402 MHz), 17 (2440 MHz), and 39 (2480 MHz). Dell Latitude 5480 Laptop used to program radio.

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 BL654. EUT tested via Cabinet Radiation method.

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3 REFERENCES

Publication	Edition	Date	AMD 1
eCFR	-	2023	-
RSS-247	3	2023	-
RSS-GEN	5	2018	2019
ANSI C63.10	-	2013	-
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

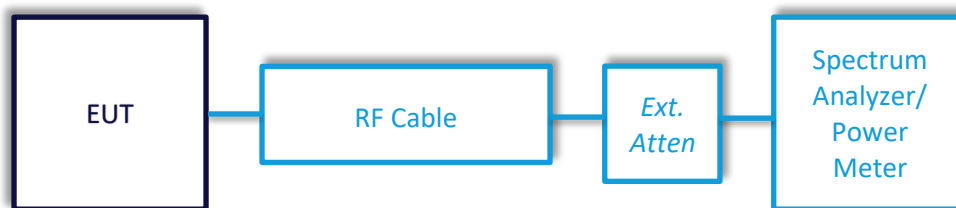
Parameter	ETSI U.C. \pm	U.C. \pm
Radio Frequency, from F0	1×10^{-7}	0.55×10^{-7}
Occupied Channel Bandwidth	5 %	2 %
RF conducted Power (Power Meter)	1.5 dB	1.2 dB
RF conducted emissions (Spectrum Analyzer)	3.0 dB	1.7 dB
All emissions, radiated	6.0 dB	5.3 dB
Temperature	1° C	0.65° C
Humidity	5 %	2.9 %
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	Anthony Smith	QA	Adam Alger
Temperature	20.7°C	R.H. %	29.4%
Test Date	3/9/2023	Location	Conducted RF Bench
Requirement	FCC 15.247 RSS-247	Method	ANSI C63.10

Limits: <30dBm

Test Parameters

Frequency	2400-2483.5 MHz	Setup	Conducted
RBW	3 MHz	VBW	50 MHz
Detector(s)	Peak	Settings	Trace Max Hold

Instrumentation

Asset #	Description	Manufacturer	Model #	Serial #	Date	Due Date	Status
AA 960173	Cable	A.H. Systems, Inc.	SAC-26G-1	388	6/13/2023	6/12/2024	Active Verification
EE 960087	Analyzer - Spectrum	Agilent	N9010A	MY53400296	4/11/2023	4/11/2024	Active Calibration

EUT Parameters

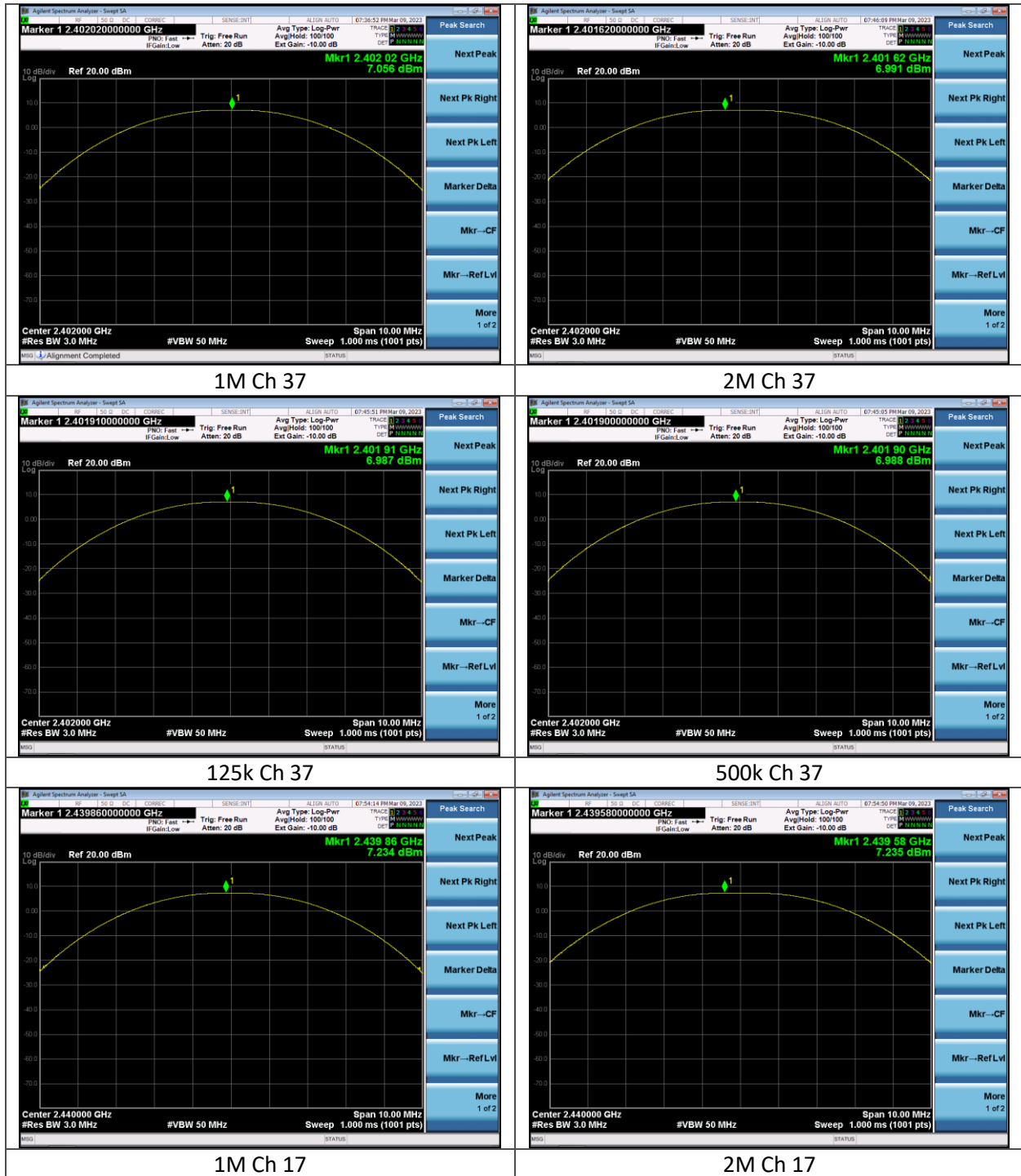
Input Power	12VDC	Mode	BLE – 125k, 500k, 1M, 2M
Frequency (MHz)	2402, 2440, 2480	Channel	37, 17, 39
Transmit Power Setting	7		

Data

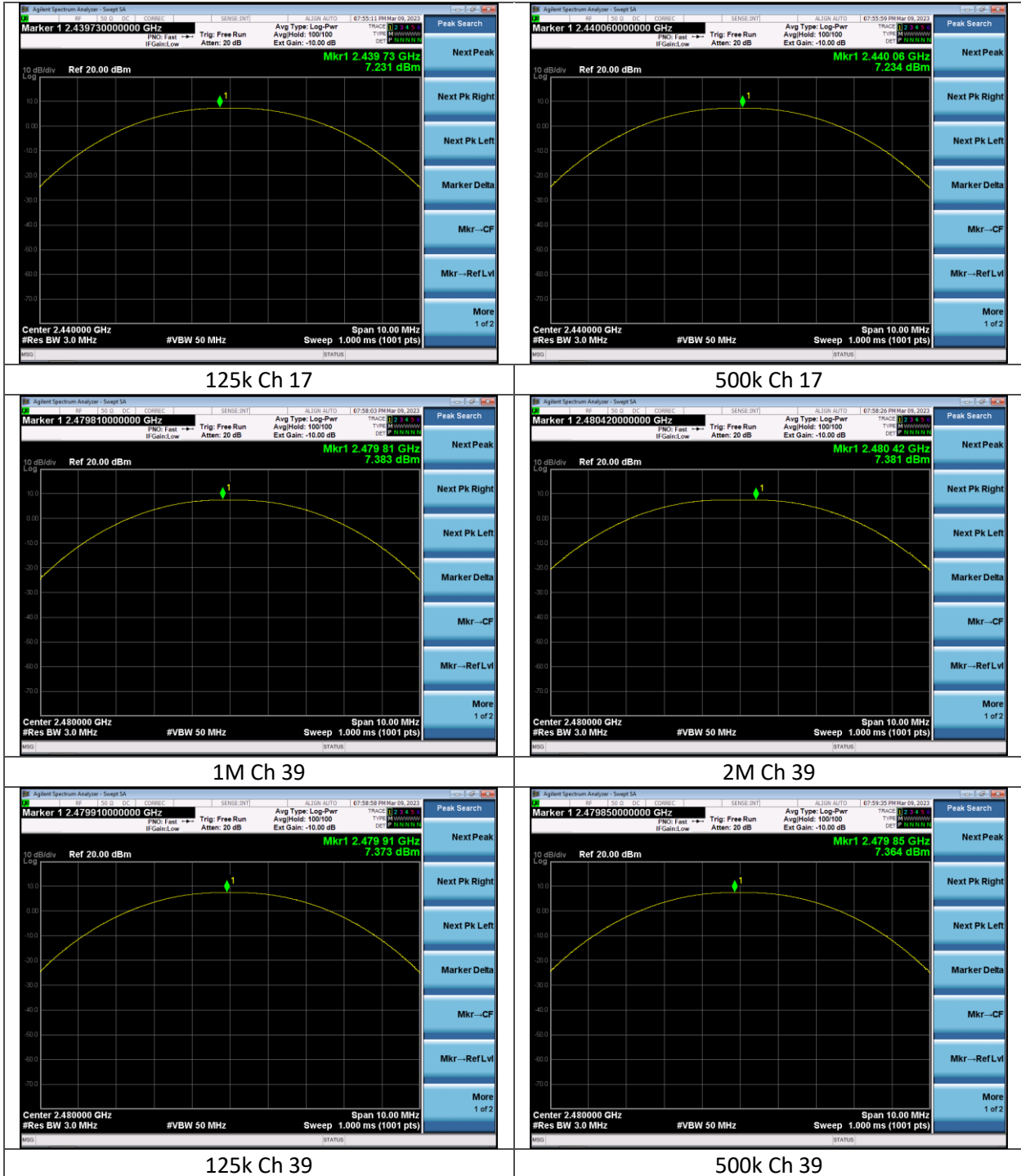
Table

Channel	Mode	Peak Conducted Power (dBm)	Limit (dBm)	Margin (dB)
37	1M	7.1	30.0	22.9
17	1M	7.2	30.0	22.8
39	1M	7.4	30.0	22.6
37	2M	7.0	30.0	23.0
17	2M	7.2	30.0	22.8
39	2M	7.4	30.0	22.6
37	125k	7.0	30.0	23.0
17	125k	7.2	30.0	22.8
39	125k	7.4	30.0	22.6
37	500k	7.0	30.0	23.0
17	500k	7.2	30.0	22.8
39	500k	7.4	30.0	22.6

Plots



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5.1.2 Antenna Port Conducted Emissions – Emissions in Restricted Frequency Bands

Operator	Anthony Smith	QA	Adam Alger
Temperature	22.2°C	R.H. %	21.2%
Test Date	3/20/2023	Location	Bench
Requirement	FCC 15.247 RSS-247	Method	ANSI C63.10 § 11.12.2 Cabinet Radiation method

Limits:

Frequency (MHz)	Quasi Peak Limit (dBµV/m)	Average Limit (dBµV/m)	Peak Limit (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	1-25 GHz	Setup	Conducted
RBW	1 MHz	VBW	3 MHz
Detector(s)	Peak, Average	Settings	Peak – Max Hold Average – Trace Average

Instrumentation

Asset #	Description	Manufacturer	Model #	Serial #	Date	Due Date	Status
AA 960172	Cable	A.H. Systems, Inc.	SAC-26G-1	387	6/13/2023	6/12/2024	Active Verification
EE 960087	Analyzer - Spectrum	Agilent	N9010A	MY53400296	4/11/2023	4/11/2024	Active Calibration

EUT Parameters

Input Power	12VDC	Mode	BLE – Packet Length 255
Frequency (MHz)	2402, 2440, 2480	Channel	37, 17, 39
Data Rate	1M, 2M (Worst Case Rates)		

Data

Table

Mode	On Time (ms)	Period (ms)	Duty Cycle (%)	Avg VBW (Hz)	DC Correction (dB)
1M	2.137	2.5	85.5	468	0.7
2M	1.078	1.875	57.5	928	2.4

Band Edge

Peak

Mode/Channel	Freq (MHz)	Meas. (dBm)	Ant. Gain (dBi)	Corrected Meas. (dBm)	Limit (dBm)	Margin (dB)
1M/Low	2378.04	-52.1	3.1	-49.0	-21.2	27.8
2M/Low	2388.9	-49.8	3.1	-46.7	-21.2	25.5
1M/High	2483.5	-37.9	3.1	-34.8	-21.2	13.6
2M/High	2483.5	-36.4	3.1	-33.3	-21.2	12.1

Mode/Channel	Freq (MHz)	Meas. (dBm)	Ant. Gain (dBi)	Duty Cycle Correction	Corrected Meas. (dBm)	Limit (dBm)	Margin (dB)
1M/Low	2346.1	-59.5	3.1	0.7	-55.7	-41.2	14.5
1M/Mid	2383.9	-58.7	3.1	0.7	-54.9	-41.2	13.7
1M/High	2352.1	-58.9	3.1	0.7	-55.1	-41.2	13.9
2M/Low	2389.9	-61.6	3.1	2.4	-56.1	-41.2	14.9
2M/Mid	2384.2	-60.2	3.1	2.4	-54.7	-41.2	13.5
2M/High	2351.8	-61.4	3.1	2.4	-55.9	-41.2	14.7
1M/Low	2497.9	-58.9	3.1	0.7	-55.1	-41.2	13.9
1M/Mid	2496.2	-58.3	3.1	0.7	-54.5	-41.2	13.3
1M/High	2483.5	-50.9	3.1	0.7	-47.1	-41.2	5.9
2M/Low	2497.8	-61.2	3.1	2.4	-55.7	-41.2	14.5
2M/Mid	2495.9	-60.1	3.1	2.4	-54.6	-41.2	13.4
2M/High	2483.5	-48.2	3.1	2.4	-42.7	-41.2	1.5

Spurious

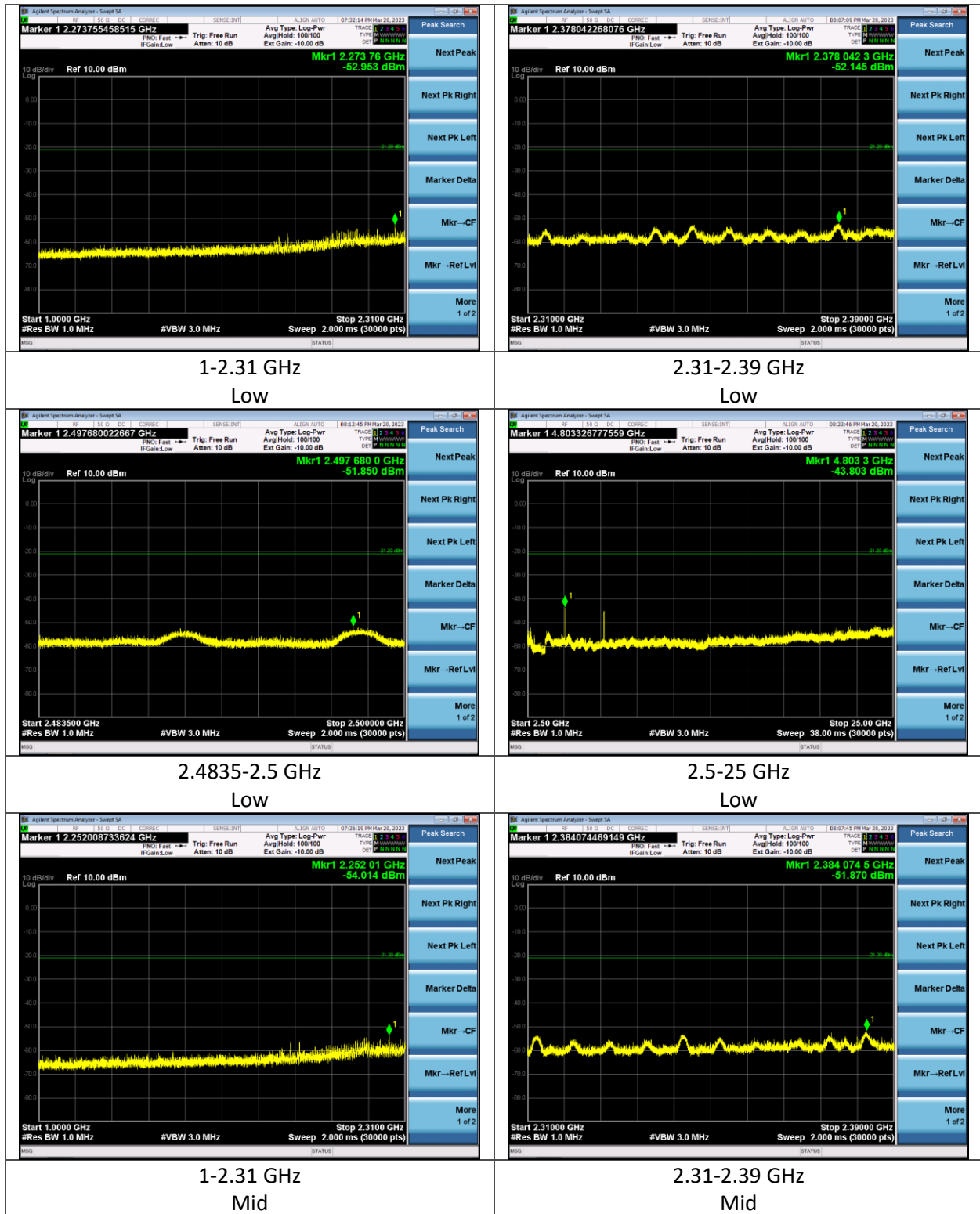
Peak

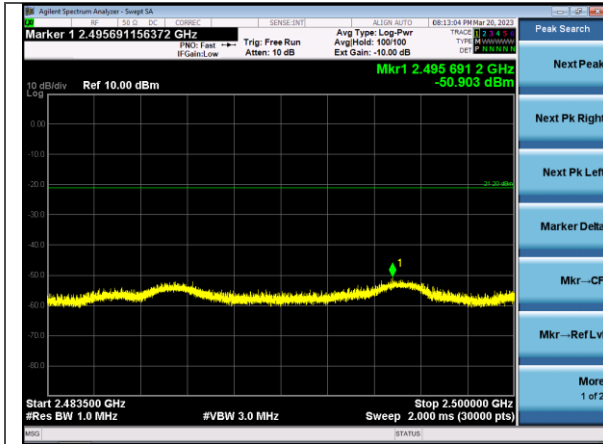
Mode/Channel	Freq (MHz)	Meas. (dBm)	Ant. Gain (dBi)	Corrected Meas. (dBm)	Limit (dBm)	Margin (dB)
1M/Low	4803.3	-43.8	3.1	-40.7	-21.2	19.5
1M/Mid	7320.4	-45.9	3.1	-42.8	-21.2	21.6
1M/High	7441.2	-46.6	3.1	-43.5	-21.2	22.3
2M/Low	4804.8	-43.8	3.1	-40.7	-21.2	19.5
2M/Mid	7318.9	-46.0	3.1	-42.9	-21.2	21.7
2M/High	7441.9	-46.9	3.1	-43.8	-21.2	22.6

Mode/Channel	Freq (MHz)	Meas. (dBm)	Ant. Gain (dBi)	Duty Cycle Correction	Corrected Meas. (dBm)	Limit (dBm)	Margin (dB)
1M/Low	4804.3	-47.5	3.1	0.7	-43.7	-41.2	2.5
1M/Mid	7319.4	-50.9	3.1	0.7	-47.1	-41.2	5.9
1M/High	7440.9	-51.6	3.1	0.7	-47.8	-41.2	6.6
2M/Low	4803.9	-51.1	3.1	2.4	-45.6	-41.2	4.4
2M/Mid	7319.0	-53.9	3.1	2.4	-48.4	-41.2	7.2
2M/High	7441.7	-54.1	3.1	2.4	-48.6	-41.2	7.4

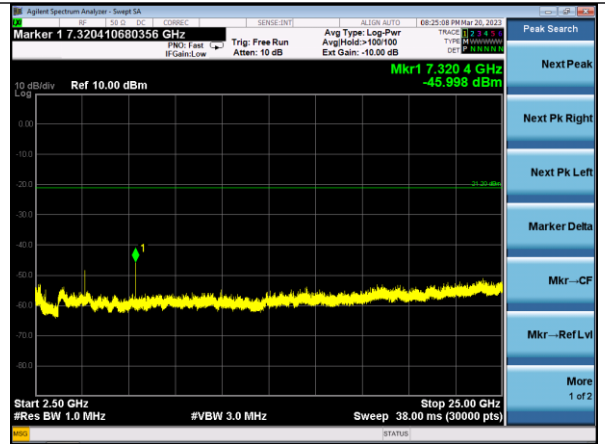
Plots

1M Peak – Worst Case 1-25 GHz, no change in 30-1000 MHz

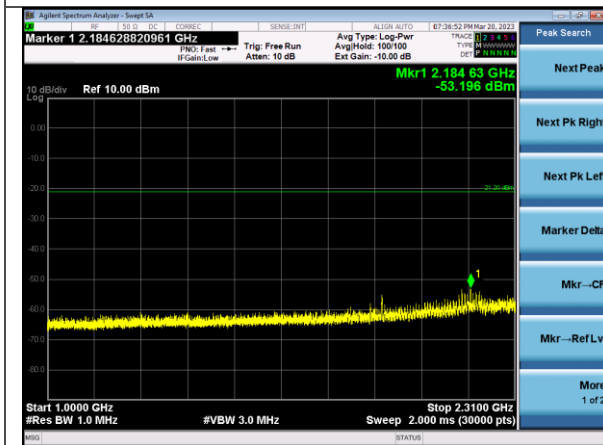




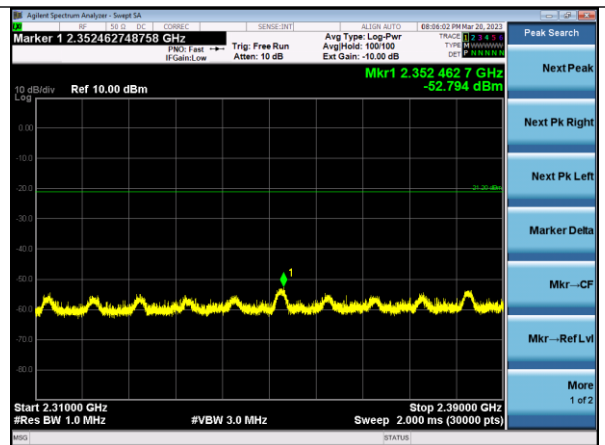
2.4835-2.5 GHz
Mid



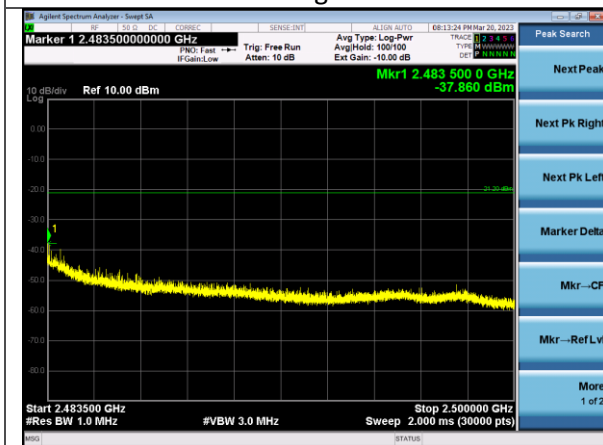
2.5-25 GHz
Mid



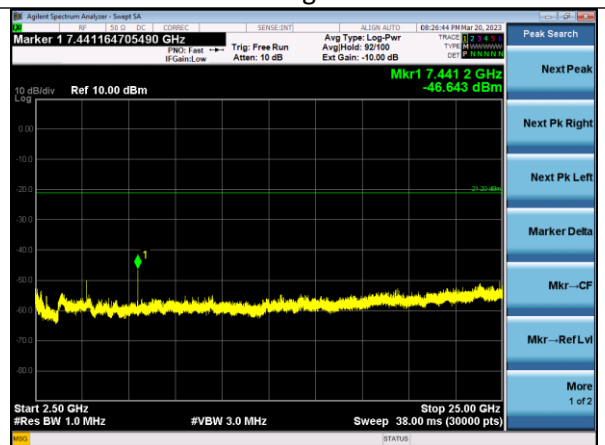
1-2.31 GHz
High



2.31-2.39 GHz
High

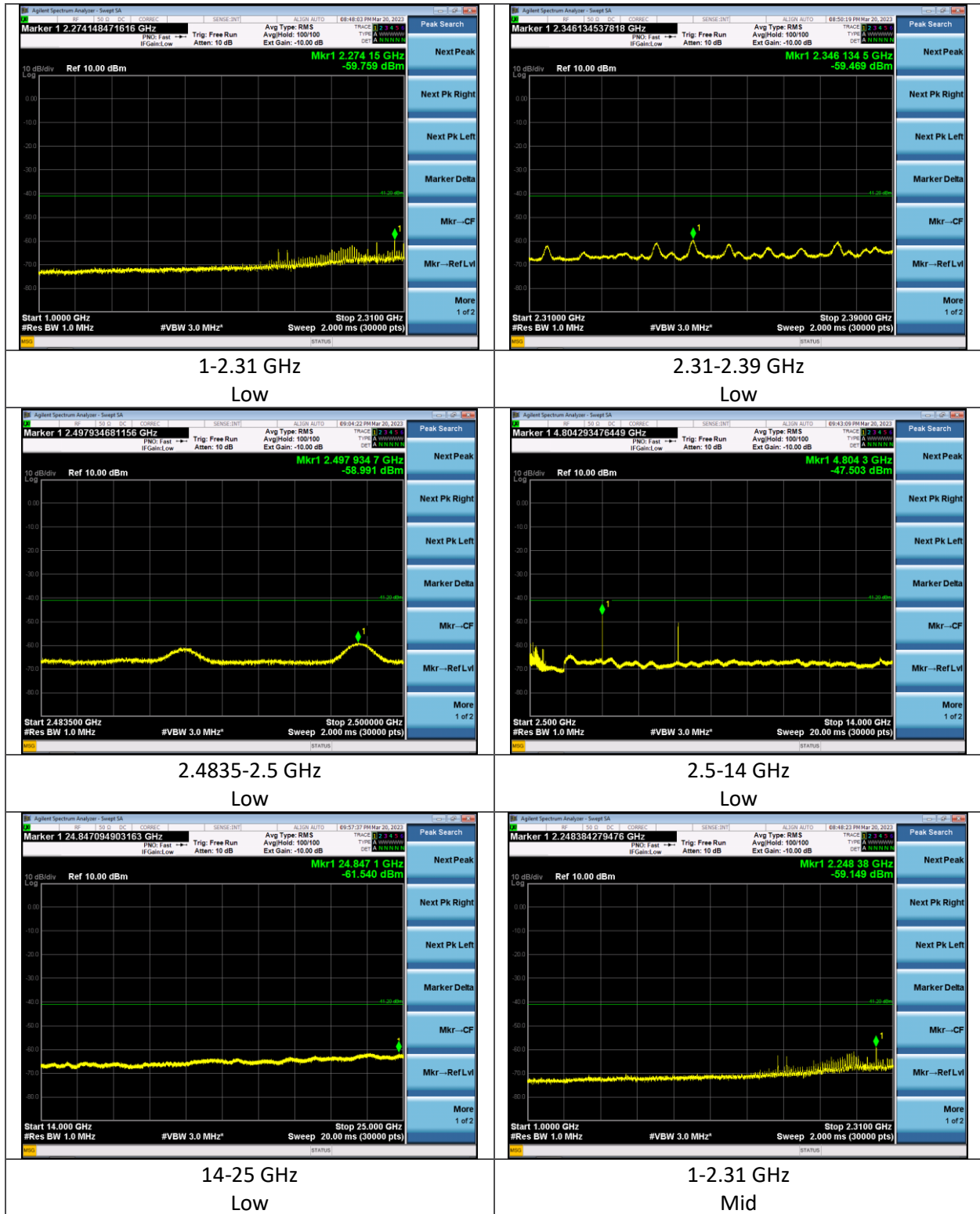


2.4835-2.5 GHz
High

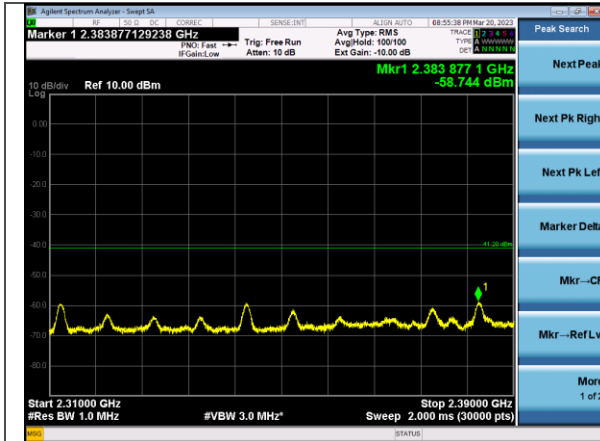


2.5-25 GHz
High

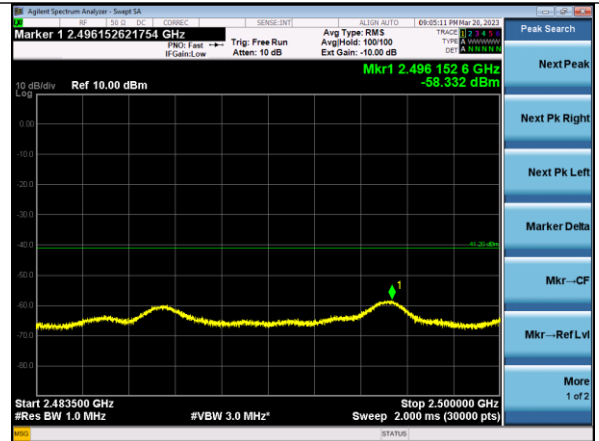
1M Average - Worst Case 1-25 GHz, no change in 30-100 MHz



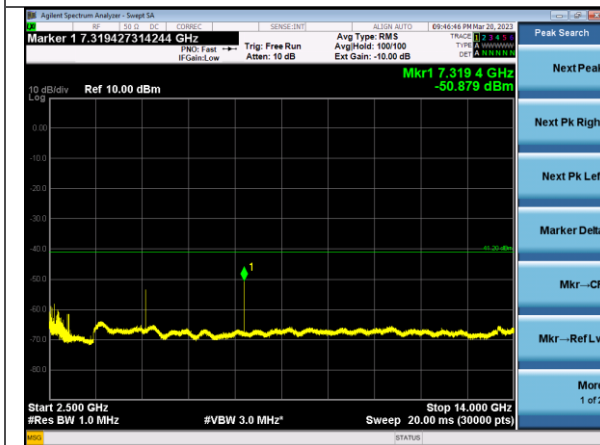
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2.31-2.39 GHz
Mid



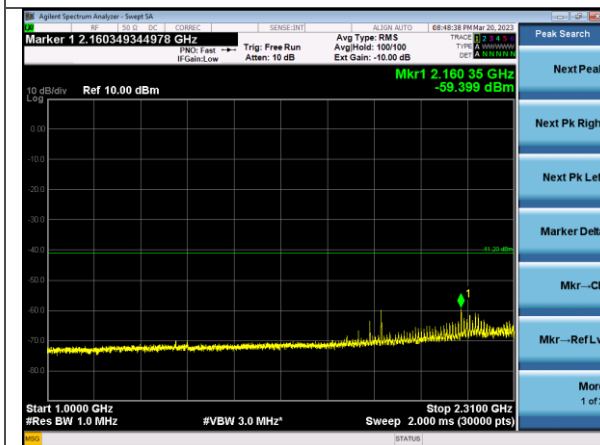
2.4835-2.5 GHz
Mid



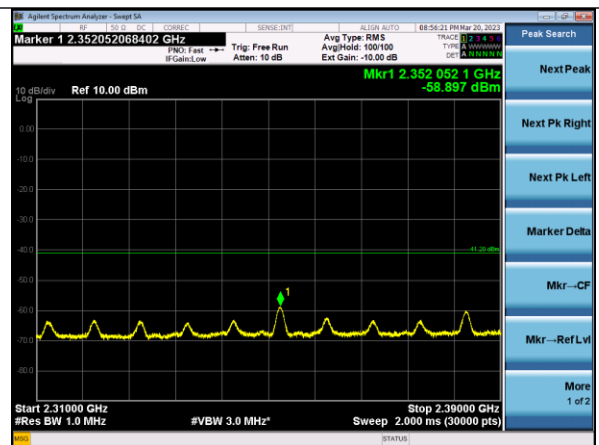
2.5-14 GHz
Mid



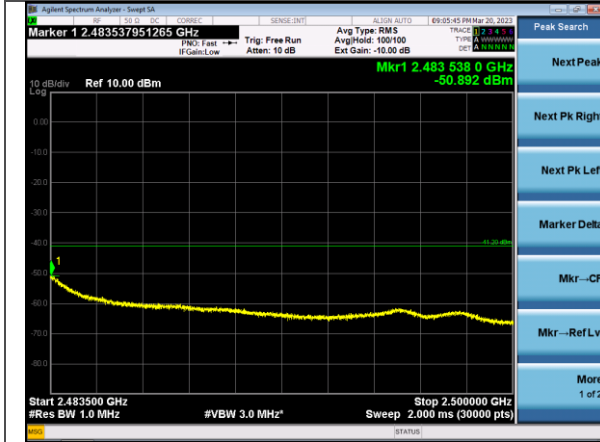
14-25 GHz
Mid



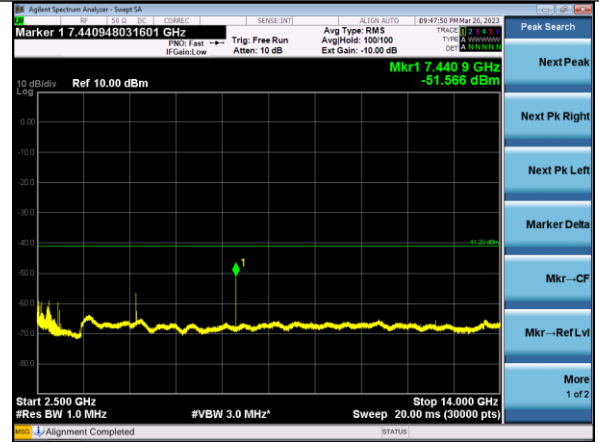
1-2.31 GHz
High



2.31-2.39 GHz
High



2.4835-2.5 GHz
High

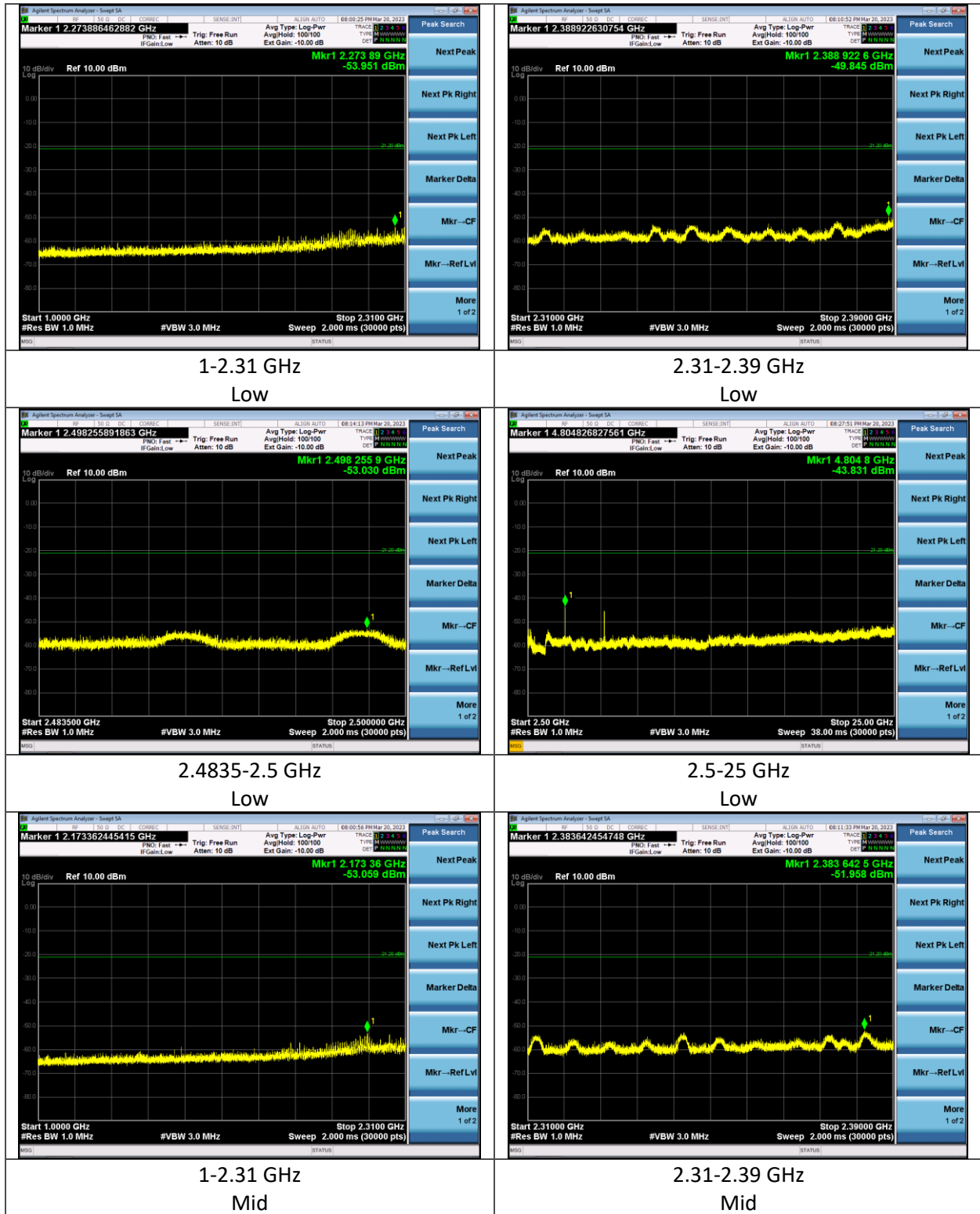


2.5-14 GHz
High

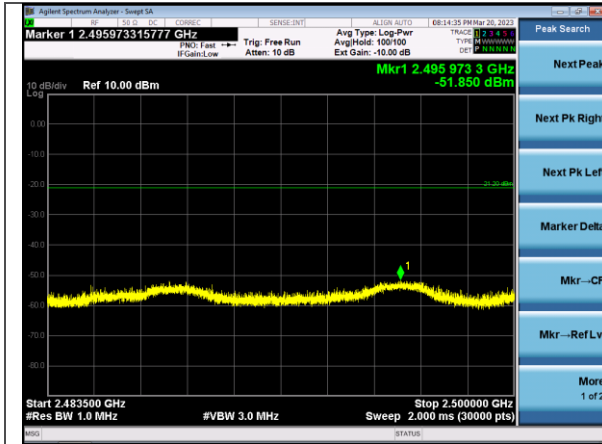


14-25 GHz
High

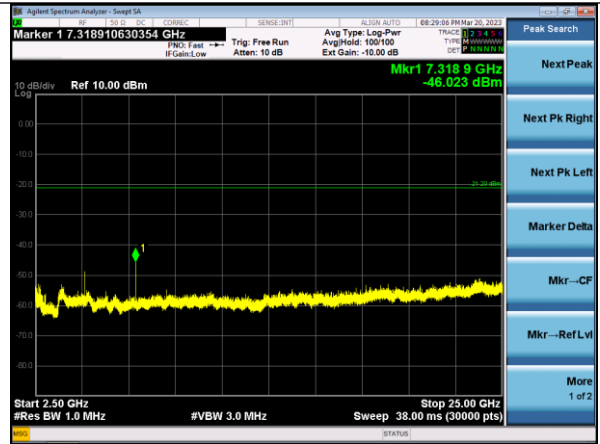
2M Peak - Worst Case 1-25 GHz, no change in 30-1000 MHz



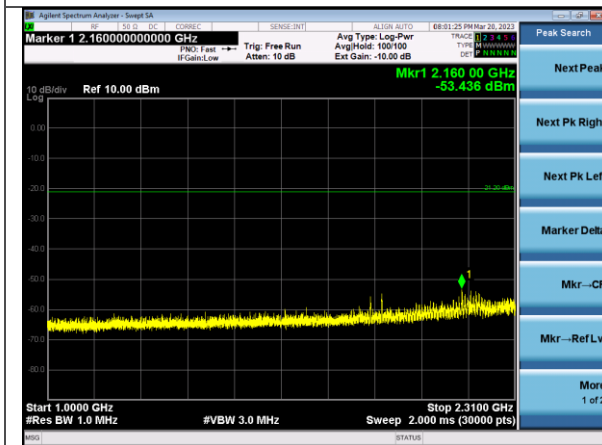
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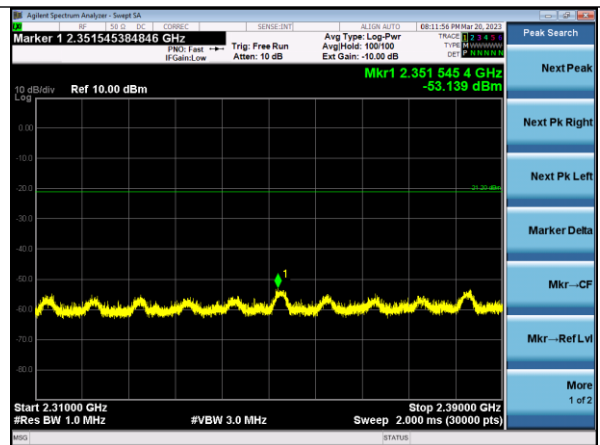
2.4835-2.5 GHz
Mid



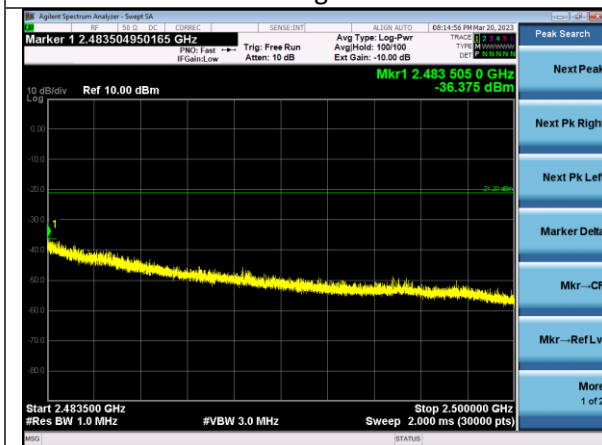
2.5-25 GHz
Mid



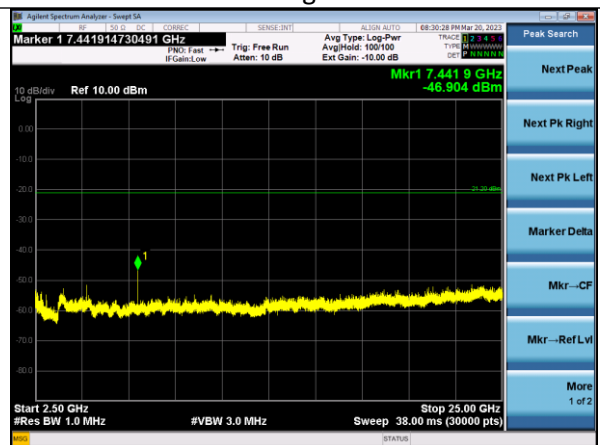
1-2.31 GHz
High



2.31-2.39 GHz
High

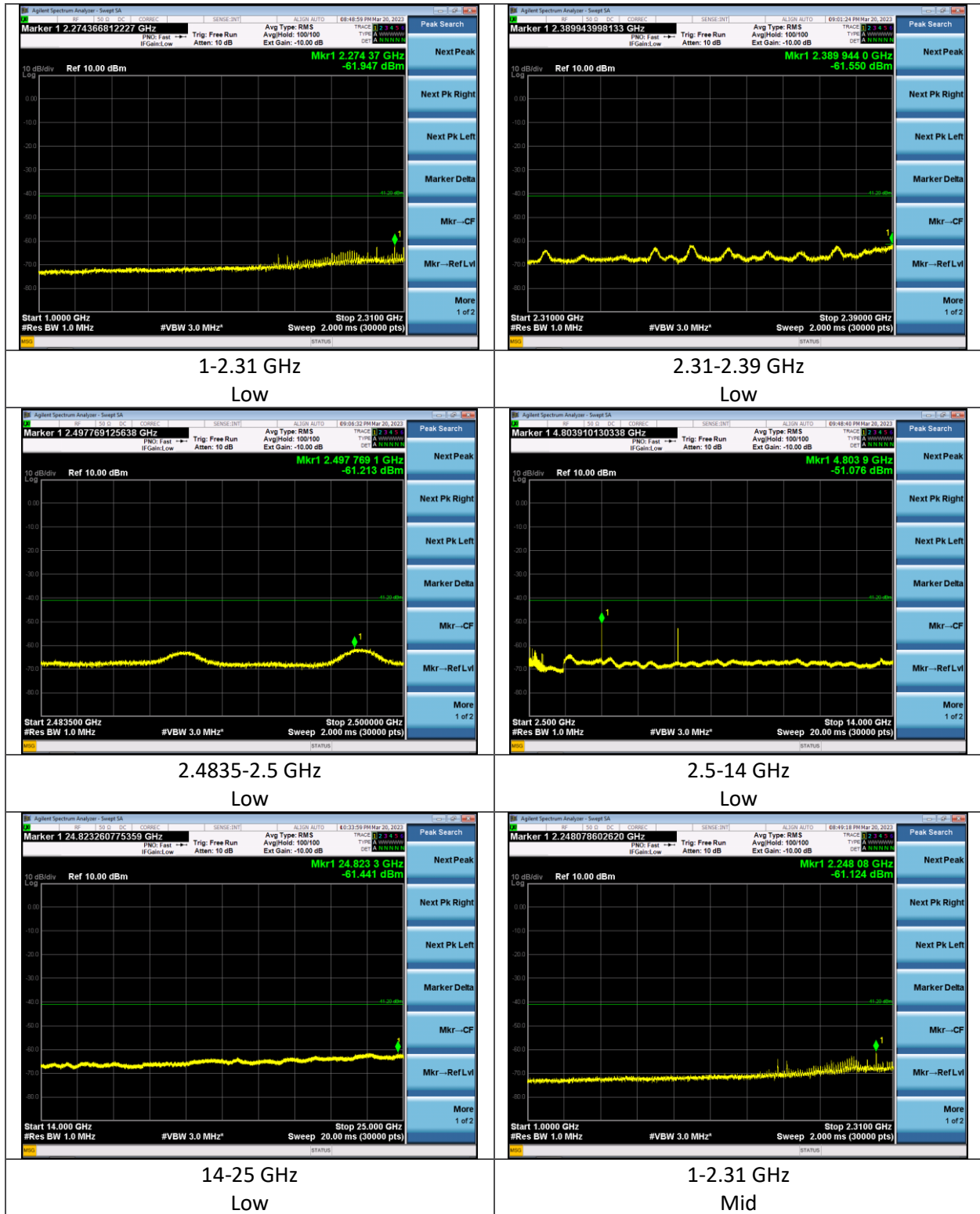


2.4835-2.5 GHz
High

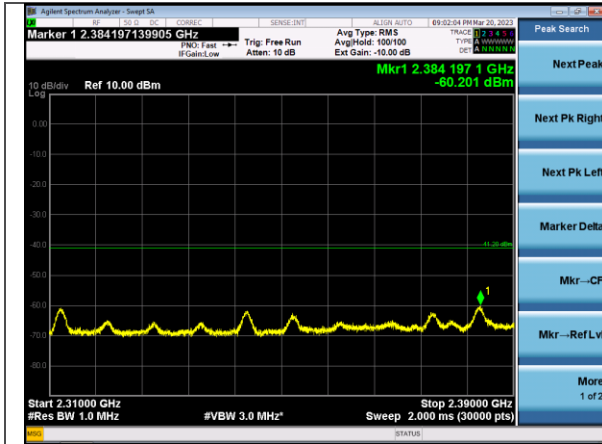


2.5-25 GHz
High

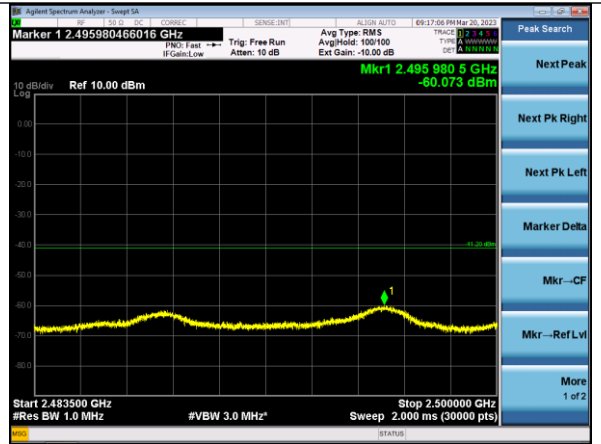
2M Average - Worst Case 1-25 GHz, no change in 30-100 MHz



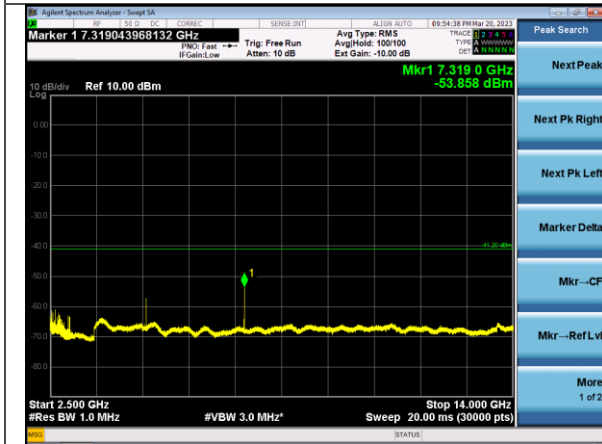
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2.31-2.39 GHz
Mid



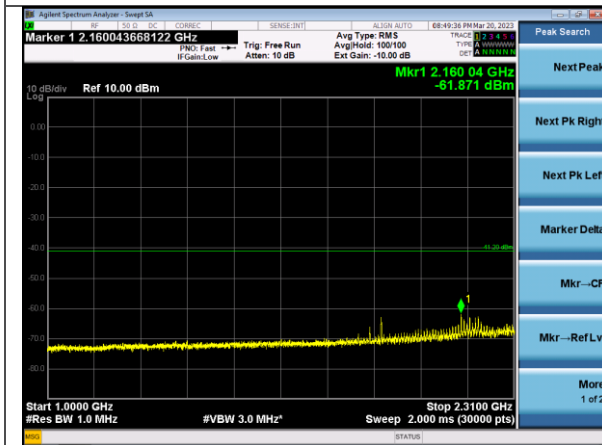
2.4835-2.5 GHz
Mid



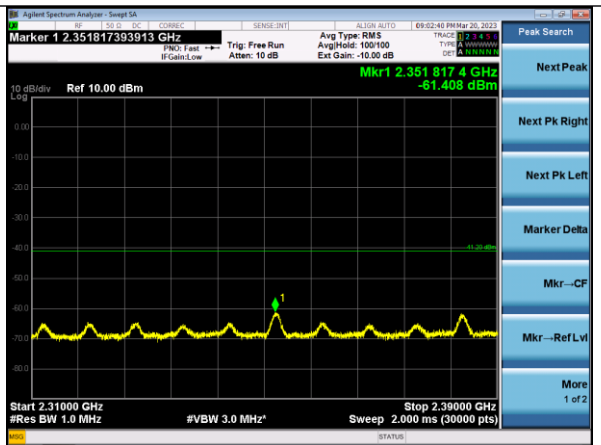
2.5-14 GHz
Mid



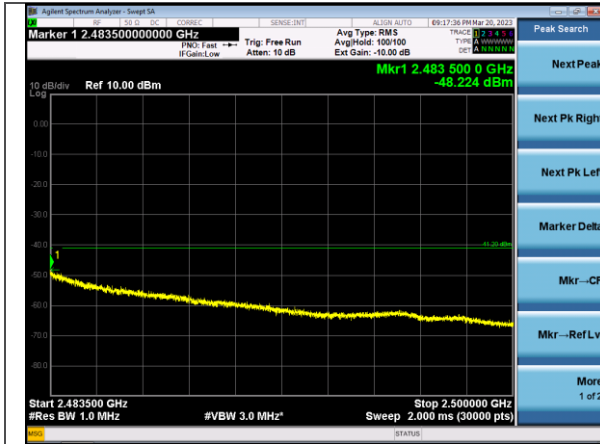
14-25 GHz
Mid



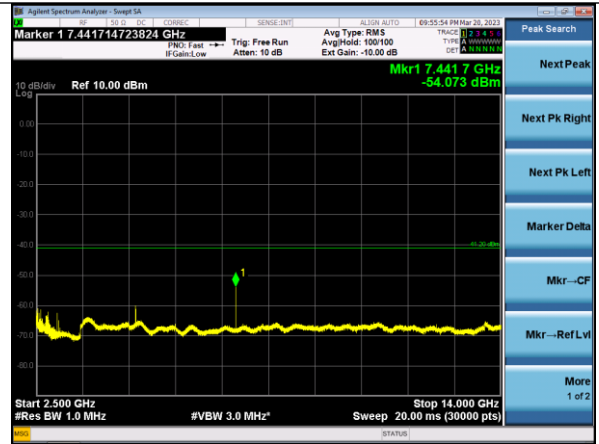
1-2.31 GHz
High



2.31-2.39 GHz
High



2.4835-2.5 GHz
High



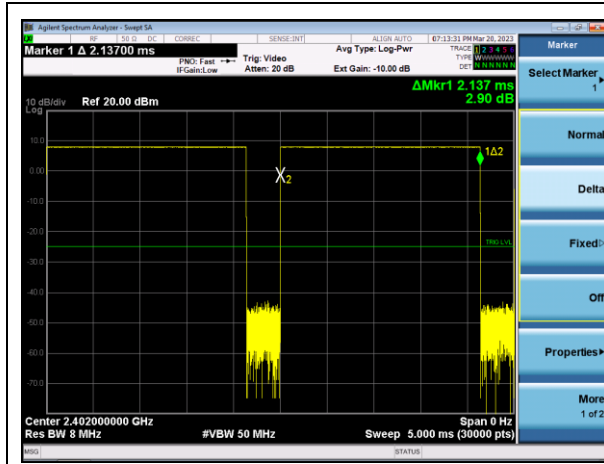
2.5-14 GHz
High



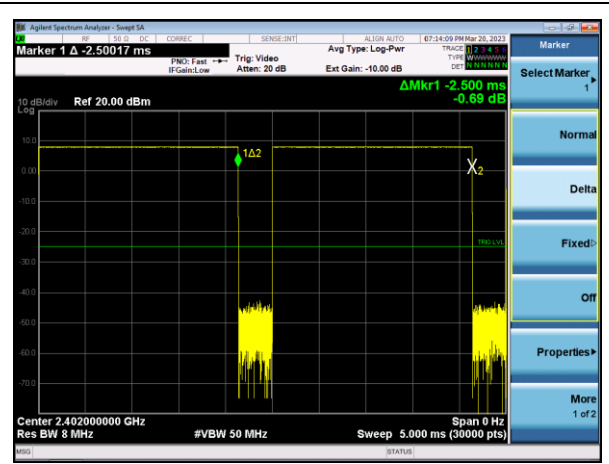
14-25 GHz
High

Company: Laird Connectivity	Page 25 of 27	Name: BL654
Report: TR3664A BL654		Model: BL654
Quote: NBO-12-2022-005678		Serial: Engineering Sample

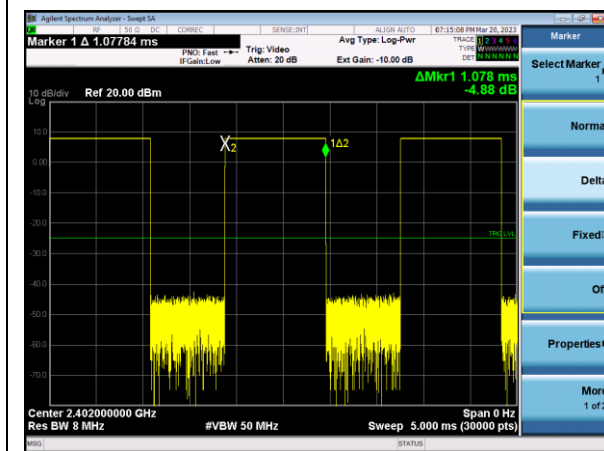
Duty Cycle Plots



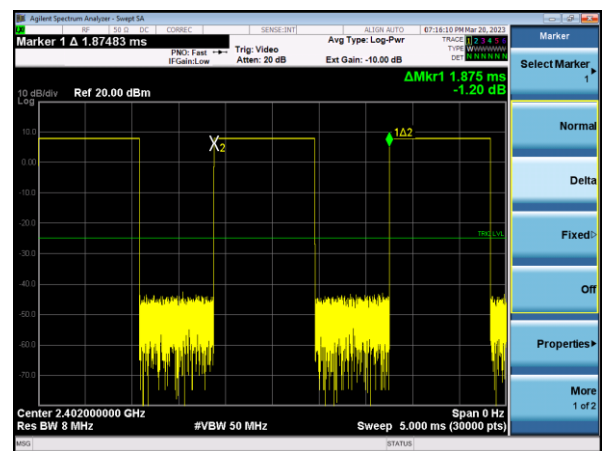
1M On Time 2.137ms



1M Period 2.5ms



2M On Time 1.078ms



2M Period 1.875ms

6 REVISION HISTORY

Version	Date	Notes	Person
0	10/20/2023	Initial Draft	Anthony Smith
1	12/8/2023	Revised Draft	Anthony Smith
2	12/11/2023	Revised Draft – Footer, method specification	Anthony Smith
3	2/29/2024	Update RSS-247 reference	Anthony Smith

END OF REPORT