

Report on the Radio Testing
For
Wearable Technologies Limited
On
M028 Connected HUB
Report no. TRA-044007-45-01B
Date: 19 December 2019

Report Number: TRA-044007-45-01B
Issue: B

REPORT ON THE RADIO TESTING OF A
Wearable Technologies Limited

M028 Connected HUB
INTERMODULATION INVESTIGATION
TO SELECTED PARTS OF SPECIFICATION
47 CFR Parts 15, 22, 24 and 27

TEST DATE: From 2019-10-30 to 2019-11-1

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Date: 19 December 2019

Disclaimers:

- [1] THIS DOCUMENT MAY BE REPRODUCED ONLY IN ITS ENTIRETY AND WITHOUT CHANGE
[2] THE RESULTS CONTAINED IN THIS DOCUMENT RELATE ONLY TO THE ITEM(S) TESTED

1 Revision Record

<i>Issue Number</i>	<i>Issue Date</i>	<i>Revision History</i>
A	2019-12-04	Original
B	2019-12-19	Updated with various information and plots

2 Summarye

TEST REPORT NUMBER:	TRA-044007-45-01B
WORKS ORDER NUMBER:	TRA-044007-03
PURPOSE OF TEST:	Intermodulation investigation for NFC, Cellular and WLAN / BLE to support a Class II permissive change 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(S):	Selected parts of 47 CFR 15, 22, 24 and 27
EQUIPMENT UNDER TEST (EUT):	M028 Connected HUB
EUT FCC IDENTIFIER:	2AU6IWTLM028
CELLULAR FCC IDENTIFIER:	XPYUBX18ZO01
WIFI / BLUETOOTH FCC IDENTIFIER:	2AC7Z-ESPWROOM32
EUT SERIAL NUMBER:	Sample number TRA-044007-S26
MANUFACTURER/AGENT:	Wearable Technologies Limited
ADDRESS:	Unit 12, Warrens Business Park, Enderby, Leicester LE19 4SA UK
CLIENT CONTACT:	Kevin Bailey ☎ +44 (0)1455 563 000 ✉ kevin.bailey@wearable.technology
ORDER NUMBER:	PO:WTL-0285
TEST DATE:	From 2019-10-30 to 2019-11-1
TESTED BY:	A. L. Y. Wong Element

2.1 Test Summary

<i>Test Method and Description</i>	<i>47CFR Requirement Clause</i>	<i>Applicable to this equipment</i>	<i>Result / Note</i>
Radiated emission limits*	15.209	☒	PASS*
Emission limitations*	22.359	☒	PASS*
Emission limits*	24.133	☒	PASS*
Emission limits	27.53	☒	PASS*

Notes:

*This report only covers the limited testing on NFC, Cellular and WiFi / Bluetooth Low Energy transmitters were operating simultaneously.

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).

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4 Introduction

This report TRA-044007-45-01A presents the results of the Radio testing on a Wearable Technologies Ltd. M028 Connected HUB, to specification 47CFR15 Radio Frequency Devices, 47CFR22 Public Mobile Devices, 47CFR24 Personal Communication Services and 47CFR27 Miscellaneous Wireless Communication Services.

The testing was carried out for Wearable Technologies Ltd 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 Skelmersdale West Lancashire WN8 9PN UK
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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:

Element is accredited for the above sites under the US-EU MRA, Designation number UK0009.

IC Registration Number(s):

Element Hull	3483A
Element North West	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.
- FCC 47 CFR Ch. I – Part 22 – Public Mobile Services
- FCC 47 CFR Ch. I – Part 24 – Personal Communication Services
- FCC 47 CFR Ch. I – Part 27 – Miscellaneous Wireless Communication Services.
- 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

Only selected parts of the standards were tested as per request from the client.

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: M028 Connected HUB
- Sample Number: TRA-044007-S26
- Model Number: M028
- Software Revision: Not Applicable
- Build Level / Revision Number: REV B1
- FCC ID: 2AU6IWTLM028

Cellular module

- Name: u-blox AG
- Model: SARA-R412M
- FCC ID: XPYUBX18ZO01

WiFi / BLE module

- Name: ESPRESSIF systems
- Model: ESP32-WROOM-32
- FCC ID: 2AC7Z-ESPWROOM32

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.

Dell Test laptop TRA-044007-S8
NFC Circuit controller TRA-044007-S27
NFC tag TRA-044007-S22
Atolla USB hub with power adapter TRA-044007-S7
Power supply unit REF160

7.3 EUT Mode of Operation

7.3.1 Transmission

The mode of operation for transmitter tests was as follows.

Using a computer, AT commands with maximum power settings were sent to cellular modem to transmit test signals.

AT commands used:

AT+UTEST=1;

AT+UTEST=3,123095,23,,,0 //4G Band 12 707.5 MHz EARFCN 23095 23 dBm

AT+UTEST=3,120525,23,,,0 //4G Band 5 836.5 MHz EARFCN 20526 23dBm

AT+UTEST=3,189,5,,,0 // 2G GSM850 / 5 836.5 MHz ARFCN 189 PCL5 33dBm

AT+UTEST=3,33429,0,,,0 // 2G GSM1900 / 5 1880 MHz ARFCN 189 PCL0 30dBm

AT+UTEST=3,33429,0,,,0 //4G Band 4 1732.5 MHz EARFCN 20175 23 dBm

Using EspRFtestTool app, WiFi transmitter with 0 dB power attenuation / BLE with maximum power setting 8, transmitter was set to transmit required signals. The NFC circuit controlled from another device was constantly activated with a tag.

7.4 EUT Radio Parameters

7.4.1 General

Radio Type:	NFC	Cellular	WLAN / BLE
Frequencies of operation:	13.56 MHz	698 MHz – 2690 MHz	2400 MHz – 2483.5 MHz
Declared output power:	22 dBµV/m at 3m	23-32 dBm	16.6 dBm
Antenna type:	Printed Trace	SMD	Integral PCB Trace
Peak Antenna gain:	Unknown	GSM 850: 1.0 dBi GSM 1900: 2.5 dBi LTE Band 2: 2.5 dBi LTE Band 4: 2.5 dBi LTE Band 5: 1.0 dBi LTE Band 12: 0.5 dBi LTE Band 13: 0.5 dBi	3.7 dBi

7.5 EUT Description

The EUT is a wearable device integrated into high-visibility vest, with various sensors such as gas etc., multiple radios and internal battery.

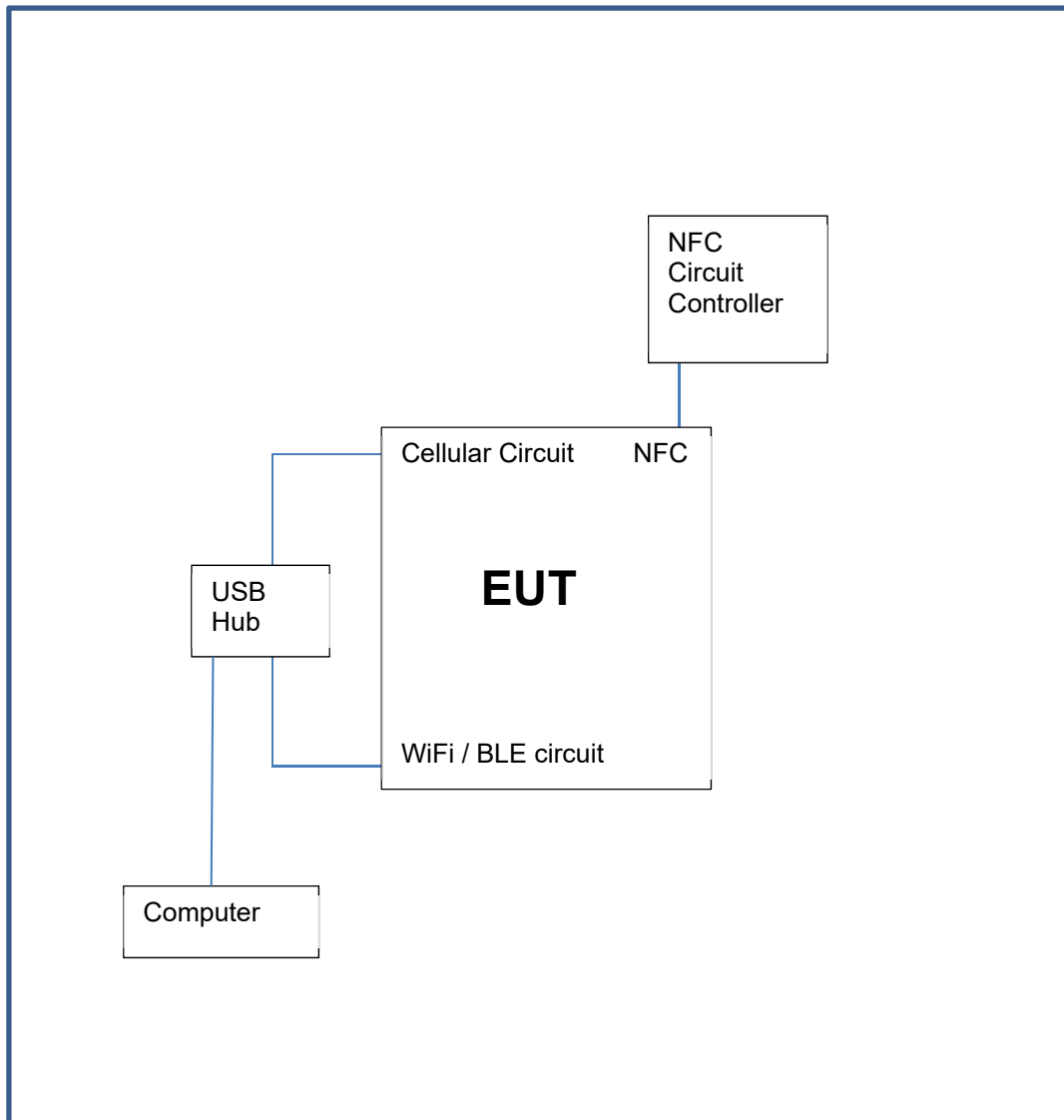
8 Modifications

No modifications were performed during this assessment.

9 EUT Test Setup

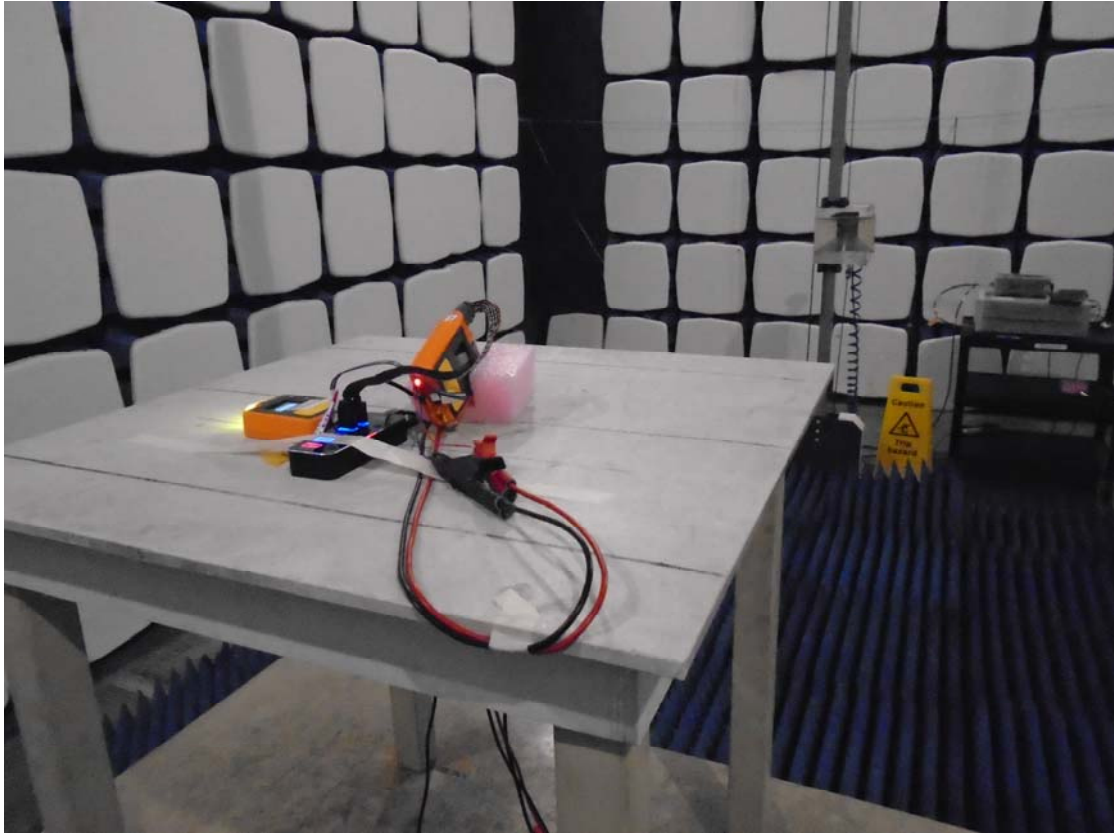
9.1 Block Diagram

The following diagram shows basic EUT interconnections:



9.2 General Set-up Photograph

The following photograph shows basic EUT set-up:



10 General Technical Parameters

10.1 Normal Conditions

The E U T was tested under the normal environmental conditions of the test laboratory, except where otherwise stated. The normal power source applied was 3.7 V dc from internal rechargeable battery.

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 Hull
Test Chamber:	Wireless Lab 3
Test Standard and Clause:	ANSI C63.10-2013, Clause 6.5 and 6.6
Frequency Measured:	13.56 MHz / 707.5 MHz / 836.5 MHz / 1732.5 MHz / 1880 MHz / 2404 MHz / 2412 MHz / 2462 MHz / 2480 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: 20 °C	+15 °C to +35 °C (as declared)
Humidity: 50 % RH	20 % RH to 75 % RH (as declared)
Supply: 3.7 V dc	

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 ($\mu\text{V/m}$ 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:

$$FS = PR + CL + AF - PA + DC - CF$$

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;

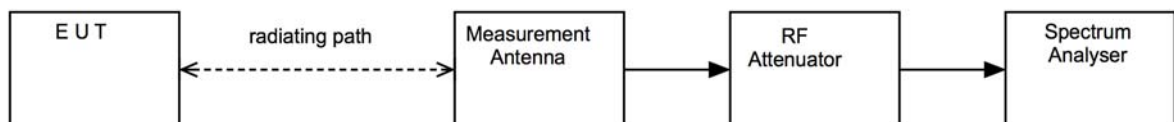
PA is the pre-amplifier gain in dB (where used);

DC is the duty correction factor in dB (where used, e.g. harmonics of pulsed fundamental);

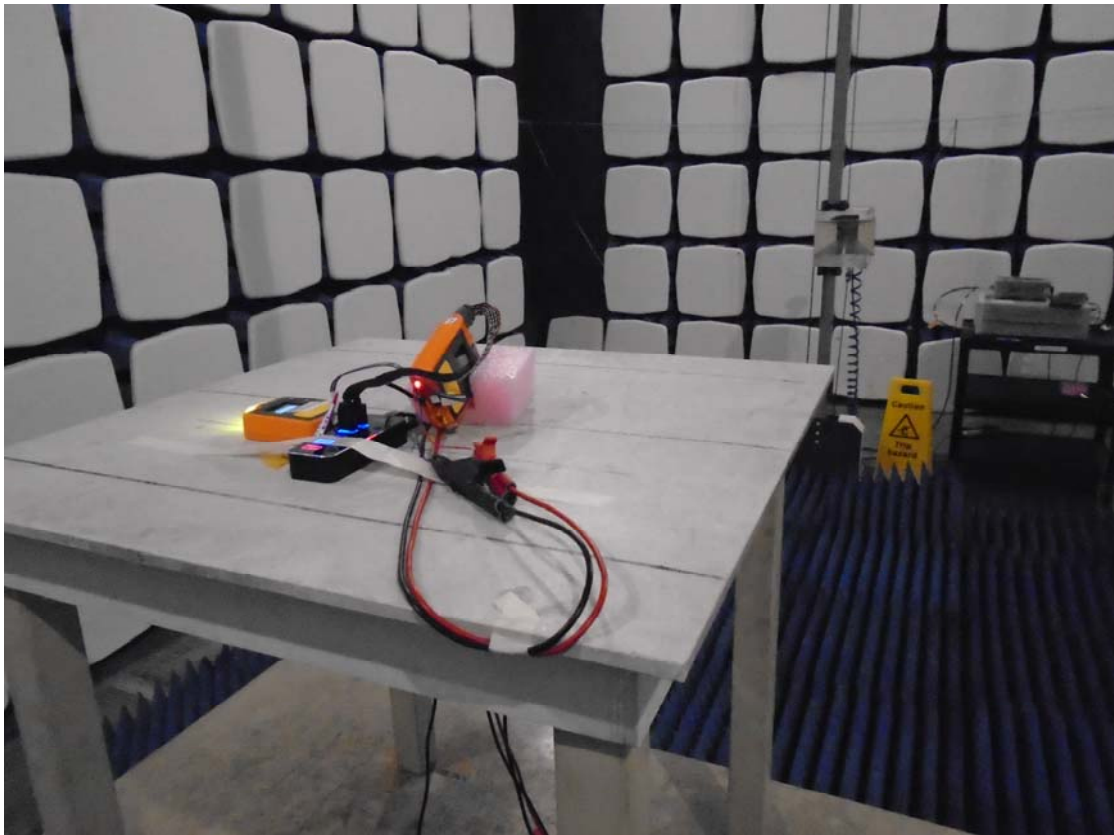
CF is the distance factor in dB (where measurement distance different to limit distance);

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

<i>Equipment Description</i>	<i>Manufacturer</i>	<i>Equipment Type</i>	<i>Element No</i>	<i>Due For Calibration</i>
Bilog Antenna	Chase	CBL6111B	REF2233	2020-08-17
Horn Antenna	EMCO	3115	RFG129	2020-02-12
Horn Antenna	EMCO	3115	L138	2020-04-13
Biconical Antenna	Schwarzbeck	VUBA9117	REF2239	2021-07-13
Pre-Amp (9 kHz - 1 GHz)	Sonoma	310	REF927	2020-05-29
Pre-Amp (1 - 26.5 GHz)	Agilent	8449B	REF913	2020-02-06
Ferrite Lined Chamber	Rainford	ATS	REF886	2020-07-29
Spectrum Analyser	Agilent	N9030A	REF2167	2020-08-12

11.7 Test Results

4G Band 12 707.5 MHz / WiFi 2412 MHz / NFC 13.56 MHz					
Emission	Frequency (MHz)	Level (dBm)	Limit (dBm)	Margin (dB)	Result
All emissions were greater than 20 dB below the limit					PASS

4G Band 12 707.5 MHz / WiFi 2462 MHz / NFC 13.56 MHz					
Emission	Frequency (MHz)	Level (dBm)	Limit (dBm)	Margin (dB)	Result
All emissions were greater than 20 dB below the limit					PASS

4G Band 12 707.5 MHz / Bluetooth LE 2404 MHz / NFC 13.56 MHz					
Emission	Frequency (MHz)	Level (dBm)	Limit (dBm)	Margin (dB)	Result
All emissions were greater than 20 dB below the limit					PASS

4G Band 12 707.5 MHz / Bluetooth LE 2480 MHz / NFC 13.56 MHz					
Emission	Frequency (MHz)	Level (dBm)	Limit (dBm)	Margin (dB)	Result
All emissions were greater than 20 dB below the limit					PASS

4G Band 5 836.5 MHz / WiFi 2412 MHz / NFC 13.56 MHz					
Emission	Frequency (MHz)	Level (dBm)	Limit (dBm)	Margin (dB)	Result
All emissions were greater than 20 dB below the limit					PASS

4G Band 5 836.5 MHz / WiFi 2462 MHz / NFC 13.56 MHz					
Emission	Frequency (MHz)	Level (dBm)	Limit (dBm)	Margin (dB)	Result
All emissions were greater than 20 dB below the limit					PASS

4G Band 5 836.5 MHz / Bluetooth LE 2404 MHz / NFC 13.56 MHz					
Emission	Frequency (MHz)	Level (dBm)	Limit (dBm)	Margin (dB)	Result
All emissions were greater than 20 dB below the limit					PASS

4G Band 5 836.5 MHz / Bluetooth LE 2480 MHz / NFC 13.56 MHz					
Emission	Frequency (MHz)	Level (dBm)	Limit (dBm)	Margin (dB)	Result
All emissions were greater than 20 dB below the limit					PASS

GSM850 836.5 MHz / WiFi 2412 MHz / NFC 13.56 MHz					
Emission	Frequency (MHz)	Level (dBm)	Limit (dBm)	Margin (dB)	Result
All emissions were greater than 20 dB below the limit					PASS

GSM850 836.5 MHz / WiFi 2462 MHz / NFC 13.56 MHz					
Emission	Frequency (MHz)	Level (dBm)	Limit (dBm)	Margin (dB)	Result
All emissions were greater than 20 dB below the limit					PASS

GSM850 836.5 MHz / Bluetooth LE 2404 MHz / NFC 13.56 MHz					
Emission	Frequency (MHz)	Level (dBm)	Limit (dBm)	Margin (dB)	Result
All emissions were greater than 20 dB below the limit					PASS

GSM850 836.5 MHz / Bluetooth LE 2480 MHz / NFC 13.56 MHz					
Emission	Frequency (MHz)	Level (dBm)	Limit (dBm)	Margin (dB)	Result
All emissions were greater than 20 dB below the limit					PASS

PCS1900 1880 MHz / WiFi 2412 MHz / NFC 13.56 MHz					
Emission	Frequency (MHz)	Level (dBm)	Limit (dBm)	Margin (dB)	Result
All emissions were greater than 20 dB below the limit					PASS

PCS1900 1880 MHz / WiFi 2462 MHz / NFC 13.56 MHz					
Emission	Frequency (MHz)	Level (dBm)	Limit (dBm)	Margin (dB)	Result
All emissions were greater than 20 dB below the limit					PASS

PCS1900 1880 MHz / Bluetooth LE 2404 MHz / NFC 13.56 MHz					
Emission	Frequency (MHz)	Level (dBm)	Limit (dBm)	Margin (dB)	Result
All emissions were greater than 20 dB below the limit					PASS

PCS1900 1880 MHz / Bluetooth LE 2480 MHz / NFC 13.56 MHz					
Emission	Frequency (MHz)	Level (dBm)	Limit (dBm)	Margin (dB)	Result
All emissions were greater than 20 dB below the limit					PASS

4G Band 4 1732.5 MHz / WiFi 2412 MHz / NFC 13.56 MHz					
Emission	Frequency (MHz)	Level (dBm)	Limit (dBm)	Margin (dB)	Result
All emissions were greater than 20 dB below the limit					PASS

4G Band 4 1732.5 MHz / WiFi 2462 MHz / NFC 13.56 MHz					
Emission	Frequency (MHz)	Level (dBm)	Limit (dBm)	Margin (dB)	Result
All emissions were greater than 20 dB below the limit					PASS

4G Band 4 1732.5 MHz / Bluetooth LE 2404 MHz / NFC 13.56 MHz					
Emission	Frequency (MHz)	Level (dBm)	Limit (dBm)	Margin (dB)	Result
All emissions were greater than 20 dB below the limit					PASS

4G Band 4 1732.5 MHz / Bluetooth LE 2480 MHz / NFC 13.56 MHz					
Emission	Frequency (MHz)	Level (dBm)	Limit (dBm)	Margin (dB)	Result
All emissions were greater than 20 dB below the limit					PASS

12 Measurement Uncertainty

[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**