Report on the Radio Testing

For

Pektron Group Limited

On

BTLE Node

Report no. TRA-051982-47-04B

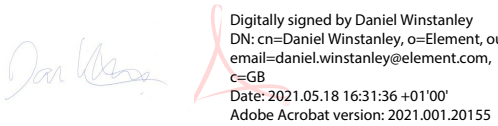
2021-05-18

Report Number: TRA-051982-47-04B
Issue: B

REPORT ON THE RADIO TESTING OF A
Pektron Group Limited
BTLE Node
WITH RESPECT TO SPECIFICATION
FCC 47CFR 15.247

TEST DATE: 2021-03-02 to 2021-03-04

Written by: Steven Garwell
Radio Test Engineer



Approved by: Daniel Winstanley
Senior Radio Test Engineer

Date: 2021-05-18

1 Revision Record

Issue Number	*Issue Date*	*Revision History*
A	2021-04-19	Original
B	2021-05-18	General Updates

2 Summary

TEST REPORT NUMBER:	TRA-051982-47-04B
WORKS ORDER NUMBER:	TRA-051982-02
PURPOSE OF TEST:	USA: Testing of radio frequency equipment per the relevant authorization procedure of chapter 47 of CFR (code of federal regulations) Part 2, subpart J.
TEST SPECIFICATION:	FCC 47CFR 15.247
FCC ID:	AQO012
EQUIPMENT UNDER TEST (EUT:	BTLE Node
EUT SERIAL NUMBER(S):	AB10001330 (Radiated) AB10001263 (Conducted)
MANUFACTURER/AGENT:	Pektron Group Limited
ADDRESS:	Alfreton Road Derby Derbyshire DE21 4AP United Kingdom
CLIENT CONTACT:	Richard Jones ☎ 01332832424 ext 382 ✉ rjones@pektron.co.uk
ORDER NUMBER:	PROJ-00000632
TEST DATE:	2021-03-02 to 2021-03-04
TESTED BY:	Steven Garwell, Michael Else Element

2.1 Test Summary

Test Method and Description		*Requirement Clause*	*Applicable to this equipment*	*Result / Note*
		47CFR15		
Radiated spurious emissions (restricted bands of operation and cabinet radiation)		15.205	☒	*Pass*
AC power line conducted emissions		15.207	☐	*Note 1*
Occupied bandwidth		15.247(a)(2)	☒	*Pass*
Conducted carrier power	Peak	15.247(b)(3)	☒	*Pass*
	Max.		☐	
Conducted / radiated RF power out-of-band		15.247(d)	☒	*Pass*
Power spectral density, conducted		15.247(e)	☒	*Pass*
Calculation of duty correction		15.35(c)	☒	-

Note 1: Not applicable, not connected to the mains.

Notes:

The results contained in this report relate only to the items tested, in the condition at time of test, and were obtained in the period between the date of initial receipt of samples and the date of issue of the report.

The apparatus was set up and exercised using the configurations, modes of operation and arrangements defined in this report only. Any modifications made are identified in Section 8 of this report.

Particular operating modes, apparatus monitoring methods and performance criteria required by the standards tested to have been performed except where identified in Section 5.2 of this test report (Deviations from Test Standards).

3 Contents

4 Introduction

This report TRA-051982-47-04B presents the results of the Radio testing on a Qualcomm Technologies International Ltd., BTLE Node to specification 47CFR15 Radio Frequency Devices.

The testing was carried out for Pektron Group Limited, by Element, at the address detailed below.

☐ Element Hull
Unit E
South Orbital Trading Park
Hedon Road
Hull
HU9 1NJ
UK

☒ Element Skelmersdale
Unit 1
Pendle Place
Skemersdale
West Lancashire
WN8 9PN
UK

This report details the configuration of the equipment, the test methods used and any relevant modifications where appropriate.

All test and measurement equipment under the control of the laboratory and requiring calibration is subject to an established programme and procedures to control and maintain measurement standards. The quality management system meets the principles of ISO 9001, and has quality control procedures for monitoring the validity of tests undertaken. Records and sufficient detail are retained to establish an audit trail of calibration records relating to its test results for a defined period. Under control of the established calibration programme, key quantities or values of the test & measurement instrumentation are within specification and comply with the relevant traceable internationally recognised and appropriate standard specifications, which are UKAS calibrated as such where these properties have a significant effect on results. Participation in inter-laboratory comparisons and proficiency testing ensures satisfactory correlation of results conform to Elements own procedures, as well as statistical techniques for analysis of test data providing the appropriate confidence in measurements.

Throughout this report EUT denotes equipment under test.

FCC Site Listing:

The test laboratory is accredited for the above sites under the US-UK MRA,

Designation number(s):

Element Hull	UK2007
Element Skelmersdale	UK2020

IC Registration Number(s):

Element Hull	3483A
Element Skelmersdale	3930B

The test site requirements of ANSI C63.4-2014 are met up to 1GHz.

The test site SVSWR requirements of CISPR 16-1-4:2010 are met over the frequency range 1 GHz to 18 GHz.

5 Test Specifications

5.1 Normative References

- FCC 47 CFR Ch. I – Part 15 – Radio Frequency Devices.
- ANSI C63.10-2013 – American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices.
- ANSI C63.4-2014 – American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz.

5.2 Deviations from Test Standards

There were no deviations from the test standard.

6 Glossary of Terms

§	denotes a section reference from the standard, not this document
AC	Alternating Current
ANSI	American National Standards Institute
BW	bandwidth
C	Celsius
CFR	Code of Federal Regulations
CW	Continuous Wave
dB	decibel
dBm	dB relative to 1 milliwatt
DC	Direct Current
DSSS	Direct Sequence Spread Spectrum
EIRP	Equivalent Isotropically Radiated Power
ERP	Effective Radiated Power
EUT	Equipment Under Test
FCC	Federal Communications Commission
FHSS	Frequency Hopping Spread Spectrum
Hz	hertz
IC	Industry Canada
ITU	International Telecommunication Union
LBT	Listen Before Talk
m	metre
max	maximum
MIMO	Multiple Input and Multiple Output
min	minimum
MRA	Mutual Recognition Agreement
N/A	Not Applicable
PCB	Printed Circuit Board
PDF	Portable Document Format
Pt-mpt	Point-to-multipoint
Pt-pt	Point-to-point
RF	Radio Frequency
RH	Relative Humidity
RMS	Root Mean Square
Rx	receiver
s	second
SVSWR	Site Voltage Standing Wave Ratio
Tx	transmitter
UKAS	United Kingdom Accreditation Service
V	volt
W	watt
Ω	ohm

7 Equipment Under Test

7.1 EUT Identification

- Name: BTLE Node
- Model Number: A-0819G06
- Serial Numbers: AB10001330 (Radiated), AB10001263 (Conducted)
- Software Versions: Bootloader: P0819B1.0.4 / Application: P0819A2.1.2
- Hardware Version: Production

7.2 System Equipment

Equipment listed below forms part of the overall test setup and is required for equipment functionality and/or monitoring during testing. The compliance levels achieved in this report relate only to the EUT and not items given in the following list.

1. *Dell Vostro Laptop*

7.3 EUT Mode of Operation

7.3.1 Transmission

The mode of operation for transmit tests was as follows:-

The EUT was transmitting modulated carrier on the frequencies indicated.

7.4 EUT Radio Parameters

Frequency of operation:	2402 MHz – 2480 MHz
Modulation:	GFSK
Declared output power:	≤10.0 dBm
Antenna type:	PCB Trace
Antenna gain:	Radiated Measurement
Nominal supply voltage:	12 Vdc

7.5 EUT Description

The EUT is a BTLE Node incorporating BTLE 2.4 GHz, and a LF 125 kHz radio, this report covers the testing of the BTLE radio only.

8 Modifications

No modifications were performed during this assessment.

9 EUT Test Setup

9.1 Block Diagram

The following diagram shows basic EUT interconnections with cable type and cable lengths identified:

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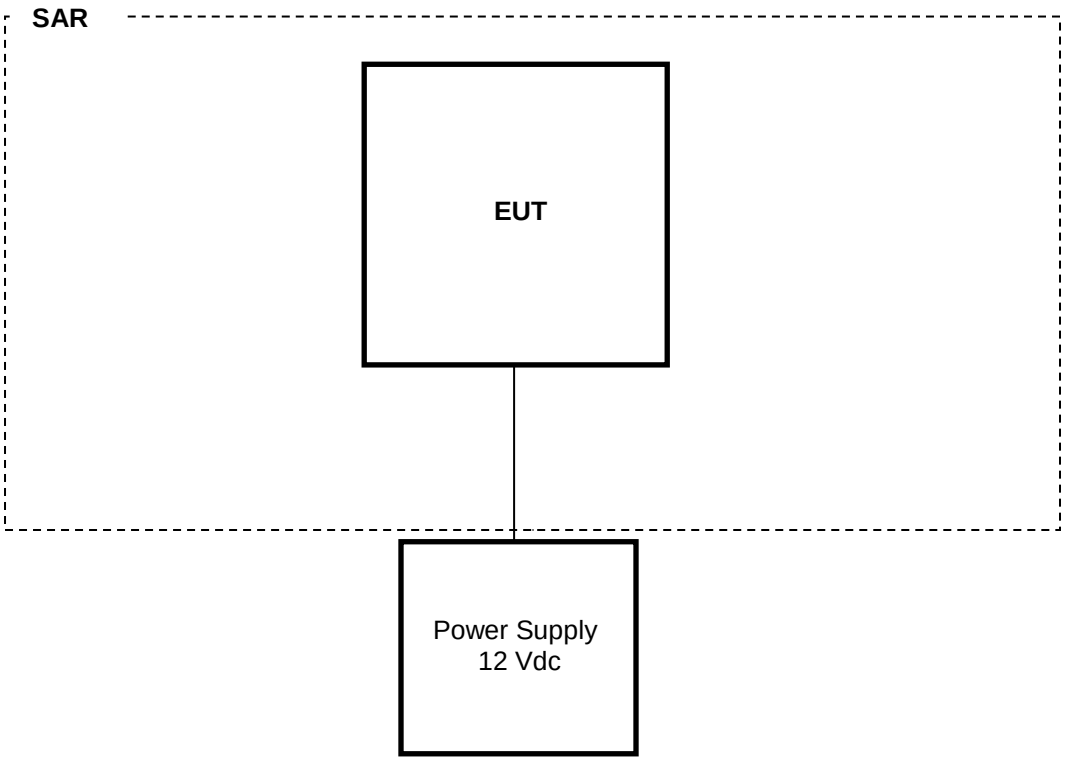
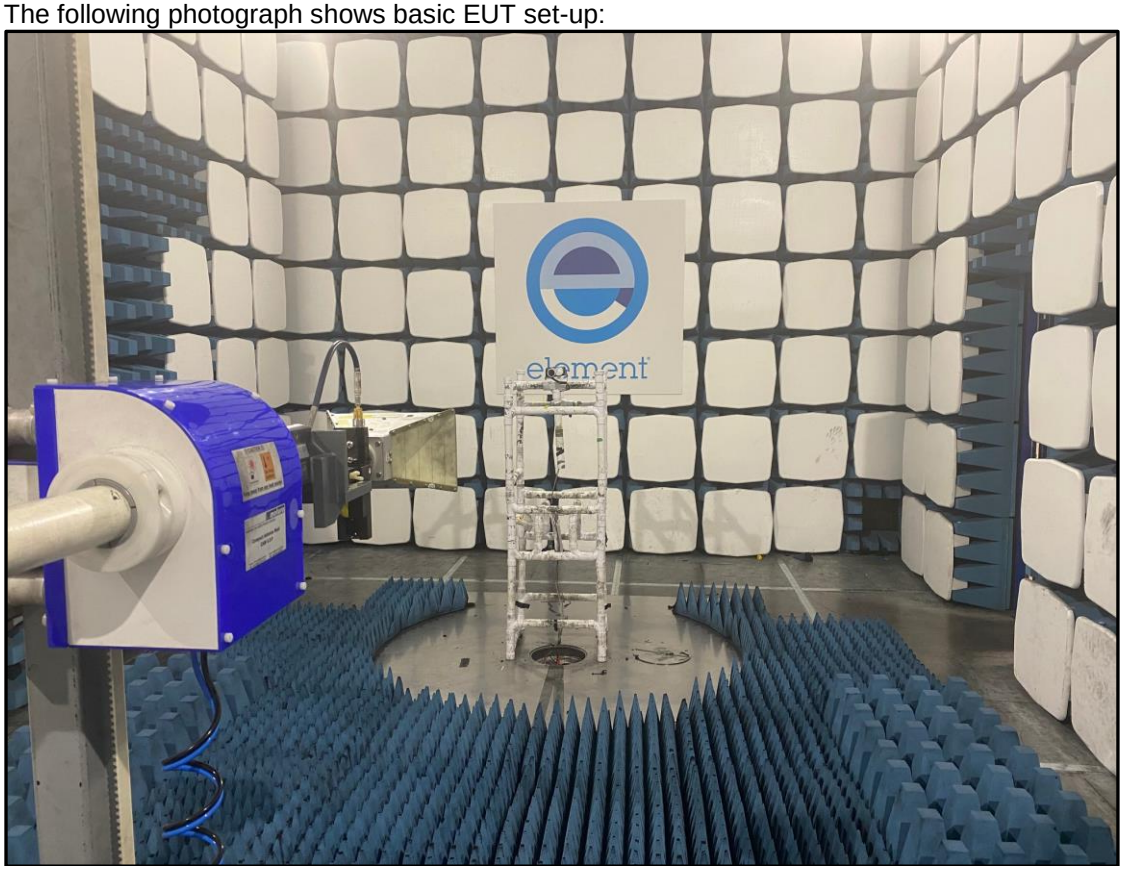


9.2 General Setup Photograph

The following photograph shows basic EUT set-up:



9.3 Measurement software

Where applicable, the following software was used to perform measurements contained within this report.

Element Emissions R5 (See Note)
Element Transmitter Bench Test (See Note)
ETS Lindgren EMPower V1.0.4.2

Note:

The version of the Element software used is recorded in the results sheets contained within this report.

10 General Technical Parameters

10.1 Normal Conditions

The EUT was tested under the normal environmental conditions of the test laboratory, except where otherwise stated. The normal power source applied was 12 Vdc from an external power supply.

11 Radiated emissions

11.1 Definitions

Spurious emissions
Emissions on a frequency or frequencies, which are outside the necessary bandwidth and the level of which may be reduced without affecting the corresponding transmission of information. Spurious emissions include harmonic emissions, parasitic emissions, intermodulation products and frequency conversion products, but exclude out-of-band emissions.

Restricted bands
A frequency band in which intentional radiators are permitted to radiate only spurious emissions but not fundamental signals.

11.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	SK03 radio chamber
Test Standard and Clause:	ANSI C63.10-2013, Clause 6.5 and 6.6
Frequencies Measured:	2402 MHz / 2440 MHz / 2480 MHz
EUT Channel Bandwidths:	1 MHz
Deviations From Standard:	None
Measurement BW:	30 MHz to 1 GHz: 120 kHz Above 1 GHz: 1 MHz
Measurement Detector:	Up to 1 GHz: quasi-peak Above 1 GHz: RMS average and Peak

Environmental Conditions (Normal Environment)

Temperature: 24 °C	+15 ºC to +35 ºC (as declared)
Humidity: 37 % RH	20 % RH to 75 % RH (as declared)
Supply: 12 Vdc	12 Vdc (as declared)

11.3 Test Limit

Unwanted emissions that fall within the restricted frequency bands shall comply with the limits specified:

General Field Strength Limits for License-Exempt Transmitters at Frequencies above 30 MHz

Frequency (MHz)	*Field Strength (µV/m at 3 m)*
30 to 88	100
88 to 216	150
216 to 960	200
Above 960	500

11.4 Test Method

With the EUT setup as per section 9 of this report and connected as per Figure i, the emissions from the EUT were measured on a spectrum analyzer / EMI receiver.

Radiated electromagnetic emissions from the EUT are checked first by preview scans. Preview scans for all spectrum and modulation characteristics are checked, using a peak detector and where applicable worst-case determined for function, operation, orientation, etc. for both vertical and horizontal polarisations. Pre-scan plots are shown with a peak detector and 100 kHz RBW.

If the EUT connects to auxiliary equipment and is table or floor standing, the configurations prescribed in ANSI C63.10 are followed. Alternatively, a layout closest to normal use (as declared by the provider) is employed, (see EUT setup photographs for more detail).

Emissions between 30 MHz and 1 GHz are measured using calibrated broadband antennas. Emissions above 1 GHz are characterized using standard gain horn antennas. Pre-amplifiers and filters are used where required. Care is taken to ensure that test receiver resolution bandwidth, video bandwidth and detector type(s) meet the regulatory requirements.

For both horizontal and vertical polarizations, the EUT is then rotated through 360 degrees in azimuth until the highest emission is detected. At the previously determined azimuth the test antenna is raised and lowered from 1 to 4 m in height until a maximum emission level is detected, this maximum value is recorded.

Power values measured on the test receiver / analyzer are converted to field strength, FS, in dBµV/m at the regulatory distance, using:

$$FS = PR + CL + AF – PA + DC – CF$$

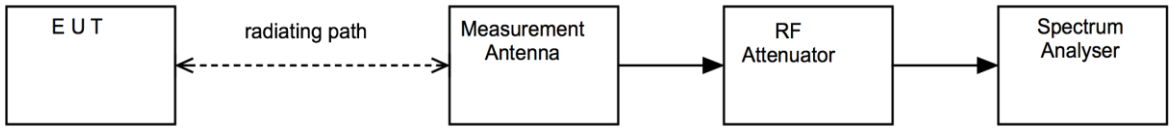
$$Factor = CL + AF – PA$$

Where,

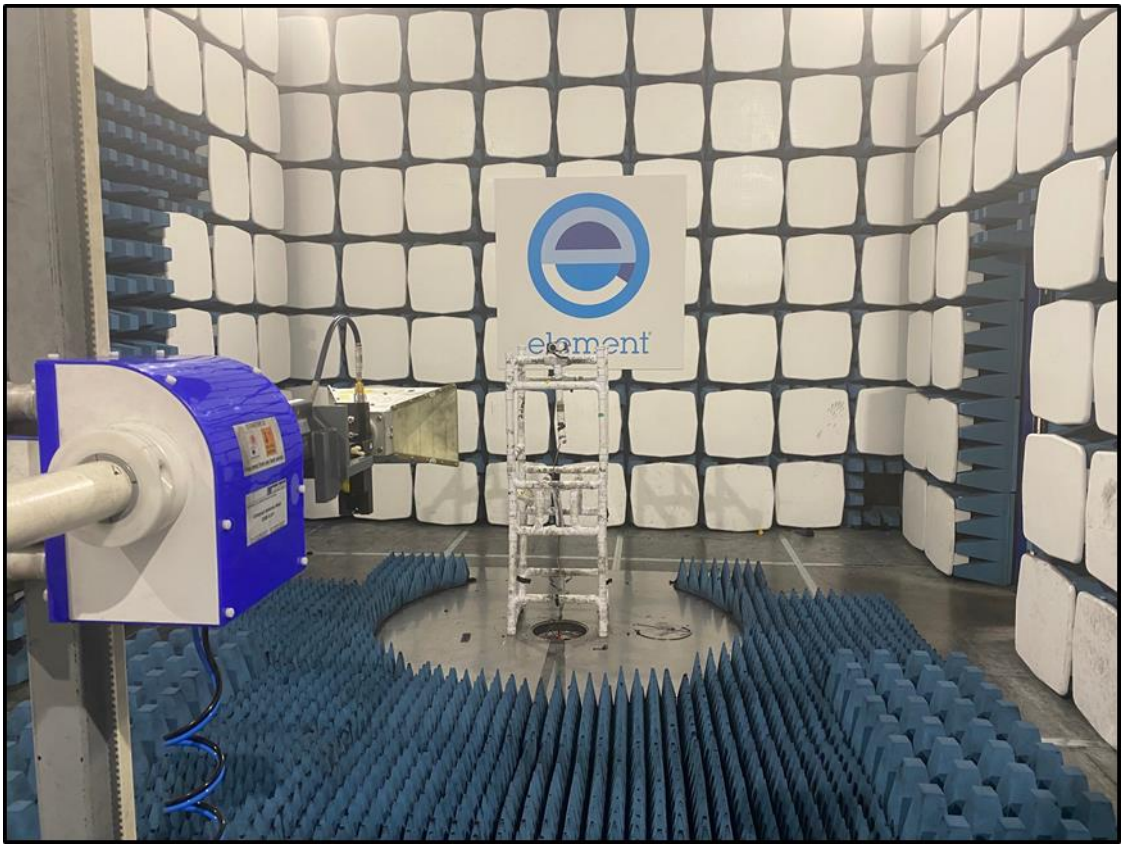
PR is the power recorded on the receiver / spectrum analyzer in dBµV;
CL is the cable loss in dB;
AF is the test antenna factor in dB/m;
PA is the pre-amplifier gain in dB (where used);
DC is the duty correction factor in dB (where used, e.g. harmonics of pulsed fundamental);
CF is the distance factor in dB (where measurement distance different to limit distance);

This field strength value is then compared with the regulatory limit.

Figure i Test Setup



11.5 Test Set-up Photograph



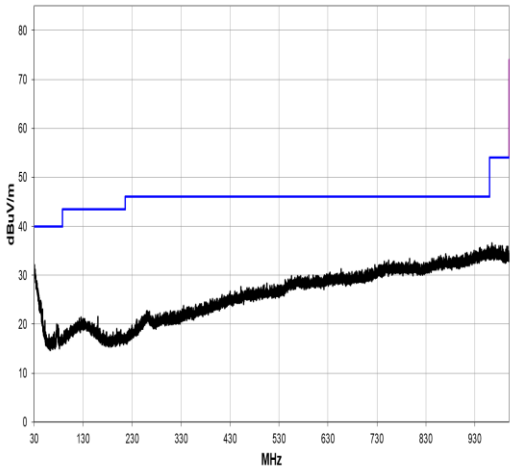
11.6 Test Equipment

Equipment Description	*Manufacturer*	*Equipment Type*	*Element No*	*Due For Calibration*
Receiver	R&S	FSW26	*101805	2021-05-23
Bilog	Chase	CBL611/A	U573	2021-09-19
1-18GHz Horn	EMCO	3115	L139	2021-07-16
PreAmp	Watkins Johnson	6201-69	U372	2022-03-01
Pre Amp	Agilent	8449B	L572	2021-10-19
Horn 18-26GHz (&U330)	Flann	20240-20	L300	2022-04-23
High Pass Filter	Atlantic Microwave	AFH-07000	U558	2022-01-30
Radio Chamber - PP	Rainford EMC	ATS	REF940	2021-12-09

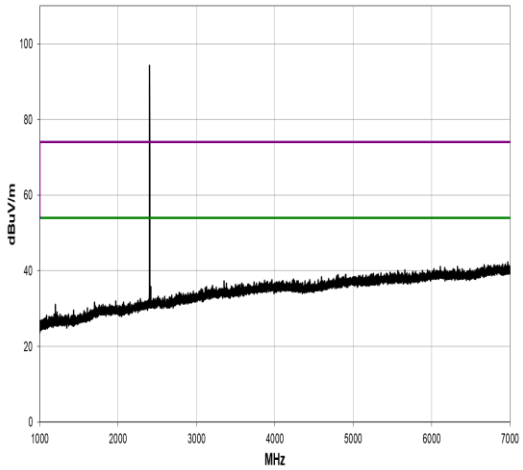
*Denotes serial number of hired test equipment

11.7 Test Results

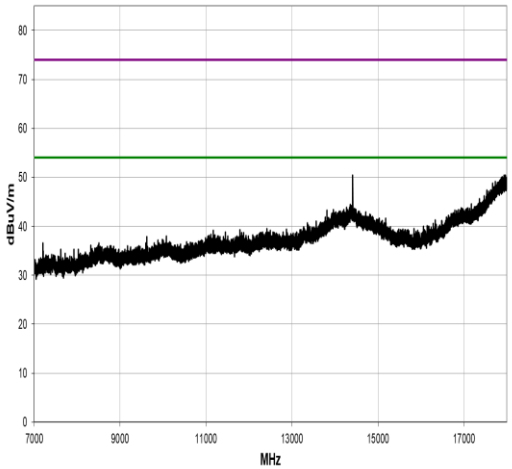
Bottom Channel 2402 MHz – BLE1



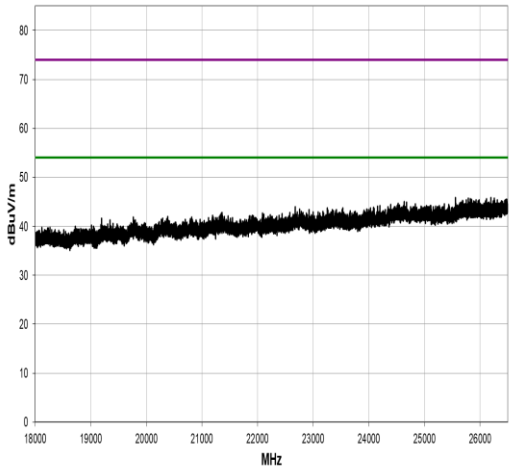
30 MHz to 1 GHz



1 GHz to 7 GHz



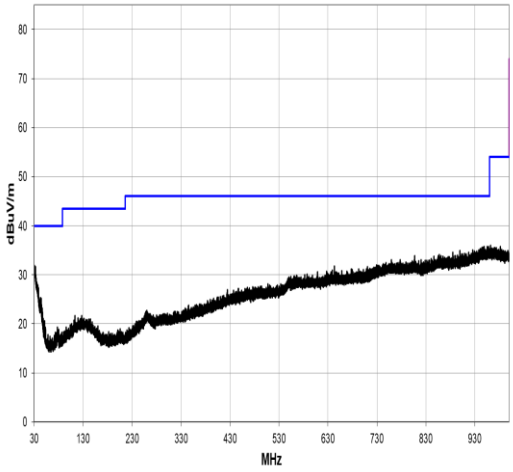
7 GHz to 18 GHz



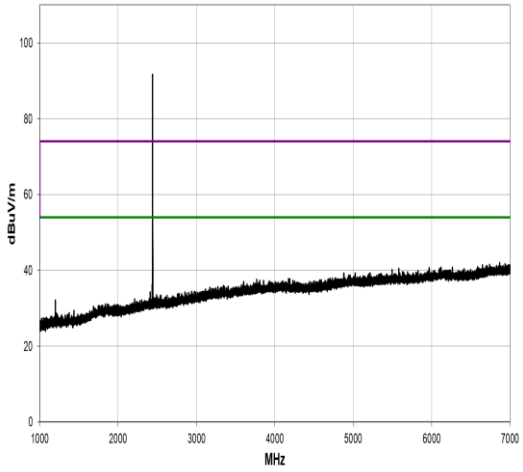
18 GHz to 26.5 GHz

Bottom Channel: 2402 MHz					
Emission	***Frequency (MHz)***	***Emission level (dBm)***	***Limit (dBm)***	***Margin (dB)***	***Result***
No significant emissions within 20 dB of the limit					Pass

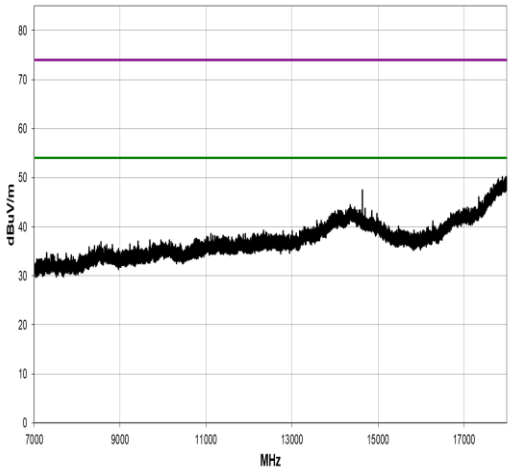
Middle Channel 2440 MHz – BLE1



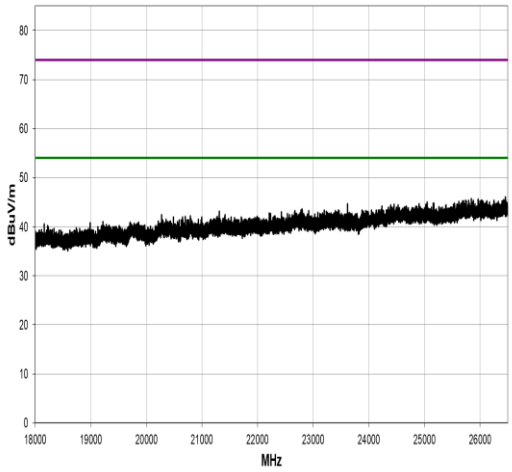
30 MHz to 1 GHz



1 GHz to 7 GHz



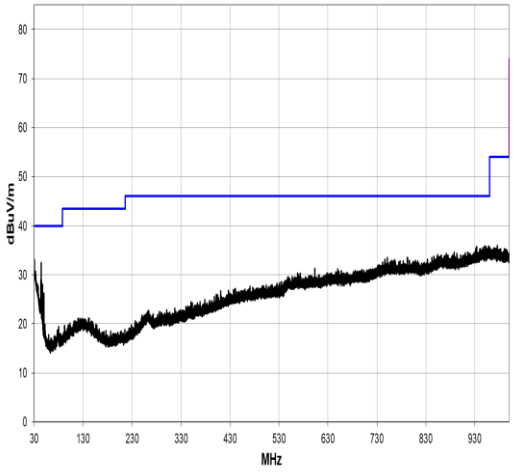
7 GHz to 18 GHz



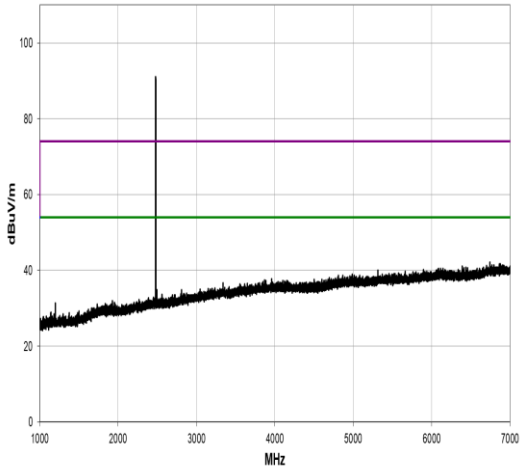
18 GHz to 26.5 GHz

Middle Channel: 2440 MHz					
Emission	***Frequency (MHz)***	***Emission level (dBm)***	***Limit (dBm)***	***Margin (dB)***	***Result***
No significant emissions within 20 dB of the limit					Pass

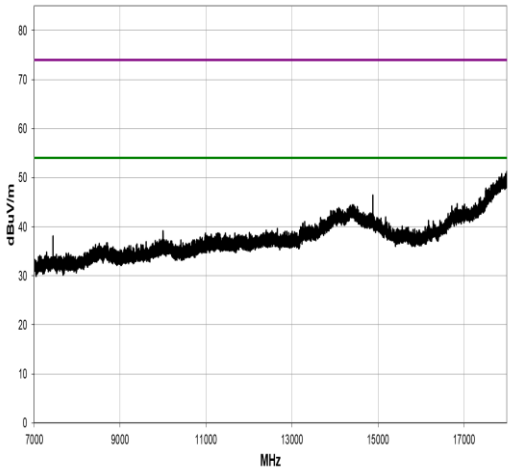
Top Channel 2480 MHz – BLE1



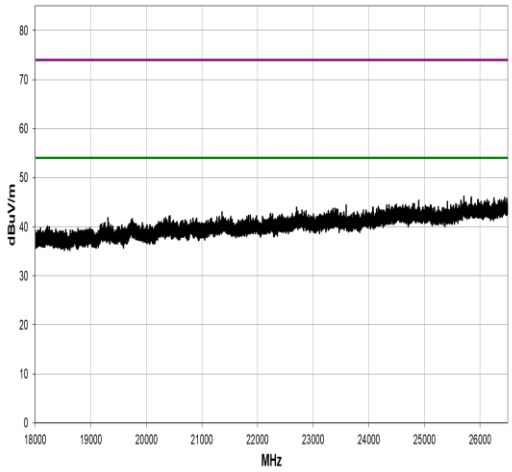
30 MHz to 1 GHz



1 GHz to 7 GHz



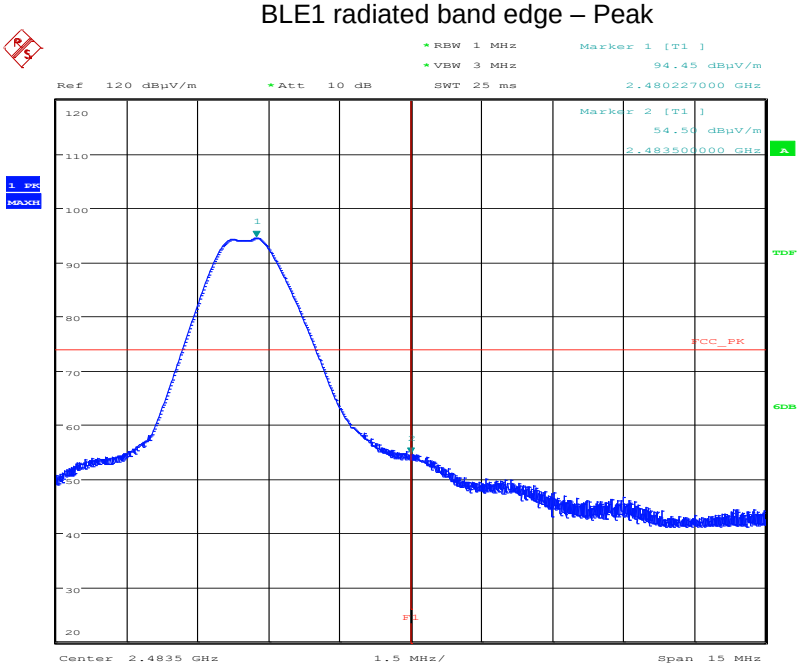
7 GHz to 18 GHz



18 GHz to 26.5 GHz

Top Channel: 2480 MHz					
Emission	***Frequency (MHz)***	***Emission level (dBm)***	***Limit (dBm)***	***Margin (dB)***	***Result***
No significant emissions within 20 dB of the limit					Pass

BLE1 radiated band edge – Peak



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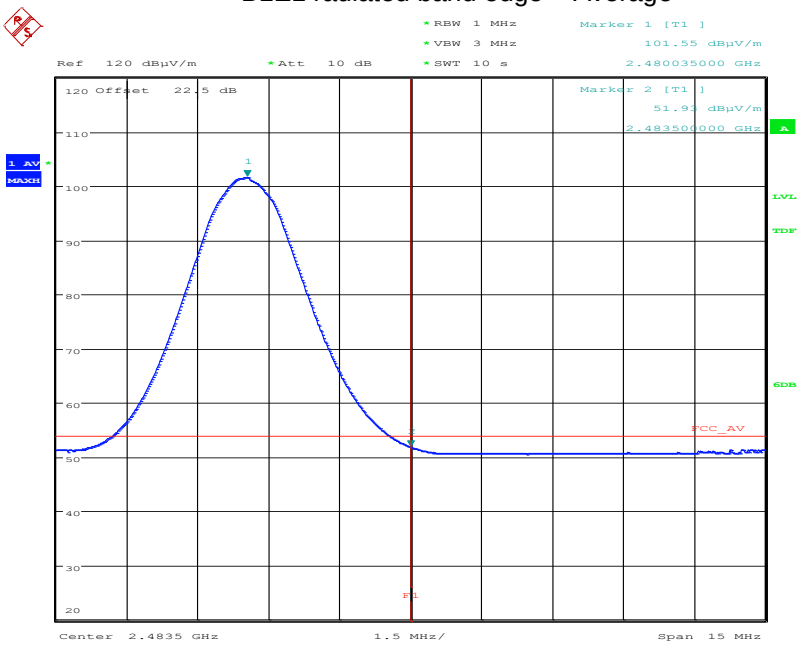
BLE1 radiated band edge – Average



Date: 4.MAR.2021 11:07:05

Note: The average band edge measurement was taken at a distance of 1 metre this was to meet the system measurement noise floor. The duty cycle offset was adjusted to facilitate the change in measurement distance.

12 Occupied Bandwidth

12.1 Definition

The emission bandwidth (x dB) is defined as the frequency range between two points, one above and one below the carrier frequency, at which the spectral density of the emission is attenuated x dB below the maximum in-band spectral density of the modulated signal.

12.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Radio Laboratory
Test Standard and Clause:	ANSI C63.10-2013, Clause 11.8
Frequencies Measured:	2402 MHz, 2440 MHz, 2480 MHz
EUT Channel Bandwidths:	1 MHz
EUT Test Modulations:	GFSK
Deviations From Standard:	None
Measurement BW:	100 kHz
Spectrum Analyzer Video BW: (requirement at least 3x RBW)	300 kHz
Measurement Span: (requirement 2 to 5 times OBW)	3 MHz
Measurement Detector:	Peak

Environmental Conditions (Normal Environment)

Temperature: 24 °C	+15 ºC to +35 ºC (as declared)
Humidity: 37 % RH	20 % RH to 75 % RH (as declared)
Supply: 12 Vdc	12 Vdc (as declared)

12.3 Test Limit

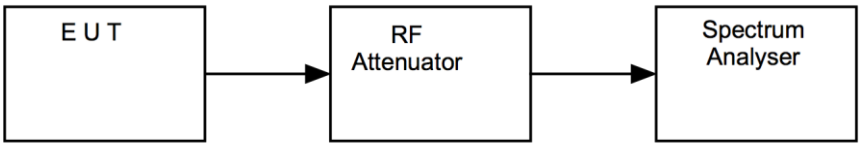
The minimum -6 dB bandwidth shall be at least 500 kHz.

12.4 Test Method

With the EUT setup as per section 9 of this report and connected as per Figure iii, the bandwidth of the EUT was measured on a spectrum analyser.

The measurements were performed with EUT set at its maximum duty. All modulation schemes, data rates and power settings were used to observe the worst-case configuration in each bandwidth.

Figure iii Test Setup

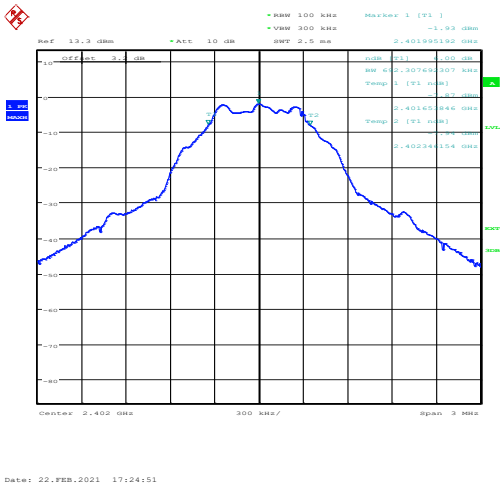


12.5 Test Equipment

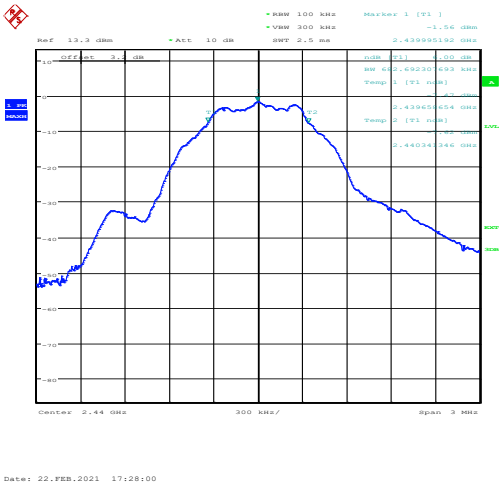
Equipment		*Equipment*	*Element*	*Due For*
Type	*Manufacturer*	*Description*	*No*	*Calibration*
Spectrum Analyser	R&S	FSU26	U405	2021-07-17
Attenuator	AtlanTechRF Microwave	3dB SMA	U639	Cal in use

12.6 Test Results

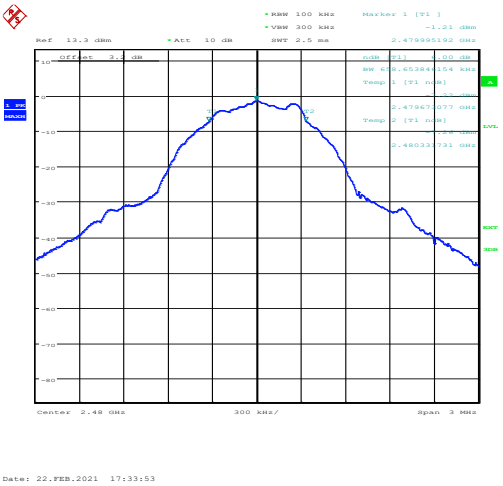
BLE1: FCC 15.247



2402 MHz



2440 MHz



2480 MHz

FCC 15.247 DTS Bandwidth; Data Rate: 1 Mbps				
Channel Frequency (MHz)	***F_L (MHz)***	***F_H (MHz)***	***6dB Bandwidth (kHz)***	***Result***
2402	2401.653846	2402.346154	692.308	Pass
2440	2439.658654	2440.341346	682.692	Pass
2480	2479.673077	2480.331731	658.654	Pass

13 Maximum peak conducted output power

13.1 Definition

The maximum peak conducted output power is defined as the maximum power level measured with a peak detector using a filter with width and shape of which is sufficient to accept the signal bandwidth.

The maximum conducted output power is defined as the total transmit power delivered to all antennas and antenna elements averaged across all symbols in the signaling alphabet when the transmitter is operating at its maximum power control level.

13.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Radio Laboratory
Test Standard and Clause:	ANSI C63.10-2013, Clause 11.9.1
Frequencies Measured:	2402 MHz, 2440 MHz, 2480 MHz
EUT Channel Bandwidths:	2 MHz
Deviations From Standard:	None
Measurement BW:	2 MHz
Spectrum Analyzer Video BW: (requirement at least 3x RBW)	10 MHz
Measurement Detector:	Peak

Environmental Conditions (Normal Environment)

Temperature: 24 °C	+15 ºC to +35 ºC (as declared)
Humidity: 37 % RH	20 % RH to 75 % RH (as declared)

13.3 Test Limit

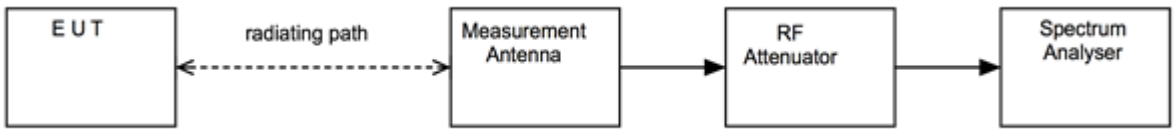
For systems employing digital modulation techniques operating in the bands 902 to 928 MHz, 2400 to 2483.5 MHz and 5725 to 5850 MHz, the maximum peak conducted output power shall not exceed 1 W.

13.4 Test Method

With the EUT setup as per section 9 of this report and connected as per Figure iv, the resolution bandwidth of the spectrum analyser was increased above the EUT occupied bandwidth and the peak emission data noted.

The measurements were performed with EUT set at its maximum duty. All modulation schemes, data rates and power settings were used to observe the worst-case configuration in each bandwidth.

Figure iv Test Setup



13.5 Test Equipment

Equipment Description	*Manufacturer*	*Equipment Type*	*Element No*	*Due For Calibration*
Receiver	R&S	FSW26	*101805	2021-05-23
1-18GHz Horn	EMCO	3115	L139	2021-07-16
Pre Amp	Agilent	8449B	L572	2021-10-19
Radio Chamber - PP	Rainford EMC	ATS	REF940	2021-12-09

*Denotes serial number of hired test equipment

13.6 Test Result

The following formula may be used to convert field strength (FS) in volts/metre to transmitter output power (TP) in watts:

$$TP = (FS \times D)^2 / (30 \times G)$$

where D is the distance in metres between the two antennas and G is the antenna numerical gain referenced to isotropic gain.

Modulation: GFSK; Data Rate 1 Mb/s; Power Setting: Default					
Frequency (MHz)	***Peak Field Strength (dBµV/m)***	***Distance (m)***	***Numerical Gain***	***Power (mW)***	***Verdict***
2402	96.4	3	1	1.30918	Pass
2440	96.0	3	1	1.19399	Pass
2480	95.6	3	1	1.08893	Pass

Note: power measurement was taken radiated as antenna gain was unknown.

14 Out-of-band and conducted spurious emissions

14.1 Definition

Out-of-band emission.
Emission on a frequency or frequencies immediately outside the necessary bandwidth that results from the modulation process but excluding spurious emissions.

Spurious emission.
Emission on a frequency or frequencies that are outside the necessary bandwidth and the level of which may be reduced without affecting the corresponding transmission of information. Spurious emissions include harmonic emissions, parasitic emissions, intermodulation products, and frequency conversion products, but exclude out-of-band emissions.

14.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Radio Laboratory
Test Standard and Clause:	ANSI C63.10-2013, Clause 11.11
Frequencies Measured:	2402 MHz / 2440 MHz / 2480 MHz
EUT Channel Bandwidths:	1 MHz
Deviations From Standard:	None
Measurement BW:	100 kHz
Spectrum Analyzer Video BW: (requirement at least 3x RBW)	300 kHz
Measurement Detector:	Peak
Measurement Range:	9 kHz to 25.0 GHz

Environmental Conditions (Normal Environment)

Temperature: 24 °C	+15 ºC to +35 ºC (as declared)
Humidity: 37 % RH	20 % RH to 75 % RH (as declared)
Supply: 12 Vdc	12 Vdc (as declared)

14.3 Test Limit

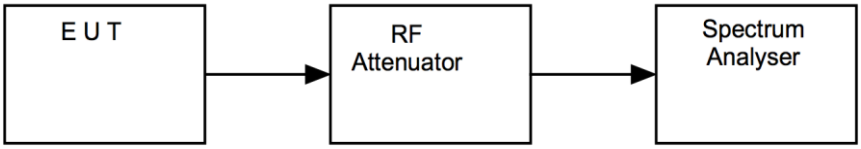
In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated device is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided that the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of root-mean-square averaging over a time interval, the attenuation required shall be 30 dB instead of 20 dB. Attenuation below the general field strength limits specified in FCC 47CFR15.209(a) / RSS-Gen is not required.

14.4 Test Method

With the EUT setup as per section 9 of this report and connected as per Figure v, the emissions from the EUT were measured on a spectrum analyser.

The measurements were performed with EUT set at its maximum duty. All modulation schemes, data rates and power settings were used to observe the worst case configuration in each bandwidth.

Figure v Test Setup

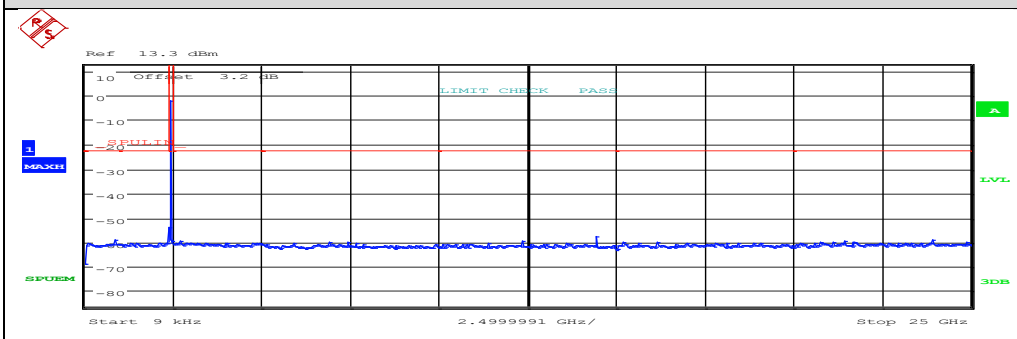


14.5 Test Equipment

Equipment Type	*Manufacturer*	*Equipment Description*	*Element No*	*Due For Calibration*
Spectrum Analyser	R&S	FSU26	U405	2021-07-17
Attenuator	AtlanTechRF Microwave	3dB SMA	U639	Cal in use

14.6 Test Results

BLE1:Frequency: 2402 MHz; Bandwidth: 1 MHz; Power setting: Default



Start [Hz]	Stop [Hz]	RBW [Hz]	Freq [Hz]	PwrAbs [dBm]	Δ Limit [dB]
9.000 k	150.000 k	1.00 k	9.677885 k	-74.53	-52.46
150.000 k	30.000 M	10.00 k	194.775000 k	-69.26	-47.19
30.000 M	1.000 G	100.00 k	839.368000 M	-59.15	-37.08
1.000 G	2.400 G	100.00 k	2.399720 G	-54.26	-32.19
2.400 G	2.483 G	100.00 k	2.402004 G	-2.11	-22.11
2.483 G	5.000 G	100.00 k	2.686078 G	-59.82	-37.75
5.000 G	10.000 G	100.00 k	6.880500 G	-60.14	-38.07
10.000 G	15.000 G	100.00 k	14.411000 G	-57.60	-35.53
15.000 G	20.000 G	100.00 k	16.165000 G	-60.32	-38.25
20.000 G	25.000 G	100.00 k	23.917000 G	-59.20	-37.13

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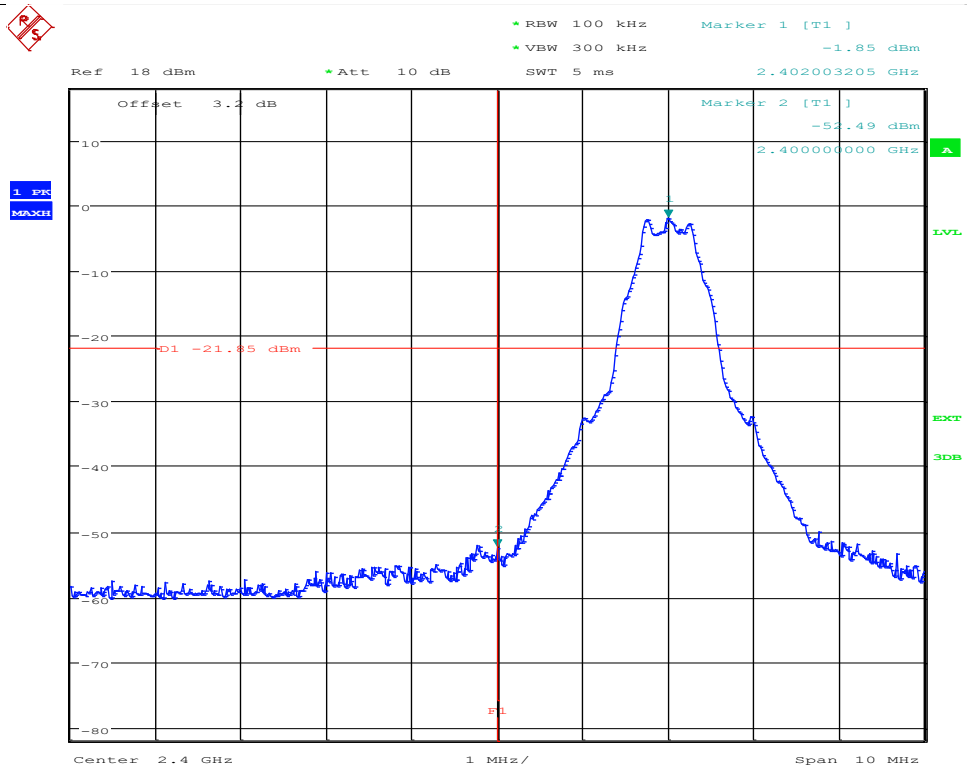

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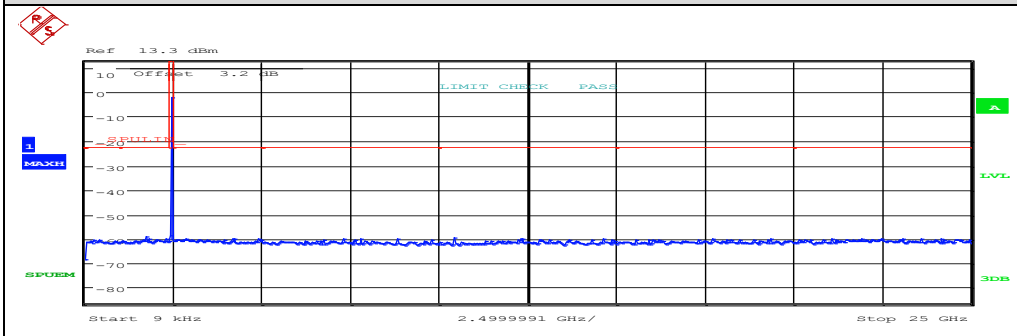
BLE1:Frequency: 2440 MHz; Bandwidth: 1 MHz; Power setting: Default



Start [Hz]	Stop [Hz]	RBW [Hz]	Freq [Hz]	PwrAbs [dBm]	Δ Limit [dB]
9.000 k	150.000 k	1.00 k	12.841346 k	−75.54	−53.47
150.000 k	30.000 M	10.00 k	164.925000 k	−68.67	−46.60
30.000 M	1.000 G	100.00 k	402.868000 M	−60.73	−38.66
1.000 G	2.400 G	100.00 k	1.702660 G	−59.21	−37.14
2.400 G	2.483 G	100.00 k	2.439996 G	−2.16	−22.16
2.483 G	5.000 G	100.00 k	3.296330 G	−59.51	−37.44
5.000 G	10.000 G	100.00 k	7.777500 G	−59.95	−37.88
10.000 G	15.000 G	100.00 k	10.410000 G	−59.94	−37.87
15.000 G	20.000 G	100.00 k	17.697000 G	−60.34	−38.27
20.000 G	25.000 G	100.00 k	21.932500 G	−60.10	−38.03

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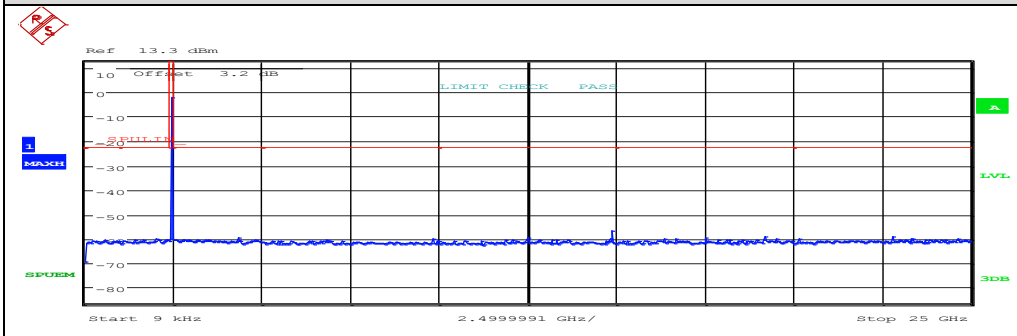
BLE1:Frequency: 2480 MHz; Bandwidth: 1 MHz; Power setting: Default



Start [Hz]	Stop [Hz]	RBW [Hz]	Freq [Hz]	PwrAbs [dBm]	Δ Limit [dB]
9.000 k	150.000 k	1.00 k	9.225962 k	−75.91	−53.84
150.000 k	30.000 M	10.00 k	185.820000 k	−69.48	−47.41
30.000 M	1.000 G	100.00 k	554.479000 M	−60.84	−38.77
1.000 G	2.400 G	100.00 k	1.999740 G	−60.33	−38.26
2.400 G	2.483 G	100.00 k	2.479993 G	−1.96	−21.96
2.483 G	5.000 G	100.00 k	4.333127 G	−59.81	−37.74
5.000 G	10.000 G	100.00 k	9.820000 G	−60.23	−38.16
10.000 G	15.000 G	100.00 k	14.879500 G	−57.00	−34.93
15.000 G	20.000 G	100.00 k	19.197000 G	−59.34	−37.27
20.000 G	25.000 G	100.00 k	22.810000 G	−59.40	−37.33

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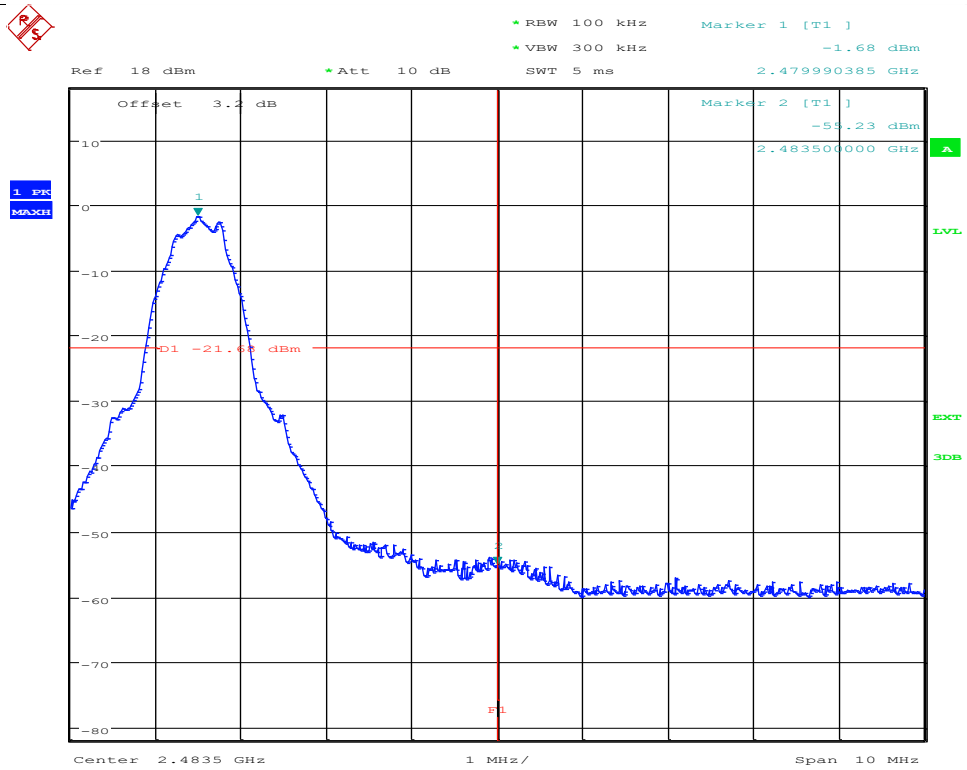

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15 Power spectral density

15.1 Definition

The power per unit bandwidth.

15.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Radio Laboratory
Test Standard and Clause:	ANSI C63.10-2013, Clause 11.10
Frequencies Measured:	2402 MHz, 2440 MHz, 2480 MHz
EUT Channel Bandwidths:	1 MHz
Deviations From Standard:	None
Measurement BW:	30 kHz
Spectrum Analyzer Video BW: (requirement at least 3x RBW)	100 kHz
Measurement Span: (requirement 1.5 times Channel BW)	1.1 MHz
Measurement Detector:	Peak

Environmental Conditions (Normal Environment)

Temperature: 24 °C	+15 ºC to +35 ºC (as declared)
Humidity: 37 % RH	20 % RH to 75 % RH (as declared)
Supply: 12 Vdc	12 Vdc (as declared)

15.3 Test Limit

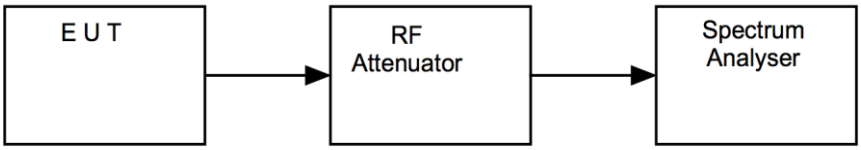
The transmitter power spectral density conducted from the transmitter to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.

15.4 Test Method

With the EUT setup as per section 9 of this report and connected as per Figure vi, the peak emission of the EUT was measured on a spectrum analyser, with path losses taken into account.

The measurements were performed with EUT set at its maximum duty. All modulation schemes, data rates and power settings were used to observe the worst case configuration in each bandwidth.

Figure vi Test Setup

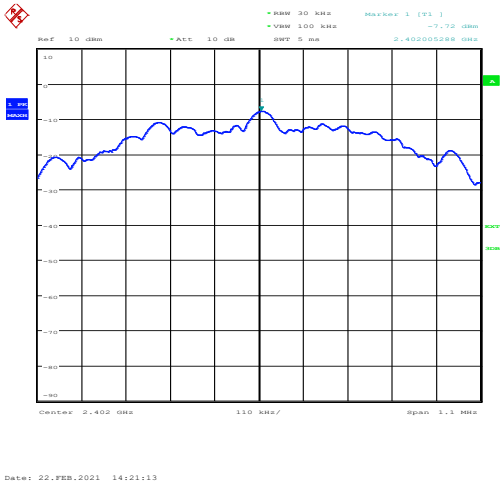


15.5 Test Equipment

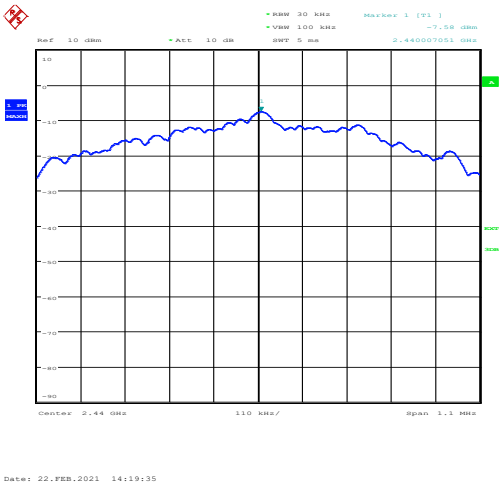
Equipment Type	*Manufacturer*	*Equipment Description*	*Element No*	*Due For Calibration*
Spectrum Analyser	R&S	FSU26	U405	2021-07-17
Attenuator	AtlanTechRF Microwave	3dB SMA	U639	Cal in use

15.6 Test Results

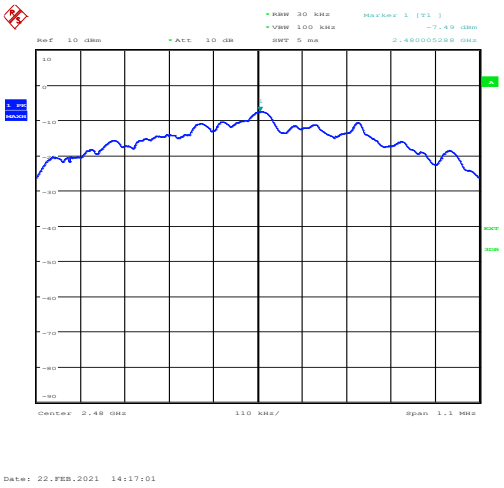
BLE1



2402 MHz



2440 MHz



2480 MHz

Modulation: GFSK; Data rate: 1Mbps; Power setting: Default				
Channel Frequency (MHz)	***Analyzer Level (dBm)***	***Cable loss (dB)***	***PSD (dBm)***	***Result***
2402	-7.72	3.06	-4.66	Pass
2440	-7.58	3.20	-4.38	Pass
2480	-7.49	3.06	-4.43	Pass

16 Duty Cycle

16.1 Definition

The ratio of the sum of all pulse durations to the total period, during a specified period of operation.

16.2 Test Parameters

Test Location:	Element Skelmersdale
Test Standard and Clause:	ANSI C63.10-2013, Clause 11.6
Deviations From Standard:	None
Temperature Extreme Environment Test Range:	N/A
Voltage Extreme Environment Test Range:	N/A

Environmental Conditions (Normal Environment)

Temperature: 24 °C	+15 ºC to +35 ºC (as declared)
Humidity: 37 % RH	20 % RH to 75 % RH (as declared)

16.3 Test Limit

N/A.

16.4 Test Method

With the EUT setup as per section 9 of this report and connected as per Figure vii, the duty of the EUT was calculated from the sum of total on and off times over the observation period.

The measurements were performed with EUT set at its maximum duty. All modulation schemes, bandwidths, data rates and power settings were measured
[1] Single antenna output devices

Duty was measured at the antenna port / at a distance of 3 m.

[2] Multiple antenna output devices

Duty was measured as the combination of all ports simultaneously / at a distance of 3 m.

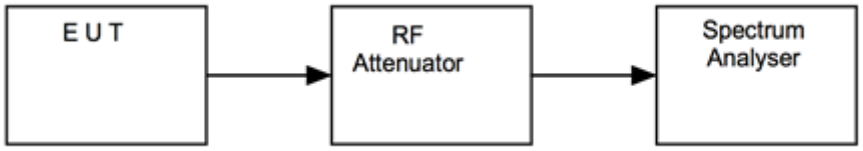
The duty cycle correction factor, DC, shall be added to the measurement results prior to comparing with the emission limit to compute the emission level that would have been measured had the test been performed at 100% duty cycle. The correction factor is computed as:

1) If power averaging (rms) mode was used in step f), then the applicable correction factor is [10 log (1 / *D*)], where *D* is the duty cycle.

2) If linear voltage averaging mode was used in step f), then the applicable correction factor is [20 log (1 / *D*)], where *D* is the duty cycle.

3) If a specific emission is demonstrated to be continuous (*D* ≥ 98%) rather than turning ON and OFF with the transmit cycle, then no duty cycle correction is required for that emission.

Figure vii Test Setup

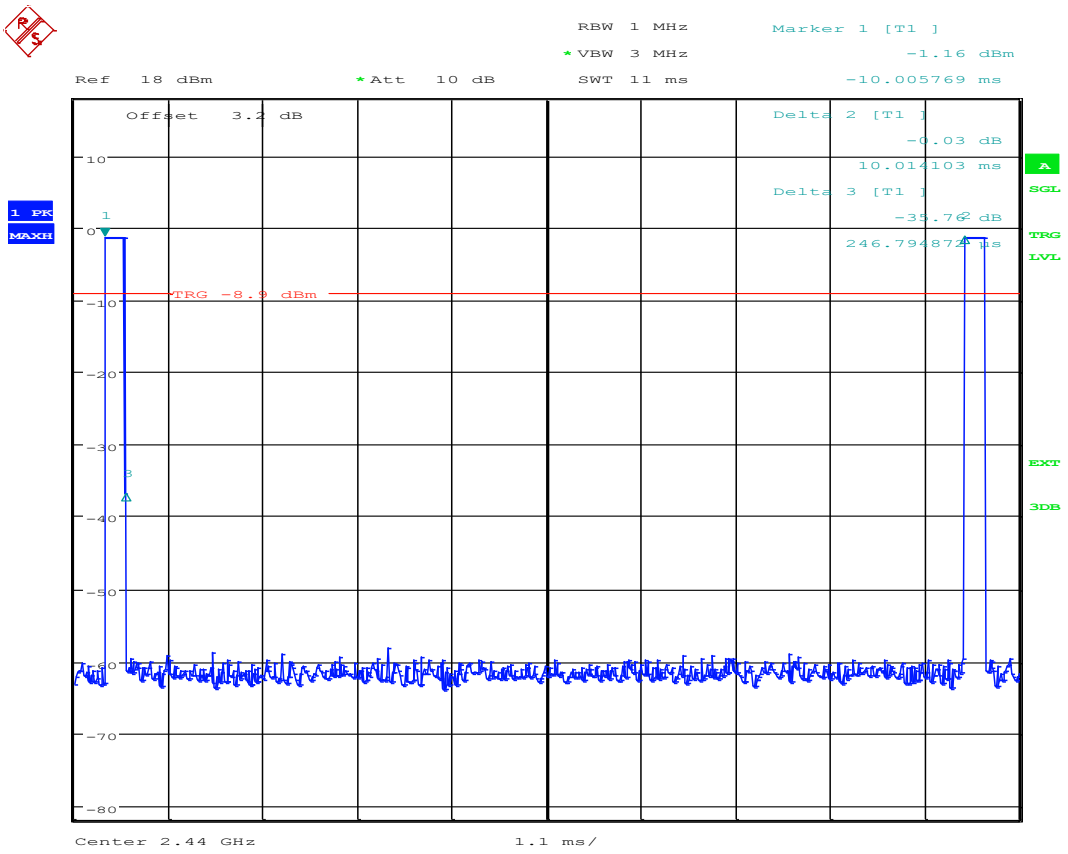


16.5 Test Equipment

Equipment Type	*Manufacturer*	*Equipment Description*	*Element No*	*Due For Calibration*
Spectrum Analyser	R&S	FSU26	U405	2021-07-17
Attenuator	AtlanTechRF Microwave	3dB SMA	U639	Cal in use

16.6 Test Results

BLE1				
Test Environment		**TxOn time (us)**	**Frame Period (ms)**	**Calculated Factor (dB)**
$V_{nominal}$	$T_{nominal}$	246.794872	10.014103	32



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17 Measurement Uncertainty

Calculated Measurement Uncertainties

All statements of uncertainty are expanded standard uncertainty using a coverage factor of 1.96 to give a 95 % confidence:

[1] Radiated spurious emissions

Uncertainty in test result (30 MHz to 1 GHz) = **4.75 dB**
Uncertainty in test result (1 GHz to 18 GHz) = **4.46 dB**

[2] AC power line conducted emissions

Uncertainty in test result = **3.2 dB**

[3] Occupied bandwidth

Uncertainty in test result = **15.58 %**

[4] Conducted carrier power

Uncertainty in test result (Power Meter) = **0.93 dB**

[5] Conducted RF power out-of-band

Uncertainty in test result – up to 8.1 GHz = **3.31 dB**
Uncertainty in test result – 8.1 GHz to 15.3 GHz = **4.43 dB**

[6] Radiated RF power out-of-band

Uncertainty in test result (30 MHz to 1 GHz) = **4.75 dB**
Uncertainty in test result (1 GHz to 18 GHz) = **4.46 dB**

[7] Power spectral density

Uncertainty in test result (Spectrum Analyser) = **3.11 dB**

[8] ERP / EIRP

Uncertainty in test result (Laboratory) = **4.71 dB**
Uncertainty in test result (Pershore OATS) = **4.26 dB**

18 MPE Calculation

Prediction of MPE limit at a given distance

For purposes of these requirements mobile devices are defined by the FCC as transmitters designed to be used in other than fixed locations and to generally be used in such a way that a separation distance of at least 20 centimeters is normally maintained between radiating structures and the body of the user or nearby persons. These devices are normally evaluated for exposure potential with relation to the MPE limits. As the 20 cm separation specified under FCC rules may not be achievable under normal operation of the EUT, an RF exposure calculation is needed to show the minimum distance required to be less than the power density limit, as required under FCC rules.

Equation from IEEE C95.1

$$S = \frac{EIRP}{4\pi R^2} \quad \text{re-arranged } R = \sqrt{\frac{EIRP}{S4\pi}}$$

Where:

S = power density
R = distance to the centre of radiation of the antenna
EIRP = EUT Maximum power

Result

Channel Frequency (MHz)	*EIRP (mW)*	*Power density limit (S) (mW/cm^2)*	*Distance (R) cm required to be less than the power density limit*
2402	1.3	1.0	0.3
2440	1.2	1.0	0.3
2480	1.1	1.0	0.3

See intermodulation report TRA-051982-47-13A for simultaneous operation assessment.