

FCC Test Report

Mix Telematics International (Pty) Ltd
Telematics Unit, Model: MiX 4401-B

In accordance with FCC 47 CFR Part 15C
(2.4 GHz Bluetooth Low Energy)

Prepared for: MiX Telematics International (Pty) Ltd
Blaauwklip Office Park 2
Cnr Strand & Webersvalley Roads
Stellenbosch, South Africa

FCC ID: 2AFMS-4401XG

COMMERCIAL-IN-CONFIDENCE

Document 75953915-06 Issue 01



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SIGNATURE

NAME	JOB TITLE	RESPONSIBLE FOR	ISSUE DATE
Steve Marshall	Senior Engineer	Authorised Signatory	05 May 2022

Signatures in this approval box have checked this document in line with the requirements of TÜV SÜD document control rules.

ENGINEERING STATEMENT

The measurements shown in this report were made in accordance with the procedures described on test pages. All reported testing was carried out on a sample equipment to demonstrate limited compliance with FCC 47 CFR Part 15C. The sample tested was found to comply with the requirements defined in the applied rules.

RESPONSIBLE FOR	NAME	DATE	SIGNATURE
Testing	Graeme Lawler	05 May 2022	
Testing	Thomas Biddlecombe	05 May 2022	

FCC Accreditation
90987 Octagon House, Fareham Test Laboratory

EXECUTIVE SUMMARY

A sample of this product was tested and found to be compliant with FCC 47 CFR Part 15C: 2020 for the tests detailed in section 1.3.



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1 Report Summary

1.1 Report Modification Record

Alterations and additions to this report will be issued to the holders of each copy in the form of a complete document.

Issue	Description of Change	Date of Issue
1	First Issue	05-May-2022

Table 1

1.2 Introduction

Applicant	Mix Telematics International (Pty) Ltd
Manufacturer	Mix Telematics International (Pty) Ltd
Model Number(s)	MiX 4401-B
Manufacturer's Declared Variant(s)	MiX 4401
Serial Number(s)	55000206 and 55000202
Hardware Version(s)	3
Software Version(s)	4.12.x
Number of Samples Tested	2
Test Specification/Issue/Date	FCC 47 CFR Part 15C: 2020
Order Number	P0096230
Date	23-November-2021
Date of Receipt of EUT	07-March-2022
Start of Test	07-March-2022
Finish of Test	12-April-2022
Name of Engineer(s)	Graeme Lawler and Thomas Biddlecombe
Related Document(s)	ANSI C63.10 (2013) ANSI C63.4 (2014)



1.3 Brief Summary of Results

A brief summary of the tests carried out in accordance with FCC 47 CFR Part 15C is shown below.

Section	Specification Clause	Test Description	Result	Comments/Base Standard
Configuration and Mode: 2.4 GHz Bluetooth Low Energy				
-	15.203	Antenna Requirement	N/T	The device complies with the provisions of this section, as it uses an integral antenna. See section 1.5 for details.
2.1	15.205	Restricted Band Edges	Pass	
2.2	15.247 (a)(2)	Emission Bandwidth	Pass	
2.3	15.247 (b)	Maximum Conducted Output Power	Pass	
2.4	15.247 (d) and 15.209	Spurious Radiated Emissions	Pass	
2.5	15.247 (d)	Authorised Band Edges	Pass	
2.6	15.247 (e)	Power Spectral Density	Pass	

Table 2



1.4 Manufacturer's Declared Variant(s)

Models MiX 4401-B and MiX 4401, present the same electrical, physical and electro mechanics characteristics, the same PCB, layout and components. The only difference between them is that the "-B" variant has an internal backup battery plugged in, allowing the device to work after the disconnection of the vehicle's battery. The functionality and purposes of the products are exactly the same.



1.5 Application Form

Equipment Description

Technical Description: (Please provide a brief description of the intended use of the equipment including the technologies the product supports)	The MiX 4000 series is a range of fleet products that incorporates the latest market trends. It consists mainly of an on-board computer, a modem, a GNSS, an accelerometer, Low Energy Bluetooth, I/O, 2 x CAN, 2 x RS232, 4 x positive drives, and an optional 434 / 915 MHz short range transceiver. The range consists of variants with a LTE CAT M1 cellular module Quectel BG96. Models MiX 4401-B and MiX 4401, present the same electrical, physical and electro mechanics characteristics, the same PCB, layout and components. The only difference between them is that the "-B" variant has an internal backup battery plugged in, allowing the device to work after the disconnection of the vehicle's battery. The functionality and purposes of the products are exactly the same.	
Manufacturer:	MiX Telematics International (Pty) Ltd.	
Model:	MiX 4401 MiX 4401-B	
Part Number:	U0071MT U0073MT	
Hardware Version:	3	
Software Version:	4.12.x	
FCC ID of the product under test – see guidance here	2AFMS-4401XG	
IC ID of the product under test – see guidance here	-	

Table 3

Intentional Radiators

Technology	LTE Band 2	LTE Band 3	LTE Band 4	LTE Band 5	LTE Band 12	LTE Band 13
Frequency Range (MHz to MHz)	1850-1910	1710-1785	1710-1755	824-849	699-716	777-787
Conducted Declared Output Power (dBm)	23	23	23	23	23	23
Antenna Gain (dBi)	2.07	1.46	1.46	0.21	0.76	1.39
Supported Bandwidth(s) (MHz) (e.g. 1 MHz, 20 MHz, 40 MHz)	1.4	1.4	1.4	1.4	1.4	1.4
Modulation Scheme(s) (e.g. GFSK, QPSK etc)	QPSK/ 16-QAM	QPSK/ 16-QAM	QPSK/ 16-QAM	QPSK/ 16-QAM	QPSK/ 16-QAM	QPSK/ 16-QAM
ITU Emission Designator (see guidance here) (not mandatory for Part 15 devices)	1M40W7D	1M40W7D	1M40W7D	1M40W7D	1M40W7D	1M40W7D
Bottom Frequency (MHz)	1850	1710	1710	824	699	777
Middle Frequency (MHz)	1880	1747.5	1747.5	836.5	707.5	782
Top Frequency (MHz)	1910	1785	1755	849	716	787

Table 4



Technology	SRD915	SRD434	Bluetooth Low Energy
Frequency Band (MHz)	902-928	434.3 ± 0.01	2400-2480
Conducted Declared Output Power (dBm)	20	10	4
Antenna Gain (dBi)	0	0	1.4
Supported Bandwidth(s) (MHz)	0.025	0.025	1
Modulation Scheme(s)	2FSK	2FSK	GFSK
ITU Emission Designator	38K4F7D	38K4F7D	1M00G7D
Bottom Frequency (MHz)	902	434.31	2402
Middle Frequency (MHz)	915	434.3	2440
Top Frequency (MHz)	928	434.29	2480

Table 5

Un-intentional Radiators

Highest frequency generated or used in the device or on which the device operates or tunes	2690 MHz
Lowest frequency generated or used in the device or on which the device operates or tunes	699MHz
Class A Digital Device (Use in commercial, industrial or business environment) ☐	
Class B Digital Device (Use in residential environment only) ☒	

Table 6

AC Power Source

AC supply frequency:	N/A	Hz
Voltage	N/A	V
Max current:	N/A	A
Single Phase ☐ Three Phase ☐		

Table 7

DC Power Source

Nominal voltage:	13.8/27.6	V
Extreme upper voltage:	32	V
Extreme lower voltage:	10.5	V
Max current:	2A typical ; 4.5A absolute max (7.5A Fused)	A

Table 8



Battery Power Source

Voltage:	3.2	V
End-point voltage:	2.7	V (Point at which the battery will terminate)
Alkaline ☐ Leclanche ☐ Lithium ☒ Nickel Cadmium ☐ Lead Acid* ☐ *(Vehicle regulated)		
Other ☐	Please detail:	

Table 9

Charging

Can the EUT transmit whilst being charged	Yes ☒ No ☐
---	---

Table 10

Temperature

Minimum temperature:	-20	°C
Maximum temperature:	60	°C

Table 11

Cable Loss

Adapter Cable Loss (Conducted sample)		dB
--	--	----

Table 12

Antenna Characteristics

Antenna connector ☒			State impedance	50	Ohm
Temporary antenna connector ☐			State impedance		Ohm
Integral antenna ☒	Type:	LTE BLE SRD915 GNSS	Gain	3 1.4 0 4	dBi
External antenna ☐	Type:	GNSS	Gain	4	dBi
For external antenna only: Standard Antenna Jack ☒ If yes, describe how user is prohibited from changing antenna (if not professional installed): Equipment is only ever professionally installed ☒ Non-standard Antenna Jack ☐					

Table 13



Ancillaries (if applicable)

Manufacturer:	MiX Telematics	Part Number:	440FT0930 440FT0623
Model:	Code Plug Harness with Socket CP2, Code Plug Socket	Country of Origin:	South Africa
Manufacturer:	MiX Telematics	Part Number:	440FT0033
Model:	Power (MP10)	Country of Origin:	South Africa
Manufacturer:	MiX Telematics	Part Number:	440FT0931
Model:	Serial Harness SR1	Country of Origin:	South Africa
Manufacturer:	RF Design	Part Number:	440FT0933
Model:	External GNSS Antenna PA2	Country of Origin:	South Africa

Table 14

I hereby declare that the information supplied is correct and complete.

Name: Ben van der Merwe
Position held: Senior Engineer
Date: 03 March 2022



1.6 Product Information

1.6.1 Technical Description

The MiX 4000 series is a range of fleet products that incorporates the latest market trends. It consists mainly of an on-board computer, a modem, a GNSS, an accelerometer, Low Energy Bluetooth, I/O, 2 x CAN, 2 x RS232, 4 x positive drives, and an optional 434 / 915 MHz short range transceiver.

The range consists of variants with a LTE CAT M1 cellular module Quectel BG96.

Models MiX 4401-B and MiX 4401, present the same electrical, physical and electro mechanics characteristics, the same PCB, layout and components. The only difference between them is that the “-B” variant has an internal backup battery plugged in, allowing the device to work after the disconnection of the vehicle’s battery. The functionality and purposes of the products are exactly the same.

1.7 Deviations from the Standard

No deviations from the applicable test standard were made during testing.

1.8 EUT Modification Record

The table below details modifications made to the EUT during the test programme.

The modifications incorporated during each test are recorded on the appropriate test pages.

Modification State	Description of Modification still fitted to EUT	Modification Fitted By	Date Modification Fitted
Model: MiX 4401-B, Serial Number: 55000202			
0	As supplied by the customer	Not Applicable	Not Applicable
Model: MiX 4401-B, Serial Number: 55000206			
0	As supplied by the customer	Not Applicable	Not Applicable

Table 15



1.9 Test Location

TÜV SÜD conducted the following tests at our Fareham Test Laboratory.

Test Name	Name of Engineer(s)	Accreditation
Configuration and Mode: 2.4 GHz Bluetooth Low Energy		
Restricted Band Edges	Graeme Lawler	UKAS
Emission Bandwidth	Thomas Biddlecombe	UKAS
Maximum Conducted Output Power	Thomas Biddlecombe	UKAS
Spurious Radiated Emissions	Graeme Lawler	UKAS
Authorised Band Edges	Graeme Lawler	UKAS
Power Spectral Density	Thomas Biddlecombe	UKAS

Table 16

Office Address:

TÜV SÜD
Octagon House
Concorde Way
Fareham
Hampshire
PO15 5RL
United Kingdom



2 Test Details

2.1 Restricted Band Edges

2.1.1 Specification Reference

FCC 47 CFR Part 15C, Clause 15.205

2.1.2 Equipment Under Test and Modification State

MiX 4401-B, S/N: 55000206 - Modification State 0

2.1.3 Date of Test

13-March-2022

2.1.4 Test Method

This test was performed in accordance with ANSI C63.10, clause 6.10.5 and 11.12.1.

Plots for average measurements were taken in accordance with ANSI C63.10, clause 11.12.2.5.2.

The following conversion can be applied to convert from dB μ V/m to μ V/m:

$10^{(\text{Field Strength in dB}\mu\text{V/m}/20)}$.

2.1.5 Environmental Conditions

Ambient Temperature 20.2 °C

Relative Humidity 26.8 %

2.1.6 Test Results

2.4 GHz Bluetooth Low Energy

Modulation	Frequency (MHz)	Band Edge Frequency (MHz)	Peak Level (dB μ V/m)	Average Level (dB μ V/m)
GFSK	2402	2390	55.40	43.27
GFSK	2480	2483.5	54.00	42.76

Table 17

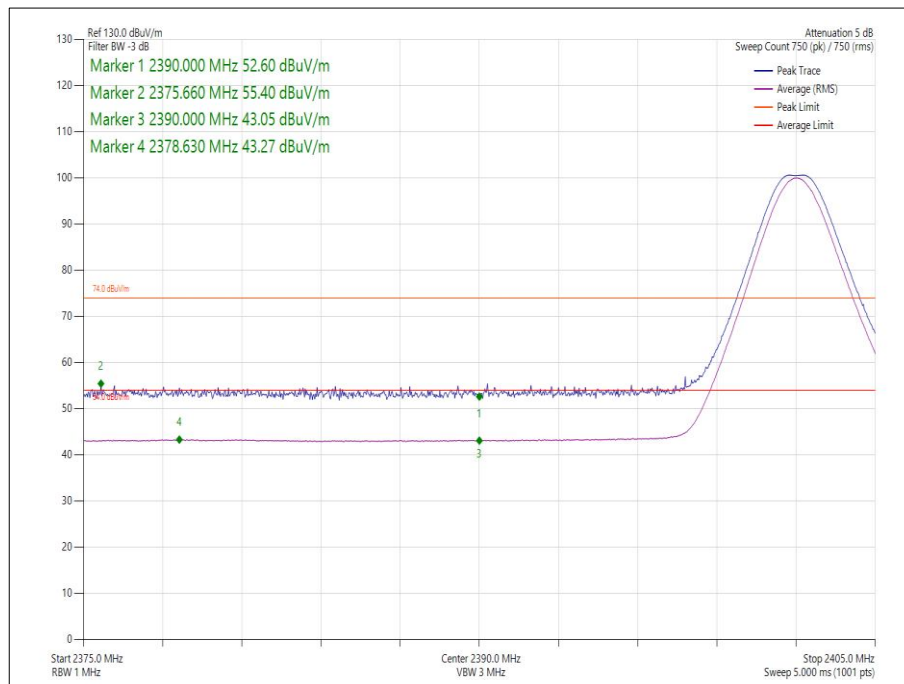


Figure 1 - GFSK - 2402 MHz - Band Edge Frequency 2390 MHz

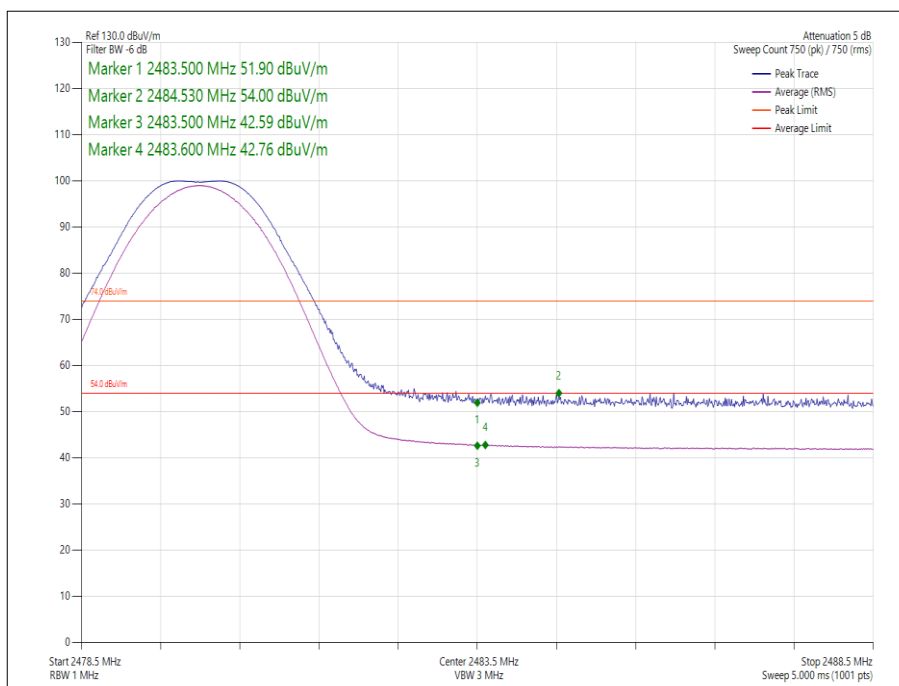


Figure 2 - GFSK - 2480 MHz - Band Edge Frequency 2483.5 MHz

FCC 47 CFR Part 15, Limit Clause 15.209

Frequency (MHz)	Field Strength ($\mu\text{V/m}$ at 3 m)
30 to 88	100
88 to 216	150
216 to 960	200
Above 960	500

Table 18



2.1.7 Test Location and Test Equipment Used

This test was carried out in EMC Chamber 12.

Instrument	Manufacturer	Type No.	TE No.	Calibration Period (months)	Calibration Expiry Date
Power Supply Unit	Hewlett Packard	6269B	113	-	O/P Mon
Test Receiver	Rohde & Schwarz	ESU40	3506	12	18-Mar-2022
Multimeter	Fluke	177	3832	12	08-Jul-2022
Emissions Software	TUV SUD	EmX V2.1.12 V.2.1.12	5125	-	Software
Cable (N-Type to N-Type, 8 m)	Teledyne	PR90-088-8MTR	5450	6	08-Mar-2022
Thermo-Hygro-Barometer	PCE Instruments	PCE-THB-40	5481	12	31-Mar-2022
Cable (K-Type to K-Type, 2 m)	Junkosha	MWX241-02000KMSKMS/A	5524	12	24-Mar-2022
Antenna (DRG, 1 GHz to 10 GHz)	Schwarzbeck	BBHA 9120 B	5611	12	15-Oct-2022
Turntable & Mast Controller	Maturo Gmbh	NCD/498/2799.01	5612	-	TU
Tilt Antenna Mast	Maturo Gmbh	TAM 4.0-P	5613	-	TU
Turntable	Maturo Gmbh	Turntable 1.5 SI-2t	5614	-	TU
Screened Room (12)	MVG	EMC-3	5621	36	11-Aug-2023

Table 19

TU – Traceability Unscheduled

O/P Mon – Output Monitored using calibrated equipment



2.2 Emission Bandwidth

2.2.1 Specification Reference

FCC 47 CFR Part 15C, Clause 15.247 (a)(2)

2.2.2 Equipment Under Test and Modification State

MiX 4401-B, S/N: 55000202 - Modification State 0

2.2.3 Date of Test

12-April-2022

2.2.4 Test Method

This test was performed in accordance with ANSI C63.10, clause 11.8.1 for 6 dB BW and 6.9.3 for 99% occupied bandwidth measurements.

2.2.5 Environmental Conditions

Ambient Temperature	23.4 °C
Relative Humidity	42.5 %



2.2.6 Test Results

2.4 GHz Bluetooth Low Energy

Test Configuration			
Frequency Range:	2400-2483.5 MHz	Band:	2.4 GHz
Limit Clause(s):	15.247 (a)(2)	Test Method(s):	C63.10 6.9.3 C63.10 11.8.1
Additional Reference(s):	-		

DUT Configuration			
Mode:	BLE GFSK (LE 1M)	Duty Cycle (%):	-
Antenna Configuration:	SISO	DCCF (dB):	-
Active Port(s):	A (BLE)	Peak Antenna Gain (dBi):	-

Test Frequency (MHz)	6 dB Bandwidth (MHz)				Limit (kHz)
	A	B	C	D	
2402	0.752	-	-	-	≥500.0
2440	0.756	-	-	-	≥500.0
2480	0.752	-	-	-	≥500.0

Table 20 - 6 dB Bandwidth Results

Test Frequency (MHz)	99% Bandwidth (MHz)				Limit (kHz)
	A	B	C	D	
2402	1.060	-	-	-	-
2440	1.060	-	-	-	-
2480	1.060	-	-	-	-

Table 21 - 99% Bandwidth Results

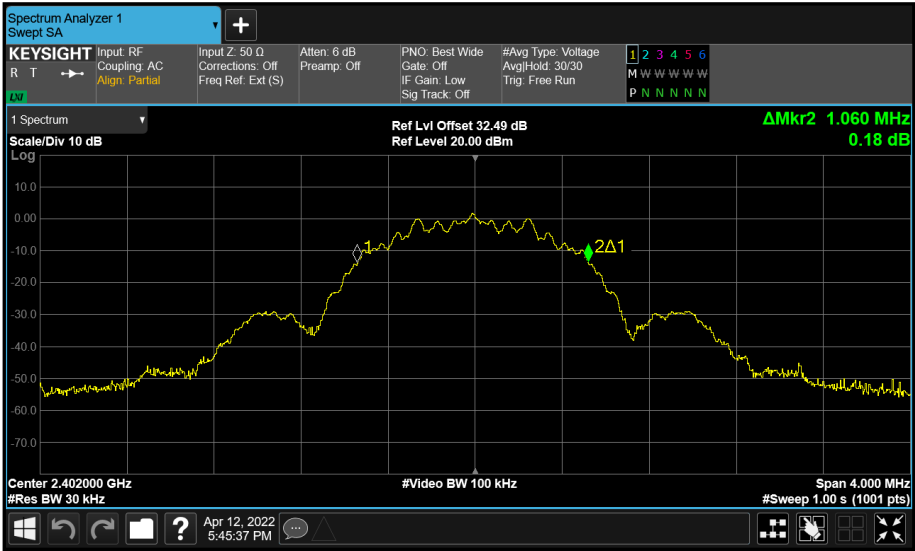


Figure 3 - BLE (A) 2402 MHz (CH37) 99% Bandwidth

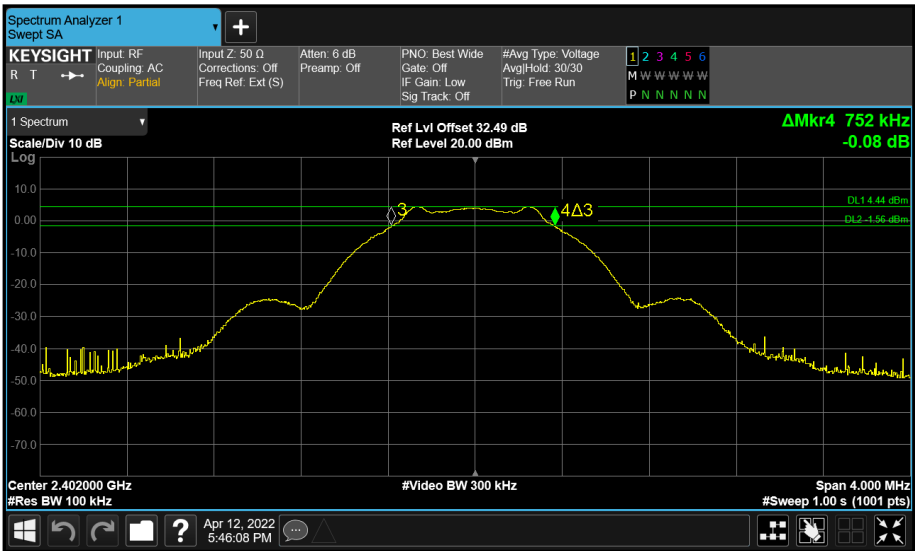


Figure 4 - BLE (A) 2402 MHz (CH37) 6 dB Bandwidth

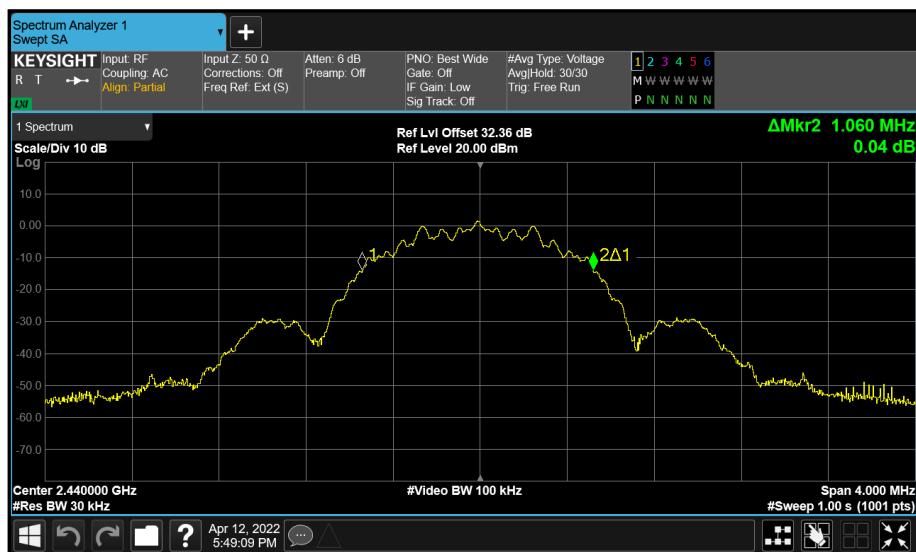


Figure 5 - BLE (A) 2440 MHz (CH17) 99% Bandwidth

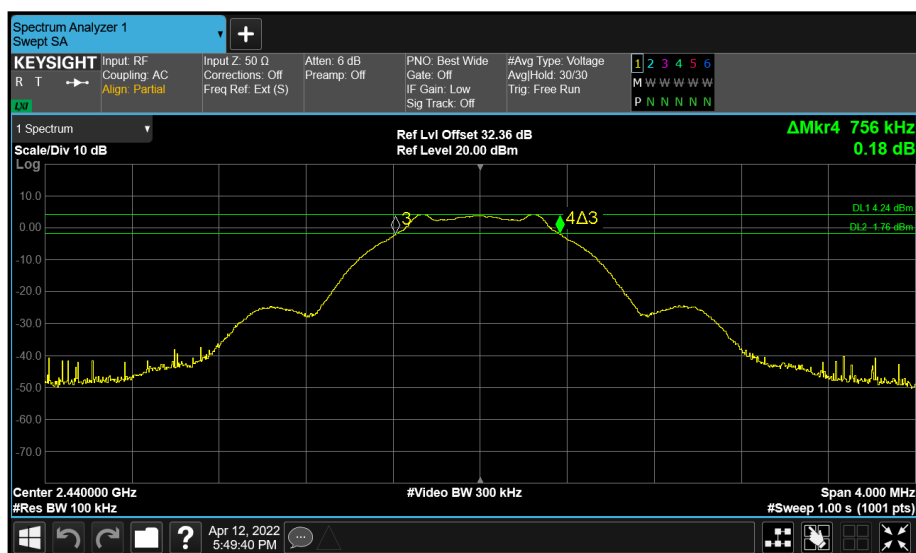


Figure 6 - BLE (A) 2440 MHz (CH17) 6 dB Bandwidth

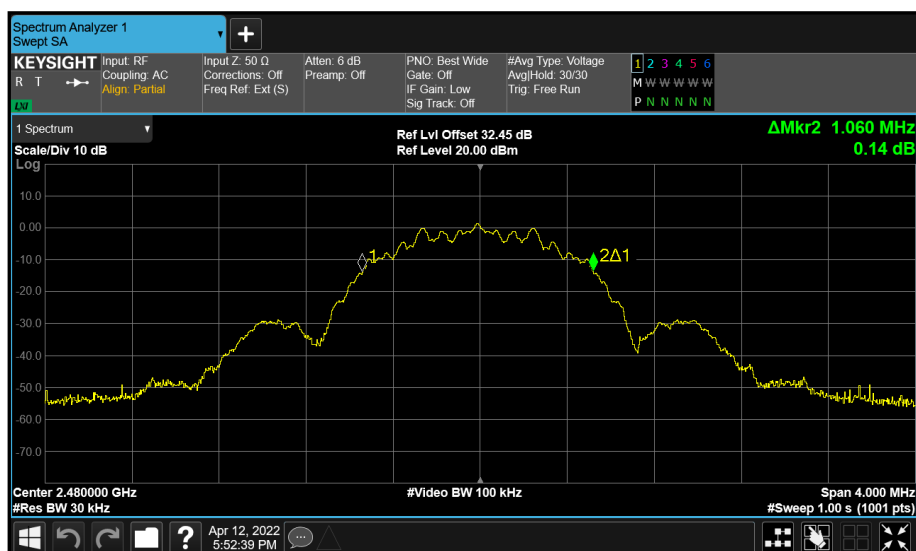


Figure 7 - BLE (A) 2480 MHz (CH39) 99% Bandwidth

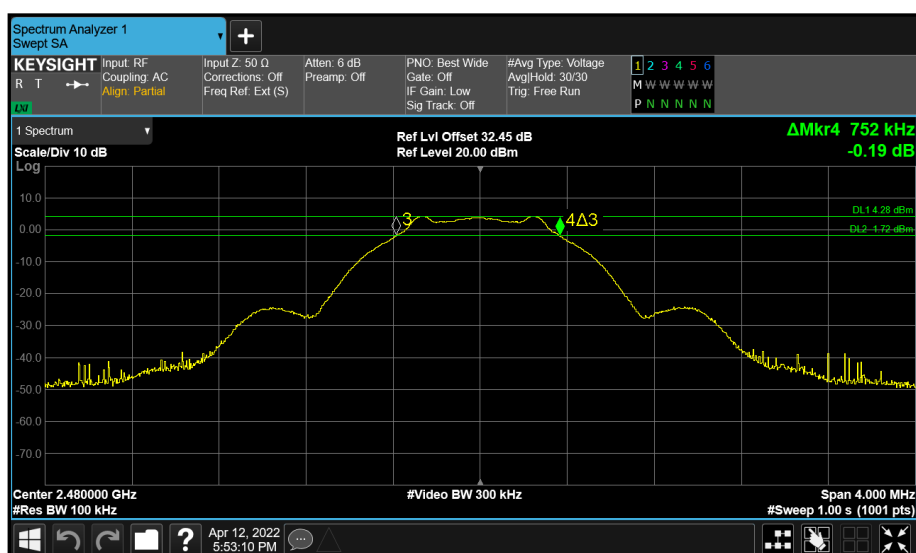


Figure 8 - BLE (A) 2480 MHz (CH39) 6 dB Bandwidth

FCC 47 CFR Part 15, Limit Clause 15.247(a)(2)

The minimum 6 dB Bandwidth shall be at least 500 kHz.



2.2.7 Test Location and Test Equipment Used

This test was carried out in RF Laboratory 1.

Instrument	Manufacturer	Type No.	TE No.	Calibration Period (months)	Calibration Expiry Date
Multimeter	Iso-tech	IDM101	2421	12	28-Oct-2022
Hygrometer	Rotronic	I-1000	3220	12	05-Nov-2022
Frequency Standard	Spectracom	SecureSync 1200-0408-0601	4393	6	30-Jun-2022
MXA Signal Analyser	Keysight Technologies	N9020B	5529	24	06-Jun-2022
Signal Commissioning Unit	TUV SUD	SCU002	5759	12	30-Jun-2022
Modular Power System Mainframe	Keysight Technologies	N6701C	5835	-	TU
DC Power Module 60V 20A 300W	Keysight Technologies	N6754A	5836	-	O/P Mon

Table 22

TU – Traceability Unscheduled

O/P Mon – Output Monitored using calibrated equipment



2.3 Maximum Conducted Output Power

2.3.1 Specification Reference

FCC 47 CFR Part 15C, Clause 15.247 (b)

2.3.2 Equipment Under Test and Modification State

MiX 4401-B, S/N: 55000202 - Modification State 0

2.3.3 Date of Test

12-April-2022

2.3.4 Test Method

The test was performed in accordance with ANSI C63.10 clause 11.9.1.2.

2.3.5 Environmental Conditions

Ambient Temperature	23.4 °C
Relative Humidity	42.5 %



2.3.6 Test Results

2.4 GHz Bluetooth Low Energy

Test Configuration			
Frequency Range:	2400-2483.5 MHz	Band:	2.4 GHz
Limit Clause(s):	15.247 (b)(3)	Test Method(s):	C63.10 11.9.1.2
Additional Reference(s):	-		

DUT Configuration			
Mode:	BLE GFSK (LE 1M)	Duty Cycle (%):	100.0
Antenna Configuration:	SISO	DCCF (dB):	-
Active Port(s):	A (BLE)	Peak Antenna Gain (dBi):	1.40

Test Frequency (MHz)	Maximum Conducted Output Power (dBm)					Limit (dBm)	Margin (dB)
	A	B	C	D	Σ		
2402	4.64	-	-	-	-	30.00	-25.36
2440	4.54	-	-	-	-	30.00	-25.46
2480	4.36	-	-	-	-	30.00	-25.64

Table 23 - FCC Maximum Conducted (peak) Output Power Results

FCC 47 CFR Part 15, Limit Clause 15.247 (b)(3)

For systems using digital modulation in the 902–928 MHz, 2400–2483.5 MHz, and 5725–5850 MHz bands: 1 Watt.



2.3.7 Test Location and Test Equipment Used

This test was carried out in RF Laboratory 1.

Instrument	Manufacturer	Type No.	TE No.	Calibration Period (months)	Calibration Expiry Date
Multimeter	Iso-tech	IDM101	2421	12	28-Oct-2022
Hygrometer	Rotronic	I-1000	3220	12	05-Nov-2022
Frequency Standard	Spectracom	SecureSync 1200-0408-0601	4393	6	30-Jun-2022
MXA Signal Analyser	Keysight Technologies	N9020B	5529	24	06-Jun-2022
Signal Commissioning Unit	TUV SUD	SCU002	5759	12	30-Jun-2022
Modular Power System Mainframe	Keysight Technologies	N6701C	5835	-	TU
DC Power Module 60V 20A 300W	Keysight Technologies	N6754A	5836	-	O/P Mon

Table 24

TU – Traceability Unscheduled

O/P Mon – Output Monitored using calibrated equipment



2.4 Spurious Radiated Emissions

2.4.1 Specification Reference

FCC 47 CFR Part 15C, Clause 15.247 (d) and 15.209

2.4.2 Equipment Under Test and Modification State

MiX 4401-B, S/N: 55000206 - Modification State 0

2.4.3 Date of Test

07-March-2022 to 16-March-2022

2.4.4 Test Method

This test was performed in accordance with ANSI C63.10, clause 6.3, 6.5 and 6.6.

For frequencies > 1 GHz, plots for average measurements were taken in accordance with ANSI C63.10, clause 11.12.2.5.2.

The EUT was placed on the non-conducting platform in a manner typical of a normal installation. As the EUT was considered mobile/portable and therefore reasonable to be used in multiple planes, pre-scans were performed with the EUT orientated in X, Y and Z planes with reference to the ground plane.

Ports on the EUT were terminated with loads as described in ANSI C63.4 clause 6.2.4. For EUT's with multiple connectors of the same type, additional interconnecting cables were connected, and pre-scans performed to determine whether the level of the emissions were increased by >2 dB.

The plots shown are the characterisation of the EUT. The limits on the plots represent the most stringent case for restricted bands, (74/54 dBuV/m) when compared to 20 dBc outside restricted bands. The limits shown have been used as a threshold to determine where further measurements are necessary. Where results are within 10 dB of the limits shown on the plots, further investigation was carried out and reported in results tables.

The following conversion can be applied to convert from dBµV/m to µV/m:
 $10^{(\text{Field Strength in dB}\mu\text{V/m}/20)}$

To determine the emission characteristic of the EUT above 18 GHz, the test antenna was swept over all faces of the EUT whilst observing a spectral display. The frequency of any emissions of interest was noted for formal measurement at the correct measurement distance of 1m. This procedure was repeated for all relevant transmit operating channels.

Representative noise floor plots for > 18 GHz have been presented for X orientation.

Above 18 GHz, the measurement distance was reduced to 1 m. The limit line was increased by $20 \cdot \text{LOG}(3/1) = 9.54$ dB.

At a measurement distance of 1 meter the limit line was increased by $20 \cdot \text{LOG}(3/1) = 9.54$ dB.

Where formal measurements have been necessary, the results have been presented in the emissions table.

2.4.5 Example Test Setup Diagram

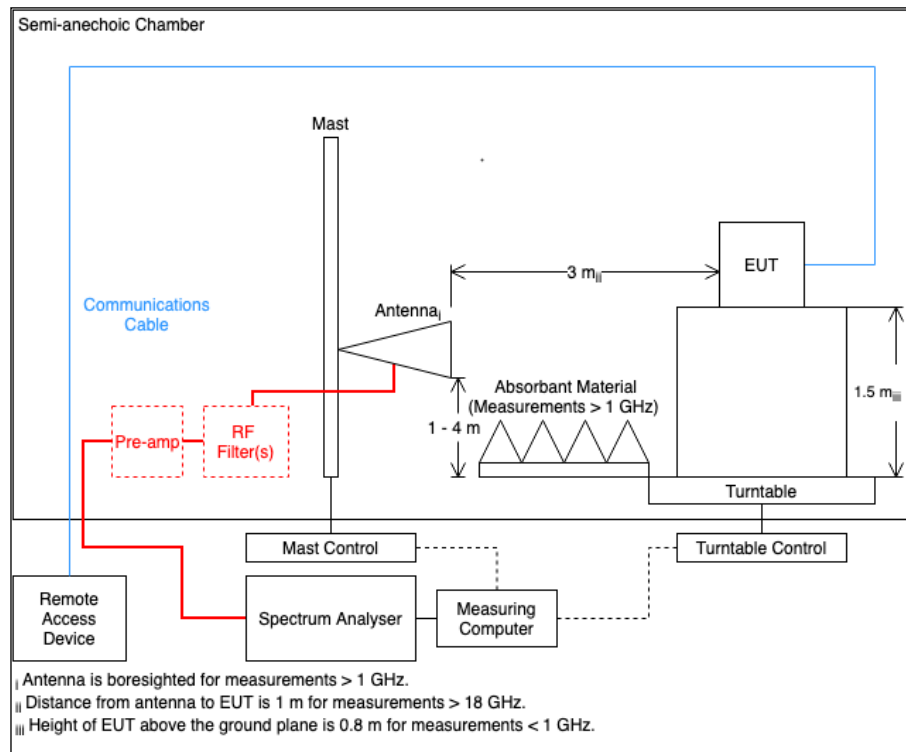


Figure 9

2.4.6 Environmental Conditions

Ambient Temperature	20.2 - 21.5 °C
Relative Humidity	26.8 - 39.9 %



2.4.7 Test Results

2.4 GHz Bluetooth Low Energy

Frequency (MHz)	Level (dBuV/m)	Limit (dBuV/m)	Margin (dB)	Detector	Angle (°)	Height (cm)	Polarisation
38.176	38.8	40.0	-1.2	Q-Peak	7	100	Vertical
2273.986	45.3	54.0	-8.7	RMS	286	100	Horizontal

Table 25 - BLE - X, 2402 MHz, 30 MHz to 25 GHz

No other emissions found within 10 dB of the limit.

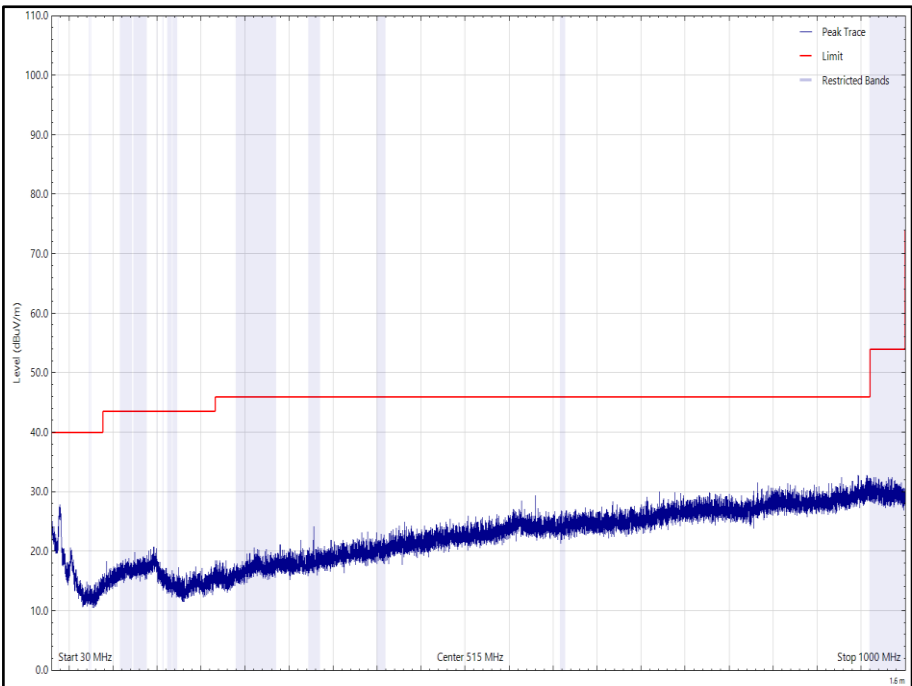


Figure 10 - BLE - X, 2402 MHz, 30 MHz to 1 GHz, Horizontal (Peak)

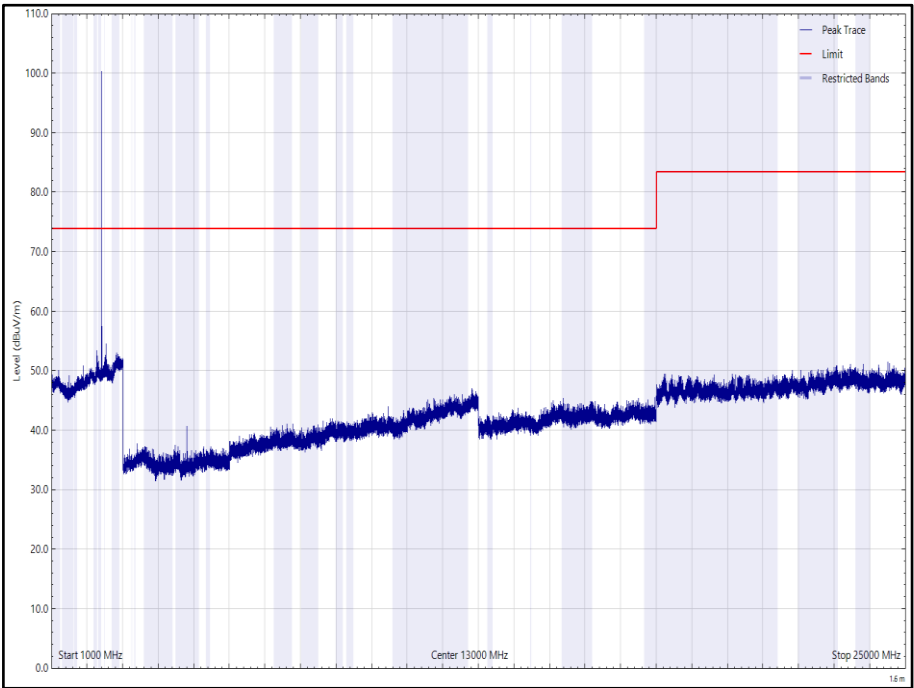


Figure 11 - BLE - X, 2402 MHz, 1 GHz to 25 GHz, Horizontal (Peak)

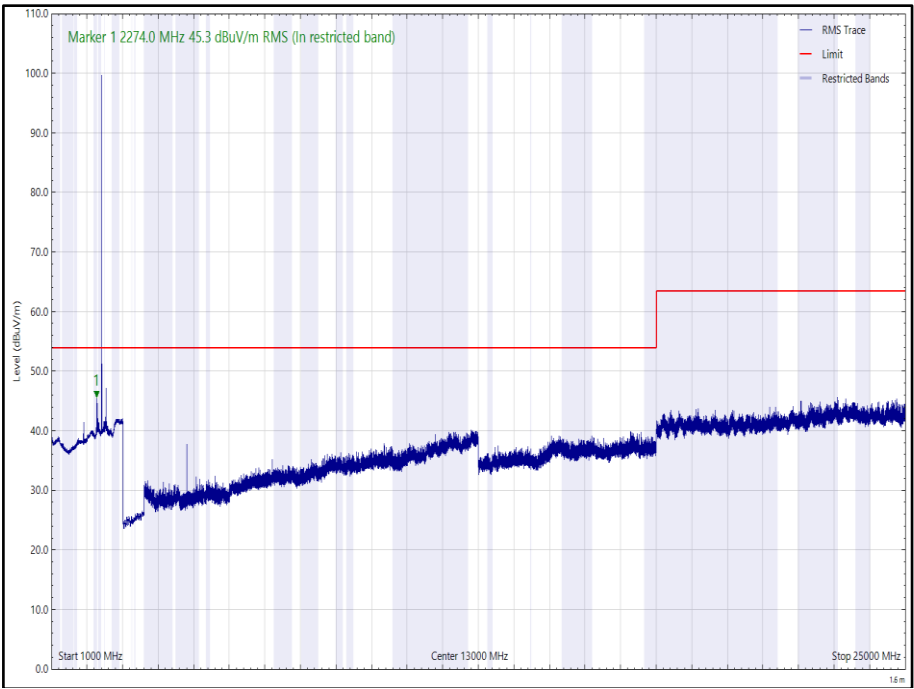


Figure 12 - BLE - X, 2402 MHz, 1 GHz to 25 GHz, Horizontal (rms)

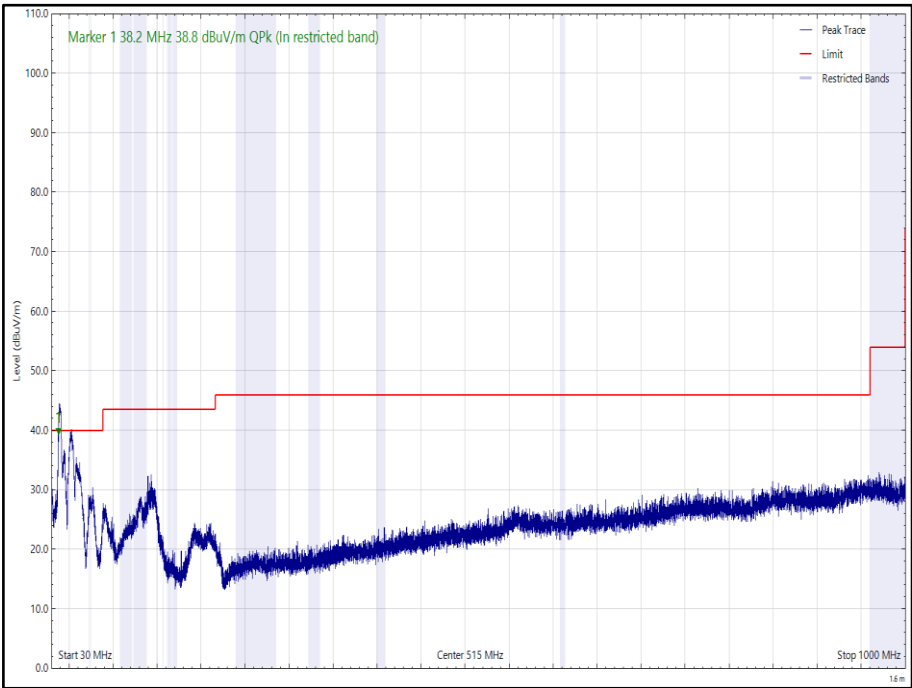


Figure 13 - BLE - X, 2402 MHz, 30 MHz to 1 GHz, Vertical (Peak)

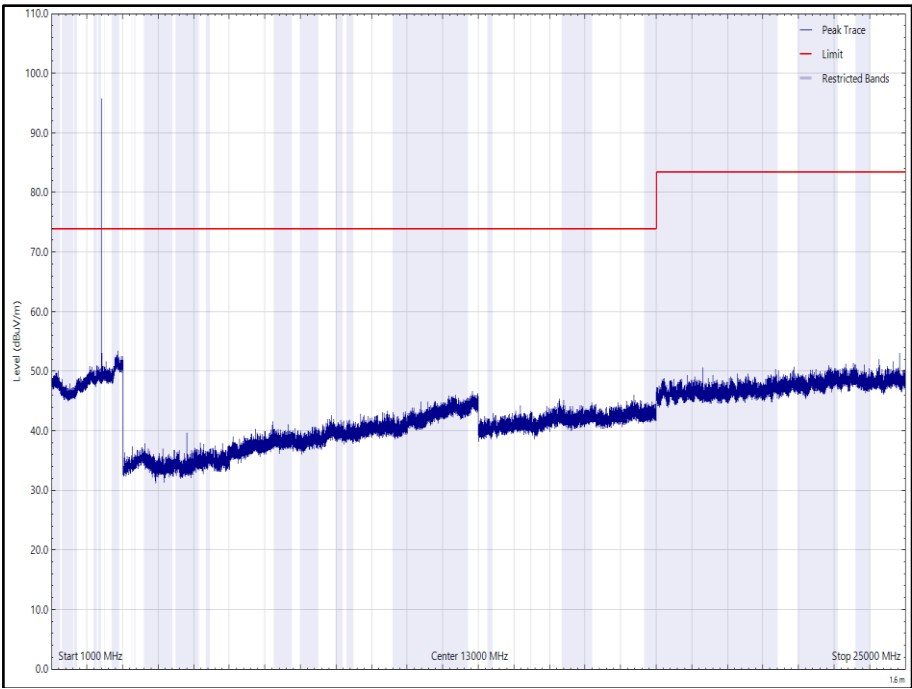


Figure 14 - BLE - X, 2402 MHz, 1 GHz to 25 GHz, Vertical (Peak)

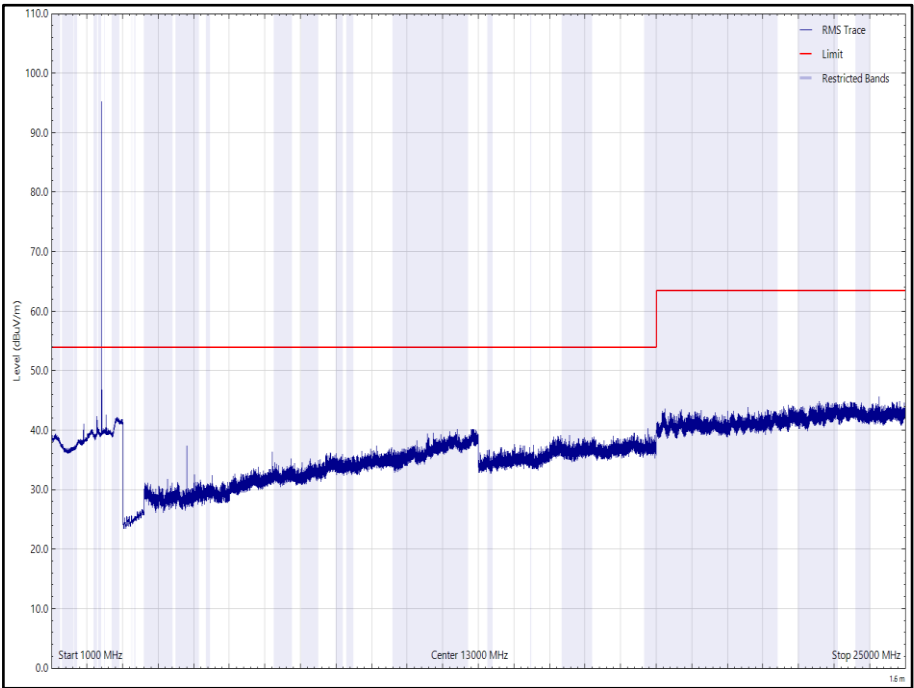


Figure 15 - BLE - X, 2402 MHz, 1 GHz to 25 GHz, Vertical (rms)



Frequency (MHz)	Level (dBuV/m)	Limit (dBuV/m)	Margin (dB)	Detector	Angle (°)	Height (cm)	Polarisation
38.079	37.6	40.0	-2.4	Q-Peak	27	110	Vertical
2311.989	46.8	54.0	-7.2	RMS	287	105	Horizontal

Table 26 - BLE - X, 2440 MHz, 30 MHz to 25 GHz

No other emissions found within 10 dB of the limit.

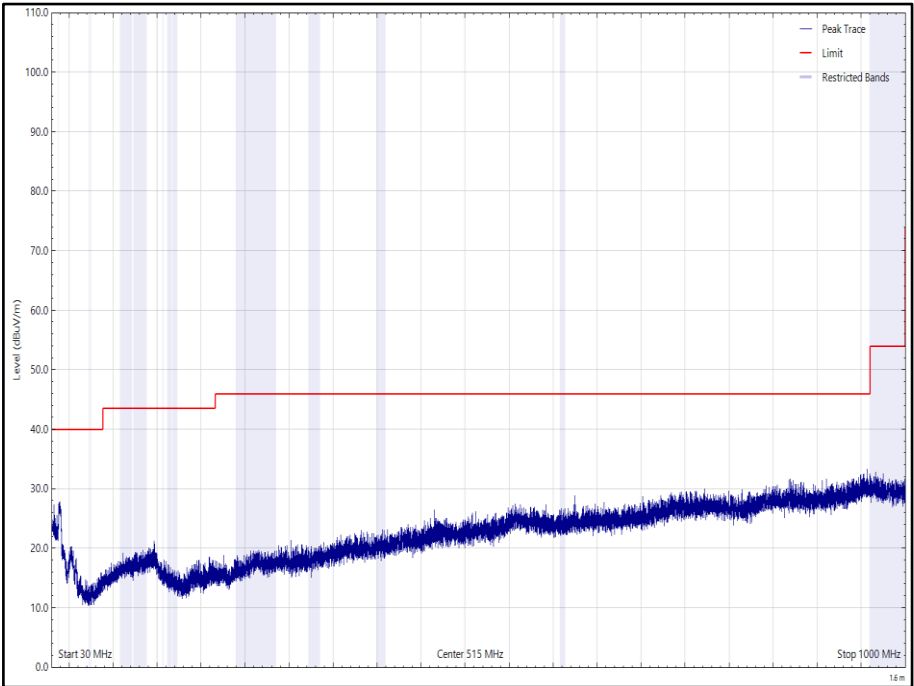


Figure 16 - BLE - X, 2440 MHz, 30 MHz to 1 GHz, Horizontal (Peak)

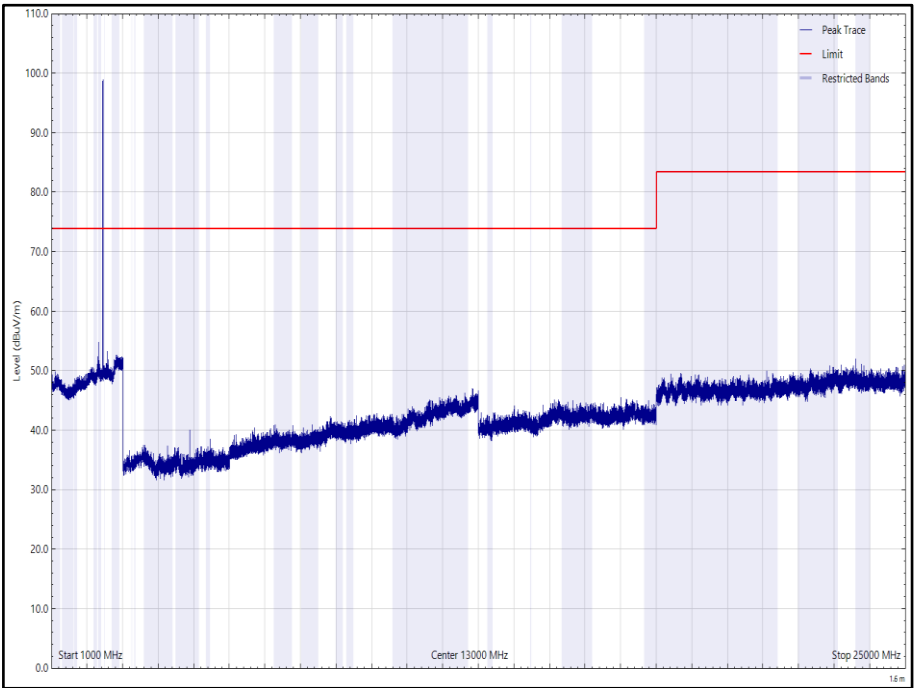


Figure 17 - BLE - X, 2440 MHz, 1 GHz to 25 GHz, Horizontal (Peak)

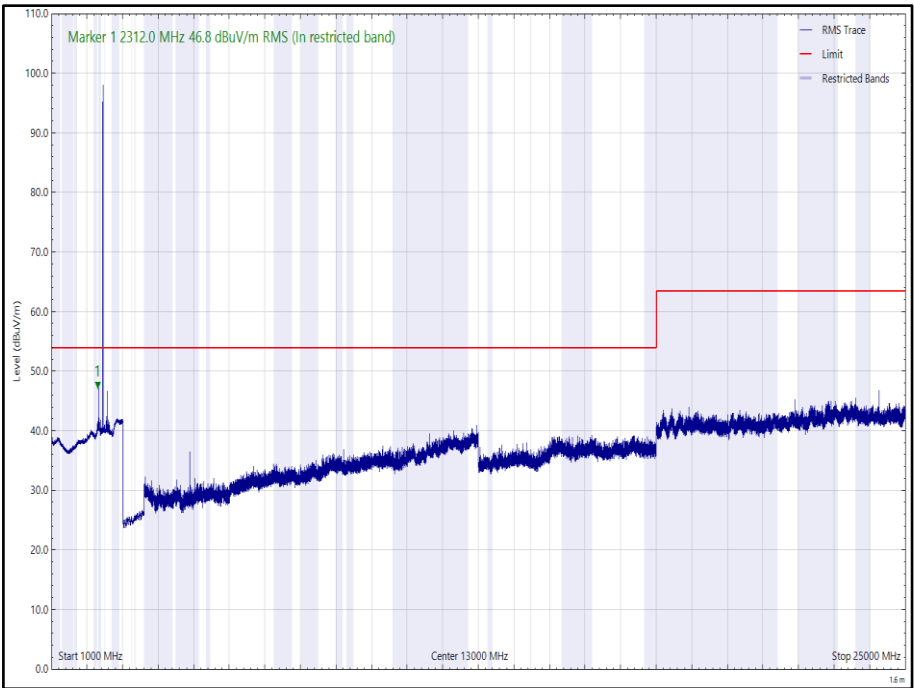


Figure 18 - BLE - X, 2440 MHz, 1 GHz to 25 GHz, Horizontal (rms)

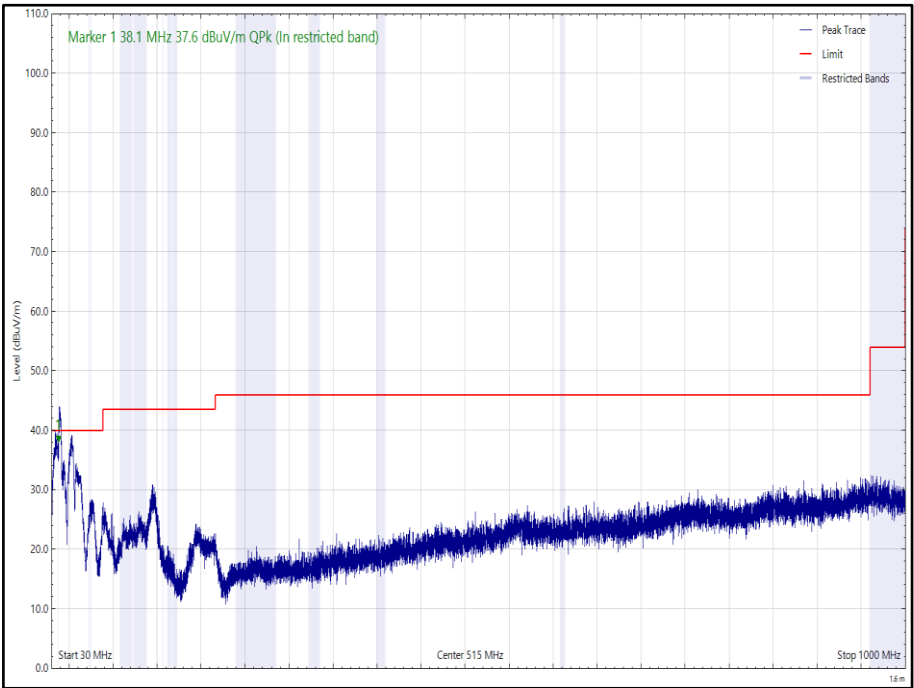


Figure 19 - BLE - X, 2440 MHz, 30 MHz to 1 GHz, Vertical (Peak)

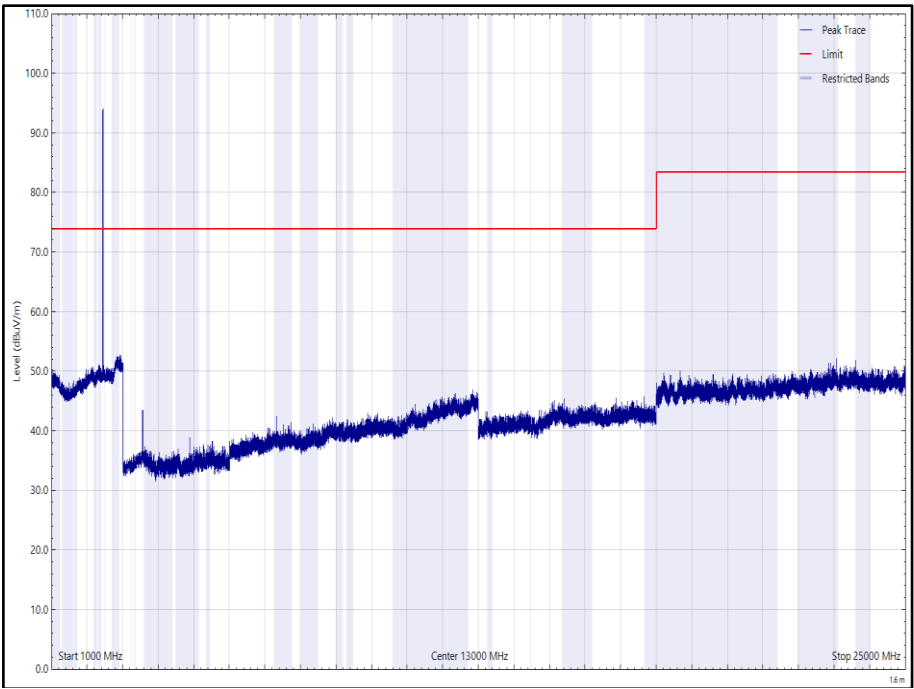


Figure 20 - BLE - X, 2440 MHz, 1 GHz to 25 GHz, Vertical (Peak)

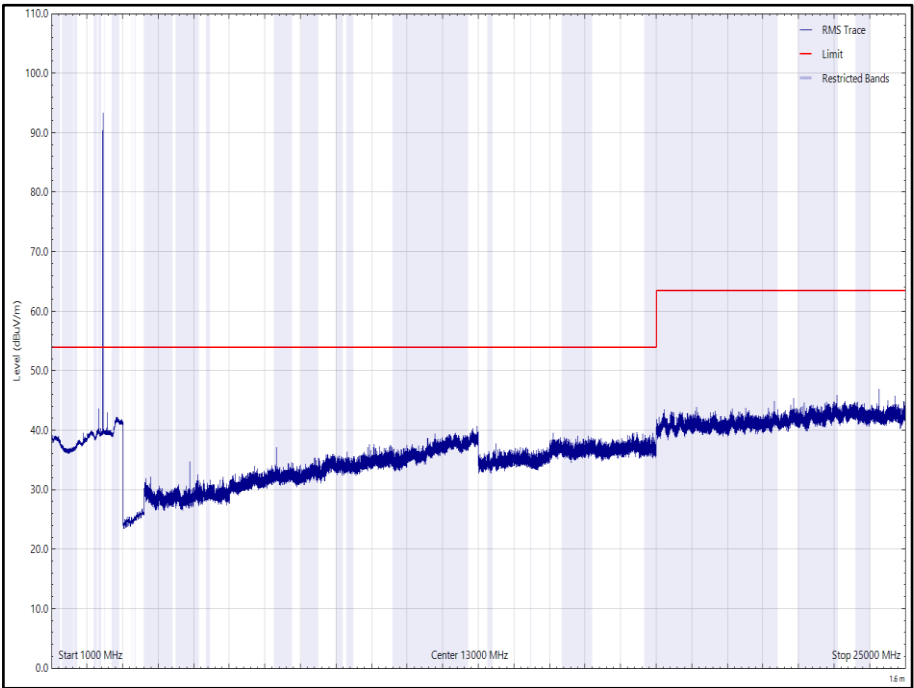


Figure 21 - BLE - X, 2440 MHz, 1 GHz to 25 GHz, Vertical (rms)



Frequency (MHz)	Level (dBuV/m)	Limit (dBuV/m)	Margin (dB)	Detector	Angle (°)	Height (cm)	Polarisation
38.249	36.5	40.0	-3.6	Q-Peak	26	100	Vertical
2351.999	48.0	54.0	-6.0	RMS	278	100	Horizontal

Table 27 - BLE - X, 2480 MHz, 30 MHz to 25 GHz

No other emissions found within 10 dB of the limit.

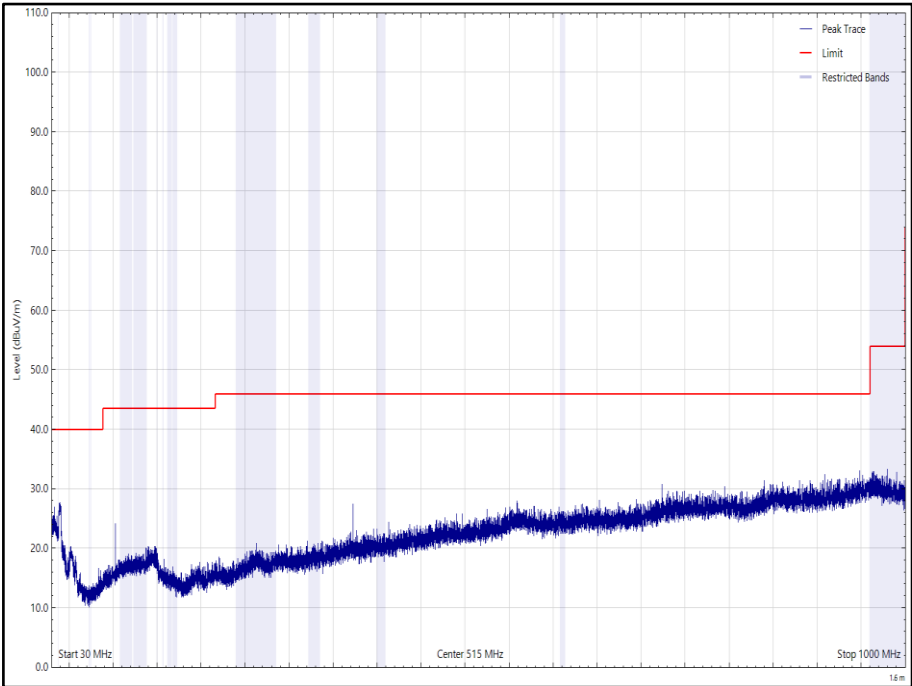


Figure 22 - BLE - X, 2480 MHz, 30 MHz to 1 GHz, Horizontal (Peak)

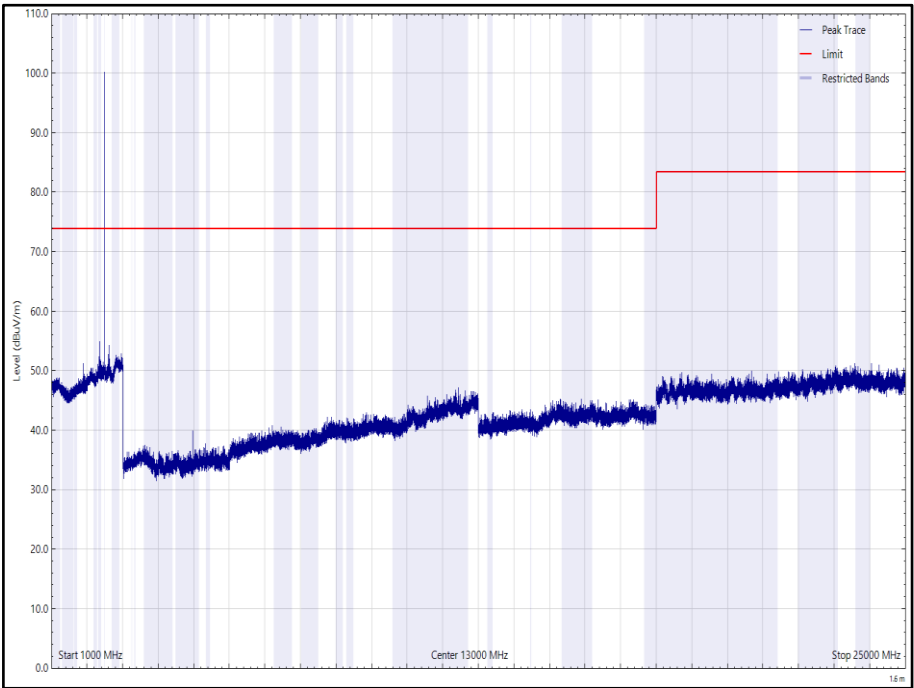


Figure 23 - BLE - X, 2480 MHz, 1 GHz to 25 GHz, Horizontal (Peak)

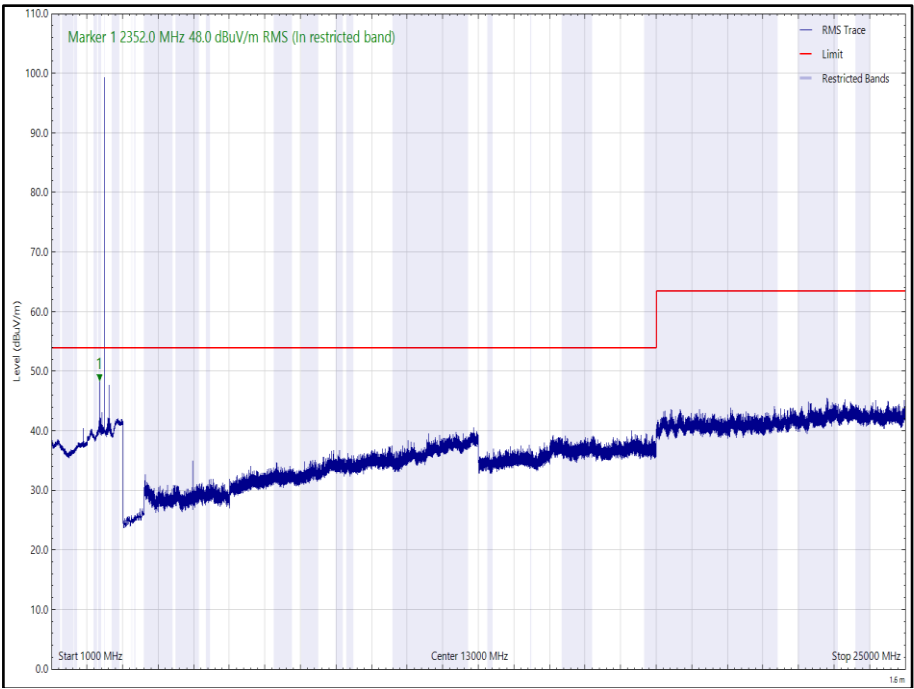


Figure 24 - BLE - X, 2480 MHz, 1 GHz to 25 GHz, Horizontal (rms)

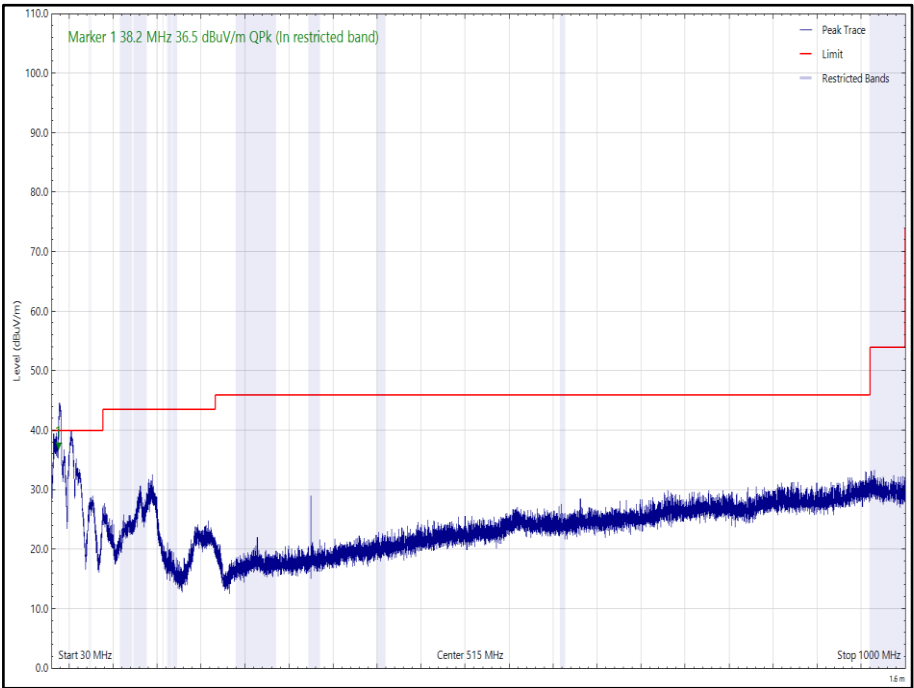


Figure 25 - BLE - X, 2480 MHz, 30 MHz to 1 GHz, Vertical (Peak)

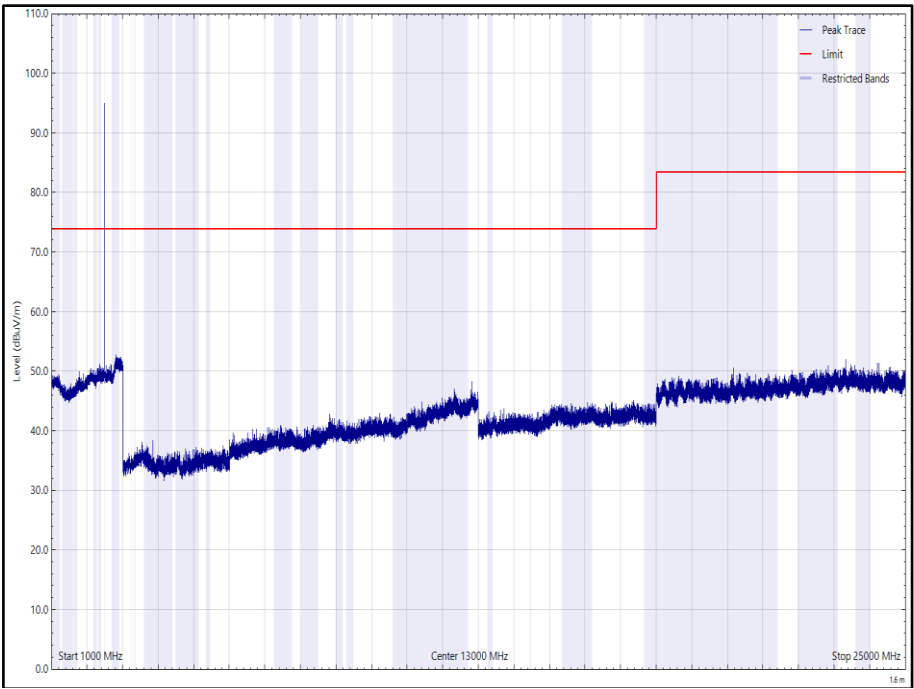


Figure 26 - BLE - X, 2480 MHz, 1 GHz to 25 GHz, Vertical (Peak)

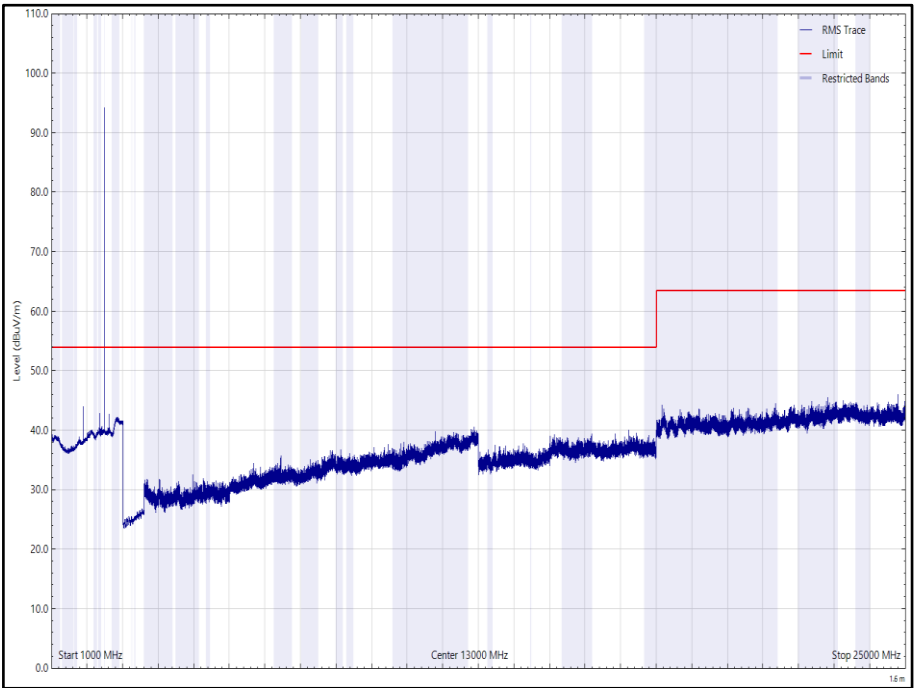


Figure 27 - BLE - X, 2480 MHz, 1 GHz to 25 GHz, Vertical (rms)



Frequency (MHz)	Level (dBuV/m)	Limit (dBuV/m)	Margin (dB)	Detector	Angle (°)	Height (cm)	Polarisation
38.046	37.9	40.0	-2.1	Q-Peak	23	100	Vertical
2272.962	44.3	54.0	-9.7	RMS	317	100	Vertical

Table 28 - BLE - Y, 2402 MHz, 30 MHz to 18 GHz

No other emissions found within 10 dB of the limit.

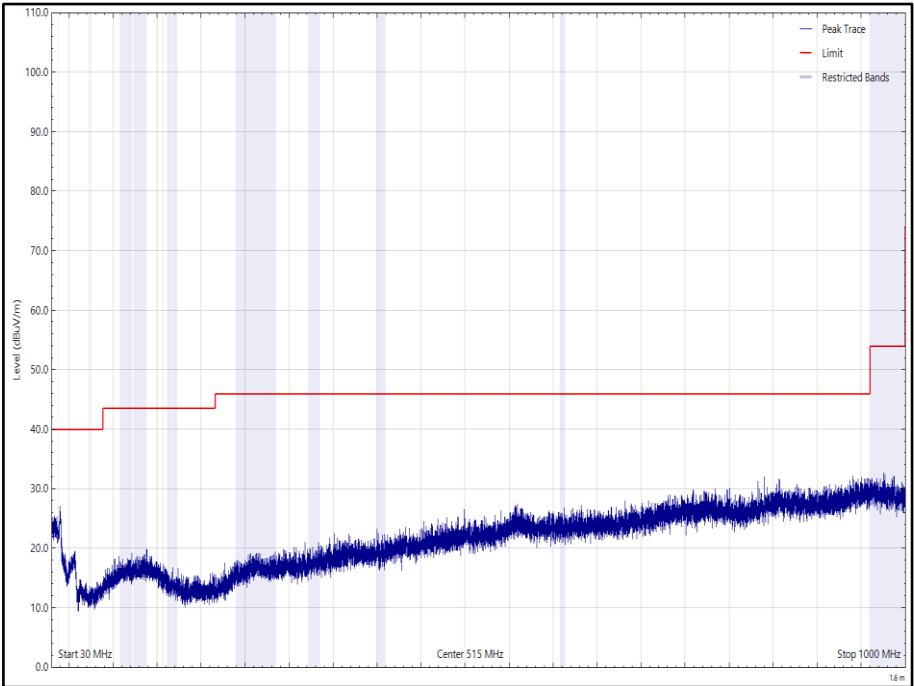


Figure 28 - BLE - Y, 2402 MHz, 30 MHz to 1 GHz, Horizontal (Peak)

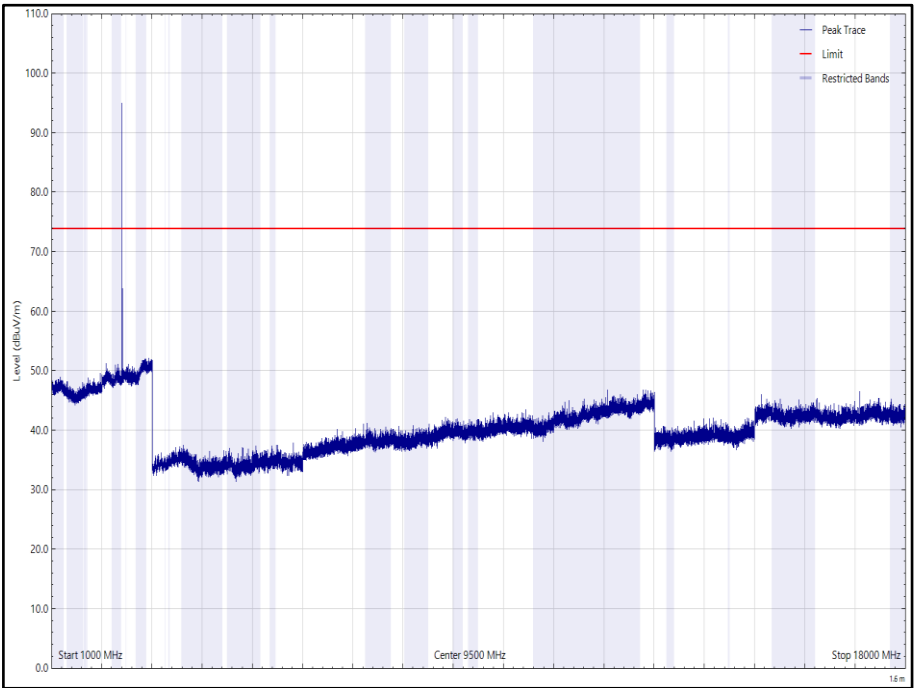


Figure 29 - BLE - Y, 2402 MHz, 1 GHz to 18 GHz, Horizontal (Peak)

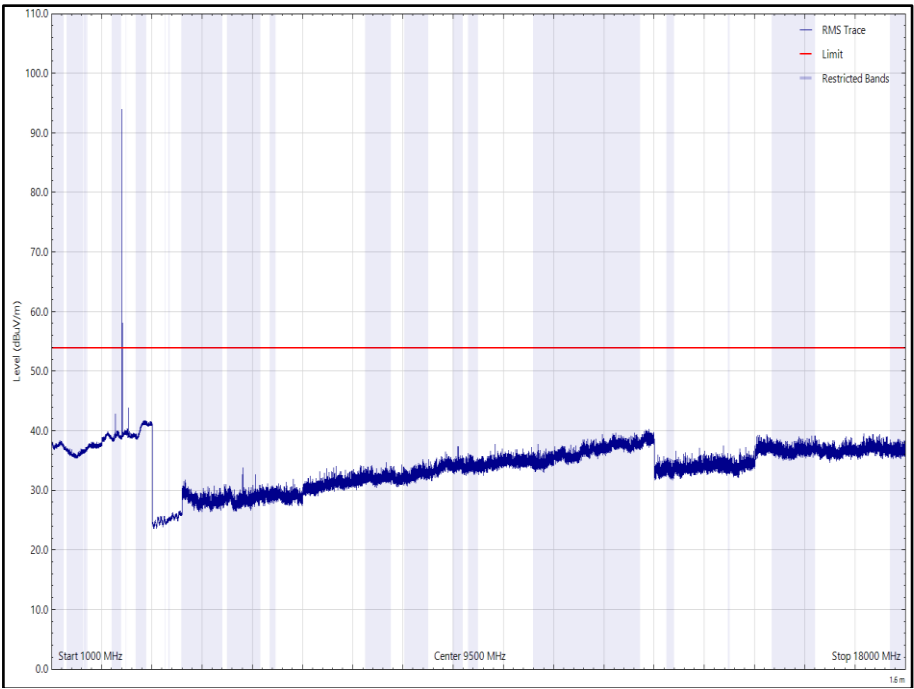


Figure 30 - BLE - Y, 2402 MHz, 1 GHz to 18 GHz, Horizontal (rms)

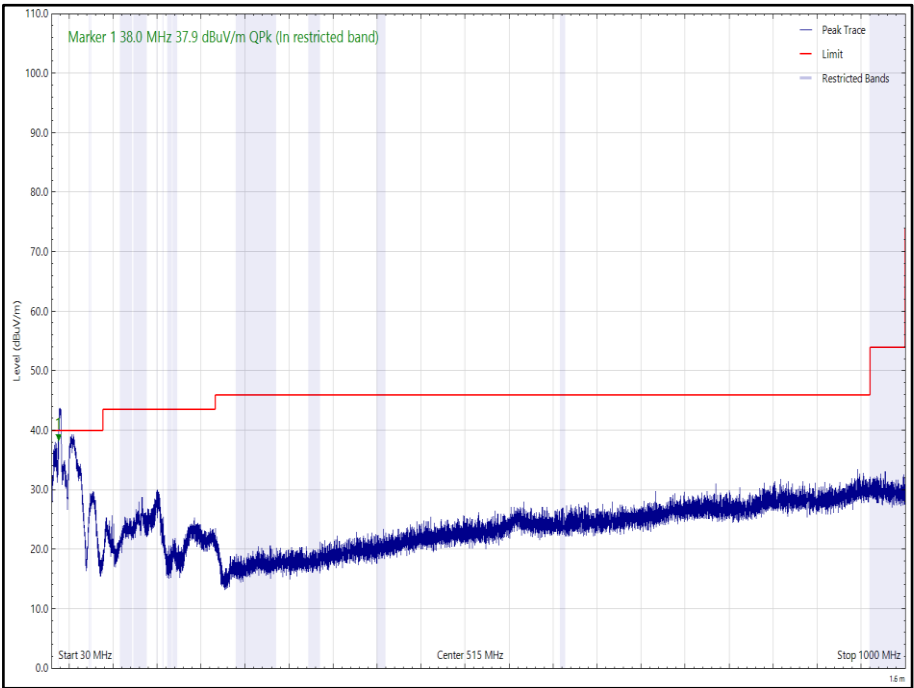


Figure 31 - BLE - Y, 2402 MHz, 30 MHz to 1 GHz, Vertical (Peak)

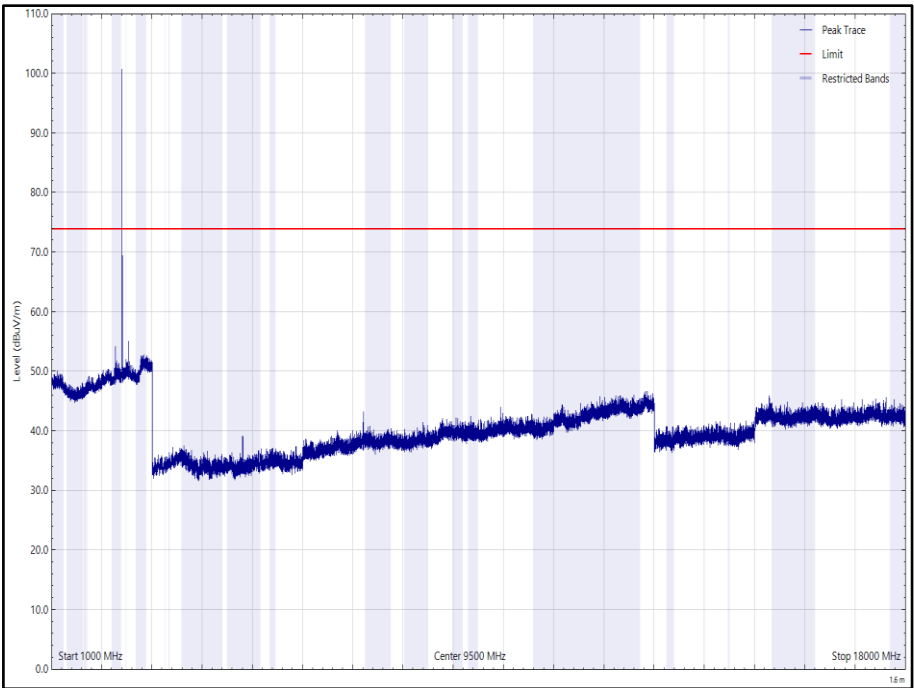


Figure 32 - BLE - Y, 2402 MHz, 1 GHz to 18 GHz, Vertical (Peak)

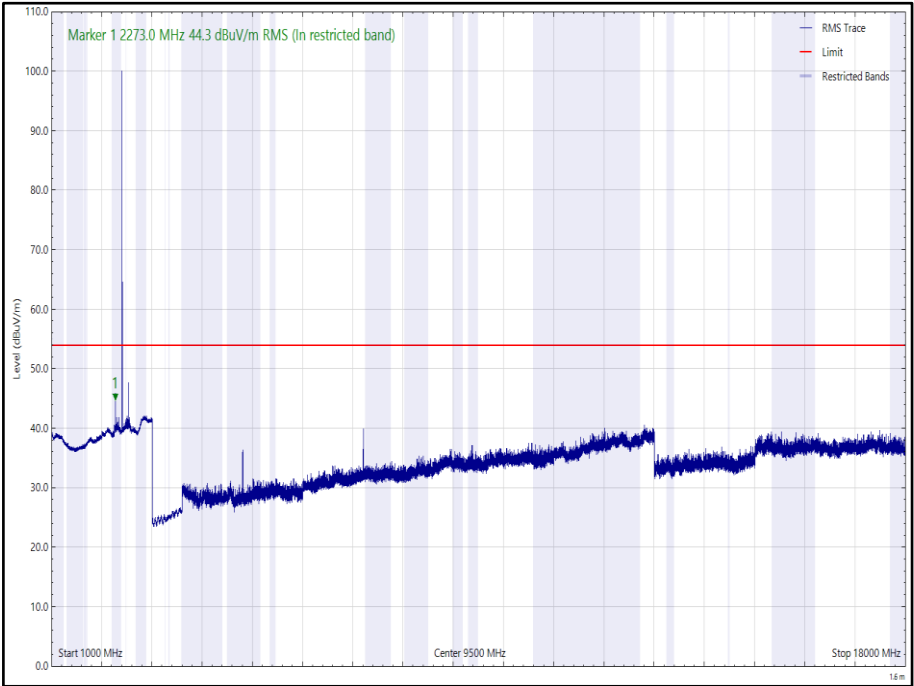


Figure 33 - BLE - Y, 2402 MHz, 1 GHz to 18 GHz, Vertical (rms)



Frequency (MHz)	Level (dBuV/m)	Limit (dBuV/m)	Margin (dB)	Detector	Angle (°)	Height (cm)	Polarisation
38.213	38.1	40.0	-1.9	Q-Peak	6	101	Vertical
2312.048	46.2	54.0	-7.8	RMS	319	100	Vertical

Table 29 - BLE - Y, 2440 MHz, 30 MHz to 18 GHz

No other emissions found within 10 dB of the limit.

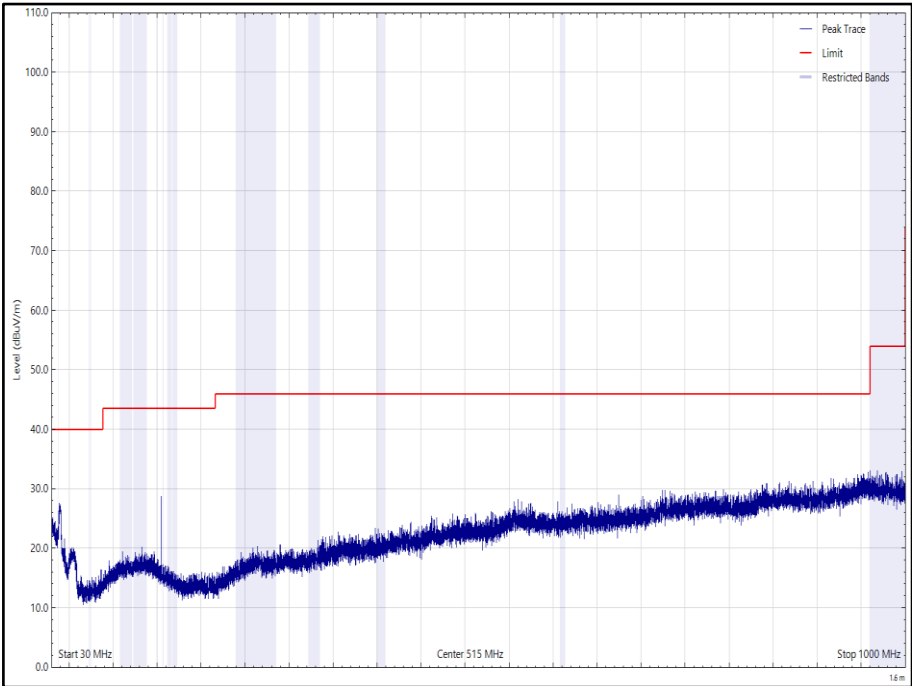


Figure 34 - BLE - Y, 2440 MHz, 30 MHz to 1 GHz, Horizontal (Peak)

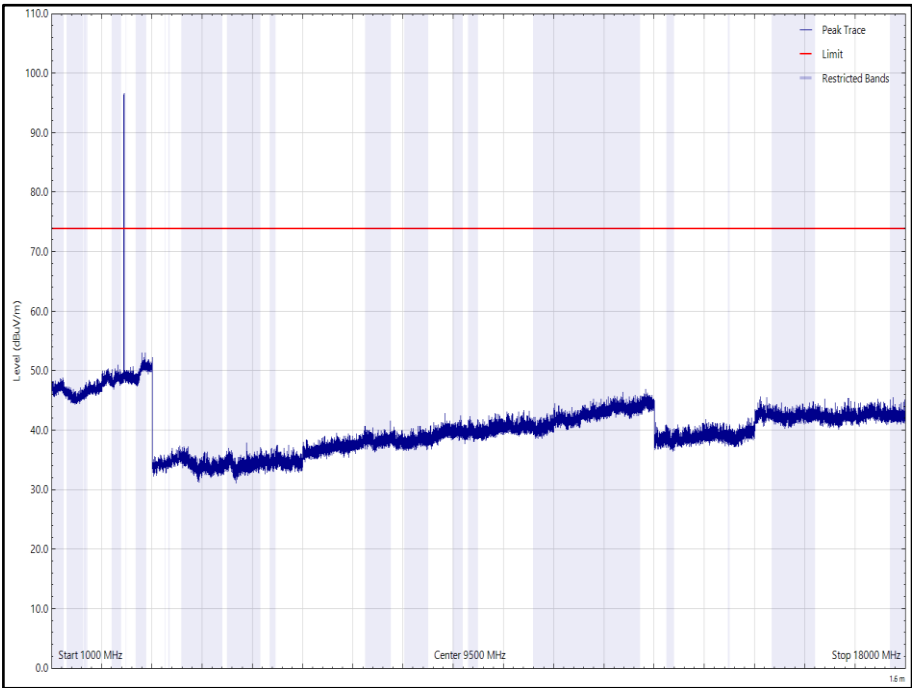


Figure 35 - BLE - Y, 2440 MHz, 1 GHz to 18 GHz, Horizontal (Peak)

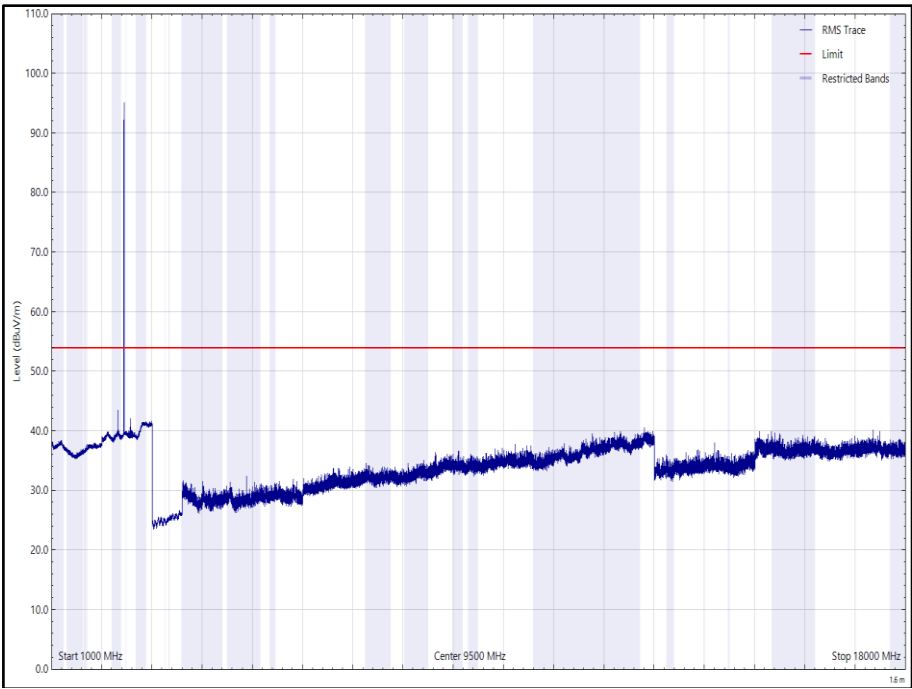


Figure 36 - BLE - Y, 2440 MHz, 1 GHz to 18 GHz, Horizontal (rms)

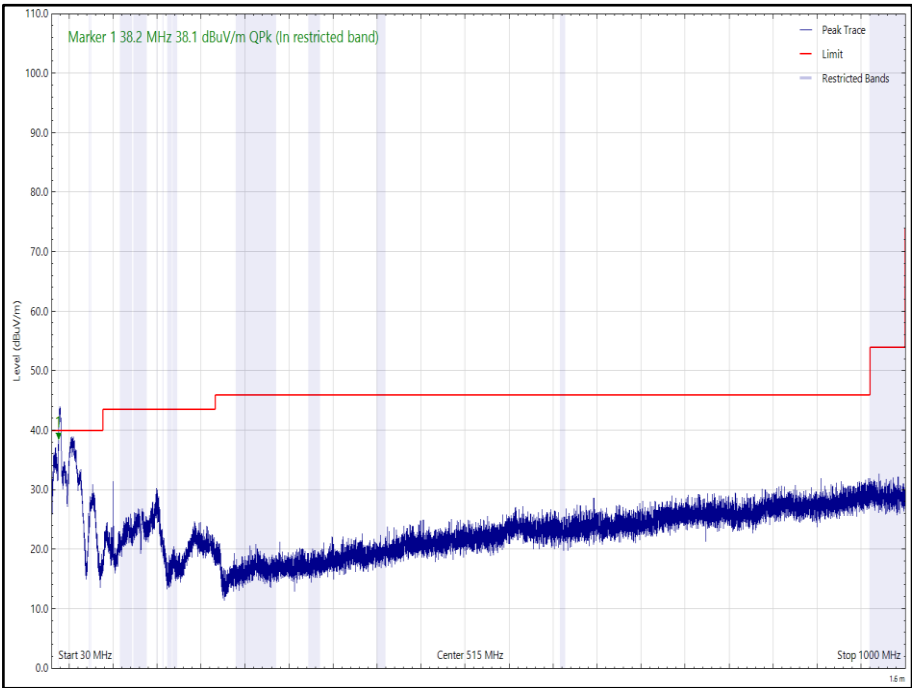


Figure 37 - BLE - Y, 2440 MHz, 30 MHz to 1 GHz, Vertical (Peak)

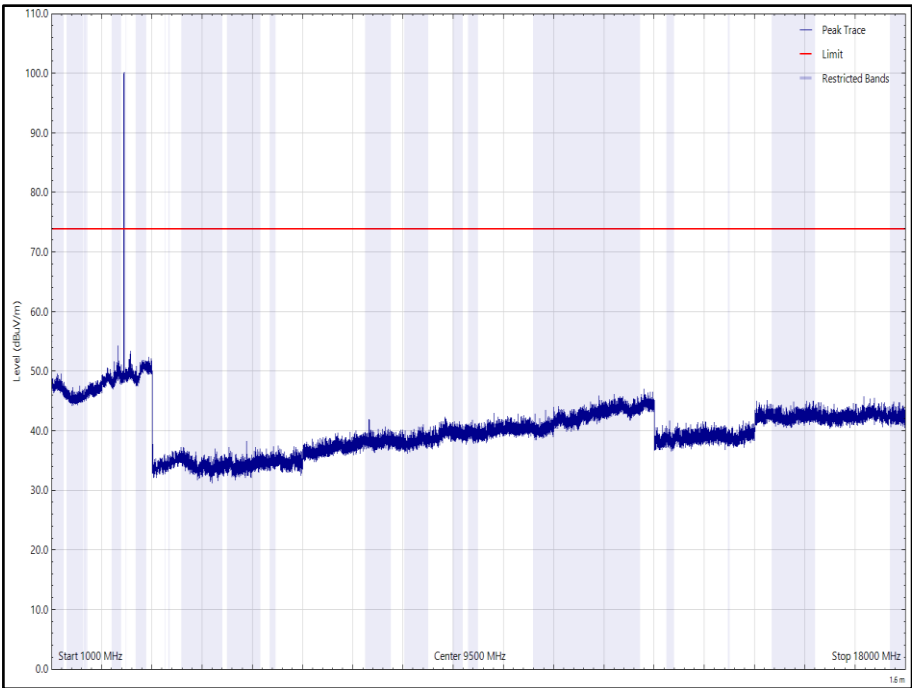


Figure 38 - BLE - Y, 2440 MHz, 1 GHz to 18 GHz, Vertical (Peak)

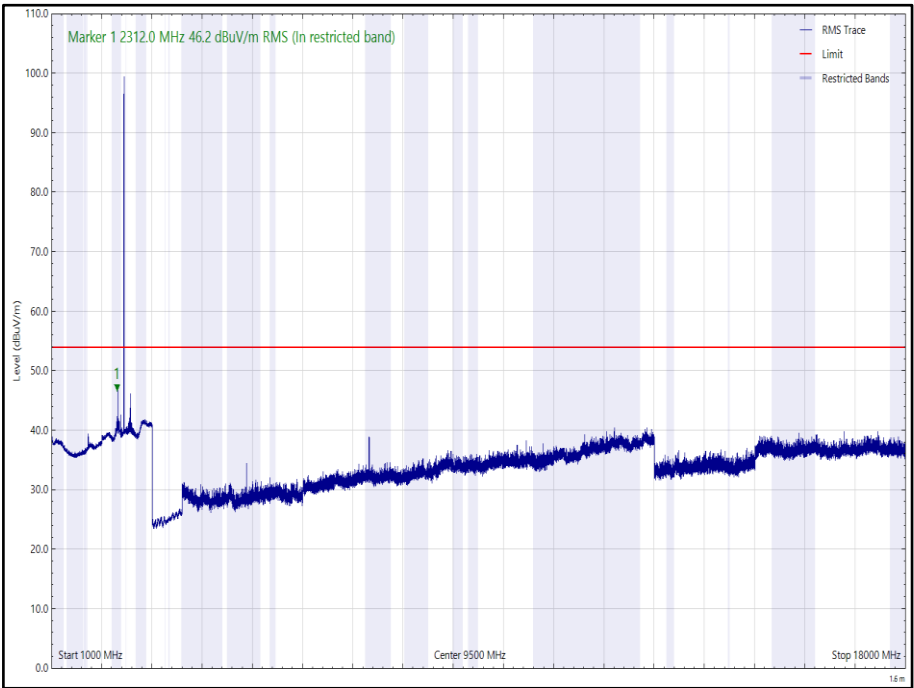


Figure 39 - BLE - Y, 2440 MHz, 1 GHz to 18 GHz, Vertical (rms)



Frequency (MHz)	Level (dBuV/m)	Limit (dBuV/m)	Margin (dB)	Detector	Angle (°)	Height (cm)	Polarisation
38.225	37.8	40.0	-2.2	Q-Peak	0	100	Vertical
2351.996	48.2	54.0	-5.8	RMS	318	135	Vertical

Table 30 - BLE - Y, 2480 MHz, 30 MHz to 18 GHz

No other emissions found within 10 dB of the limit.

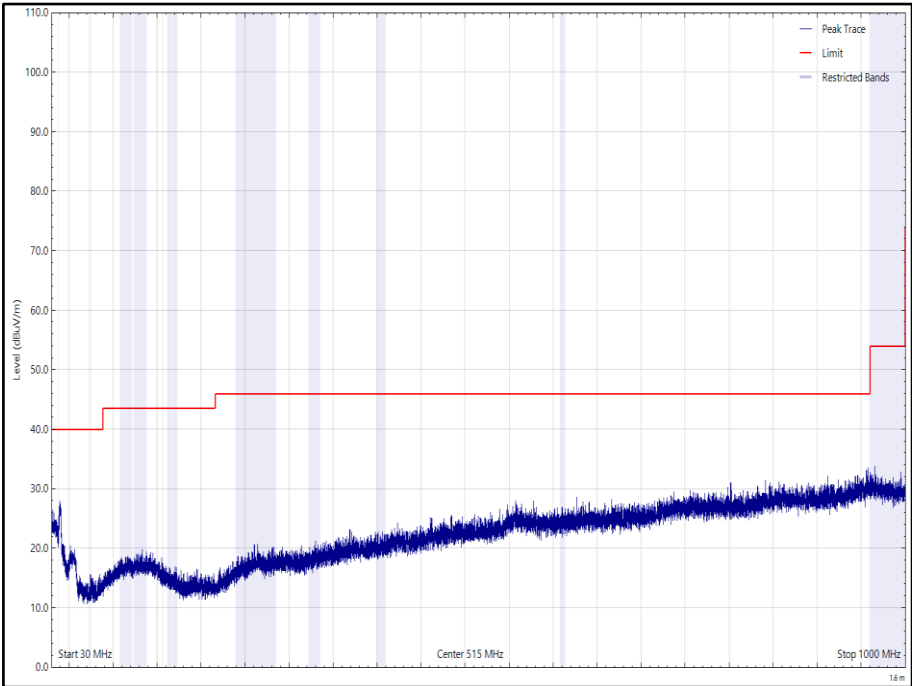


Figure 40 - BLE - Y, 2480 MHz, 30 MHz to 1 GHz, Horizontal (Peak)

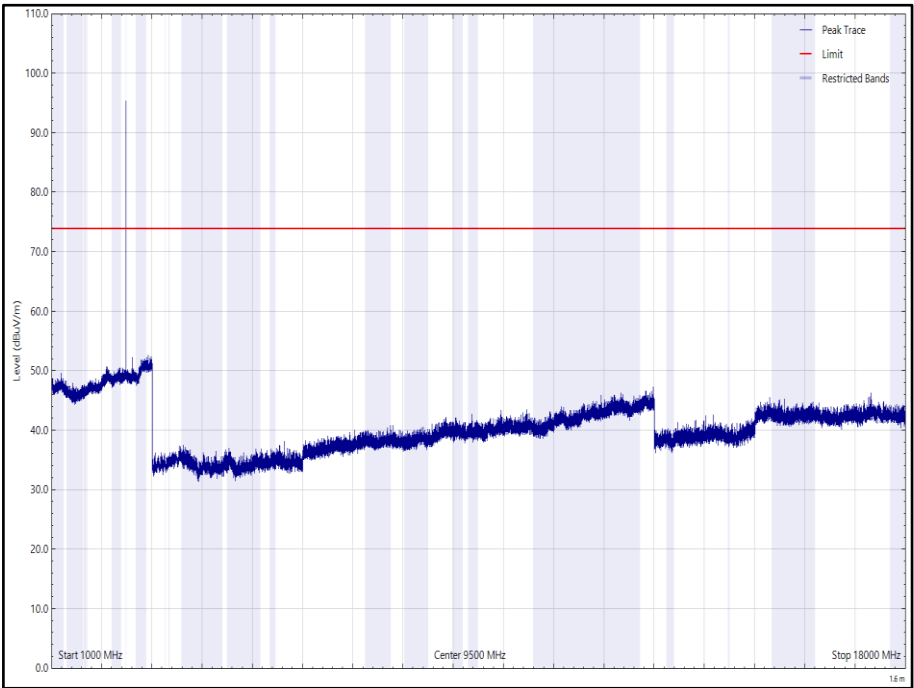


Figure 41 - BLE - Y, 2480 MHz, 1 GHz to 18 GHz, Horizontal (Peak)

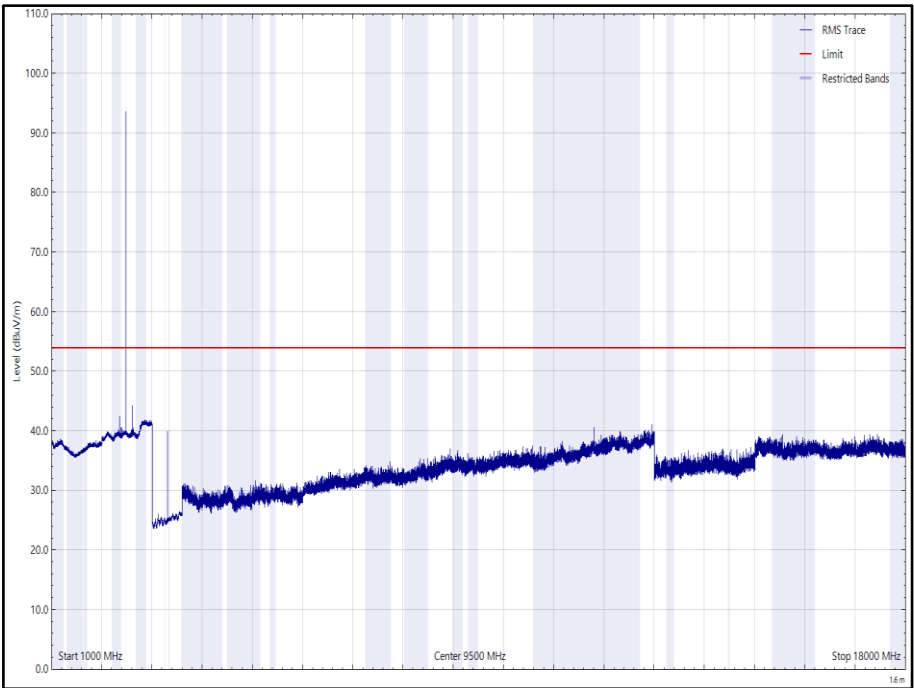


Figure 42 - BLE - Y, 2480 MHz, 1 GHz to 18 GHz, Horizontal (rms)

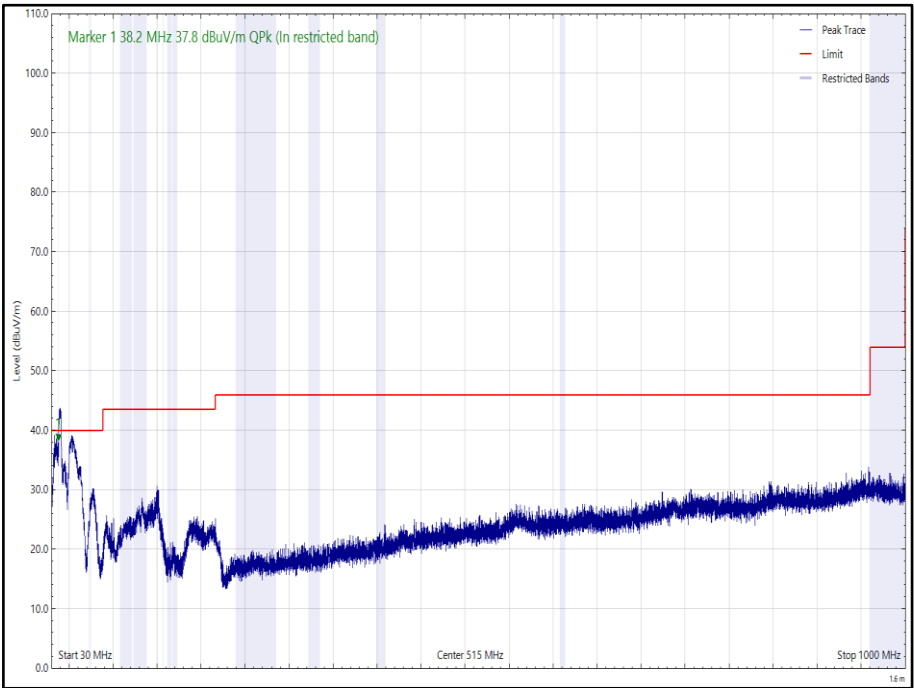


Figure 43 - BLE - Y, 2480 MHz, 30 MHz to 1 GHz, Vertical (Peak)

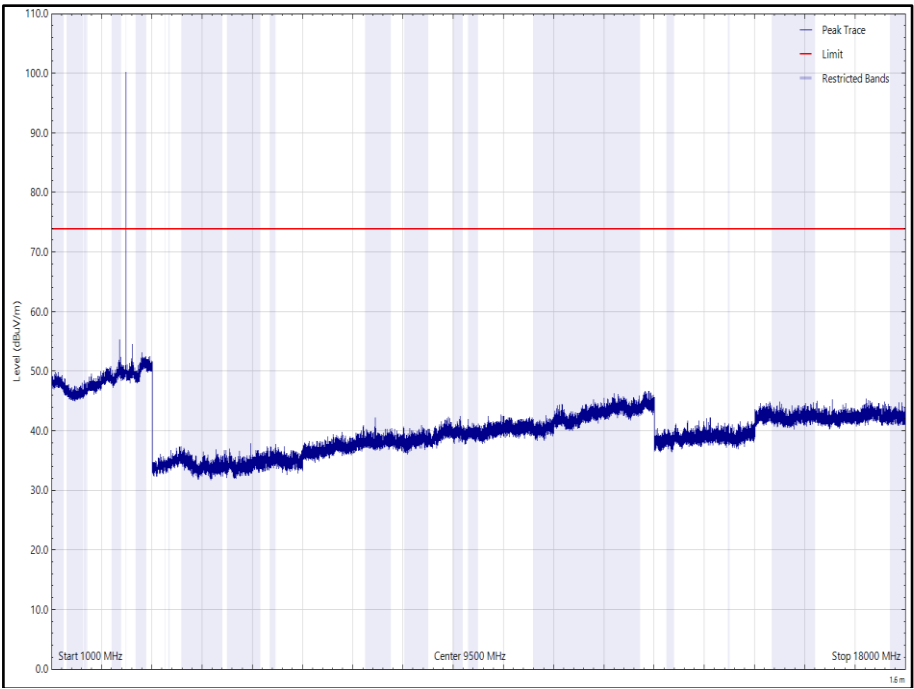


Figure 44 - BLE - Y, 2480 MHz, 1 GHz to 18 GHz, Vertical (Peak)

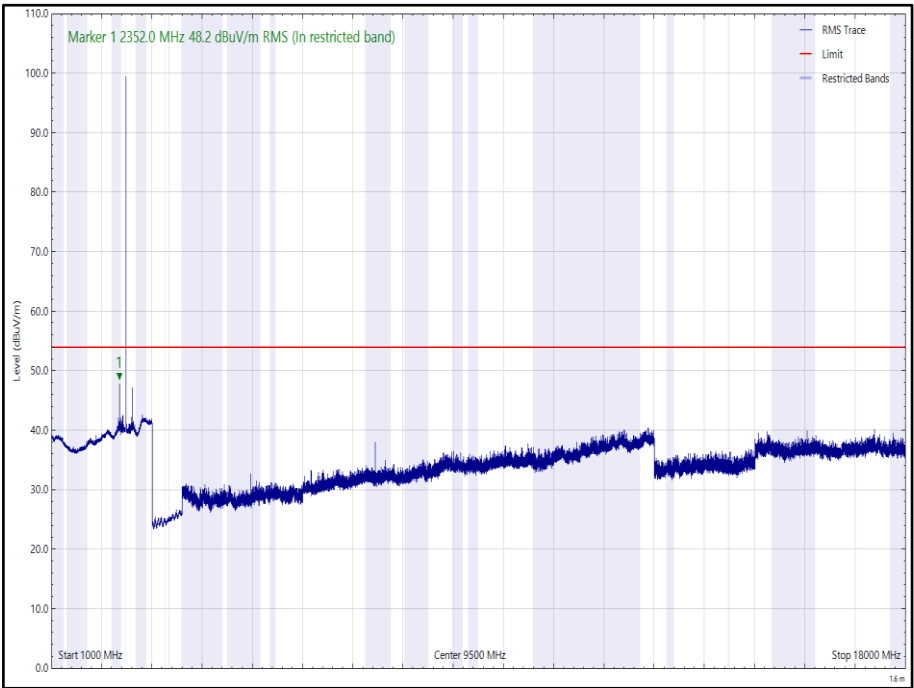


Figure 45 - BLE - Y, 2480 MHz, 1 GHz to 18 GHz, Vertical (rms)

Frequency (MHz)	Level (dBuV/m)	Limit (dBuV/m)	Margin (dB)	Detector	Angle (°)	Height (cm)	Polarisation
38.243	37.7	40.0	-2.3	Q-Peak	232	100	Vertical

Table 31 - BLE - Z, 2402 MHz, 30 MHz to 18 GHz

No other emissions found within 10 dB of the limit.

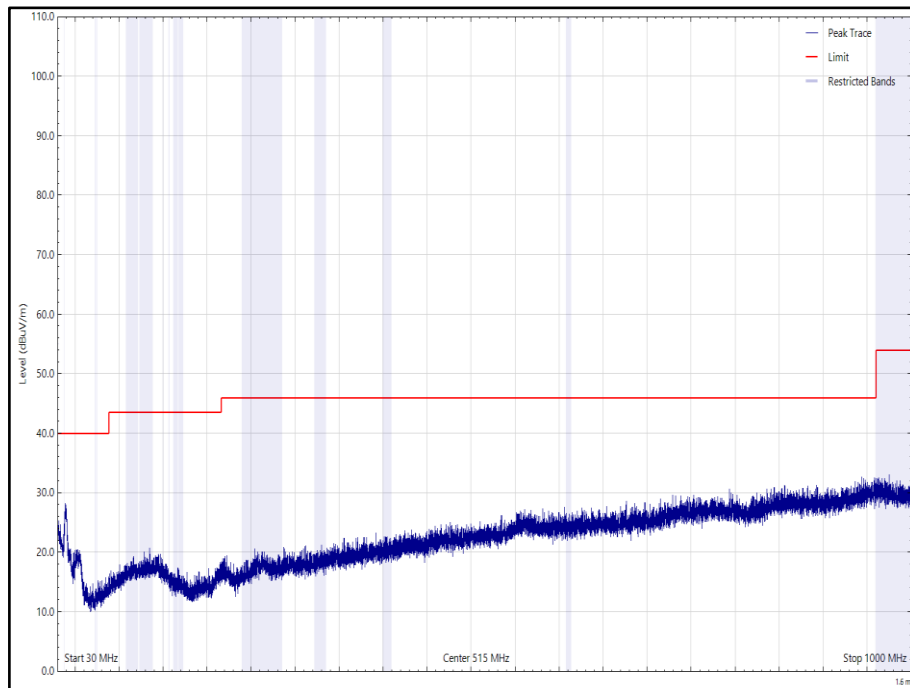


Figure 46 - BLE - Z, 2402 MHz, 30 MHz to 1 GHz, Horizontal (Peak)

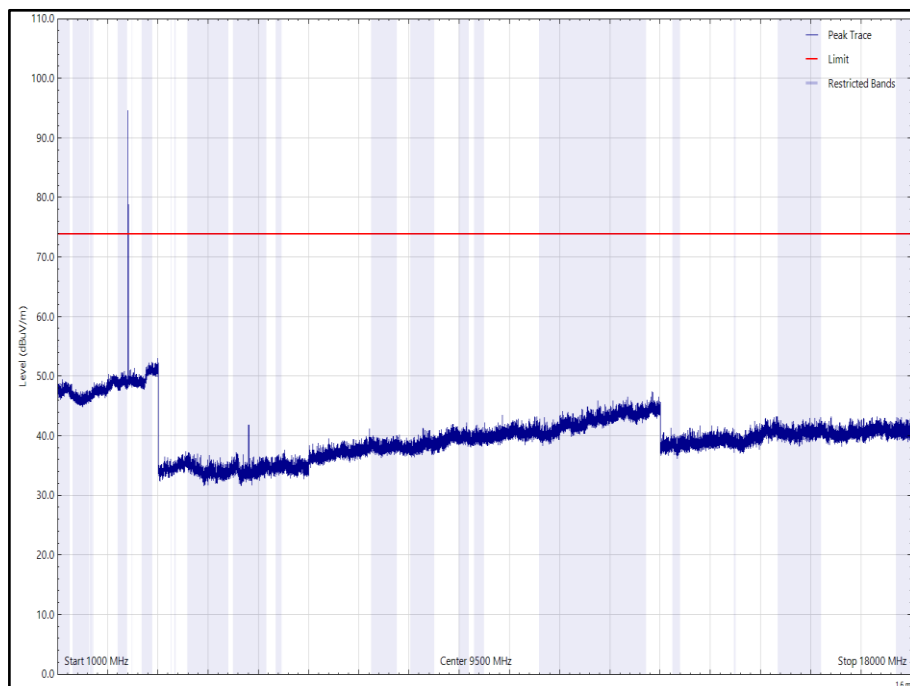


Figure 47 - BLE - Z, 2402 MHz, 1 GHz to 18 GHz, Horizontal (Peak)

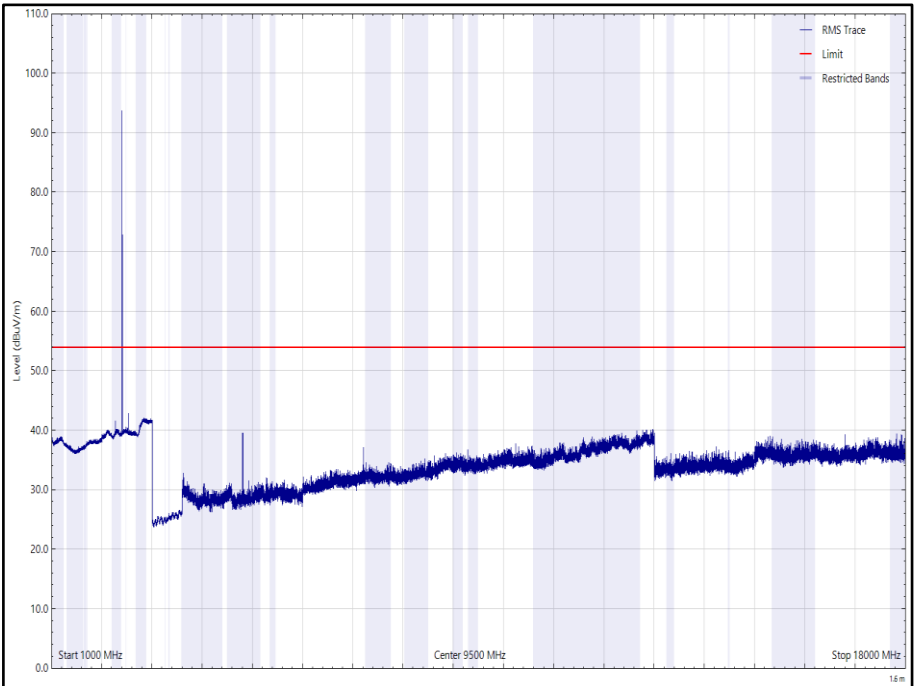


Figure 48 - BLE - Z, 2402 MHz, 1 GHz to 18 GHz, Horizontal (rms)

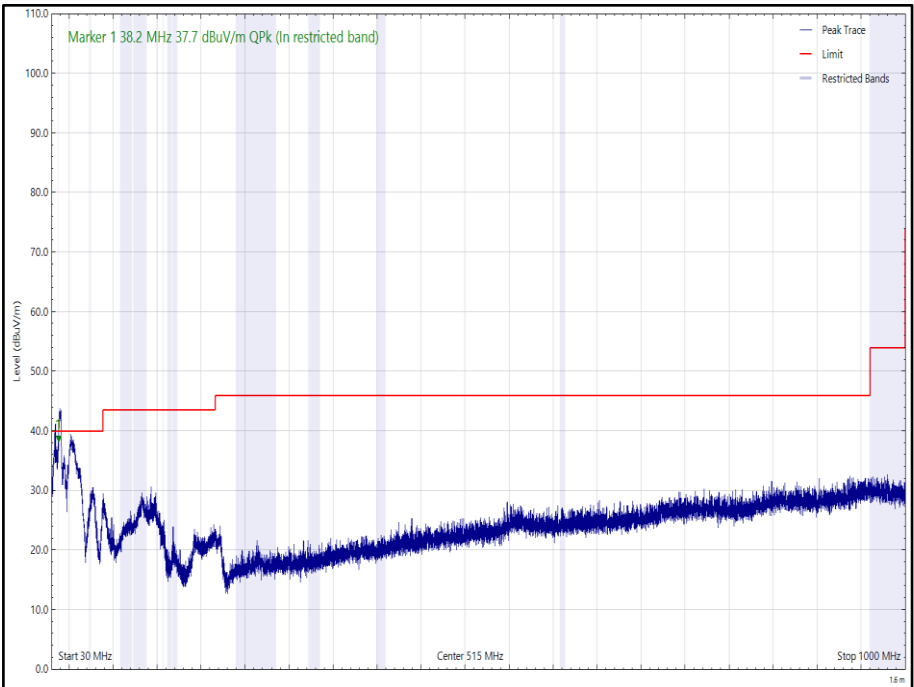


Figure 49 - BLE - Z, 2402 MHz, 30 MHz to 1 GHz, Vertical (Peak)

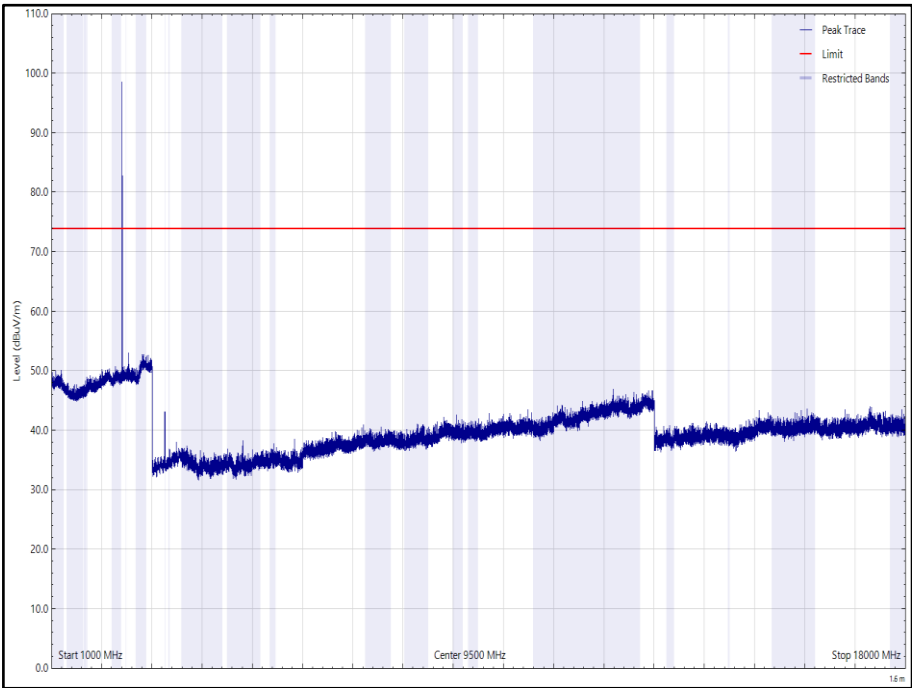


Figure 50 - BLE - Z, 2402 MHz, 1 GHz to 18 GHz, Vertical (Peak)

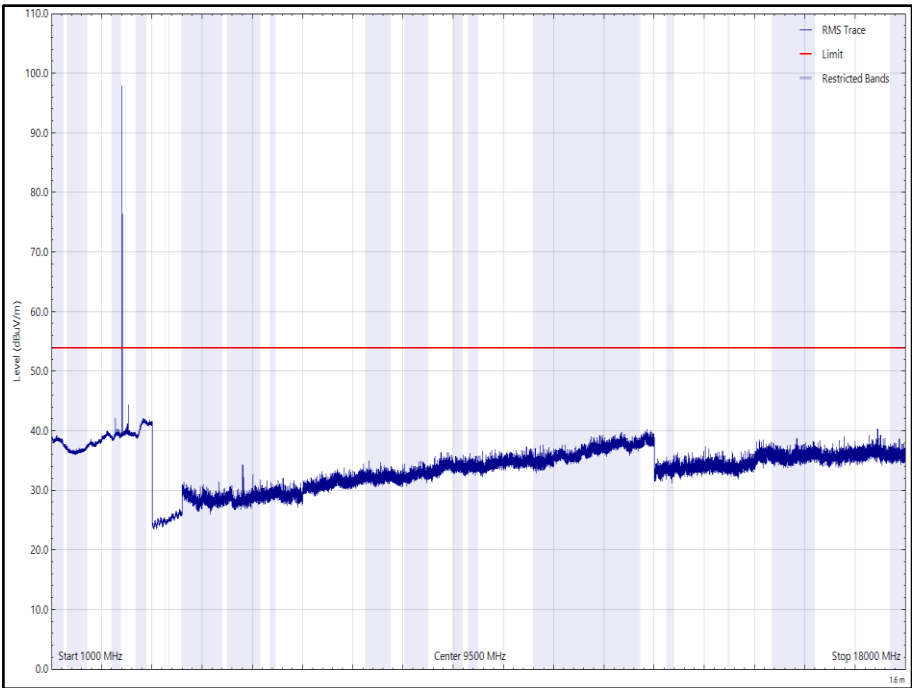


Figure 51 - BLE - Z, 2402 MHz, 1 GHz to 18 GHz, Vertical (rms)

Frequency (MHz)	Level (dBuV/m)	Limit (dBuV/m)	Margin (dB)	Detector	Angle (°)	Height (cm)	Polarisation
38.215	36.7	40.0	-3.3	Q-Peak	208	107	Vertical

Table 32 - BLE - Z, 2440 MHz, 30 MHz to 18 GHz

No other emissions found within 10 dB of the limit.

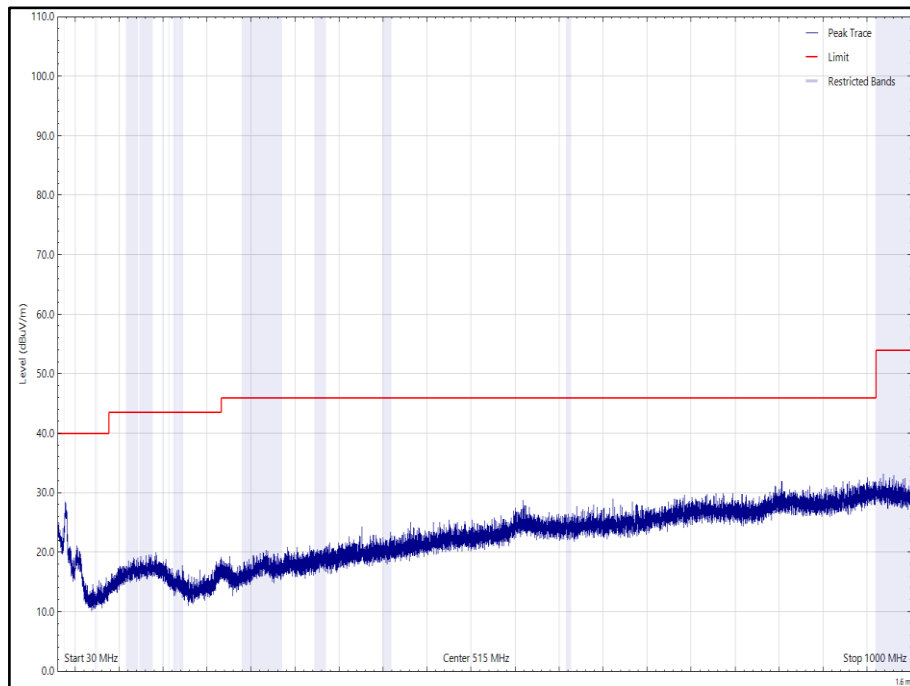


Figure 52 - BLE - Z, 2440 MHz, 30 MHz to 1 GHz, Horizontal (Peak)

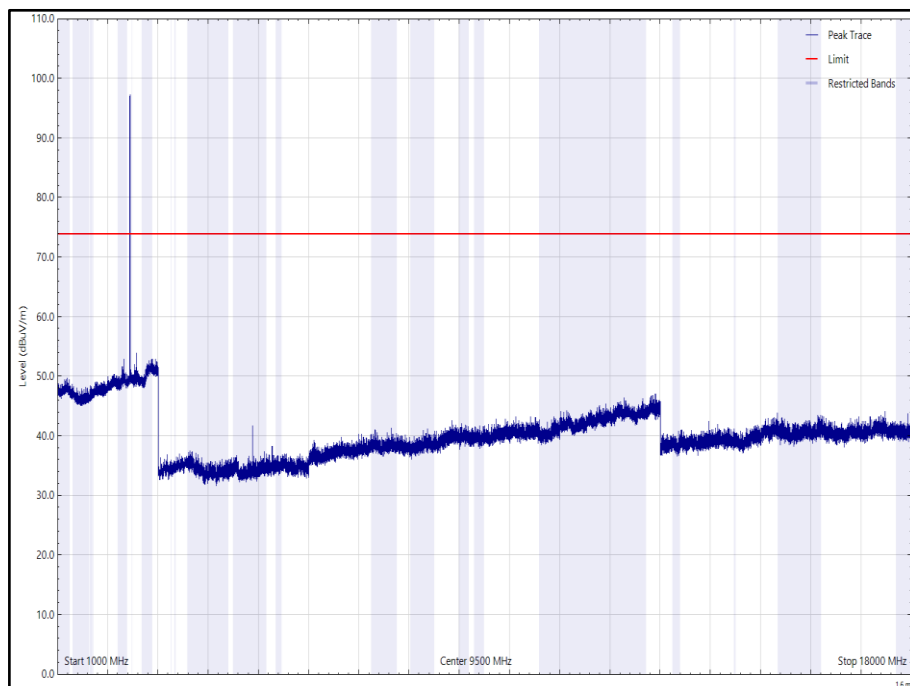


Figure 53 - BLE - Z, 2440 MHz, 1 GHz to 18 GHz, Horizontal (Peak)

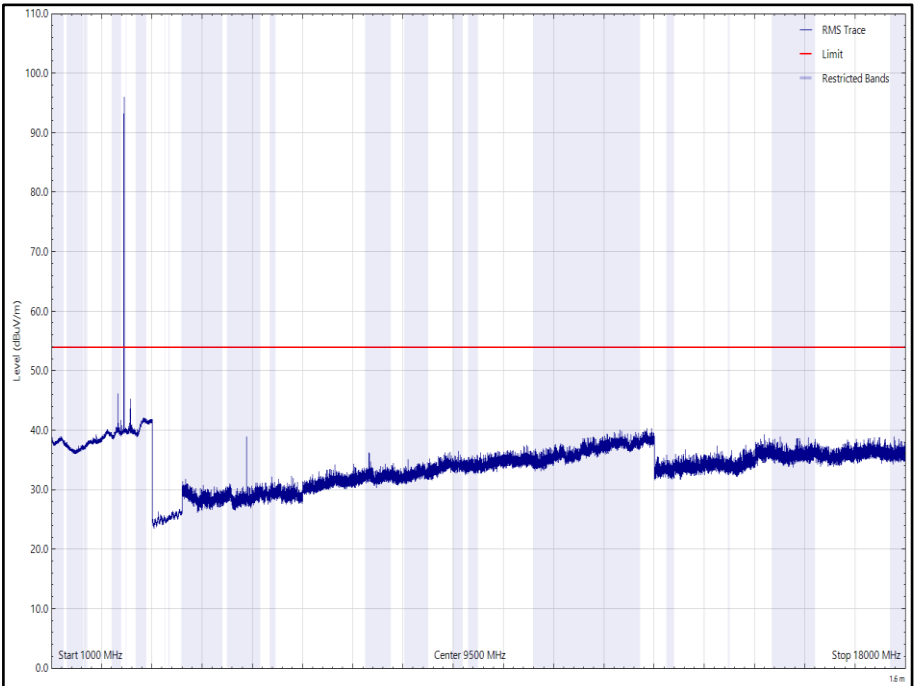


Figure 54 - BLE - Z, 2440 MHz, 1 GHz to 18 GHz, Horizontal (rms)

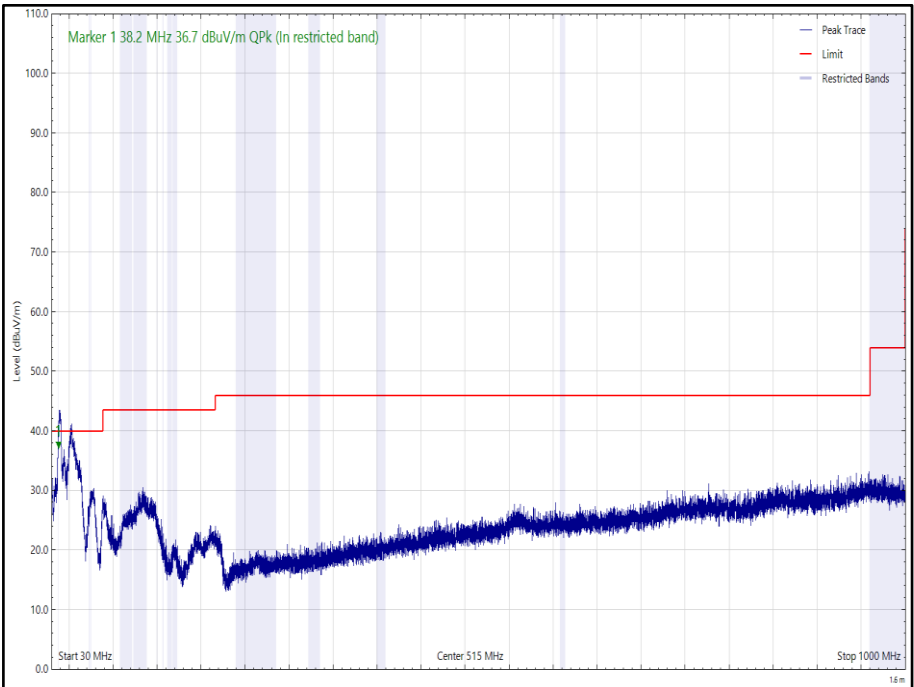


Figure 55 - BLE - Z, 2440 MHz, 30 MHz to 1 GHz, Vertical (Peak)

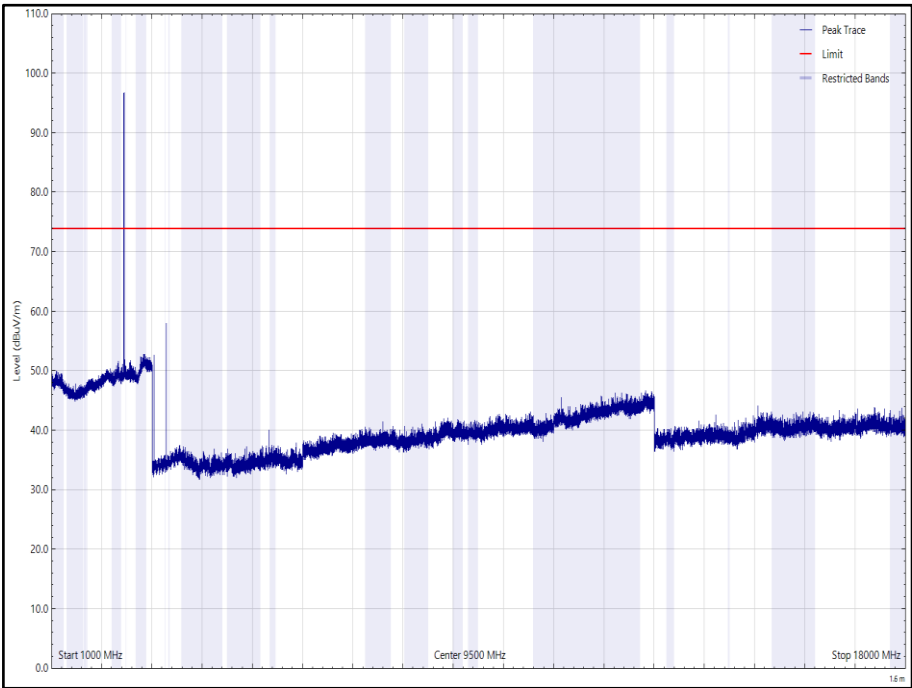


Figure 56 - BLE - Z, 2440 MHz, 1 GHz to 18 GHz, Vertical (Peak)

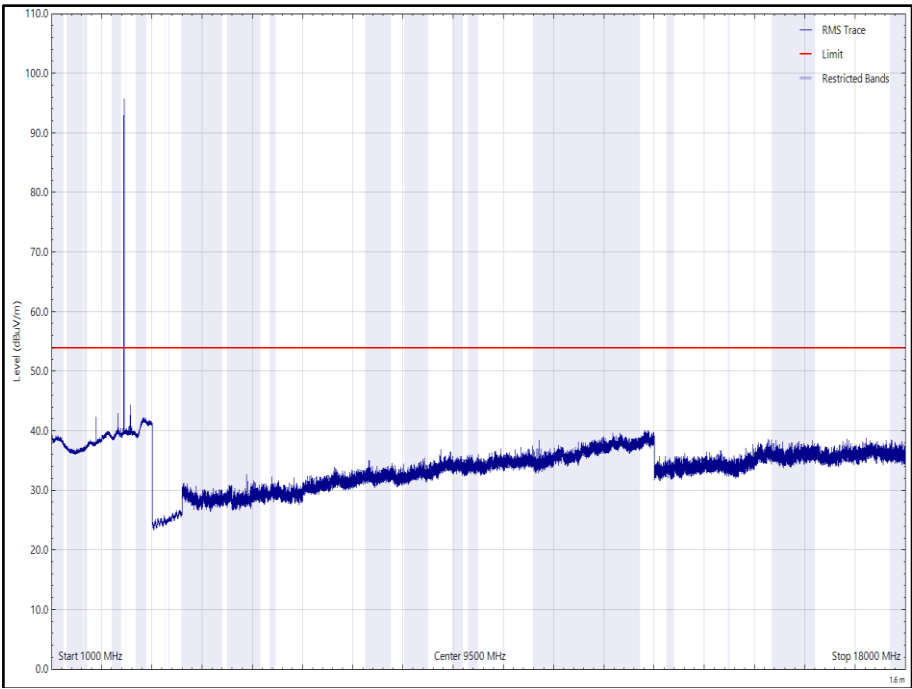


Figure 57 - BLE - Z, 2440 MHz, 1 GHz to 18 GHz, Vertical (rms)



Frequency (MHz)	Level (dBuV/m)	Limit (dBuV/m)	Margin (dB)	Detector	Angle (°)	Height (cm)	Polarisation
38.237	38.2	40.0	-1.8	Q-Peak	28	100	Vertical
2351.991	46.4	54.0	-7.6	RMS	191	171	Horizontal
2352.045	45.7	54.0	-8.3	RMS	307	275	Vertical

Table 33 - BLE - Z, 2480 MHz, 30 MHz to 18 GHz

No other emissions found within 10 dB of the limit.

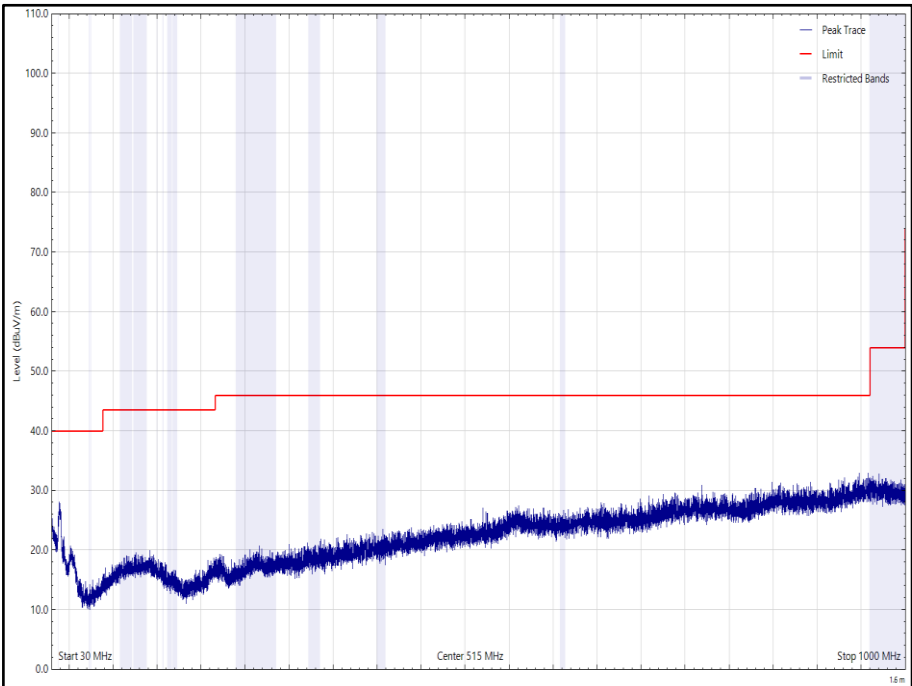


Figure 58 - BLE - Z, 2480 MHz, 30 MHz to 1 GHz, Horizontal (Peak)

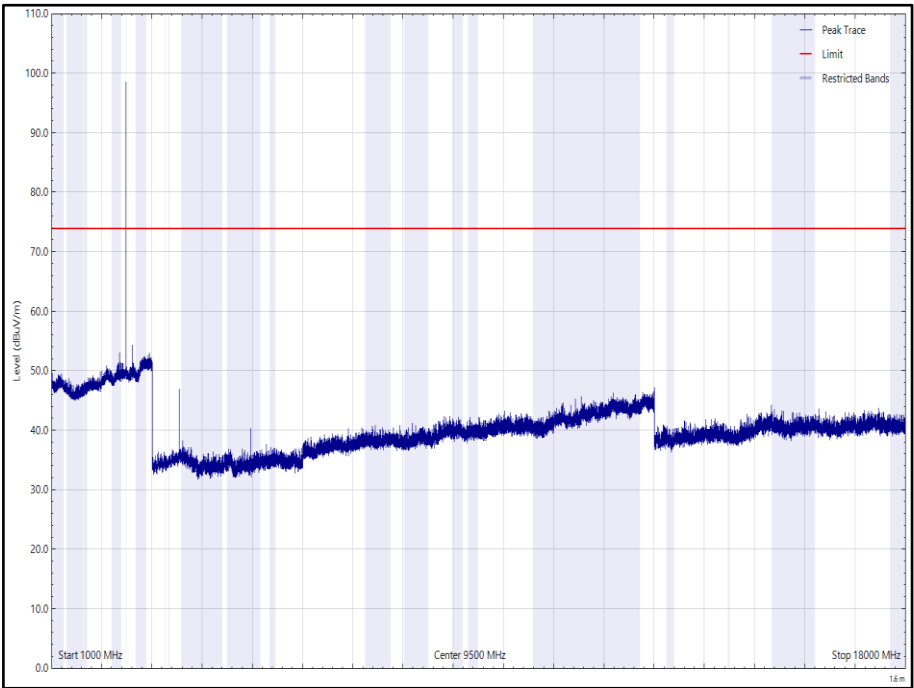


Figure 59 - BLE - Z, 2480 MHz, 1 GHz to 18 GHz, Horizontal (Peak)

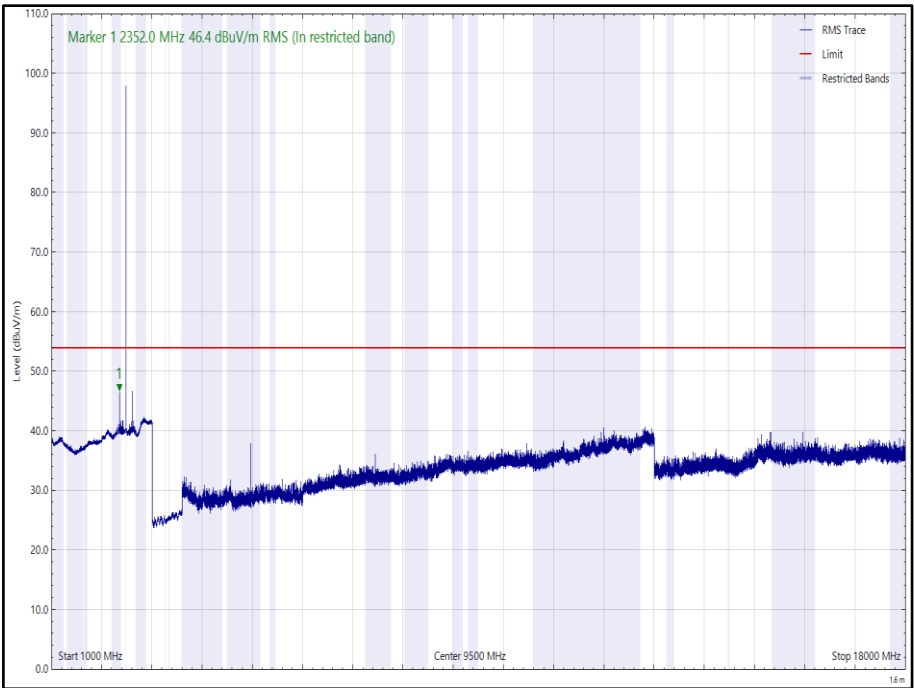


Figure 60 - BLE - Z, 2480 MHz, 1 GHz to 18 GHz, Horizontal (rms)

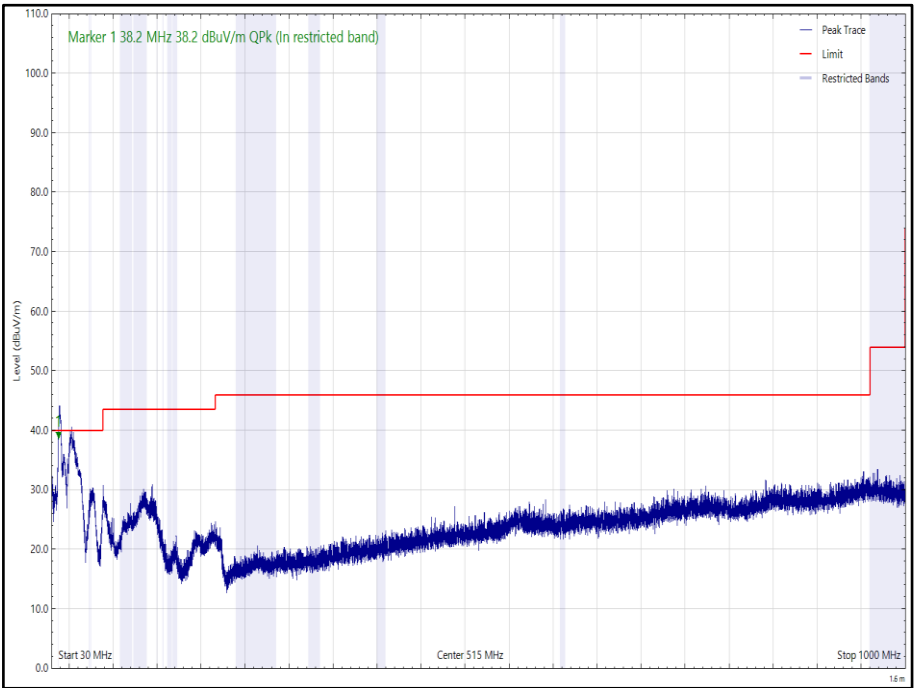


Figure 61 - BLE - Z, 2480 MHz, 30 MHz to 1 GHz, Vertical (Peak)

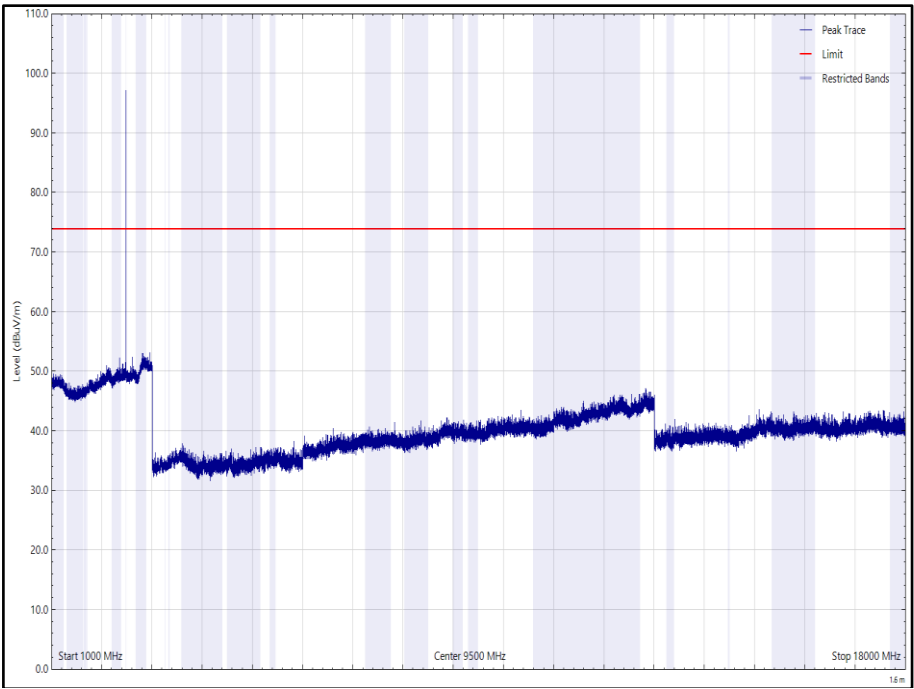


Figure 62 - BLE - Z, 2480 MHz, 1 GHz to 18 GHz, Vertical (Peak)

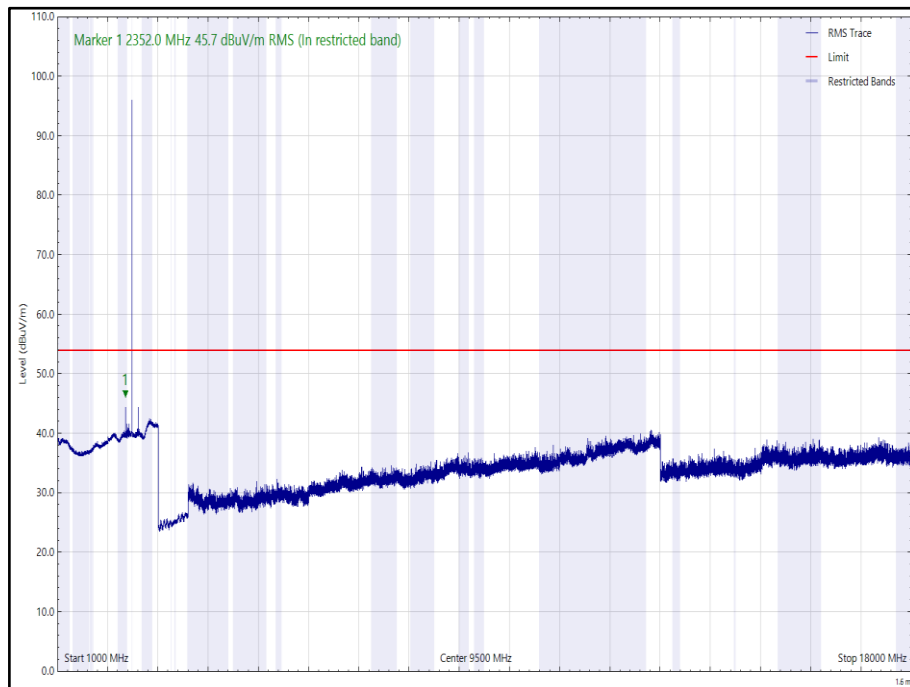


Figure 63 - BLE - Z, 2480 MHz, 1 GHz to 18 GHz, Vertical (rms)

FCC 47 CFR Part 15, Limit Clause 15.247 (d)

In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30 dB instead of 20 dB.

Attenuation below the general limits specified in § 15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in § 15.205(a), must also comply with the radiated emission limits specified in 15.209(a)



2.4.8 Test Location and Test Equipment Used

This test was carried out in EMC Chamber 12.

Instrument	Manufacturer	Type No.	TE No.	Calibration Period (months)	Calibration Expiry Date
Power Supply Unit	Hewlett Packard	6269B	113	-	O/P Mon
Comb Generator	Schaffner	RSG1000	3034	-	TU
Test Receiver	Rohde & Schwarz	ESU40	3506	12	18-Mar-2022
Multimeter	Fluke	177	3832	12	08-Jul-2022
Cable (SMA to SMA, 2 m)	Rhophase	3PS-1801A-2000-3PS	4113	12	27-Jan-2023
Emissions Software	TUV SUD	EmX V2.1.12 V.2.1.12	5125	-	Software
Horn Antenna (15-40 GHz)	Schwarzbeck	BBHA9170	5217	12	25-Jan-2023
Preamplifier (30 dB 18-40 GHz)	Schwarzbeck	BBV9721	5218	12	25-Jan-2023
Cable (N-Type to N-Type, 8 m)	Teledyne	PR90-088-8MTR	5450	6	01-Apr-2022
Thermo-Hygro-Barometer	PCE Instruments	PCE-THB-40	5481	12	31-Mar-2022
Antenna (DRG, 7.5 GHz to 18 GHz)	Schwarzbeck	HWRD750	5610	12	15-Oct-2022
Antenna (DRG, 1 GHz to 10 GHz)	Schwarzbeck	BBHA 9120 B	5611	12	15-Oct-2022
Turntable & Mast Controller	Maturo Gmbh	NCD/498/2799.01	5612	-	TU
Tilt Antenna Mast	Maturo Gmbh	TAM 4.0-P	5613	-	TU
Turntable	Maturo Gmbh	Turntable 1.5 SI-2t	5614	-	TU
Antenna (Bi-Log, 30 MHz to 1 GHz)	Teseq	CBL6111D	5615	24	16-Oct-2022
Screened Room (12)	MVG	EMC-3	5621	36	11-Aug-2023

Table 34

TU – Traceability Unscheduled

O/P Mon – Output Monitored using calibrated equipment



2.5 Authorised Band Edges

2.5.1 Specification Reference

FCC 47 CFR Part 15C, Clause 15.247 (d)

2.5.2 Equipment Under Test and Modification State

MiX 4401-B, S/N: 55000206 - Modification State 0

2.5.3 Date of Test

07-March-2022

2.5.4 Test Method

The test was performed in accordance with ANSI C63.10, clause 6.10.4.

2.5.5 Environmental Conditions

Ambient Temperature	20.2 °C
Relative Humidity	26.8 %



2.5.6 Test Results

2.4 GHz Bluetooth Low Energy

Modulation	Frequency (MHz)	Band Edge Frequency (MHz)	Level (dBc)
GFSK	2402	2400	-52.78
GFSK	2480	2483.6	-55.26

Table 35

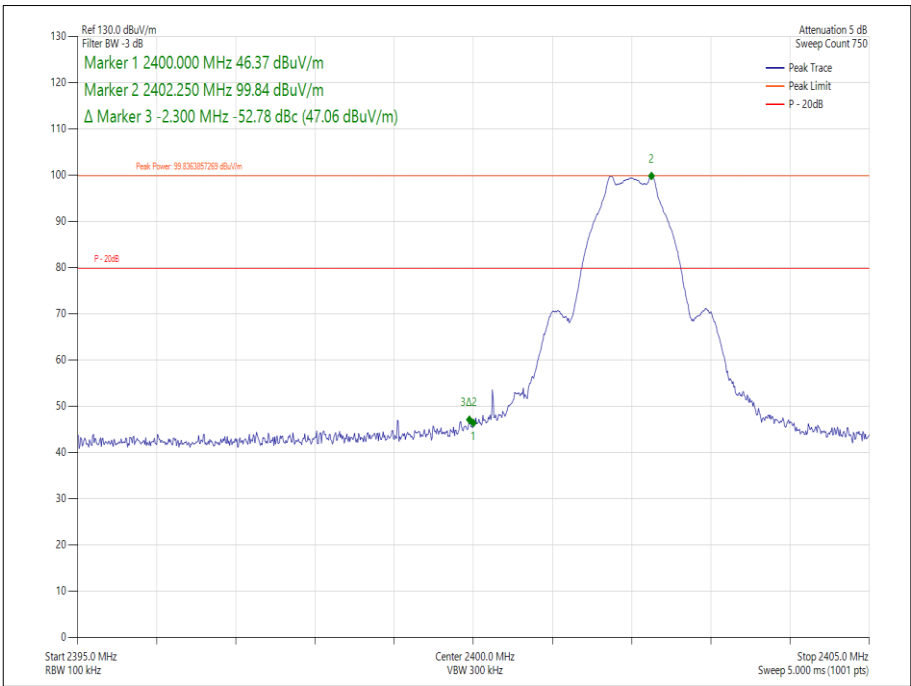


Figure 64 - GFSK, 2402 MHz - Measured Frequency 2400 MHz

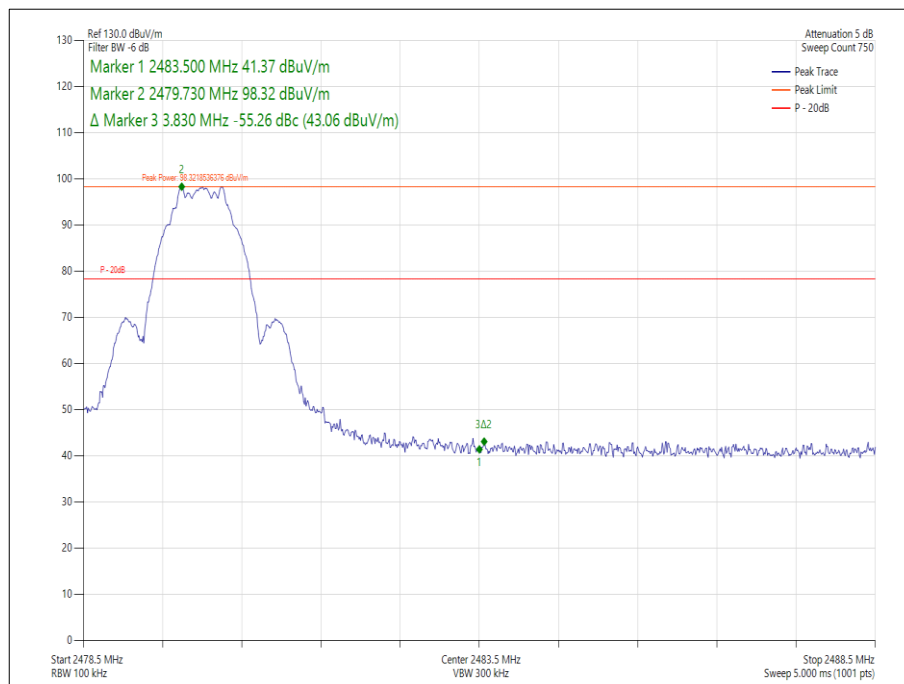


Figure 65 - GFSK, 2480 MHz - Measured Frequency 2483.6 MHz

FCC 47 CFR Part 15, Limit Clause 15.247 (d)

20 dB below the fundamental measured in a 100 kHz bandwidth using a peak detector. If the transmitter complies with the conducted power limits, based on the use of RMS averaging over a time interval, the attenuation required shall be 30 dB below the fundamental instead of 20 dB.



2.5.7 Test Location and Test Equipment Used

This test was carried out in EMC Chamber 12.

Instrument	Manufacturer	Type No.	TE No.	Calibration Period (months)	Calibration Expiry Date
Power Supply Unit	Hewlett Packard	6269B	113	-	O/P Mon
Test Receiver	Rohde & Schwarz	ESU40	3506	12	18-Mar-2022
Multimeter	Fluke	177	3832	12	08-Jul-2022
Emissions Software	TUV SUD	EmX V2.1.12 V.2.1.12	5125	-	Software
Cable (N-Type to N-Type, 8 m)	Teledyne	PR90-088-8MTR	5450	6	08-Mar-2022
Thermo-Hygro-Barometer	PCE Instruments	PCE-THB-40	5481	12	31-Mar-2022
Cable (K-Type to K-Type, 2 m)	Junkosha	MWX241-02000KMSKMS/A	5524	12	24-Mar-2022
Antenna (DRG, 1 GHz to 10 GHz)	Schwarzbeck	BBHA 9120 B	5611	12	15-Oct-2022
Turntable & Mast Controller	Maturo Gmbh	NCD/498/2799.01	5612	-	TU
Tilt Antenna Mast	Maturo Gmbh	TAM 4.0-P	5613	-	TU
Turntable	Maturo Gmbh	Turntable 1.5 SI-2t	5614	-	TU
Screened Room (12)	MVG	EMC-3	5621	36	11-Aug-2023

Table 36

TU – Traceability Unscheduled

O/P Mon – Output Monitored using calibrated equipment



2.6 Power Spectral Density

2.6.1 Specification Reference

FCC 47 CFR Part 15C, Clause 15.247 (e)

2.6.2 Equipment Under Test and Modification State

MiX 4401-B, S/N: 55000202 - Modification State 0

2.6.3 Date of Test

12-April-2022

2.6.4 Test Method

This test was performed in accordance with ANSI C63.10, clause 11.10.2

2.6.5 Environmental Conditions

Ambient Temperature	23.4 °C
Relative Humidity	42.5 %



2.6.6 Test Results

2.4 GHz Bluetooth Low Energy

Test Configuration			
Frequency Range:	2400-2483.5 MHz	Band:	2.4 GHz
Limit Clause(s):	15.247 (e) RSS-247 5.2 b)	Test Method(s):	C63.10 11.10.2
Additional Reference(s):	-		

DUT Configuration			
Mode:	BLE GFSK (LE 1M)	Duty Cycle (%):	100.0
Antenna Configuration:	SISO	DCCF (dB):	-
Active Port(s):	A (BLE)	Peak Antenna Gain (dBi):	-

Test Frequency (MHz)	RBW (kHz)	PSD (dBm/RBW)					Limit (dBm/3 kHz)	Margin (dB)
		A	B	C	D	Σ		
2402	3.0	-8.61	-	-	-	-	8.00	-16.61
2440	3.0	-9.78	-	-	-	-	8.00	-17.78
2480	3.0	-8.33	-	-	-	-	8.00	-16.33

Table 37 - Maximum Power Spectral Density Results

FCC 47 CFR Part 15, Limit Clause 15.247 (e)

The power spectral density conducted from the intentional radiator to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.



2.6.7 Test Location and Test Equipment Used

This test was carried out in RF Laboratory 1.

Instrument	Manufacturer	Type No.	TE No.	Calibration Period (months)	Calibration Expiry Date
Multimeter	Iso-tech	IDM101	2421	12	28-Oct-2022
Hygrometer	Rotronic	I-1000	3220	12	05-Nov-2022
Frequency Standard	Spectracom	SecureSync 1200-0408-0601	4393	6	30-Jun-2022
MXA Signal Analyser	Keysight Technologies	N9020B	5529	24	06-Jun-2022
Signal Commissioning Unit	TUV SUD	SCU002	5759	12	30-Jun-2022
Modular Power System Mainframe	Keysight Technologies	N6701C	5835	-	TU
DC Power Module 60V 20A 300W	Keysight Technologies	N6754A	5836	-	O/P Mon

Table 38

TU – Traceability Unscheduled

O/P Mon – Output Monitored using calibrated equipment

3 Photographs

3.1 Test Setup Photographs

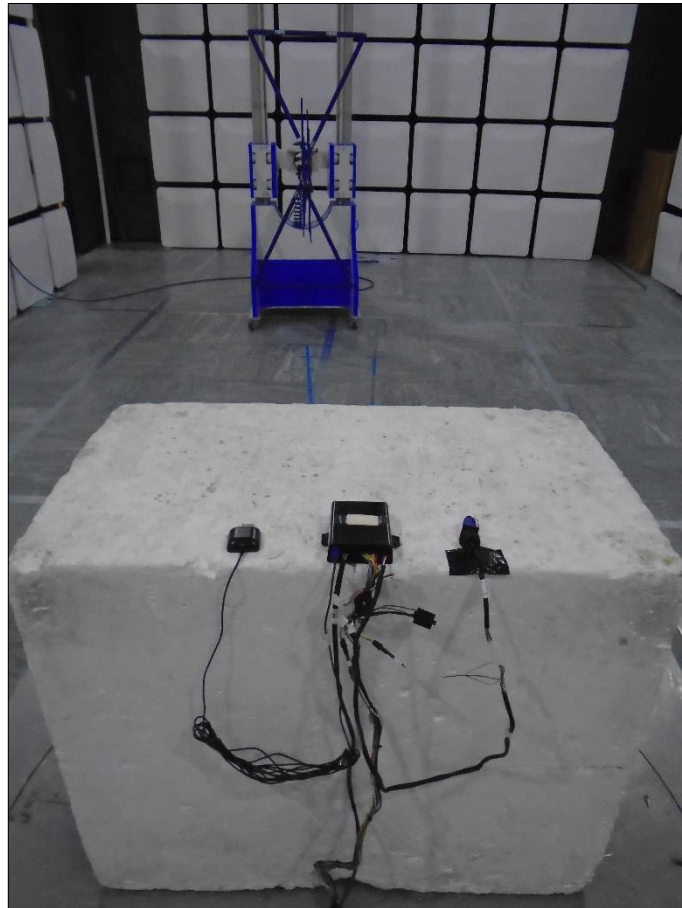


Figure 66 - Test Setup - 30 MHz to 1 GHz - X Orientation

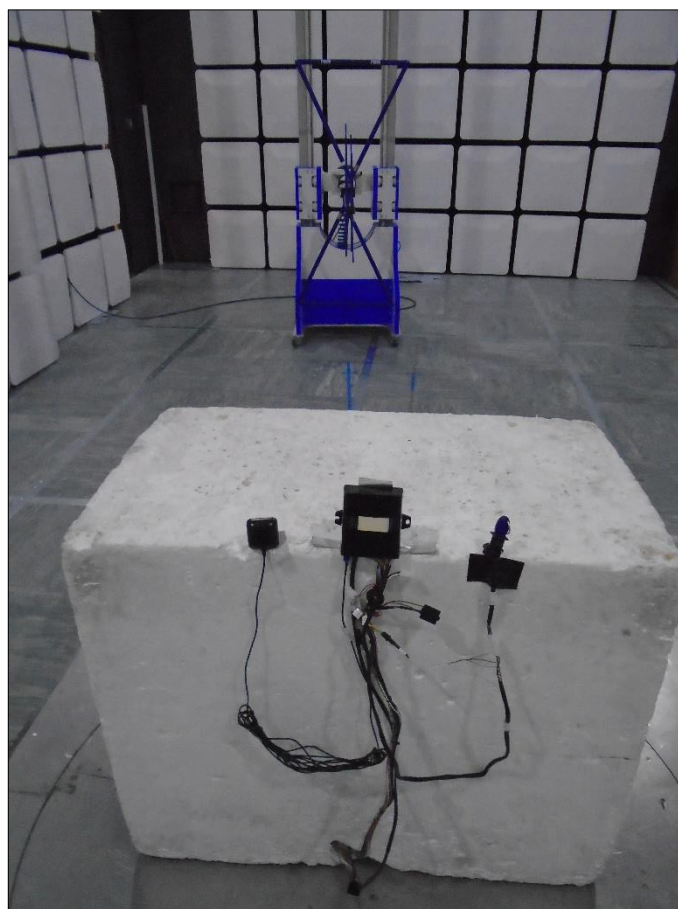


Figure 67 - Test Setup - 30 MHz to 1 GHz - Y Orientation

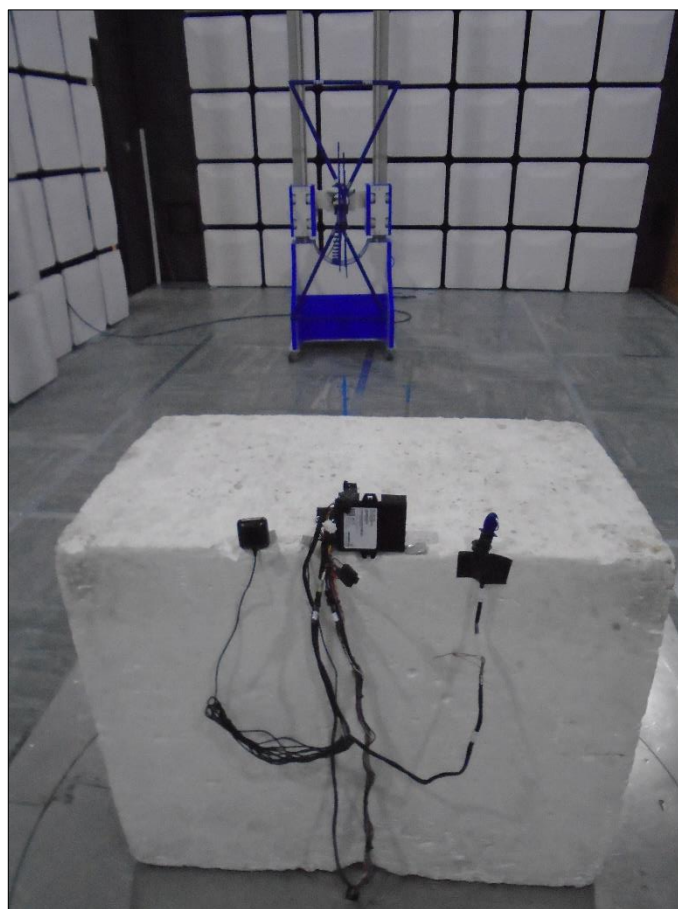


Figure 68 - Test Setup - 30 MHz to 1 GHz - Z Orientation

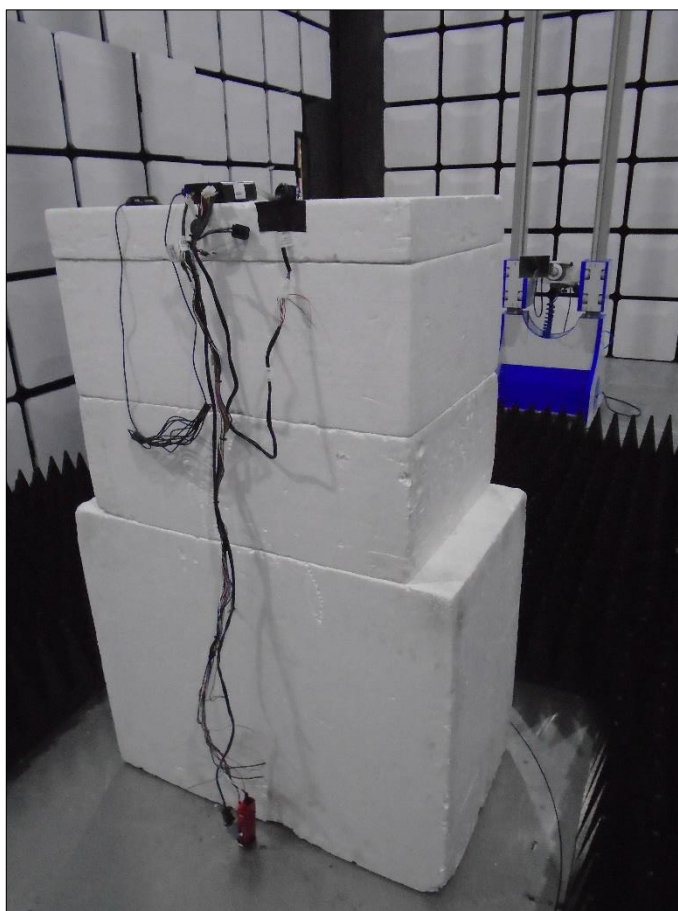


Figure 69 - Test Setup - 1 GHz to 18 GHz - X Orientation

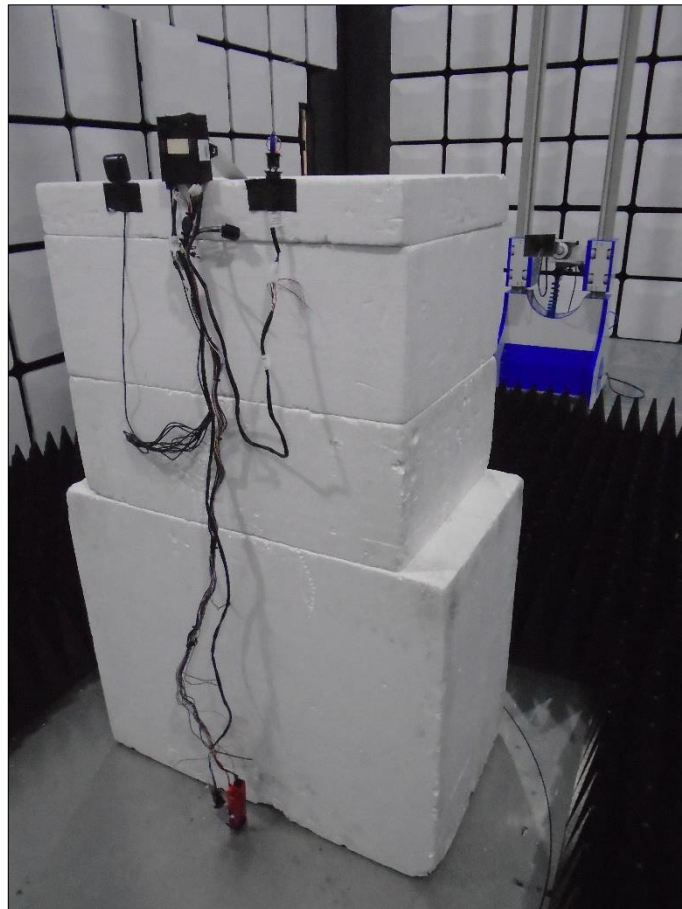


Figure 70 - Test Setup - 1 GHz to 18 GHz - Y Orientation

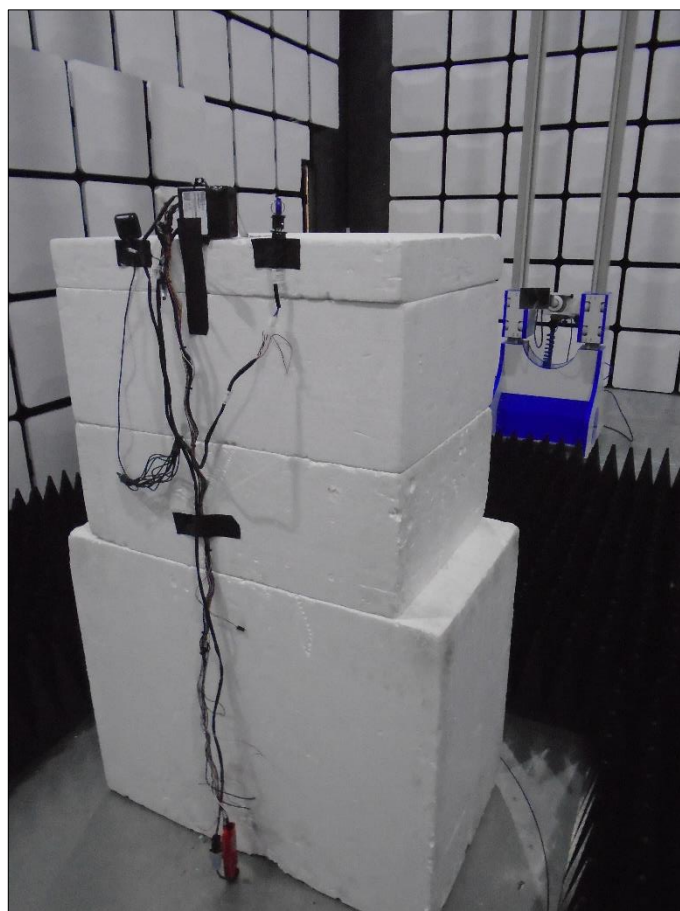


Figure 71 - Test Setup - 1 GHz to 18 GHz - Z Orientation



Figure 72 - Test Setup - 18 GHz to 25 GHz - X Orientation



Figure 73 - Test Setup - 18 GHz to 25 GHz - Y Orientation



Figure 74 - Test Setup - 18 GHz to 25 GHz - Z Orientation



4 Measurement Uncertainty

For a 95% confidence level, the measurement uncertainties for defined systems are:

Test Name	Measurement Uncertainty
Restricted Band Edges	30 MHz to 1 GHz: ± 5.2 dB 1 GHz to 40 GHz: ± 6.3 dB
Emission Bandwidth	± 25.35 kHz
Maximum Conducted Output Power	± 3.2 dB
Spurious Radiated Emissions	30 MHz to 1 GHz: ± 5.2 dB 1 GHz to 40 GHz: ± 6.3 dB
Authorised Band Edges	30 MHz to 1 GHz: ± 5.2 dB 1 GHz to 40 GHz: ± 6.3 dB
Power Spectral Density	± 3.2 dB

Table 39

Measurement Uncertainty Decision Rule – Accuracy Method

Determination of conformity with the specification limits is based on the decision rule according to IEC Guide 115:2007, Clause 4.4.3 and 4.5.1. (Procedure 2). The measurement results are directly compared with the test limit to determine conformance with the requirements of the standard.

Risk: The uncertainty of measurement about the measured result is negligible with regard to the final pass/fail decision. The measurement result can be directly compared with the test limit to determine conformance with the requirement (compare IEC Guide 115). The level of risk to falsely accept and falsely reject items is further described in ILAC-G8.