

Test Report # TR 3664 B BL653μ V2

Equipment Under Test: BL653μ

Requirement(s): FCC: 2.1091
ISED: RSS-102

Test Date(s): 3/9/2023-3/13/2023


Prepared for: Laird Connectivity
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Report Issued by: Dylan Rosenfeldt, EMC Engineer

Signature: 

Date: 2/23/2024

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Signature: 

Date: 11/02/2023

Report Constructed by: Dylan Rosenfeldt, EMC Engineer

Signature: 

Date: 2/13/2024

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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 **3/9/2023, 3/15/2023 – 3/16/2023** the Equipment Under Test (EUT), **BL653μ**, 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: 1.1310, 2.1091	Radiofrequency Radiation Exposure Limits	KDB 447498	Yes
ISED: RSS-102	Radiofrequency Radiation Exposure Limits	RSS-102	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	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.

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3 REFERENCES

Publication	Edition	Date	AMD 1
FCC eCFR	-	2023	-
RSS-102	5	2015	2021
KDB 447498	-	2015	-
ANSI C95.1	-	2006	-
ANSI C95.3	-	2002	-

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

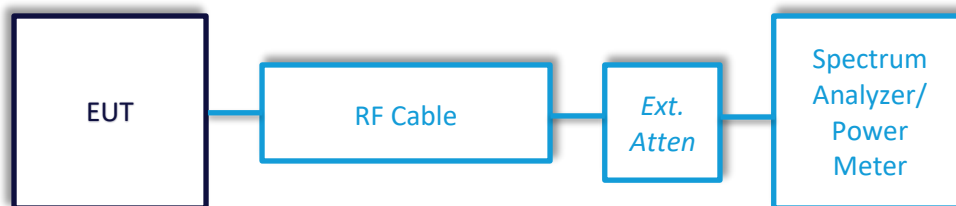
Parameter	ETSI U.C. ±	U.C. ±
Radio Frequency, from F0	1x10 ⁻⁷	0.55x10 ⁻⁷
Occupied Channel Bandwidth	5 %	2 %
RF conducted Power (Power Meter)	1.5 dB	1.2 dB
RF conducted emissions (Spectrum Analyzer)	3.0 dB	1.7 dB
All emissions, radiated	6.0 dB	5.3 dB
Temperature	1° C	0.65° C
Humidity	5 %	2.9 %
Supply voltages	3 %	1 %

5 TEST DATA

5.1 Antenna Port Conducted Emissions

Description of Measurement	<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

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

Figure 1: Conducted power measurements from Laird Test Report # TR3664A BL653μ

6 SPHERICAL EVALUATION FORMULA FOR FRESNEL AND FAR-FIELD

$$S = \frac{GP_T}{4\pi d^2} = \frac{A_e P_T}{\lambda^2 d^2}$$

Figure 2: Equation to compute maximum power density IEEE C95.3

FCC

S = Power density (mW/cm²)

P = Conducted power output (mW)

G = Antenna gain

d = distance to center of radiating antenna (cm)

ISED

S = Power density (W/m²)

P = Conducted power output (W)

G = Antenna gain

d = distance to center of radiating antenna (m)

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7 FCC RF EXPOSURE

7.1 Limits

The device shall comply with the relevant limits for Maximum Permissible Exposure to radiofrequency electromagnetic fields for mobile equipment as shown in the table below

(ii) 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
300–1,500			f/1500	<30
1,500–100,000			1.0	<30

Figure 3: Limits for Maximum Permissible Exposure eCFR Part 1.1310

7.2 Calculation

Tune-up Tolerance = 1.00 dB

P = 8.40 dBm + Tune-up Tolerance = 9.40 dB = 8.71mW

G = 3.1dBi = 2.04

S = (G*P)/(4*π*d²) = 0.0035 mW/cm² at 20cm

The power density limit for the general population in the Frequency range 2402 – 2480 MHz is 1.0 mW/cm².

7.3 Minimum Distance

Minimum distance away from the device to meet the Maximum Permissible Exposure requirement for power density.

$$\text{mW/cm}^2 = P * G / (4 * \pi * r^2)$$

$$1.00 = 8.71 * 2.04 / (4 * \pi * r^2)$$

The EUT meets the requirements of FCC 1.1310 for all r values greater than 1.2 cm.

8 ISED CANADA RF EXPOSURE

8.1 Limits

The device shall comply with the relevant limits for Maximum Permissible Exposure to radiofrequency electromagnetic fields for mobile equipment as shown in the table below

Table 4: RF Field Strength Limits for Devices Used by the General Public (Uncontrolled Environment)				
Frequency Range (MHz)	Electric Field (V/m rms)	Magnetic Field (A/m rms)	Power Density (W/m ²)	Reference Period (minutes)
0.003-10 ²¹	83	90	-	Instantaneous*
0.1-10	-	0.73/ f	-	6**
1.1-10	87/ f ^{0.5}	-	-	6**
10-20	27.46	0.0728	2	6
20-48	58.07/ f ^{0.25}	0.1540/ f ^{0.25}	8.944/ f ^{0.5}	6
48-300	22.06	0.05852	1.291	6
300-6000	3.142 f ^{0.3417}	0.008335 f ^{0.3417}	0.02619 f ^{0.6834}	6
6000-15000	61.4	0.163	10	6
15000-150000	61.4	0.163	10	616000/ f ^{1.2}
150000-300000	0.158 f ^{0.5}	4.21 x 10 ⁻⁴ f ^{0.5}	6.67 x 10 ⁻⁵ f	616000/f ^{1.2}

Figure 4: RF Exposure Limits ISED RSS-102

8.2 Calculation

Tune-up Tolerance = 1.00 dB

P = 8.40 dBm + Tune-up Tolerance = 9.40 dB = 0.00871W

G = 3.1dBi = 2.04

S = (G*P)/(4*π*d²) = 0.0353 W/m² at 20cm

Power Density Limit = 0.02619(2402)^{0.6834}

The power density limit for the general population at the frequency 2402MHz is 5.35W/m².

8.3 Minimum Distance

Minimum distance away from the device to meet the Maximum Permissible Exposure requirement for power density.

$$W/m^2 = P \cdot G / (4 \cdot \pi \cdot r^2)$$

$$5.35 = 0.00871 \cdot 2.04 / (4 \cdot \pi \cdot r^2)$$

The EUT meets the requirements of RSS-102 for all r values greater than 1.6 cm.

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9 REVISION HISTORY

Version	Date	Notes	Person
0	11/2/2023	Initial Draft	Dylan Rosenfeldt
1	2/13/2024	Final Draft	Dylan Rosenfeldt
2	2/23/2024	Updated Report number	Dylan Rosenfeldt

END OF REPORT