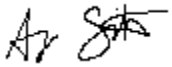
Test Report TR3664C BL654

Equipment Under Test:	BL654
Requirement(s):	FCC 15.247 RSS-102
Test Date(s):	3/9/2023
Prepared for:	Laird Connectivity Attn: Jonathan Kaye W66 N220 Commerce Ct. Cedarburg, WI 53012

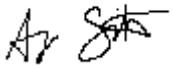
Report Issued by: Anthony Smith, EMC Engineering Specialist

Signature:  Date: 03/05/2024

Report Reviewed by: Adam Alger, Laboratory Manager

Signature:  Date: 03/05/2024

Report Constructed by: Anthony Smith, EMC Engineering Specialist

Signature:  Date: 12/8/2023

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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

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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

1 Test Report Summary

During **March 9th, 2023** the Equipment Under Test (EUT), **BL654**, as provided by **Laird Connectivity** was tested to the following requirements for the purpose of a Class 2 permissive change to add an antenna:

Requirements	Description	Method	Compliant
FCC 1.1307, 2.1091, 2.1093	Radiofrequency Radiation Exposure Limits	FCC KDB 447498	Yes
ISED Canada: RSS-102	Radiofrequency Radiation Exposure Limits	RSS-102 § 2.5.2	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 and 802.15.4 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

USB to Serial connection to program radio utilizing Tera Term v4.105 terminal simulation software. Zigbee 802.15.4 250kbit signal utilizing channels 11 (2405 MHz), 18 (2440 MHz), 25 (2475 MHz), and 26 (2480 MHz).

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.

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	-
RSS-102	5	2015	2021
KDB 447498	-	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 ±
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

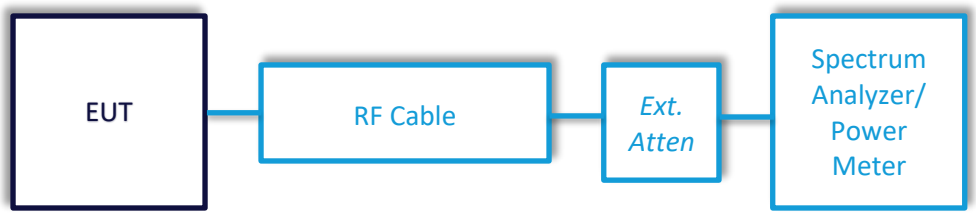
Parameter	ETSI U.C. ±	U.C. ±
Radio Frequency, from F0	$1x10^{-7}$	$0.55x10^{-7}$
Occupied Channel Bandwidth	5 %	2 %
RF conducted Power (Power Meter)	1.5 dB	1.2 dB
RF conducted emissions (Spectrum Analyzer)	3.0 dB	1.7 dB
All emissions, radiated	6.0 dB	5.3 dB
Temperature	1° C	0.65° C
Humidity	5 %	2.9 %
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 - Zigbee

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

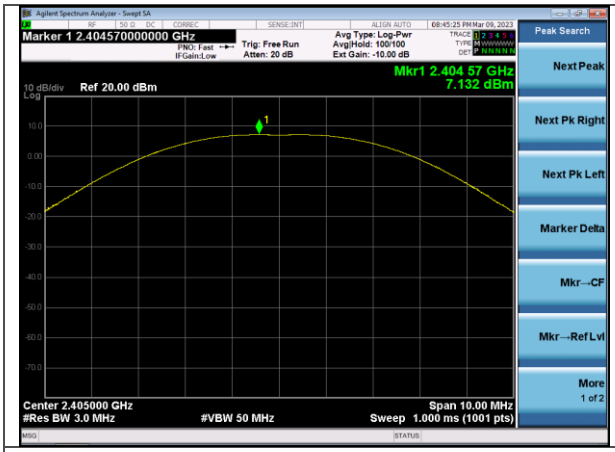
Input Power	12VDC	**Mode**	802.15.4 250kbit
Frequency	2405, 2440, 2475, 2480 MHz	**Channel**	11, 18, 25, 26
Notes	Power Index: 7 for channels 11, 18, and 25; -8 for channel 26		

Data

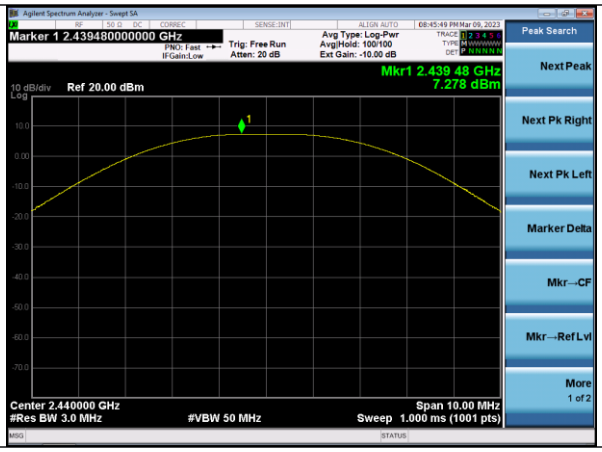
Table

Channel	Mode	Peak Conducted Power (dBm)	Limit (dBm)	Margin (dB)	Transmit Power Setting
11	Zigbee	7.1	30.0	22.9	7
18	Zigbee	7.3	30.0	22.7	7
25	Zigbee	7.4	30.0	22.6	7
26	Zigbee	-7.4	30.0	37.4	-8

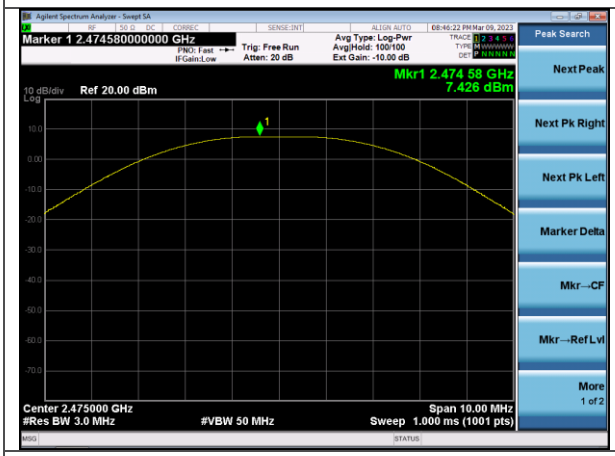
Plots



Ch 11



Ch 18



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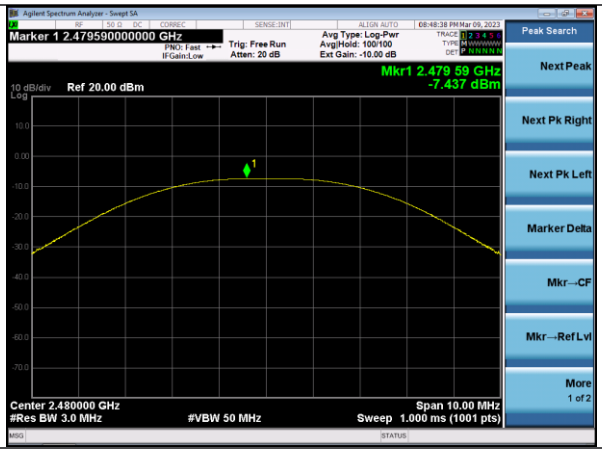


Ch 26

5.1.2 Antenna Port Conducted Emissions – RF Output Power - BLE

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

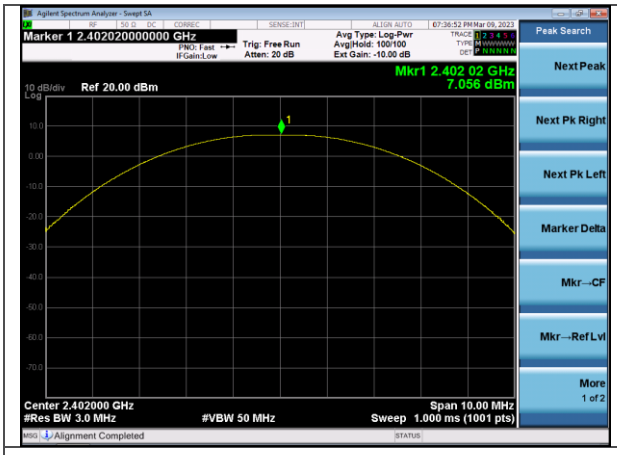
Input Power	12VDC	**Mode**	BLE – 125k, 500k, 1M, 2M
Frequency (MHz)	2402, 2440, 2480	**Channel**	37, 17, 39
Transmit Power Setting	7		

Data

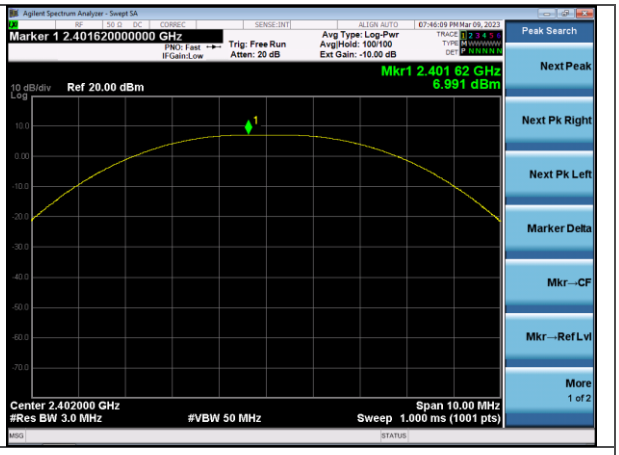
Table

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

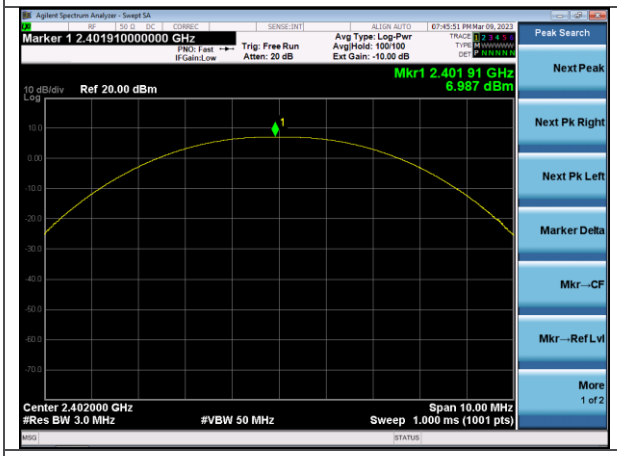
Plots



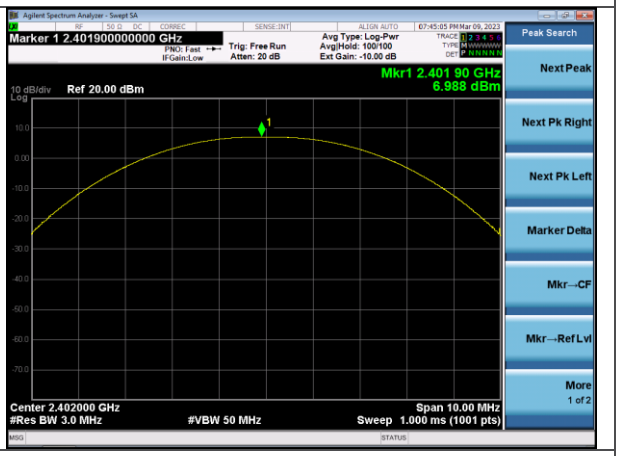
1M Ch 37



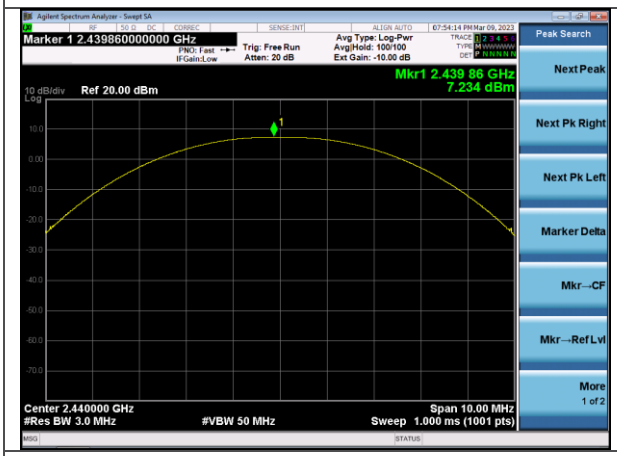
2M Ch 37



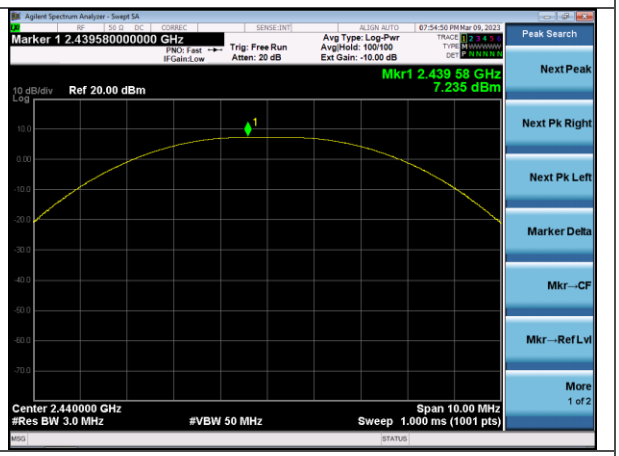
125k Ch 37



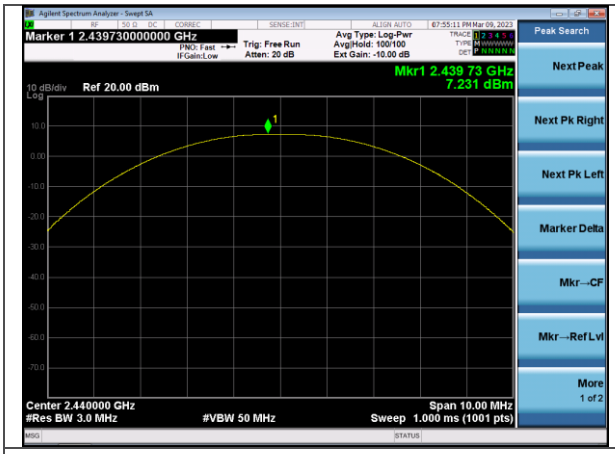
500k Ch 37



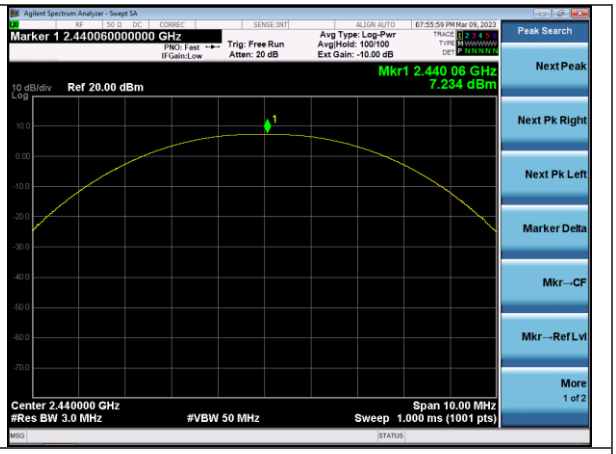
1M Ch 17



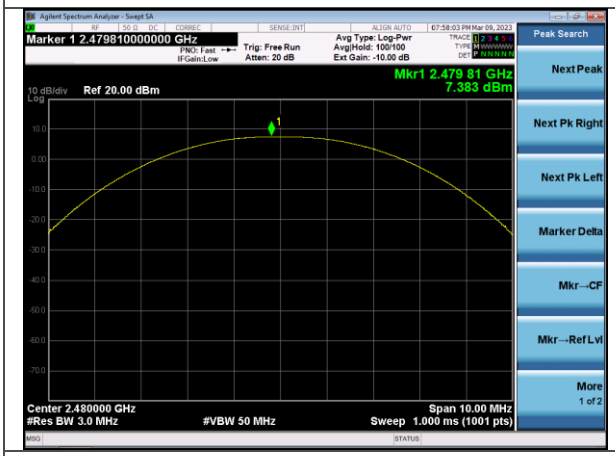
2M Ch 17



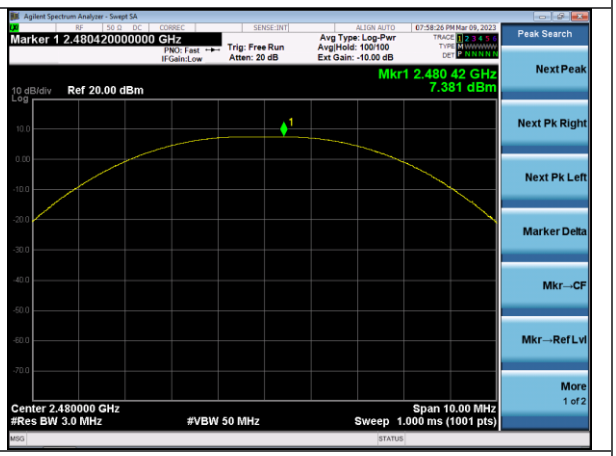
125k Ch 17



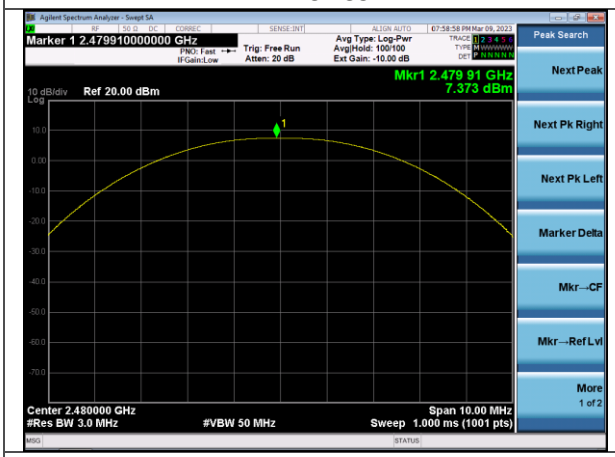
500k Ch 17



1M Ch 39



2M Ch 39



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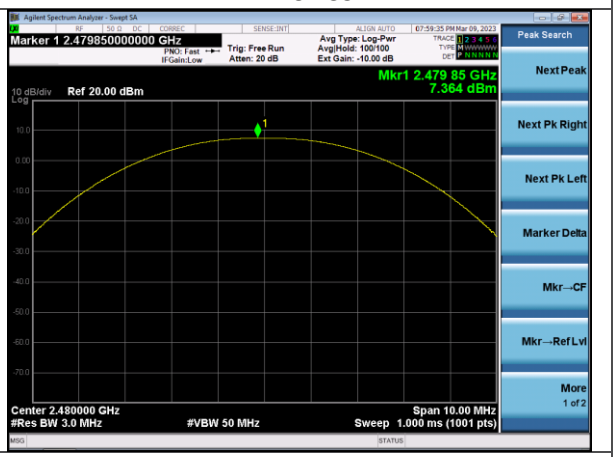

500k Ch 39

6 FCC RF EXPOSURE

6.1 Calculations

Prediction of MPE limit at a given distance

$$S = \frac{PG}{4\pi R^2}$$

where: S = power density
P = power input to the antenna
G = power gain of the antenna in the direction of interest relative to an isotropic radiator
R = distance to the center of radiation of the antenna

BT LE:

Maximum peak output power at antenna input terminal:	7.40	(dBm)
Tune-up tolerance:	1.00	(dB)
Maximum peak output power at antenna input terminal:	6.918	(mW)
Antenna gain:	3.1	(dBi)
Maximum antenna gain:	2.042	(numeric)
Prediction distance:	20	(cm)
Prediction frequency:	2440	(MHz)
MPE limit for uncontrolled exposure at prediction frequency:	1.00	(mW/cm²)
Power density at prediction frequency:	0.00281	(mW/cm²)

802.15.4:

Maximum peak output power at antenna input terminal:	7.40	(dBm)
Tune-up tolerance:	1.00	(dB)
Maximum peak output power at antenna input terminal:	6.918	(mW)
Antenna gain:	3.1	(dBi)
Maximum antenna gain:	2.042	(numeric)
Prediction distance:	20	(cm)
Prediction frequency:	2440	(MHz)
MPE limit for uncontrolled exposure at prediction frequency:	1.00	(mW/cm²)
Power density at prediction frequency:	0.00281	(mW/cm²)

7 ISED CANADA RF EXPOSURE

7.1 Calculations

Prediction of MPE limit at a given distance

$$S = \frac{PG}{4\pi R^2}$$

where: S = power density
P = power input to the antenna
G = power gain of the antenna in the direction of interest relative to an isotropic radiator
R = distance to the center of radiation of the antenna

BT LE:

Maximum peak output power at antenna input terminal:	7.40	(dBm)
Maximum peak output power at antenna input terminal:	0.005495	(W)
Antenna gain(typical):	3.1	(dBi)
Maximum antenna gain:	2.042	(numeric)
Prediction distance:	0.2	(m)
Prediction frequency:	2480	(MHz)
MPE limit for uncontrolled exposure at prediction frequency:	2.74	(1.31x10^-2* ƒ ^(0.6834)) (W/m²)
Power density at prediction frequency:	0.02	(W/m²)

802.15.4:

Maximum peak output power at antenna input terminal:	7.40	(dBm)
Maximum peak output power at antenna input terminal:	0.005495	(W)
Antenna gain(typical):	3.1	(dBi)
Maximum antenna gain:	2.042	(numeric)
Prediction distance:	0.2	(m)
Prediction frequency:	2480	(MHz)
MPE limit for uncontrolled exposure at prediction frequency:	2.74	(1.31x10^-2* ƒ ^(0.6834)) (W/m²)
Power density at prediction frequency:	0.02	(W/m²)

8 REVISION HISTORY

Version	Date	Notes	Person
1	12/8/2023	Initial Draft	Anthony Smith
2	12/11/2023	Revised Draft – footer added	Anthony Smith
3	2/29/2024	Update RSS-247 reference	Anthony Smith
4	3/05/2024	Title Page update	Anthony Smith

END OF REPORT