Report on the Intermodulation Testing

For

Pektron Group Limited

on

BTLE NFC Node

Report no. TRA-051982-47-08B

YYYY-MM-DD

Report Number: TRA-051982-47-08B
Issue: B

REPORT ON THE INTERMODULATION TESTING OF A
Pektron Group LImited
BTLE NFC Node
WITH RESPECT TO SPECIFICATIONS
47CFR15 & RSS-GEN
INTERMODULATION EMISSIONS INVESTIGATION

TEST DATE: 2021-02-24 to 2021-02-26

Written by: Steven Garwell
Radio Test Engineer

Approved by: Daniel Winstanley
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Date: YYYY-MM-DD

Element Materials Technology Warwick Ltd.
Registered in England and Wales. Registered Office: 5 Fleet Place, London, EC4M 7RD
Company Reg No. 02536659

1 Revision Record

Issue Number	*Issue Date*	*Revision History*
A	YYYY-MM-DD	Original
B	2021-04-19	

2 Summary

TEST REPORT NUMBER:	TRA-051982-47-08B
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. Canada: Testing of radio apparatus for TAC (technical acceptance certificate) per subsections 4(2) of the Radiocommunication Act and 21(1) of the Radiocommunication Regulations.
TEST SPECIFICATION(S):	Intermodulation emissions investigation using 47CFR15 & RSS-GEN
EQUIPMENT UNDER TEST (EUT):	BTLE NFC Node
FCC ID: ISED ID:	AQO011 10176A-011
EUT SERIAL NUMBER:	AB10001253 (Radiated)
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:	2021-02-24 to 2021-02-26
TESTED BY:	Michael Else Element

2.1 Test Summary

Test Method and Description	*Requirement Clause*		*Applicable to this equipment*	*Result / Note*
	RSS	*47CFR*		
Multi-radio Simultaneous Transmission Spurious Emissions	Gen, 8.10	Part 15	☒	*Pass*

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-051982-47-08B presents the results of the Radio testing on a Pektron Group Limited, BTLE / Node.

The BTLE NFC Node contains a BTLE 2.4 GHz radio, an NFC 13.56 MHz radio and a LF 125 kHz radio that are able to operate simultaneously.

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 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

6 Equipment Under Test

6.1 EUT Identification

- Name: BTLE NFC Node
- Serial Number: AB10001253 (Radiated)
- Model Numbers: A-819G02
- Software Revision: Bootloader: P0819B1.0.4 / Application: P0819A2.1.2
- Hardware Version: Production

6.2 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*

6.3 EUT Mode of Operation

6.3.1 Transmission

The mode of operation for transmitter tests was as follows:

Radios were set to transmit permanently in various combinations, the spectrum was checked to determine if any intermodulation products were generated due to multiple radios operating simultaneously. The worst case emission plots are shown in this document.

EUT was operated with worst case modes of operation for each radio device.

6.4 EUT Description

The EUT is a BTLE NFC node incorporating BTLE 2.4 GHz, NFC 13.56 MHz and LF 125 kHz radios. This report covers the testing of inter-modulations produced by all radio technologies operating simultaneously.

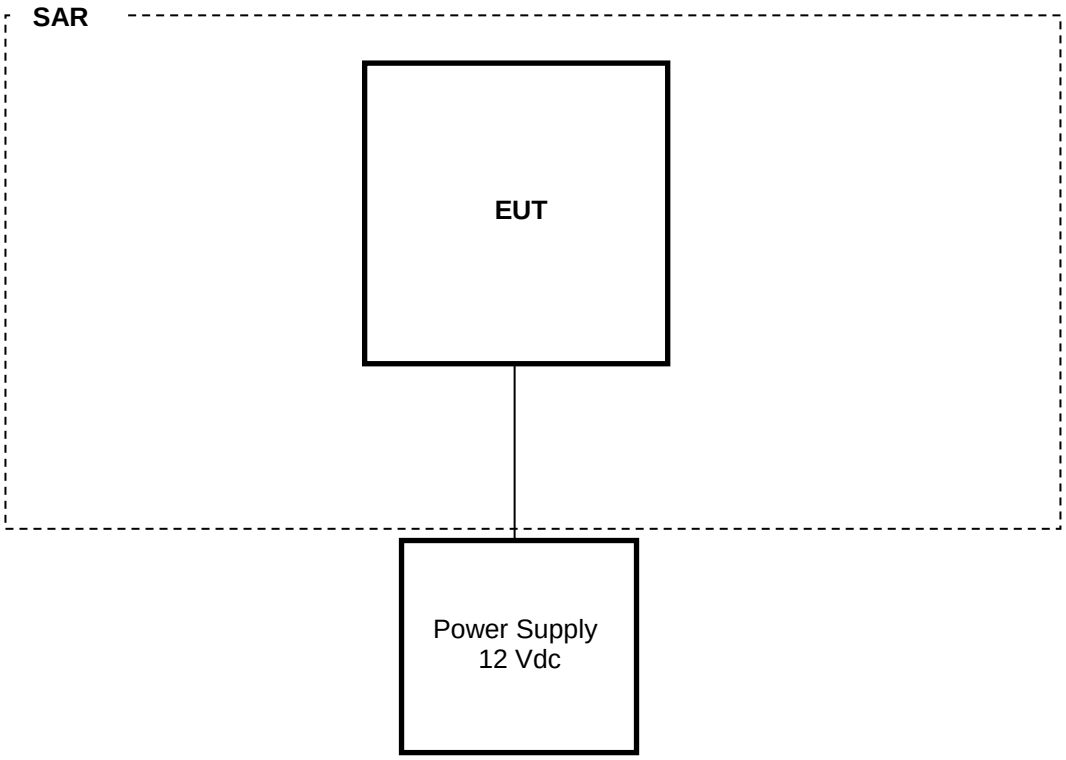
7 Modifications

No modifications were performed during this assessment.

8 EUT Test Setup

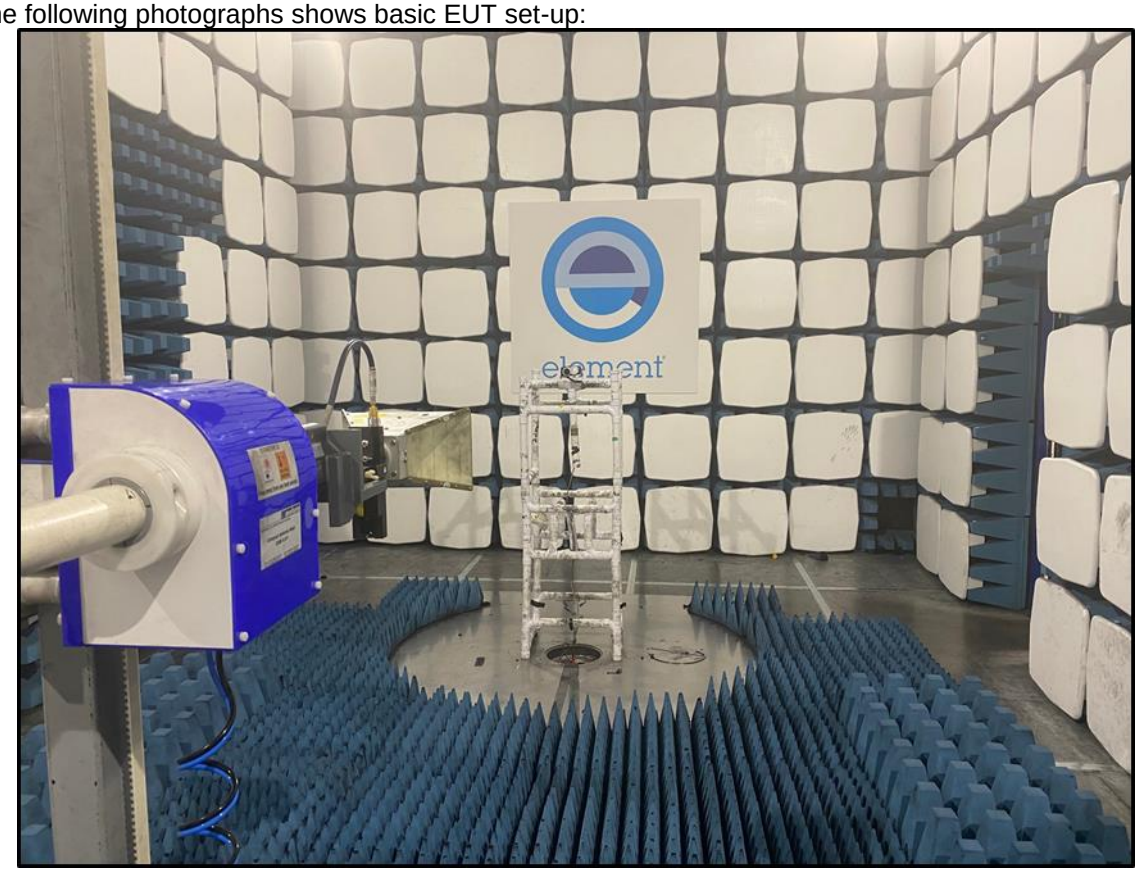
8.1 Block Diagram

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



8.2 General Set-up Photograph

The following photographs shows basic EUT set-up:



8.3 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.

9 General Technical Parameters

9.1 Normal Conditions

The BTLE / Node 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.

Modes of operation:	**BTLE**	**NFC**	**LF**
Frequencies of operation:	2402 MHz to 2480 MHz	13.56 MHz	125 kHz
Antenna type(s):	PCB Trace	Inductive Loop	LF Antenna
Modulation type(s)	GFSK	ASK	ASK
Nominal Supply Voltage:	12 Vdc	12 Vdc	12 Vdc

10 Multi-radio Simultaneous Transmission Spurious Emissions below 30 MHz

10.1 Definitions

Out-of-band emissions
Emissions on a frequency or frequencies immediately outside the necessary bandwidth which result from the modulation process, but exclude spurious emissions.

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.

10.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	SK03 radio chamber
Test Standard and Clause:	ANSI C63.10-2013, Clause 6.4
Frequencies Measured:	2402 MHz, 2480 MHz, (BTLE) 13.56 MHz (NFC) 125 kHz (LF)
Deviations From Standard:	None
Measurement Distance and Site	3 m
EUT Height:	1 m
Measurement Antenna and Height:	60 cm shielded loop; 1 m
Measurement BW:	9 kHz to 150 kHz: 200 Hz; 150 kHz to 30 MHz: 9 kHz
Measurement Detector:	9 kHz to 90 kHz and 110 kHz to 490 kHz: Average, RMS Other frequencies below 30 MHz: Quasi-peak.

Environmental Conditions (Normal Environment)

Temperature: 22 °C	+15 ºC to +35 ºC (as declared)
Humidity: 42 % RH	20 % RH to 75 % RH (as declared)
Supply: 12 Vdc	12 Vdc (as declared)

10.3 Test Limit

Emissions from license-exempt transmitters shall comply with the field strength limits shown in the table below. Additionally, the level of any transmitter emission shall not exceed the level of the transmitter's fundamental emission.

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

Frequency, f (kHz)	*Field Strength*	*Measurement Distance (m)*
9 to 490	2,400 / 377.f (µA/m) 2,400 / f (µV/m)	300
490 to 1,750	24,000 / 377.f (µA/m) 24,000 / f (µV/m)	30
1,750 to 30,000	30 (µV/m)	30

n.b. Devices operated pursuant to §15.225 / RSS-210 B.6 are exempt from complying with the restricted band requirements for the 13.36–13.41 MHz band only.

10.4 Test Method

With the EUT setup as per section 9 of this report and connected as per Figure I, the EUT fundamental frequency was maximised by rotating the EUT through 360º, in three orthogonal planes, and adjusting the measurement antenna azimuth.

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 9 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 9 kHz and 30 MHz are measured using a calibrated 60cm active loop antenna. 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.

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

$$FS = 10\ (PR - CF) / 20$$

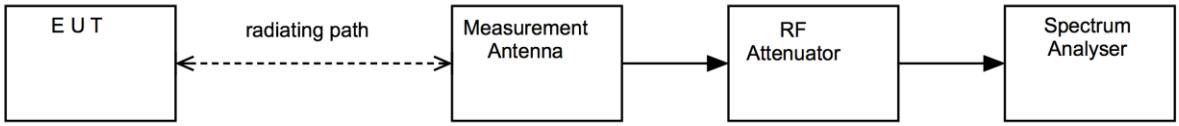
Where,

PR is the power recorded on the receiver / spectrum analyzer in dBµV and includes any cable loss, antenna factor and pre-amplifier gain;
CF is the distance extrapolation factor in dB (where measurement distance different to limit distance);

Per FCC 47CFR15.31(f)(2) / RSS-Gen 6.4, an extrapolation factor of 40 dB per decade was used for extrapolation from 3 m to 30 m and from 3 m to 300 m.

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

Figure I Test Setup



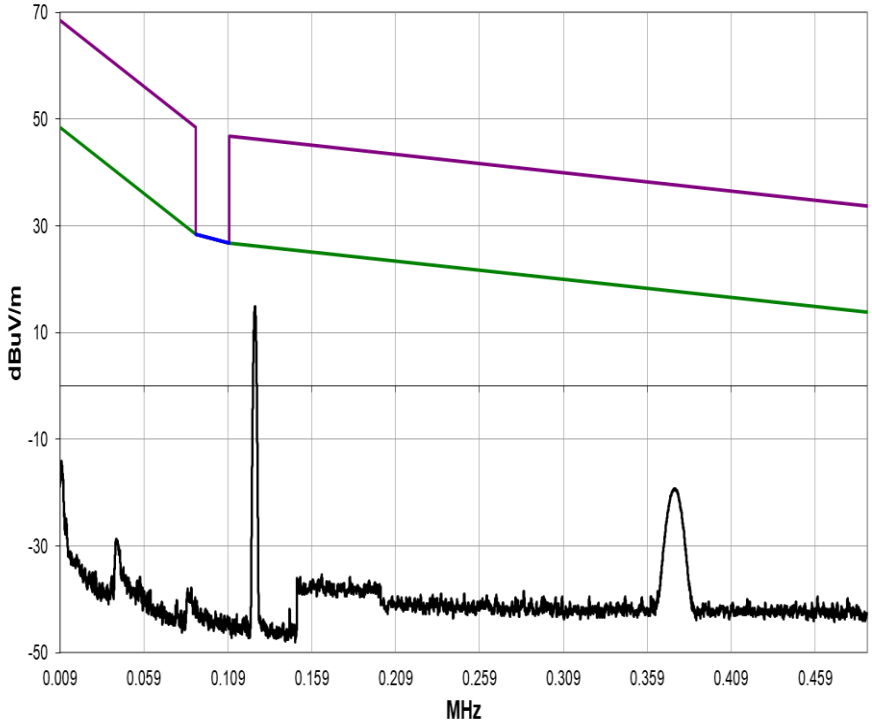
10.5 Test setup photograph

10.6 Test Equipment

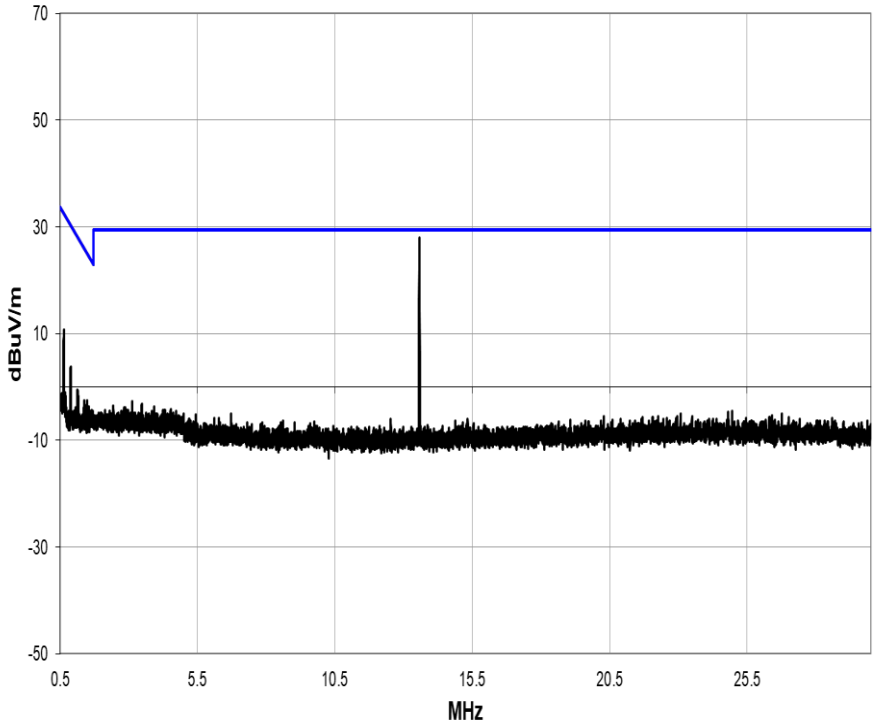
Equipment Type	*Manufacturer*	*Equipment Description*	*Element No*	*Due For Calibration*
Spectrum Analyser	R&S	FSU46	REF910	2021-11-18
Loop Antenna	R&S	hfh2	L007	2021-07-09
ATS	Rainford EMC	Radio Chamber – PP	REF940	2021-12-09

10.7 Test Results

BTLE; Frequency 2402 MHz; NFC: 13.56 MHz; LF: 125 kHz



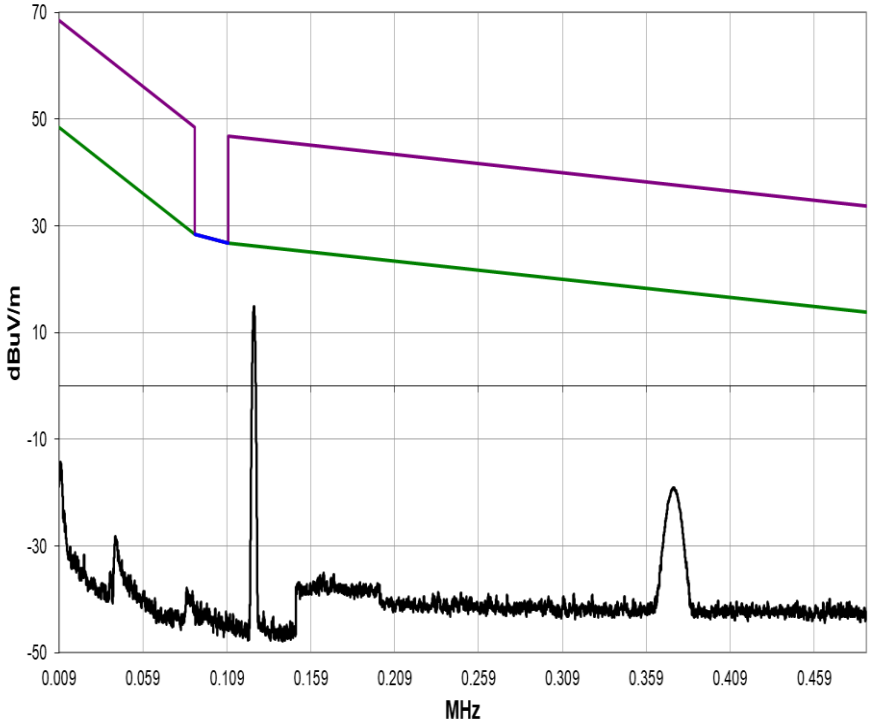
9 kHz to 490 kHz



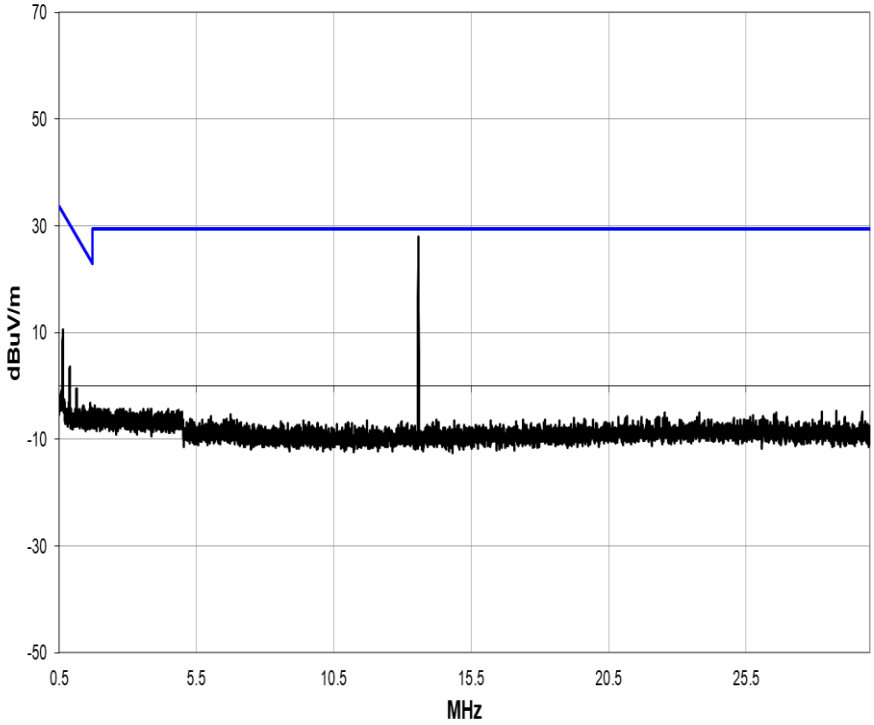
490 kHz to 30 MHz

All emissions on graphs are related to either the BTLE 2.4 GHz, NFC 13.56 MHz or LF 125 kHz operation and are not intermodulation products.

BTLE; Frequency 2480 MHz; NFC: 13.56 MHz; LF: 125 kHz



9 kHz to 490 kHz



490 kHz to 30 MHz

All emissions on graphs are related to either the BTLE 2.4 GHz, NFC 13.56 MHz or LF 125 kHz operation and are not intermodulation products.

11 Multi-radio Simultaneous Transmission Spurious Emissions above 30 MHz

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.

Intermodulation products
Emissions of two or more electromagnetic waves transmitted simultaneously through a nonlinear electronic system.

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 Tested:	2402 MHz, 2480 MHz, (BTLE) 13.56 MHz (NFC) 125 kHz (LF)
Deviations From Standard:	None
Measurement BW:	9 kHz to 150 kHz: 1 kHz 150 kHz to 30 MHz: 10 kHz 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: 22 °C	+15 ºC to +35 ºC (as declared)
Humidity: 33% RH	20 % RH to 75 % RH (as declared)
Supply: 12 Vdc	12 Vdc (as declared)

11.3 Test Limits

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

Least stringent limit applied to any intermodulation products.

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:

$$FS = PR + CL + AF – PA + DC – CF$$

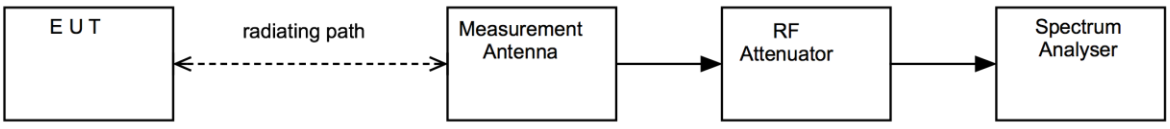
$$Factor = CL + AF - PA$$

Where,

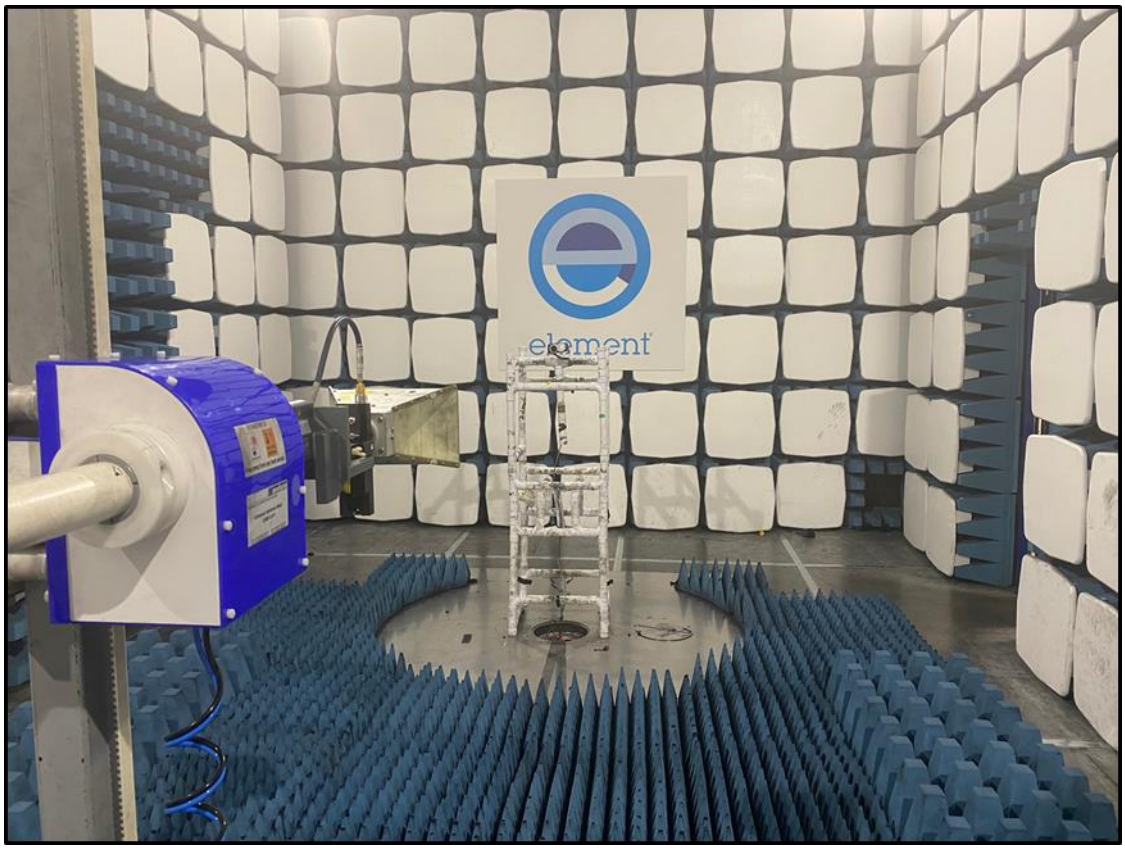
PR is the power recorded on the receiver / spectrum analyzer in dBµV;
CL is the cable loss in dB;
AF is the test antenna factor in dB/m;
PA is the pre-amplifier gain in dB (where used);
DC is the duty correction factor in dB (where used, e.g. harmonics of pulsed fundamental);
CF is the distance factor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

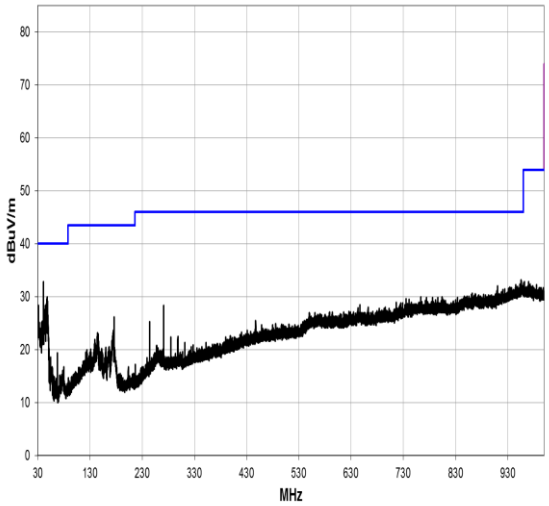


11.6 Test Equipment

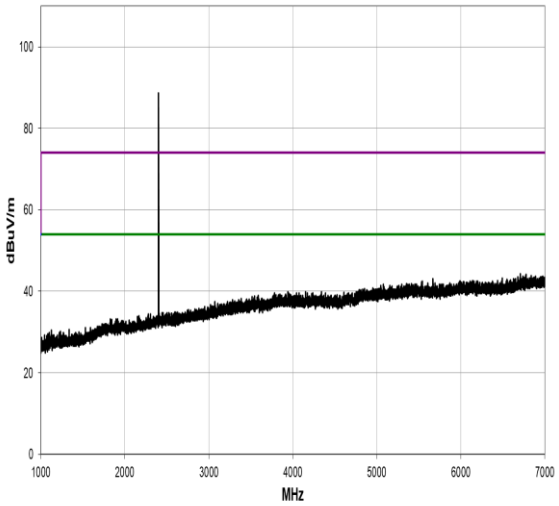
Equipment Description	*Manufacturer*	*Equipment Type*	*Element No*	*Due For Calibration*
Spectrum Analyser	R&S	FSU46	REF910	2021-11-16
Bilog	Chase	CBL611/A	U573	2021-09-19
1-18GHz Horn	EMCO	3115	L139	2021-07-16
Pre Amp	Watkins Johnson	6201-69	U372	2021-02-26
Pre Amp	Agilent	8449B	L572	2021-10-19
Horn 18-26GHz (&U330)	Flann	20240-20	L300	2022-04-23
Loop Antenna	R&S	hfh2	L007	2021-07-09
Radio Chamber - PP	Rainford EMC	ATS	REF940	2021-12-09

11.7 Results

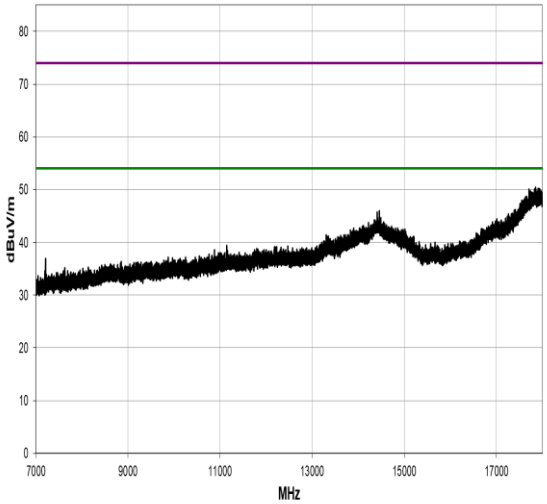
BTLE; Frequency 2402 MHz; NFC: 13.56 MHz; LF: 125 kHz



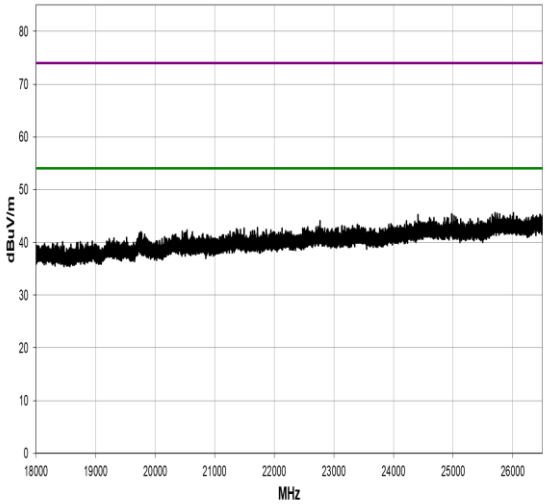
30 MHz to 1 GHz



1 GHz to 7 GHz



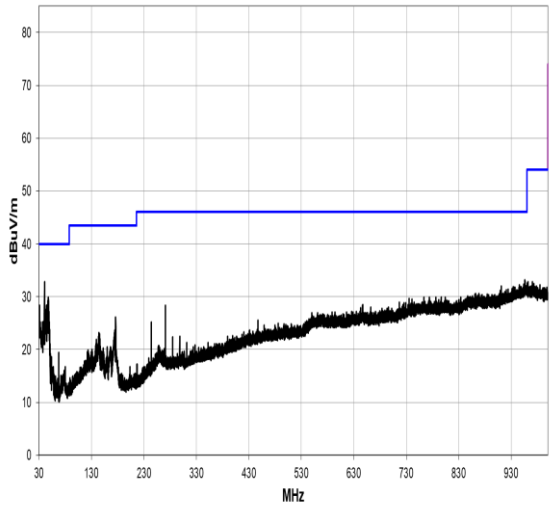
7 GHz to 18 GHz



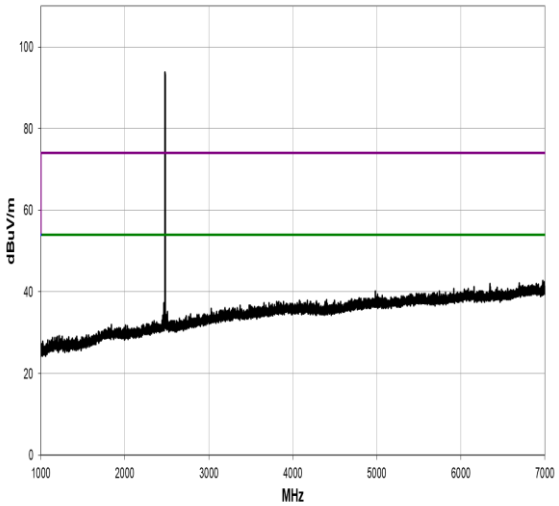
18 GHz to 26.5 GHz

All emissions on graphs are related to either the BTLE 2.4 GHz, NFC 13.56 MHz or LF 125 kHz operation and are not intermodulation products.

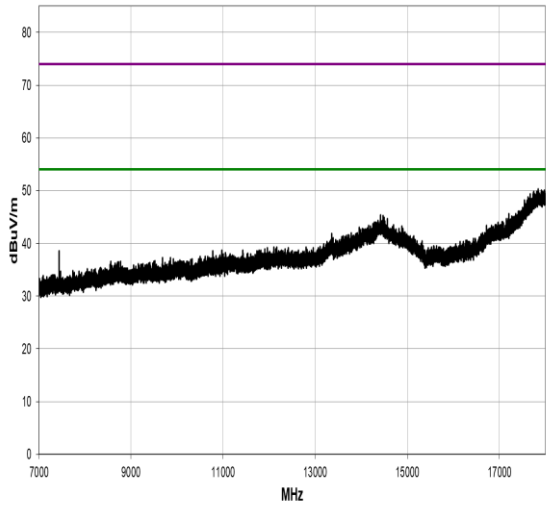
BTLE; Frequency 2480 MHz; NFC: 13.56 MHz; LF: 125 kHz



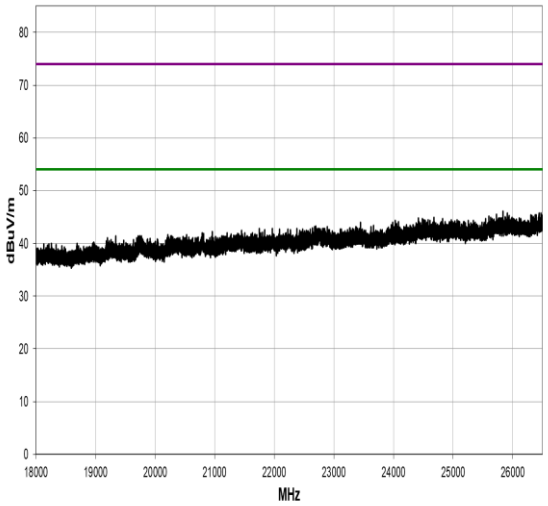
30 MHz to 1 GHz



1 GHz to 7 GHz



7 GHz to 18 GHz



18 GHz to 26.5 GHz

All emissions on graphs are related to either the BTLE 2.4 GHz, NFC 13.56 MHz or LF 125 kHz operation and are not intermodulation products.

12 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) = **4.6 dB**
Uncertainty in test result (1 GHz to 18 GHz) = **4.7 dB**

13 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

Radio	*Lowest frequency (MHz)*	*EIRP (mW)*	*Power density at 20 cm (mW/cm²)*	*Power density limit (mW/cm²)*	*Ratio*	*Sum of Ratios*	*RF Exposure Evaluation*
LF	0.125	12.3	0.002	11520.000	0.000	0.001	Not Required
NFC	13.56	0.7	0.000	0.979	0.000		
BTLE	2402	1.9	0.000	1.000	0.000		

14 RF EXPOSURE TECHNICAL BRIEF

RSS-102 issue 5

2.5.2 Exemption Limits for Routine Evaluation – RF Exposure Evaluation

RF exposure evaluation is required if the separation distance between the user and/or bystander and the device's radiating element is greater than 20 cm, except when the device operates as follows:

- below 20 MHz and the source-based, time-averaged maximum e.i.r.p. of the device is equal to or less than 1 W (adjusted for tune-up tolerance);
- at or above 20 MHz and below 48 MHz and the source-based, time-averaged maximum e.i.r.p. of the device is equal to or less than $4.49/f^{0.5}$W (adjusted for tune-up tolerance), where f is in MHz;
- at or above 48 MHz and below 300 MHz and the source-based, time-averaged maximum e.i.r.p. of the device is equal to or less than 0.6 W (adjusted for tune-up tolerance);
- at or above 300 MHz and below 6 GHz and the source-based, time-averaged maximum e.i.r.p. of the device is equal to or less than $1.31 \times 10^{-2}\ f^{0.6834}$ W (adjusted for tune-up tolerance), where f is in MHz;
- at or above 6 GHz and the source-based, time-averaged maximum e.i.r.p. of the device is equal to or less than 5 W (adjusted for tune-up tolerance).

Radio Type	***Frequency (MHz)***	***EIRP (mW)***	***RF Exposure Exclusion Threshold (W)***	***Ratio***	***Sum of Ratios***	***RF Exposure Evaluation***
LF	0.125	12.3	1.0	0.012	0.014	Not Required
NFC	13.56	0.7	1.0	0.001		
BTLE	2402	1.9	2.7	0.001		