



A part of



Radio Test Report

Eccel Technology Ltd

10xRS485 Reader

47 CFR Part 15.225 Effective Date 1st October 2020
DXX: Part 15 Low Power Communication Device Transmitter
Test Date: 22nd June 2022 to 24th June 2022
Report Number: 06-13629-1-22 Issue 01

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Certificate of Test 13629-1

The equipment noted below has been fully tested by R.N. Electronics Limited and, where appropriate, conforms to the relevant subpart of 47 CFR Part 15C. This is a certificate of test only and should not be confused with an equipment authorisation. Other standards may also apply.

Equipment (PMN):	10xRS485 Reader
Model Number(HVIN):	1.1
Unique Serial Number:	ACT32P-102-2P-TL01
Applicant:	Eccel Technology Ltd 198 Station Road, Glenfield Leicester, Leicestershire LE3 8GT
Proposed FCC ID	2ALHY000537
Full measurement results are detailed in Report Number:	06-13629-1-22 Issue 01
Test Standards:	47 CFR Part 15.225 Effective Date 1st October 2020 DXX: Part 15 Low Power Communication Device Transmitter

NOTE:

Certain tests were not performed based upon applicant's declarations. Certain other requirements are subject to applicant's declaration only and have not been tested/verified. For details refer to section 3 of this report.

DEVIATIONS:

No deviations have been applied.

This certificate relates only to the unit tested as identified by a unique serial number and in the condition at the time it was tested. It does not relate to any other similar equipment and performance of the product before or after the test cannot be guaranteed. Whilst every effort is made to assure quality of testing, type tests are not exhaustive and although no non-conformances may be found, this doesn't exclude the possibility of unit not meeting the intentions of the standard or the requirements of the Federal Regulations, particularly under different conditions to those during testing. Any compliance statements are made reliant on (a) the application of the product and use of the assigned band being acceptable to the FCC and (b) the modes of operation as instructed to us by the Customer based on their specific knowledge of the application and functionality of the EUT. Statements of compliance, where measurements were made, do not include the measurement uncertainty. The measurement uncertainty, where stated, is the expanded uncertainty based on a standard uncertainty multiplied by a coverage factor of k=2, providing a level of confidence of approximately 95%.

Date Of Test: 22nd June 2022 to 24th June 2022

Test Engineer:

Approved By:
Radio Manager

Customer
Representative:



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2 Equipment under test (EUT)

2.1 Equipment specification

Applicant	Eccel Technology Ltd 198 Station Road Glenfield Leicester Leicestershire LE3 8GT	
Manufacturer of EUT	Eccel Technology Limited	
Full Name of EUT	10xRS485 Reader	
Model Number of EUT	1.1	
Serial Number of EUT	ACT32P-102-2P-TL01	
Date Received	6th June 2022	
Date of Test:	22nd June 2022 to 24th June 2022	
Purpose of Test	To demonstrate design compliance to the relevant rules of Chapter 47 of the Code of Federal Regulations.	
Date Report Issued	27th July 2022	
Main Function	Reading RFID tags	
Information Specification	Height	7.5 mm
	Width	70 mm
	Depth	40 mm
	Weight	0.015 kg
	Voltage	5 V
	Current	0.25 A

2.2 Configurations for testing

General Parameters	
EUT Normal use position	Application dependant inside a host
Choice of model(s) for type tests	Production Sample
Antenna details	PCB track antenna/coil
Antenna port	Not Applicable
Baseband Data port (yes/no)?	No
Highest Signal generated in EUT	240 MHz
Lowest Signal generated in EUT	2 MHz
Hardware Version (HVIN)	1.1
Software Version	1.5
Firmware Version (FVIN)	2.3
Type of Equipment	Tag reader
Technology Type	RFID
Geo-location (yes/no)	No
TX Parameters	
Alignment range – transmitter	13.56 MHz
EUT Declared Modulation Parameters	ASK
EUT Declared Power level	Not declared
EUT Declared Signal Bandwidths	Not declared
EUT Declared Channel Spacing's	Single channel
EUT Declared Duty Cycle	100%
Unmodulated carrier available?	Yes
Declared frequency stability	20 ppm
RX Parameters	
Alignment range – receiver	13.56 MHz
EUT Declared RX Signal Bandwidth	Not declared
Receiver Signal Level (RSL)	Not applicable
Method of Monitoring Receiver BER	Not applicable
FCC Parameters	
FCC Transmitter Class	DXX: Part 15 Low Power Communication Device Transmitter

2.3 Functional description

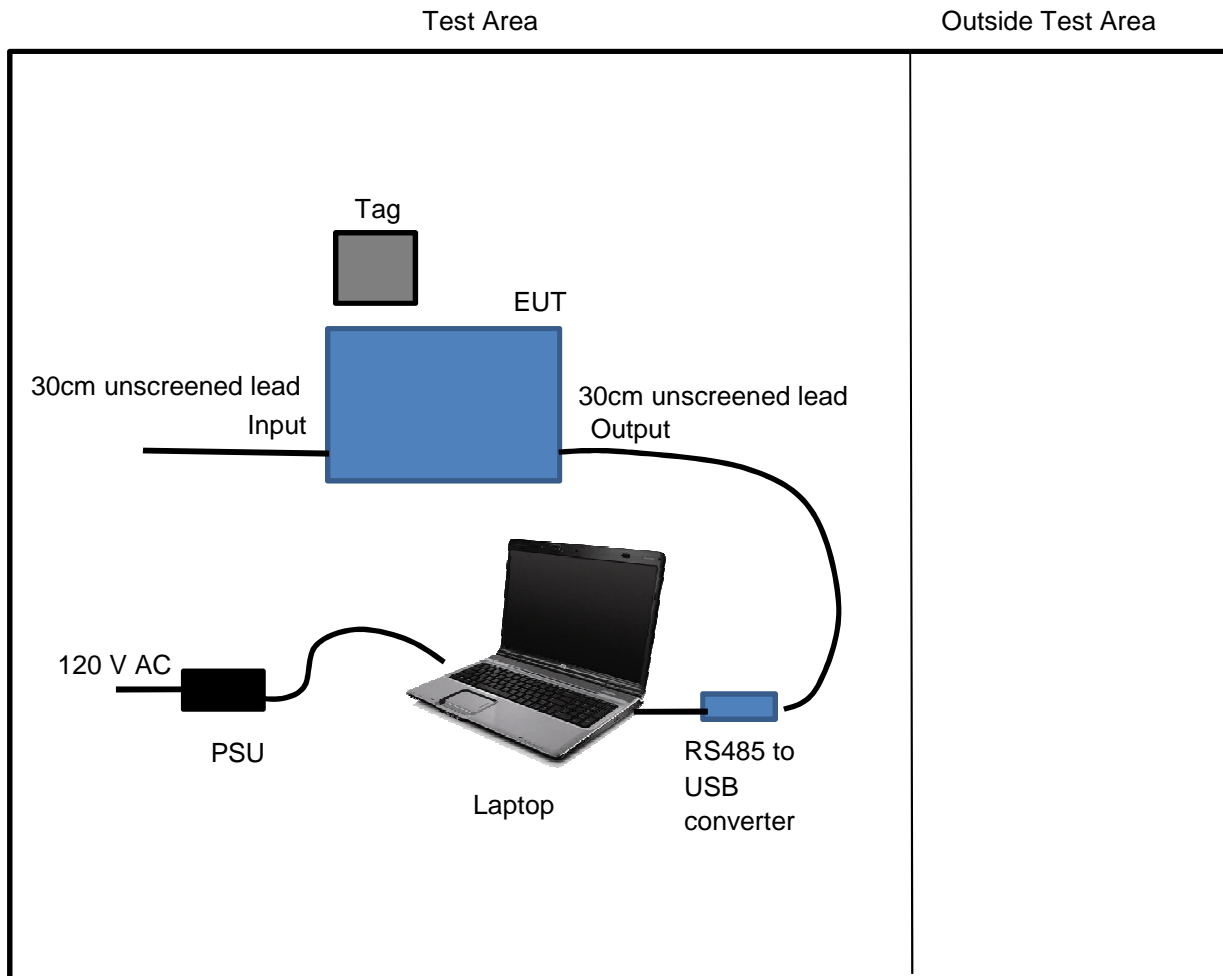
Device is connected via RS485 to the host. Host is initiating communication and have full control over the device(s). More devices (up to 4) can be connected in chain by custom cables. Last device in chain should have line termination enabled. It can be done by special boot function enabled in device. When device is powered up it searches for special tag. If it's found, device will set its internal address (addressing is needed for RS485 communication) and enables line termination if needed and if proper tag was found.

2.4 Modes of operation

Mode Reference	Description	Used for testing
TX1	13.56 MHz max power CW	Yes
TX2	13.56 MHz max power no tag	Yes
TX3	13.56 MHz max power tag presented	Yes
TX4	13.56 MHz Antenna disconnected	Yes

Note: The Tag presented to the reader was the NTAG and was used with TX3 mode for all tests.

2.5 Emissions configuration



The EUT was powered from a RS485 to USB converter via a USB port on a laptop powered from 120 V AC mains. As the EUT is a module for use inside a host it was tested a minimum of 10cm away from the controlling Laptop using the provided 30cm unscreened lead. The laptop ran software that was used to put the reader into polling mode and to read back the tag identification as stated within section 2.4 of this report. Two different types of tag were provided for tests, the ICODE tag and the NTAG, checks were performed with both tags and no difference was observed in performance/results between the tags. CW mode is achieved by shorting two pads on the PCB before and during power up. For radiated tests the worst case was found to be with the laptop positioned below the reader so that the EUT wasn't blocked during rotation or during measuring antenna height scanning. The transmit mode was 100% continuous with modulation and the power setting was as stated below:-

Single Channel (13.56 MHz) = max (default) power

2.5.1 Signal leads

Port Name	Cable Type	Connected
5 VDC in RS485	Custom cable	Yes
5 VDC out RS485	Custom cable	Yes

3 Summary of test results

The 10xRS485 Reader was tested for compliance to the following standard(s) :

47 CFR Part 15.225 Effective Date 1st October 2020

Any compliance statements are made reliant on (a) the application of the product and use of the assigned band being acceptable to the FCC and (b) the modes of operation as instructed to us by the Customer based on their specific knowledge of the application and functionality of the EUT. Whilst every effort is made to assure quality of testing, type tests are not exhaustive and although no non-conformances may be found, this doesn't exclude the possibility of equipment not meeting the intentions of the standard or the essential requirements of the directive, particularly under different conditions to those during testing. Statements of compliance, where measurements were made, do not include the measurement uncertainty. The measurement uncertainty, where stated, is the expanded uncertainty based on a standard uncertainty multiplied by a coverage factor of k=2, providing a level of confidence of approximately 95%.

Title	References	Results
Transmitter Tests		
1. AC power line conducted emissions	47 CFR Part 15C Part 15.207	PASSED
2. Radiated emissions 9 - 150 kHz	47 CFR Part 15C Part 15.209	PASSED
3. Radiated emissions 150 kHz - 30 MHz	47 CFR Part 15C Part 15.209	PASSED
4. Radiated emissions 30 MHz -1 GHz	47 CFR Part 15C Part 15.225(d)	PASSED
5. Radiated emissions above 1 GHz	47 CFR Part 15C Part 15.209	PASSED ¹
6. Intentional radiator field strength	47 CFR Part 15C Part 15.225(a)	PASSED
7. Occupied bandwidth	47 CFR Part 15C Part 15.215	PASSED
8. Spectrum mask	47 CFR Part 15C Part 15.225	PASSED
9. Frequency stability	47 CFR Part 15C Part 15.225(e)	PASSED

1 Spectrum investigated up to a frequency of 2.4 GHz based on 10 times the highest signal generated in equipment of 240 MHz.

4 Specifications

The tests were performed and operated in accordance with R.N. Electronics Ltd procedures and the relevant standards listed below.

4.1 Relevant standards

Ref.	Standard Number	Version	Description
4.1.1	47 CFR Part 15C	2020	Federal Communications Commission PART 15 – RADIO FREQUENCY DEVICES
4.1.2	ANSI C63.10	2013	American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices
4.1.3	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

4.2 Deviations

No deviations were applied

4.3 Tests at extremes of temperature & voltage

The following test conditions were used to simulate testing at nominal or extremes.

Temperature Test Conditions		Voltage Test Conditions	
T nominal	20 °C	V nominal	5V DC (USB)
T minimum	-20 °C	V minimum	4.75V DC (USB)
T maximum	50 °C	V maximum	5.25V DC (USB)

Extremes of voltage are based on nominal USB spec of +/-0.25V.

Extremes of temperature are based upon the requirements of 47 CFR Part 15C.

The ambient test conditions of humidity and pressure in the laboratory were as specified in each specific test section within this report

4.4 Test fixtures

In order to measure RF parameters at temperature extremes, the EUT was tested in a temperature controlled chamber as follows:

A test fixture was used for testing.

5 Tests, methods and results

5.1 AC power line conducted emissions

5.1.1 Test methods

Test Requirements:	47 CFR Part 15C Part 15.207 [Reference 4.1.1 of this report]
Test Method:	ANSI C63.10 Clause 6.2 [Reference 4.1.2 of this report]
Limits:	47 CFR Part 15C Part 15.207 [Reference 4.1.1 of this report]

5.1.2 Configuration of EUT

The EUT was placed on a wooden table 0.8m above the ground plane and connected to a LISN via a 1m mains cable.

Details of the Peripheral and Ancillary Equipment connected for this test are listed in section 10.

During the initial scan, all modes were assessed and TX3 mode was deemed to be worst case and used for final measurements.

The fundamental failed the limit and then as per ANSI C63.10 was repeated in mode TX4 (with antenna coil disconnected/terminated) which passed showing the fundamental was radiating and coupling into the LISN.

5.1.3 Test procedure

Tests were made in accordance with FCC Part 15 using the measuring equipment noted in the 'Test Equipment' Section. Measurements were made on the live and neutral conductors using both average and quasi-peak detection.

At least 6 signals were investigated.

Tests were performed in Test Site F.

5.1.4 Test equipment

E150, E035, ZSW1, E624, E411

See Section 9 for more details

5.1.5 Test results

Temperature of test environment	19 - 20°C
Humidity of test environment	50%
Pressure of test environment	102kPa

Band	13.11-14.01 MHz
Power Level	Maximum
Channel Spacing	Single Channel
Mod Scheme	ASK
Single channel	13.56 MHz

TX3

Plot refs
13629-1 Cond 1 AC Live 150k-30M Average
13629-1 Cond 1 AC Live 150k-30M Quasi-Peak
13629-1 Cond 1 AC Neutral 150k-30M Average
13629-1 Cond 1 AC Neutral 150k-30M Quasi-Peak

Table of signals measured for Cond 1 AC Live 150k-30M

Signal No.	Freq (MHz)	Peak Amp (dBuV)	QP Amp (dBuV)	QP -Lim (dB)	AV Amp (dBuV)	AV -Lim (dB)
1	0.178	50.7	42.4	-22.2	26.2	-28.4
2	0.187	49.1	42.2	-22.0	25.7	-28.5
3	0.251	46.0	38.1	-23.6	21.8	-29.9
4	0.261	45.0	34.3	-27.1	19.1	-32.3
5	0.289	41.5	30.5	-30.1	17.2	-33.4
6	0.299	38.1	32.2	-28.1	19.4	-30.9
7	0.411	34.0	25.5	-32.1	14.4	-33.2
8	0.431	34.7	26.0	-31.2	11.1	-36.1
9	0.546	33.5	25.5	-30.5	16.7	-29.3
10	0.579	27.8	23.5	-32.5	12.7	-33.3
11	0.791	25.2	21.1	-34.9	14.9	-31.1
12	0.824	22.2	22.8	-33.2	16.5	-29.5
13	2.168	38.9	30.8	-25.2	24.9	-21.1
14	2.319	36.5	31.9	-24.1	24.4	-21.6
15	2.383	37.4	33.1	-22.9	25.7	-20.3
16	2.470	37.3	29.7	-26.3	22.7	-23.3
17	2.646	36.0	30.4	-25.6	22.2	-23.8
18	2.733	33.8	30.3	-25.7	22.4	-23.6
19	2.868	29.5	27.4	-28.6	20.2	-25.8
20	13.257	33.0	19.7	-40.3	14.2	-35.8
21	13.560	60.9	60.8	0.8	60.3	10.3
22	13.583	43.1	23.3	-36.7	15.4	-34.6

Table of signals measured for Cond 1 AC Neutral 150k-30M

Signal No.	Freq (MHz)	Peak Amp (dBuV)	QP Amp (dBuV)	QP -Lim (dB)	AV Amp (dBuV)	AV -Lim (dB)
1	0.159	43.8	45.5	-20.0	28.5	-27.0
2	0.174	46.2	42.2	-22.6	29.1	-25.7
3	0.174	45.6	43.9	-20.9	27.1	-27.7
4	0.200	40.5	42.6	-21.0	27.0	-26.6
5	0.253	44.5	34.5	-27.2	23.6	-28.1
6	0.295	40.2	31.0	-29.4	16.0	-34.4
7	0.339	33.3	32.9	-26.3	19.1	-30.1
8	0.358	31.9	30.7	-28.1	19.0	-29.8
9	2.188	38.8	32.8	-23.2	25.6	-20.4
10	2.216	37.1	34.3	-21.7	24.4	-21.6
11	2.279	35.5	33.1	-22.9	23.3	-22.7
12	2.417	37.1	33.0	-23.0	23.8	-22.2
13	2.476	36.6	33.6	-22.4	23.8	-22.2
14	2.783	34.4	31.5	-24.5	21.9	-24.1
15	13.560	61.3	61.2	1.2	60.7	10.7

*The results tables above show the fundamental frequency of the EUT at 13.56 MHz exceeding the limit. This was due to the EUTs integral antenna radiating the fundamental carrier on to the 1 metre mains lead used as part of the test setup. To confirm that the emission was radiated by the EUTs' radio and not conducted, the test was repeated with the EUTs' integral antenna terminated in a suitable load per FCC requirements. As seen below.

Band	13.11-14.01 MHz
Power Level	Maximum
Channel Spacing	Single Channel
Mod Scheme	ASK
Single channel	13.56 MHz

TX4

Plot refs
13629-1 Cond 2 AC Live 150k-30M Average
13629-1 Cond 2 AC Live 150k-30M Quasi-Peak
13629-1 Cond 2 AC Neutral 150k-30M Average
13629-1 Cond 2 AC Neutral 150k-30M Quasi-Peak

Table of signals measured for Cond 1 AC Live 150k-30M

Signal No.	Freq (MHz)	Peak Amp (dBuV)	QP Amp (dBuV)	QP -Lim (dB)	AV Amp (dBuV)	AV -Lim (dB)
1	0.156	49.0	45.7	-20.0	30.1	-25.6
2	0.186	46.3	44.9	-19.3	30.4	-23.8
3	0.225	44.0	42.0	-20.6	28.0	-24.6
4	0.225	44.2	41.7	-20.9	28.7	-23.9
5	0.237	42.5	41.0	-21.2	24.6	-27.6
6	0.261	38.2	35.7	-25.7	21.2	-30.2
7	0.289	34.3	30.1	-30.5	15.9	-34.7
8	0.289	33.1	30.5	-30.1	15.5	-35.1
9	0.343	32.5	27.4	-31.7	15.4	-33.7
10	0.368	31.9	30.3	-28.2	21.0	-27.5
11	0.385	29.3	24.3	-33.9	12.6	-35.6
12	0.396	29.4	25.8	-32.1	13.2	-34.7
13	0.424	32.9	29.9	-27.5	23.7	-23.7
14	0.454	29.1	26.9	-29.9	19.4	-27.4
15	0.476	26.1	23.5	-32.9	14.3	-32.1
16	0.504	27.7	24.6	-31.4	16.7	-29.3
17	0.534	26.7	23.7	-32.3	15.6	-30.4
18	2.051	36.8	33.4	-22.6	25.3	-20.7
19	2.135	38.0	33.8	-22.2	24.9	-21.1
20	2.187	38.3	34.4	-21.6	26.0	-20.0

21	2.268	36.8	33.0	-23.0	22.9	-23.1
22	2.361	38.2	33.8	-22.2	20.2	-25.8
23	2.394	37.7	34.4	-21.6	25.8	-20.2

Table of signals measured for Cond 1 AC Neutral 150k-30M

Signal No.	Freq (MHz)	Peak Amp (dBuV)	QP Amp (dBuV)	QP -Lim (dB)	AV Amp (dBuV)	AV -Lim (dB)
1	0.156	49.0	45.7	-20.0	30.1	-25.6
2	0.186	46.3	44.9	-19.3	30.4	-23.8
3	0.225	44.0	42.0	-20.6	28.0	-24.6
4	0.225	44.2	41.7	-20.9	28.7	-23.9
5	0.237	42.5	41.0	-21.2	24.6	-27.6
6	0.261	38.2	35.7	-25.7	21.2	-30.2
7	0.289	34.3	30.1	-30.5	15.9	-34.7
8	0.289	33.1	30.5	-30.1	15.5	-35.1
9	0.343	32.5	27.4	-31.7	15.4	-33.7
10	0.368	31.9	30.3	-28.2	21.0	-27.5
11	0.385	29.3	24.3	-33.9	12.6	-35.6
12	0.396	29.4	25.8	-32.1	13.2	-34.7
13	0.424	32.9	29.9	-27.5	23.7	-23.7
14	0.454	29.1	26.9	-29.9	19.4	-27.4
15	0.476	26.1	23.5	-32.9	14.3	-32.1
16	0.504	27.7	24.6	-31.4	16.7	-29.3
17	0.534	26.7	23.7	-32.3	15.6	-30.4
18	2.051	36.8	33.4	-22.6	25.3	-20.7
19	2.135	38.0	33.8	-22.2	24.9	-21.1
20	2.187	38.3	34.4	-21.6	26.0	-20.0
21	2.268	36.8	33.0	-23.0	22.9	-23.1
22	2.361	38.2	33.8	-22.2	20.2	-25.8
23	2.394	37.7	34.4	-21.6	25.8	-20.2

Peak detector "Max held" Analyser plots against the Quasi-Peak / Average limit line(s) can be found in Section 6 of this report.

LIMITS:

15.207: as given in the above tables / drawn on the respective plots.

These results show that the EUT has PASSED this test.

The uncertainty gives a 95% confidence interval in the measurement. Expanded uncertainty (K=2) is as follows:
(For LISN) 150kHz to 30MHz ± 3.6 dB.

5.2 Radiated emissions 9 - 150 kHz

5.2.1 Test methods

Test Requirements:	47 CFR Part 15C Part 15.209 [Reference 4.1.1 of this report]
Test Method:	ANSI C63.10 Clause 6.4 [Reference 4.1.2 of this report]
Limits:	47 CFR Part 15C Part 15.225(d) [Reference 4.1.1 of this report]

5.2.2 Configuration of EUT

The EUT was placed on a 0.8 metres high turntable. The front edge of the EUT was initially positioned facing the antenna. The EUT was measured at a distance of 3 metres. The antenna was orientated in both Parallel and Perpendicular polarisations. The EUT was rotated in all three orthogonal planes. During the initial scan, all modes were assessed and no discernible difference was noted between modes therefore TX3 mode was used for final measurements.

5.2.3 Test procedure

Tests were made in accordance with FCC Part 15 using the measuring equipment noted below.

Measurements were made in a semi-anechoic chamber (pre-scan) with any final measurements required performed on an OATS without a ground plane. The antenna was placed 1m above the ground. The equipment was rotated 360 degrees to record the worst case emissions.

At least 6 signals within 20dB and all signals within 10dB of the limit were investigated.

Tests were performed using Test Site M.

5.2.4 Test equipment

TMS81, ZSW1, E624, E411

See Section 9 for more details

5.2.5 Test results

Temperature of test environment	22°C
Humidity of test environment	50%
Pressure of test environment	102kPa

Band	13.11-14.01 MHz
Power Level	Maximum
Channel Spacing	Single Channel
Mod Scheme	ASK
Single channel	13.56 MHz

Plot refs	
13629-1 Rad 1 9k-150kHz Para	
13629-1 Rad 1 9k-150kHz Perp	

Peak detector "Max held" Analyser plots against the Quasi-Peak / Average limit line(s) can be found in Section 6 of this report.

LIMITS:

15.209 limits are applicable in the restricted bands of 15.205 with the relevant detector.

n.b. the general limits of 15.209 are as drawn on the respective plots.

These results show that the EUT has PASSED this test.

The uncertainty gives a 95% confidence interval in the measurement. Expanded uncertainty (K=2) is as follows:
9kHz - 30MHz \pm 3.9dB

5.3 Radiated emissions 150 kHz - 30 MHz

5.3.1 Test methods

Test Requirements: 47 CFR Part 15C Part 15.209 [Reference 4.1.1 of this report]
 Test Method: ANSI C63.10 Clause 6.4 [Reference 4.1.2 of this report]
 Limits: 47 CFR Part 15C Part 15.225(d) [Reference 4.1.1 of this report]

5.3.2 Configuration of EUT

The EUT was placed on a 0.8 metres high turntable. The front edge of the EUT was initially positioned facing the antenna. The EUT was measured at a distance of 3 metres. The antenna was orientated in both Parallel and Perpendicular polarisations. The EUT was rotated in all three orthogonal planes During the initial scan, all modes were assessed and no discernible difference was noted between modes therefore TX3 mode was used for final measurements.

5.3.3 Test procedure

Tests were made in accordance with FCC Part 15 using the measuring equipment noted below.

Measurements were made in a semi-anechoic chamber (pre-scan) with any final measurements required performed on an OATS without a ground plane. The antenna was placed 1m above the ground. The equipment was rotated 360 degrees to record the worst case emissions.

At least 6 signals within 20dB and all signals within 10dB of the limit were investigated.

Tests were performed using Test Site M.

5.3.4 Test equipment

TMS81, ZSW1, E624, E411

See Section 9 for more details

5.3.5 Test results

Temperature of test environment 22°C
 Humidity of test environment 50%
 Pressure of test environment 102kPa

Band	13.11-14.01 MHz
Power Level	Maximum
Channel Spacing	Single Channel
Mod Scheme	ASK
Single channel	13.56 MHz

Plot refs	
13629-1 Rad 1 150k-30MHz Para	
13629-1 Rad 1 150k-30MHz Perp	

Peak detector "Max held" Analyser plots against the Quasi-Peak / Average limit lines can be found in Section 6 of this report.

LIMITS:

15.209 limits are applicable in the restricted bands of 15.205 with the relevant detector.

n.b. the general limits of 15.209 are as drawn on the respective plots.

These results show that the EUT has PASSED this test.

The uncertainty gives a 95% confidence interval in the measurement. Expanded uncertainty (K=2) is as follows:
9kHz - 30MHz \pm 3.9dB

5.4 Radiated emissions 30 MHz -1 GHz

5.4.1 Test methods

Test Requirements:	47 CFR Part 15C Part 15.225(d) [Reference 4.1.1 of this report]
Test Method:	ANSI C63.10 Clause 6.4 [Reference 4.1.2 of this report]
Limits:	47 CFR Part 15C Part 15.225(d) [Reference 4.1.1 of this report]

5.4.2 Configuration of EUT

The EUT was placed on a 0.8 metres high turntable. The front edge of the EUT was initially positioned facing the antenna. The EUT was measured at a distance of 3 metres. The EUT was rotated in all three orthogonal planes. During the initial scan, all modes were assessed and TX3 mode was deemed to be worst case and used for final measurements.

5.4.3 Test procedure

Tests were made in accordance with FCC Part 15 using the measuring equipment noted below. Measurements were made in a semi-anechoic chamber. The antenna was height scanned between 1 and 4 metres and the equipment was rotated 360 degrees to record the worst case emissions. Both Horizontal and vertical polarisations of measuring antenna were tested. Tests were performed in Test Site M

5.4.4 Test equipment

LPE364, E743, NSA-M, ZSW1, E624, E411

See Section 9 for more details

5.4.5 Test results

Temperature of test environment	22°C
Humidity of test environment	50%
Pressure of test environment	102kPa

Band	13.11-14.01 MHz
Power Level	Maximum
Channel Spacing	Single Channel
Mod Scheme	ASK
Single channel	13.56 MHz

Plot refs
13629-1 Rad 1 VHF Horiz
13629-1 Rad 1 VHF Vert
13629-1 Rad 1 UHF Horiz
13629-1 Rad 1 UHF Vert

Table of signals measured for Rad 1 Horizontal Sig List

Signal No.	Freq (MHz)	Peak Amp (dBuV/m)	QP Amp (dBuV/m)	QP -Lim (dB)
1	94.921	25.8	22.7	-20.8
2	120.972	23.8	17.1	-26.4
3	153.331	22.7	15.7	-27.8
4	161.931	22.2	14.7	-28.8
5	485.391	36.4	30.2	-15.8
6	651.562	36.2	30.5	-15.5

Table of signals measured for Rad 1 Vertical Sig List

Signal No.	Freq (MHz)	Peak Amp (dBuV/m)	QP Amp (dBuV/m)	QP -Lim (dB)
1	30.800	33.7	26.8	-13.2
2	30.999	31.1	27.1	-12.9

3	31.890	33.4	25.2	-14.8
4	32.573	33.2	25.5	-14.5
5	40.680	32.8	29.2	-10.8
6	53.259	23.6	17.0	-23.0
7	54.647	21.6	16.1	-23.9
8	56.742	29.1	23.8	-16.2
9	58.885	22.1	17.3	-22.7
10	65.847	26.3	21.4	-18.6
11	67.590	27.6	24.2	-15.8
12	67.801	29.4	26.0	-14.0
13	67.801	28.3	25.8	-14.2
14	68.677	23.8	17.3	-22.7
15	71.626	28.6	23.9	-16.1
16	72.753	21.9	17.3	-22.7
17	73.982	22.7	19.5	-20.5
18	76.779	23.6	17.1	-22.9
19	79.620	26.4	21.0	-19.0
20	80.044	24.2	17.4	-22.6
21	81.872	24.4	18.5	-21.5
22	94.921	33.3	30.3	-13.2
23	167.999	30.1	28.0	-15.5
24	215.999	33.5	31.0	-12.5
25	516.544	31.5	25.7	-20.3
26	517.867	31.9	25.3	-20.7
27	799.544	34.8	28.1	-17.9

Peak detector "Max held" Analyser plots against the Quasi-Peak / Average limit line(s) can be found in Section 6 of this report.

LIMITS:

15.209 limits are applicable in the restricted bands of 15.205 with the relevant detector.

n.b. the general limits of 15.209 are as drawn on the respective plots.

These results show that the EUT has PASSED this test.

The uncertainty gives a 95% confidence interval in the measurement. Expanded uncertainty (K=2) is as follows:
30MHz - 1000MHz ±6.1dB

5.5 Radiated emissions above 1 GHz

5.5.1 Test methods

Test Requirements:	47 CFR Part 15C Part 15.209 [Reference 4.1.1 of this report]
Test Method:	ANSI C63.10 Clause 6.6 [Reference 4.1.2 of this report]
Limits:	47 CFR Part 15C Part 15.209/15.225(d) [Reference 4.1.1 of this report]

5.5.2 Configuration of EUT

The EUT was placed on a 1.5 metres high turntable. The front edge of the EUT was initially positioned facing the antenna. The EUT was measured at a distance of 3 metres. The EUT was rotated in all three orthogonal planes. During the initial scan, all modes were assessed and TX3 mode was deemed to be worst case and used for final measurements.

5.5.3 Test procedure

Tests were made in accordance with FCC Part 15 using the measuring equipment noted below. Measurements were made in a semi-anechoic chamber with appropriate absorbing material for use in this range. The EUT was raised and antenna was placed 1.5m above the ground in line with the EUT and scanned to maximise emissions, which was rotated through 360 degrees to record the worst case emissions. A measurement distance of 3m was used between the test range 1GHz – 2.5GHz. Tests were performed in Test Site M.

5.5.4 Test equipment

E136, TMS82, VSWR-M, ZSW1, E624, E411

See Section 9 for more details

5.5.5 Test results

Temperature of test environment	22°C
Humidity of test environment	54%
Pressure of test environment	102kPa

Setup Table

Band	13.11-14.01 MHz
Power Level	Maximum
Channel Spacing	Single Channel
Mod Scheme	ASK
Single channel	13.56 MHz

Plots Refs	
	13629-1 Rad 1 1-2GHz Horiz
	13629-1 Rad 1 1-2GHz Vert
	13629-1 Rad 1 2-5GHz Horiz
	13629-1 Rad 1 2-5GHz Vert

Table of signals measured for Rad 1 Horizontal Sig List

Signal No.	Freq (MHz)	Peak Amp (dBuV/m)	Pk -Lim (dB)	AV Amp (dBuV/m)	AV -Lim (dB)
1	1599.997	42.5	-31.5	30.8	-23.2
2	1600.018	49.3	-24.7	30.7	-23.3
3	2074.286	42.5	-31.5	29.8	-24.2
4	2082.959	42.7	-31.3	30.2	-23.8
5	2093.815	43.0	-31.0	30.2	-23.8
6	2108.107	42.2	-31.8	29.5	-24.5
7	2128.487	43.2	-30.8	30.8	-23.2
8	2165.799	43.7	-30.3	30.4	-23.6
9	2179.704	42.4	-31.6	30.7	-23.3

10	2206.142	43.1	-30.9	30.7	-23.3
11	2227.176	44.4	-29.6	32.2	-21.8
12	2242.229	44.8	-29.2	32.1	-21.9
13	2261.132	44.0	-30.0	32.1	-21.9
14	2268.362	45.7	-28.3	31.2	-22.8
15	2286.692	47.9	-26.1	35.3	-18.7
16	2286.693	44.0	-30.0	30.8	-23.2
17	2286.698	45.2	-28.8	30.8	-23.2
18	2289.130	47.1	-26.9	35.8	-18.2
19	2312.473	44.5	-29.5	29.6	-24.4
20	2325.950	42.1	-31.9	28.9	-25.1
21	2361.866	42.5	-31.5	28.3	-25.7
22	2399.913	47.9	-26.1	35.2	-18.8
23	2400.027	45.2	-28.8	30.9	-23.1
24	2428.800	47.6	-26.4	32.4	-21.6
25	2429.901	45.3	-28.7	32.1	-21.9
26	2450.610	45.6	-28.4	32.6	-21.4
27	2450.613	44.8	-29.2	32.6	-21.4
28	2451.064	43.9	-30.1	31.7	-22.3

Table of signals measured for Rad 1 Vertical Sig List

Signal No.	Freq (MHz)	Peak Amp (dBuV/m)	Pk -Lim (dB)	AV Amp (dBuV/m)	AV -Lim (dB)
1	1799.798	52.3	-21.7	28.3	-25.7
2	2373.337	44.7	-29.3	28.0	-26.0
3	2399.927	54.4	-19.6	28.9	-25.1
4	2399.976	49.3	-24.7	32.6	-21.4
5	2400.113	48.3	-25.7	32.5	-21.5
6	2403.907	42.4	-31.6	26.9	-27.1
7	2405.113	45.8	-28.2	28.3	-25.7
8	2489.807	42.2	-31.8	26.0	-28.0
9	2496.529	38.6	-35.4	25.9	-28.1

LIMITS:

15.209 limits are applicable in the restricted bands of 15.205 with the relevant detector.

15.247(d) other emissions, outside the intentional band, must be attenuated by at least 20/30dB from the level of the fundamental / meet the general limits of 15.209.

The general limits of 15.209 are as drawn on the respective plots.

These results show that the EUT has PASSED this test.

The uncertainty gives a 95% confidence interval in the measurement. Expanded uncertainty (K=2) is as follows:

1 – 2.5 GHz ±4.7dB

5.6 Intentional radiator field strength

5.6.1 Test methods

Test Requirements:	47 CFR Part 15C Part 15.225(a) [Reference 4.1.1 of this report]
Test Method:	ANSI C63.10 Clause 6.4 [Reference 4.1.2 of this report]
Limits:	47 CFR Part 15C Part 15.225(a)/(b)/(c)/(d) [Reference 4.1.1 of this report]

5.6.2 Configuration of EUT

The EUT was placed on a 0.8 metres high turntable. The front edge of the EUT was initially positioned facing the antenna. The EUT was measured at a distance of 3 metres. The antenna was orientated in both Parallel and Perpendicular polarisations. The EUT was rotated in all three orthogonal planes. The EUT was initially operated in TX2 and TX3 modes. TX3 mode was found to be highest for fundamental field strength power and used for full tests.

5.6.3 Test procedure

Tests were made in accordance with FCC Part 15 using the measuring equipment noted below.

Measurements were made in a semi-anechoic chamber (pre-scan) with final measurements performed on an OATS without a ground plane. The antenna was placed 1m above the ground. Both the equipment and the antenna were rotated 360 degrees to record the maximised emission.

Measurements were made at Site OATS.

5.6.4 Test equipment

E136, E411, E624, E743, LPE364, NSA-M, TMS81, TMS82, VSWR-M, ZSW1

See Section 9 for more details

5.6.5 Test results

Temperature of test environment	20°C
Humidity of test environment	50%
Pressure of test environment	102kPa

Band	13.11-14.01 MHz
Power Level	Maximum
Channel Spacing	Single Channel
Mod Scheme	ASK
Single channel	13.56 MHz

	Single channel
Duty Cycle (%)	100
Duty Cycle correction	0

	Single channel
Peak Level (dBµV/m @3m)	65.30
Plot reference	13629 FS Para side tag Q OATS
Antenna Polarisation	Parallel
EUT Polarisation	Side

Analyser plots can be found in Section 6 of this report.

The above 3 m worst case measurement is extrapolated to 30 m using ANSI C63.10:2013 clause 6.4.4 as follows: -

Using clause 6.4.4.1 Equation (1)

$$\begin{aligned}d_{\text{near field}} &= 47.77 / f_{\text{MHz}} \\ &= 47.77 / 13.56 \\ &= 3.523 \text{ m}\end{aligned}$$

Using clause 6.4.4.2 Equation (2)

$$\begin{aligned}FS_{\text{limit}} &= FS_{\text{max}} - 40 \log(d_{\text{near field}} / d_{\text{measure}}) - 20 \log(d_{\text{limit}} / d_{\text{near field}}) \\ &= 65.3 - 40 \log(3.523 / 3) - 20 \log(30 / 3.523) \\ &= 43.9 \text{ dB}\mu\text{V/m @ 30 m.}\end{aligned}$$

LIMITS:

15.225(a) QP/Peak = the field strength of any emissions within the band 13.553-13.567 MHz shall not exceed 15,848 $\mu\text{V/m}$ @ 30m = 84 dB $\mu\text{V/m}$ @ 30m.

15.225(b) QP/Peak = within the bands 13.410-13.553 MHz and 13.567-13.710 MHz, the field strength of any emissions shall not exceed 334 $\mu\text{V/m}$ @ 30m = 50.5 dB $\mu\text{V/m}$ @ 30m.

15.225(c) QP/Peak = within the bands 13.110-13.410 MHz and 13.710-14.010 MHz the field strength of any emissions shall not exceed 106 $\mu\text{V/m}$ @ 30m = 40.5 dB $\mu\text{V/m}$ @ 30m.

15.225(d) QP/Peak = outside of the 13.110-14.010 MHz band shall not exceed the general radiated emissions limits of 15.209.

These results show that the EUT has PASSED this test.

The uncertainty gives a 95% confidence interval in the measurement. Expanded uncertainty (K=2) is as follows:

< \pm 3.9 dB

5.7 Occupied bandwidth

5.7.1 Test methods

Test Requirements:	47 CFR Part 15C Part 15.215 [Reference 4.1.1 of this report]
Test Method:	ANSI C63.10 Clause 6.9 [Reference 4.1.2 of this report]
Limits:	47 CFR Part 15C Part 15.215 [Reference 4.1.1 of this report]

5.7.2 Configuration of EUT

The EUT was placed on a 0.8 metres high turntable. The front edge of the EUT was initially positioned facing the antenna. The EUT was measured at a distance of 3 metres. The EUT was tested whilst connected to the AC power for maximised emissions. The EUT was operated in TX3 mode as worst case.

5.7.3 Test procedure

Tests were made in accordance with FCC Part 15 using the measuring equipment noted below. A 10kHz RBW, 3x VBW, auto sweep time and max hold settings were used for the 20 dB bandwidth.

5.7.4 Test equipment

E411, E624, E932, TMS81

See Section 9 for more details

5.7.5 Test results

Temperature of test environment	20°C
Humidity of test environment	50%
Pressure of test environment	102kPa

Band	13.11-14.01 MHz
Power Level	Maximum
Channel Spacing	Single Channel
Mod Scheme	ASK
Single channel	13.56 MHz

	Single channel
20 dB Bandwidth (MHz) Nominal Temp & Volts	431.017 kHz
Plot for 20 dB Bandwidth (MHz) Nominal Temp & Volts	13629-1 OBW PERP upright tag

FLOW Worst case (MHz)	13.552323
FHIGH Worst case (MHz)	13.983340

Analyser plots can be found in Section 6 of this report.

LIMITS:

No limits apply however, per 15.215, the 20dB bandwidth of the emission is to remain within the band over expected variations in temperature and supply voltage. It is recommended that the fundamental emission be kept within at least the central 80% of the permitted band in order to minimise the possibility of out-of-band operation.

These results show that the EUT has PASSED this test.

The uncertainty gives a 95% confidence interval in the measurement. Expanded uncertainty (K=2) is as follows:
<± 1.9 %

5.8 Spectrum mask

5.8.1 Test methods

Test Requirements:	47 CFR Part 15C Part 15.225 [Reference 4.1.1 of this report]
Test Method:	ANSI C63.10 Clause 6.4 [Reference 4.1.2 of this report]
Limits:	47 CFR Part 15C Part 15.225(a)/(b)/(c)/(d) [Reference 4.1.1 of this report]

5.8.2 Configuration of EUT

The EUT was placed on a 0.8 metres high turntable. The EUT was measured at a distance of 3 metres. The EUT and antenna were positioned for maximum field strength and referenced to the field strength measured on the OATS. The EUT was operated in TX3 mode as worst case.

5.8.3 Test procedure

Tests were made in accordance with FCC Part 15 using the measuring equipment noted below.

Plots were taken and results were referenced to limits at 30m by using the extrapolation factor as referenced below, which gave 43.9dBuV/m @30m.

Measurements were made at Site M.

5.8.4 Test equipment

E411, E624, E932, TMS81

See Section 9 for more details

5.8.5 Test results

Temperature of test environment	20°C
Humidity of test environment	50%
Pressure of test environment	102kPa

Band	13.11-14.01 MHz
Power Level	Maximum
Channel Spacing	Single Channel
Mod Scheme	ASK
Single channel	13.56 MHz

	Single channel
Nominal, Maximised RF Output / field strength	65.3 dBuV/m
Nominal plot reference	13629-1 Spectrum mask at 30metres - RFID reading Tag

Analyser plots can be found in Section 6 of this report.

The above 3 m worst case measurement is extrapolated to 30 m using ANSI C63.10:2013 clause 6.4.4 as follows: -

Using clause 6.4.4.1 Equation (1)

$$\begin{aligned}
 d_{\text{near field}} &= 47.77 / f_{\text{MHz}} \\
 &= 47.77 / 13.56 \\
 &= 3.523 \text{ m}
 \end{aligned}$$

Using clause 6.4.4.2 Equation (2)

$$\begin{aligned}
 FS_{\text{limit}} &= FS_{\text{max}} - 40 \log(d_{\text{near field}} / d_{\text{measure}}) - 20 \log(d_{\text{limit}} / d_{\text{near field}}) \\
 &= 65.3 - 40 \log(3.523 / 3) - 20 \log(30 / 3.523) \\
 &= 43.9 \text{ dBuV/m @ 30 m.}
 \end{aligned}$$

LIMITS:

15.225(a) QP/Peak = the field strength of any emissions within the band 13.553-13.567 MHz shall not exceed 15,848 $\mu\text{V/m}$ @ 30m = 84 dB $\mu\text{V/m}$ @ 30m.

15.225(b) QP/Peak = within the bands 13.410-13.553 MHz and 13.567-13.710 MHz, the field strength of any emissions shall not exceed 334 $\mu\text{V/m}$ @ 30m = 50.5 dB $\mu\text{V/m}$ @ 30m.

15.225(c) QP/Peak = within the bands 13.110-13.410 MHz and 13.710-14.010 MHz the field strength of any emissions shall not exceed 106 $\mu\text{V/m}$ @ 30m = 40.5 dB $\mu\text{V/m}$ @ 30m.

15.225(d) QP/Peak = outside of the 13.110-14.010 MHz band shall not exceed the general radiated emissions limits of 15.209.

These results show that the EUT has PASSED this test.

The uncertainty gives a 95% confidence interval in the measurement. Expanded uncertainty (K=2) is as follows:
< \pm 4.1 dB

5.9 Frequency stability

5.9.1 Test methods

Test Requirements:	47 CFR Part 15C Part 15.225(e) [Reference 4.1.1 of this report]
Test Method:	ANSI C63.10 Clause 6.8 [Reference 4.1.2 of this report]
Limits:	47 CFR Part 15C Part 15.225(e) [Reference 4.1.1 of this report]

5.9.2 Configuration of EUT

The EUT's USB Cable input was connected to split USB lead and then to a variable power supply. This allowed the voltage end points to be set as required by the specification.

The EUT was placed in a temperature controlled chamber. The EUT emissions were observed by means of a test fixture. The EUT was operated in TX1 mode.

5.9.3 Test procedure

Tests were made in accordance with FCC Part 15 using the measuring equipment noted below.

Temperature stability was achieved at each test level before taking measurements. A frequency count was made on a CW signal. At nominal temperature the EUT supply was varied to the applicant declared end points for USB of 4.75 and 5.25 DC V.

A max-held spectrum analyser was used to monitor the frequency of the carrier. The analyser was set with a suitable span, RBW and VBW to allow for a measurement resolution of 1Hz.

Tests were performed using Test Site N.

5.9.4 Test equipment

E555, E623, E807, E843, H071, N607, TMS57

See Section 9 for more details

5.9.5 Test results

Temperature of test environment	20°C
Humidity of test environment	42%
Pressure of test environment	100kPa

Band	13.11-14.01 MHz
Power Level	Maximum
Channel Spacing	Single Channel
Mod Scheme	ASK
Single channel	13.56 MHz

Test conditions		Frequency Error (MHz) Single channel
-20°C	Volts Nominal (5)	13.560167
-20°C	Volts Nominal (5)	13.560167
-10°C	Volts Nominal (5)	13.560184
0°C	Volts Nominal (5)	13.560193
10°C	Volts Nominal (5)	13.560183
20°C	Volts Minimum (4.75)	13.560136
	Volts Nominal (5)	13.560136
	Volts Maximum (5.25)	13.560136
30°C	Volts Nominal (5)	13.560147
40°C	Volts Nominal (5)	13.560136
50°C	Volts Nominal (5)	13.560140
Max Frequency Error per chan (Hz)		+193 / -0
Max Frequency Error observed (MHz)		0.000193

Note: Error shown is referenced to nominal Channel frequency value

Maximum variation observed was 0.000193 MHz

LIMITS:

+/- 0.01%. (+/- 1.356kHz)

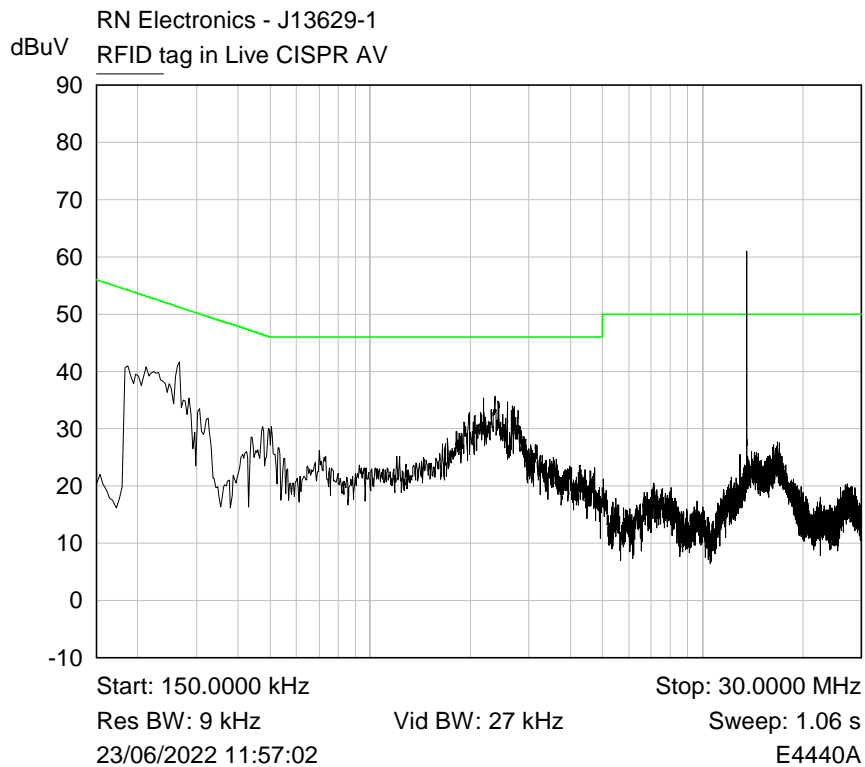
These results show that the EUT has PASSED this test.

The uncertainty gives a 95% confidence interval in the measurement. Expanded uncertainty (K=2) is as follows:
<± 0.0002 ppm (PSA Ext Ref)

6 Plots/Graphical results

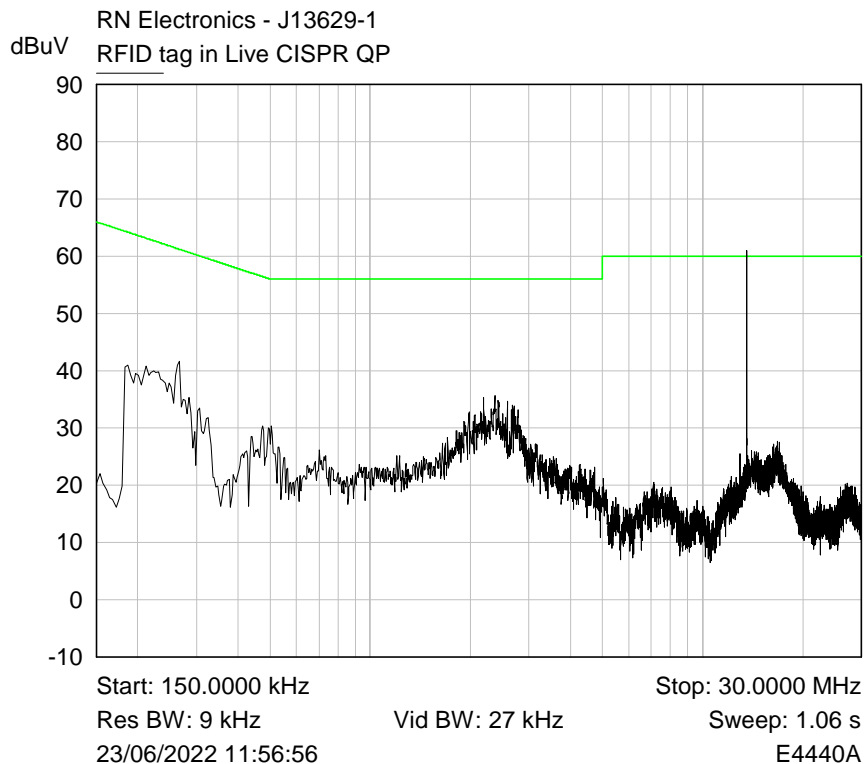
6.1 AC power line conducted emissions

RF Parameters: Band 13.11-14.01 MHz, Power Maximum, Channel Spacing Single Channel,
Modulation ASK, Channel 13.56 MHz



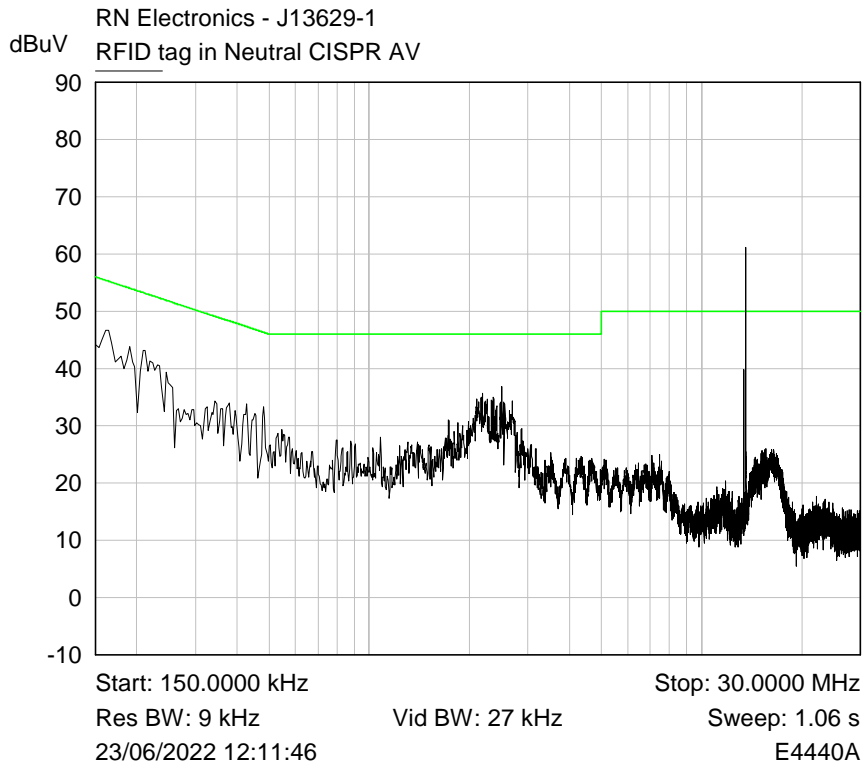
Plot of Live150k-30M Average

Note: The emission that exceeds the limit line is the fundamental carrier of the 13.56 MHz transmitter radiating on to the mains lead



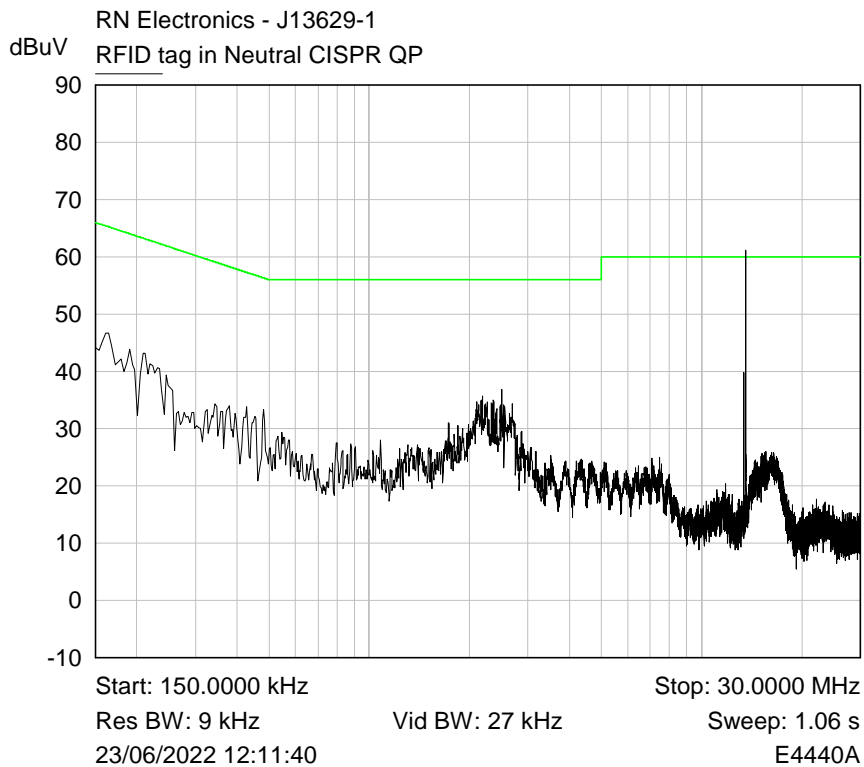
Plot of Live150k-30M Quasi-Peak

Note: The emission that exceeds the limit line is the fundamental carrier of the 13.56 MHz transmitter radiating on to the mains lead



Plot of Neutral150k-30M Average

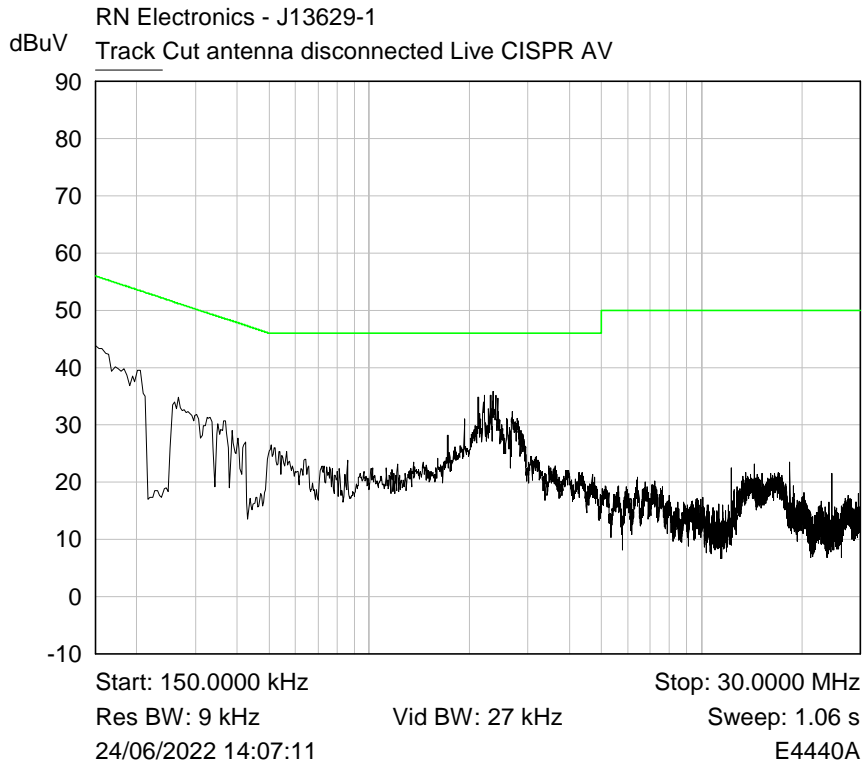
Note: The emission that exceeds the limit line is the fundamental carrier of the 13.56 MHz transmitter radiating on to the mains lead



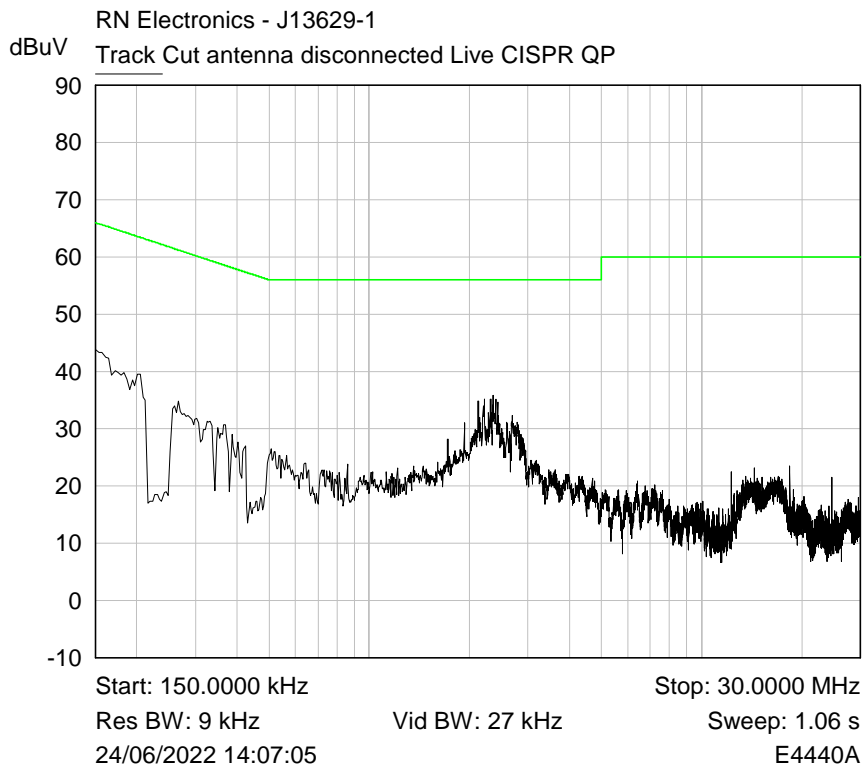
Plot of Neutral150k-30M Quasi-Peak

Note: The emission that exceeds the limit line is the fundamental carrier of the 13.56 MHz transmitter radiating on to the mains lead

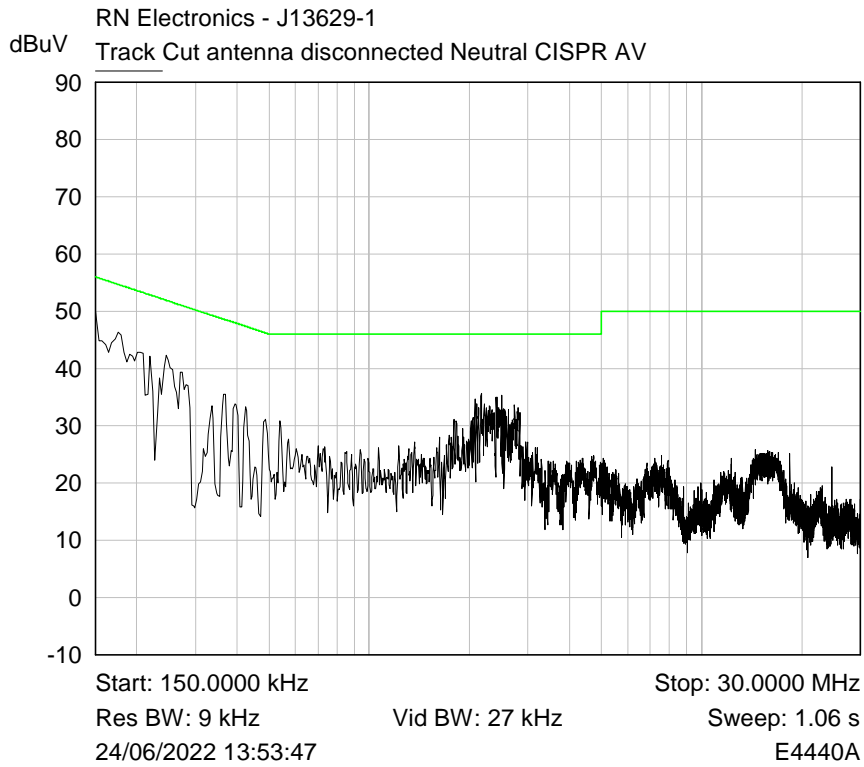
RF Parameters: Band 13.11-14.01 MHz, Power Maximum, Channel Spacing Single Channel, Modulation ASK (Antenna disconnected), Channel 13.56 MHz



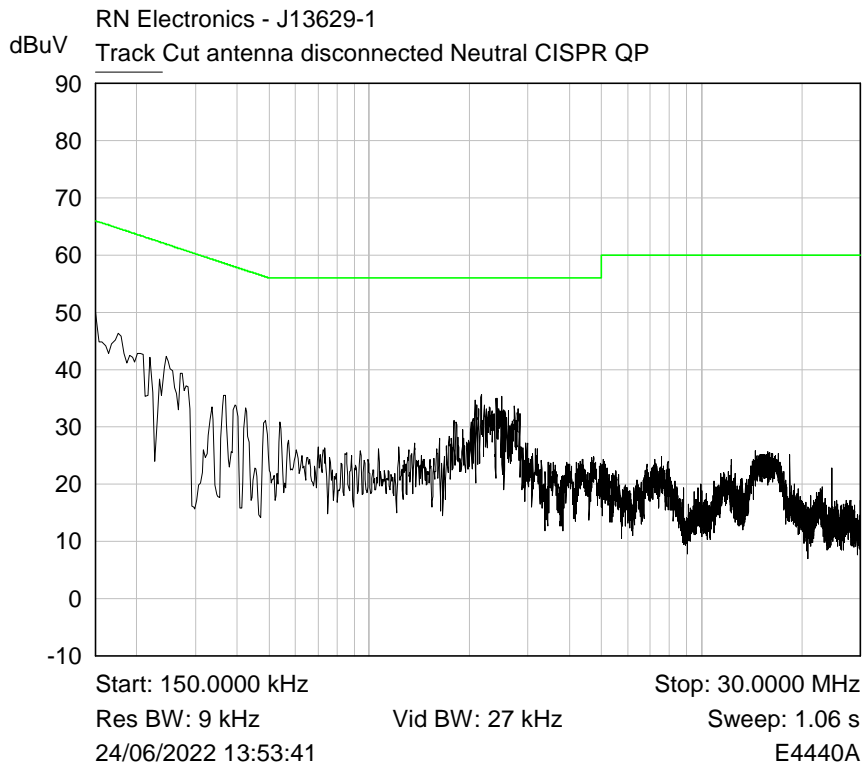
Plot of Live150k-30M Average



Plot of Live150k-30M Quasi-Peak



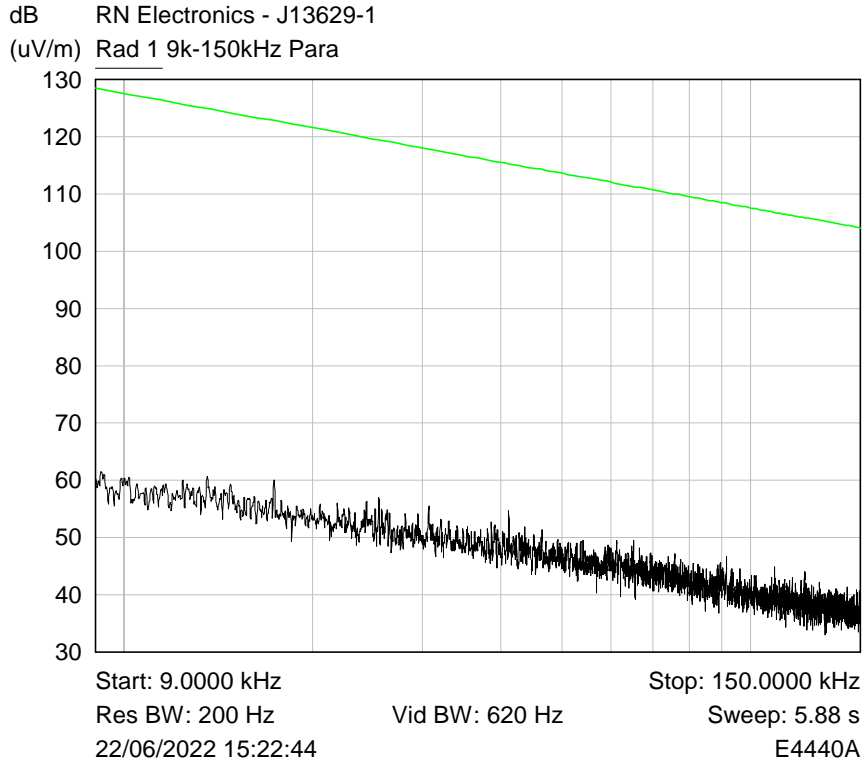
Plot of Neutral150k-30M Average



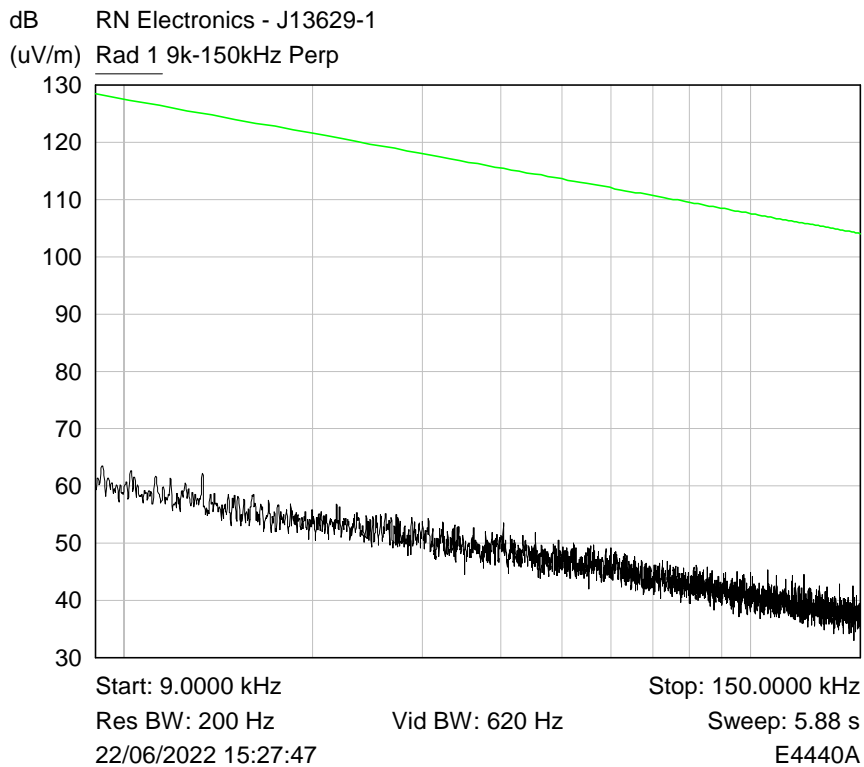
Plot of Neutral150k-30M Quasi-Peak

6.2 Radiated emissions 9 - 150 kHz

RF Parameters: Band 13.11-14.01 MHz, Power Maximum, Channel Spacing Single Channel,
Modulation ASK, Channel 13.56 MHz



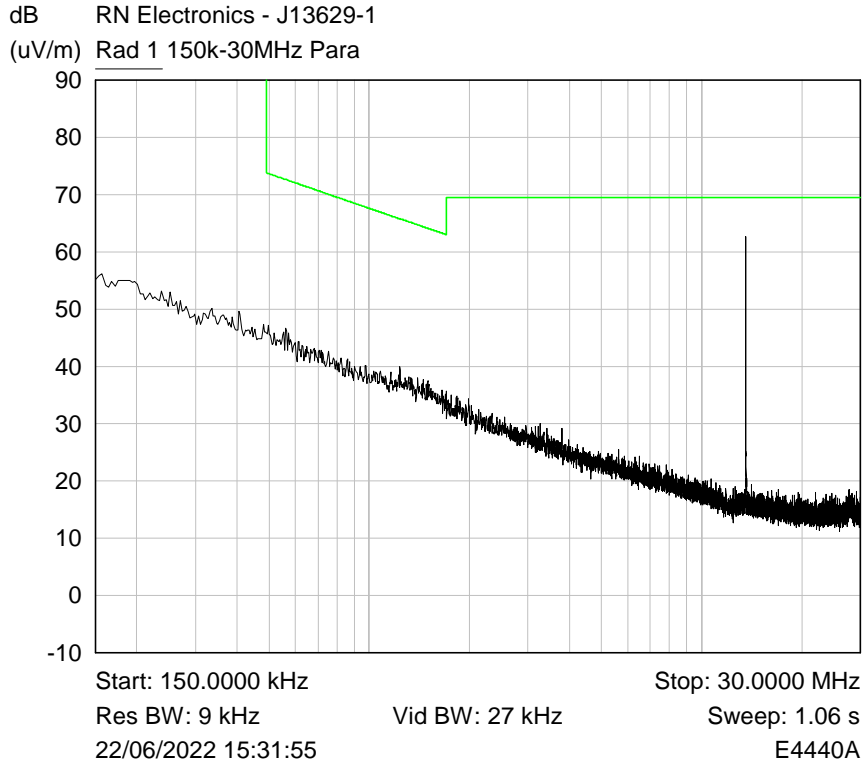
Plot of 9k-150kHz Parallel



Plot of 9k-150kHz Perpendicular

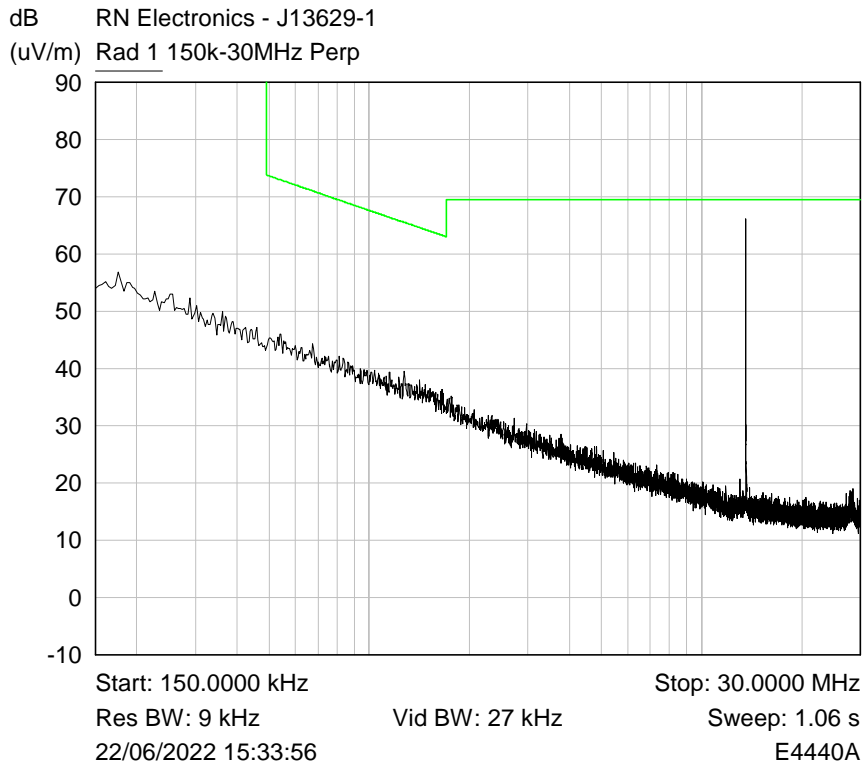
6.3 Radiated emissions 150 kHz - 30 MHz

RF Parameters: Band 13.11-14.01 MHz, Power Maximum, Channel Spacing Single Channel, Modulation ASK, Channel 13.56 MHz



Plot of 150kHz-30MHz Parallel

Note: Plot shows the fundamental carrier at 13.56 MHz

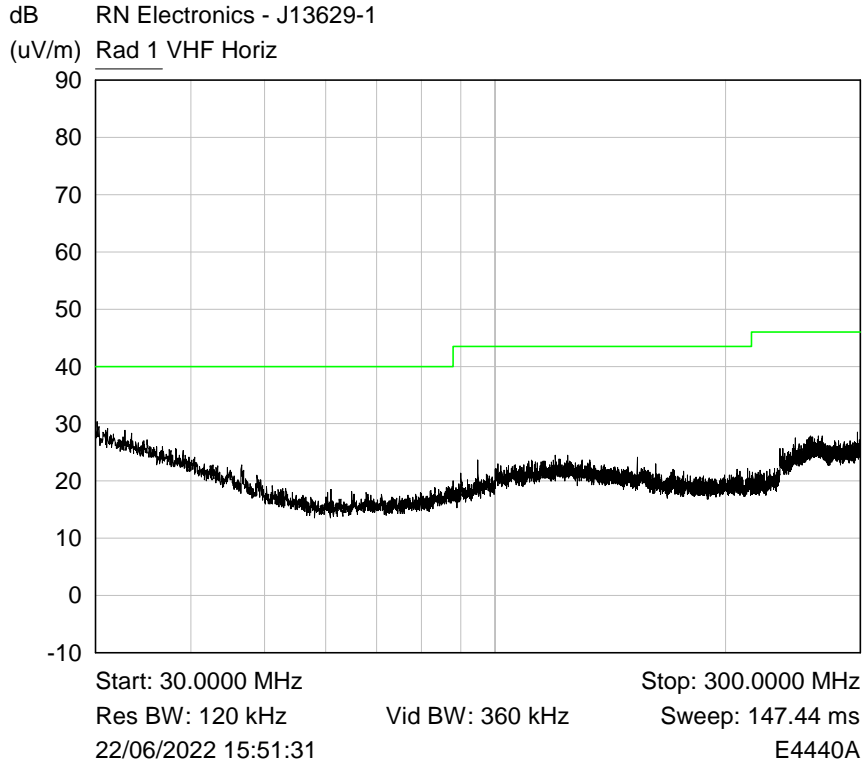


Plot of 150kHz-30MHz Perpendicular

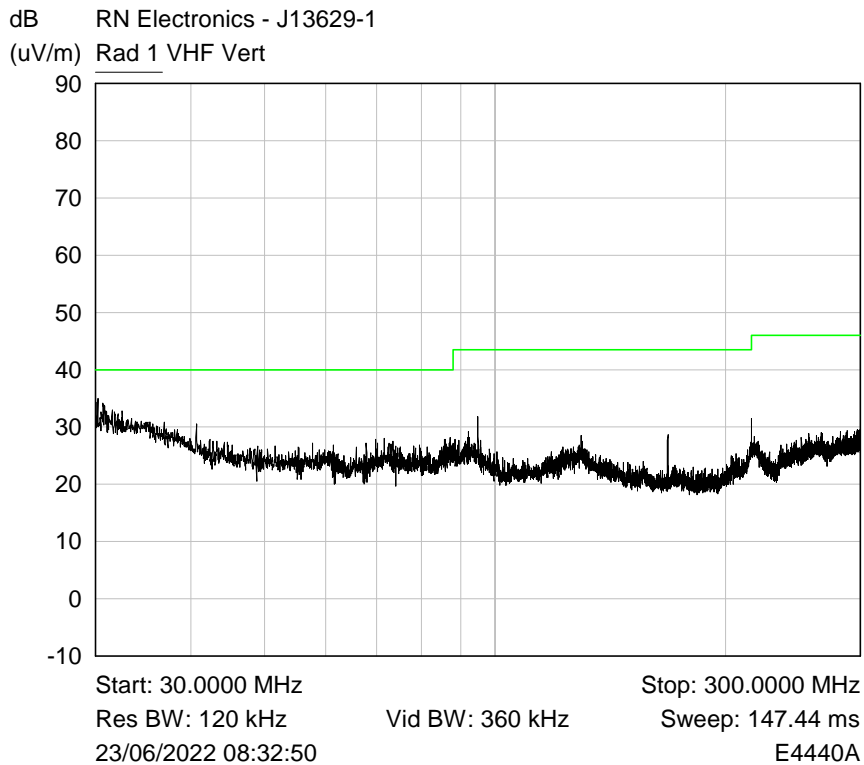
Note: Plot shows the fundamental carrier at 13.56 MHz

6.4 Radiated emissions 30 MHz -1 GHz

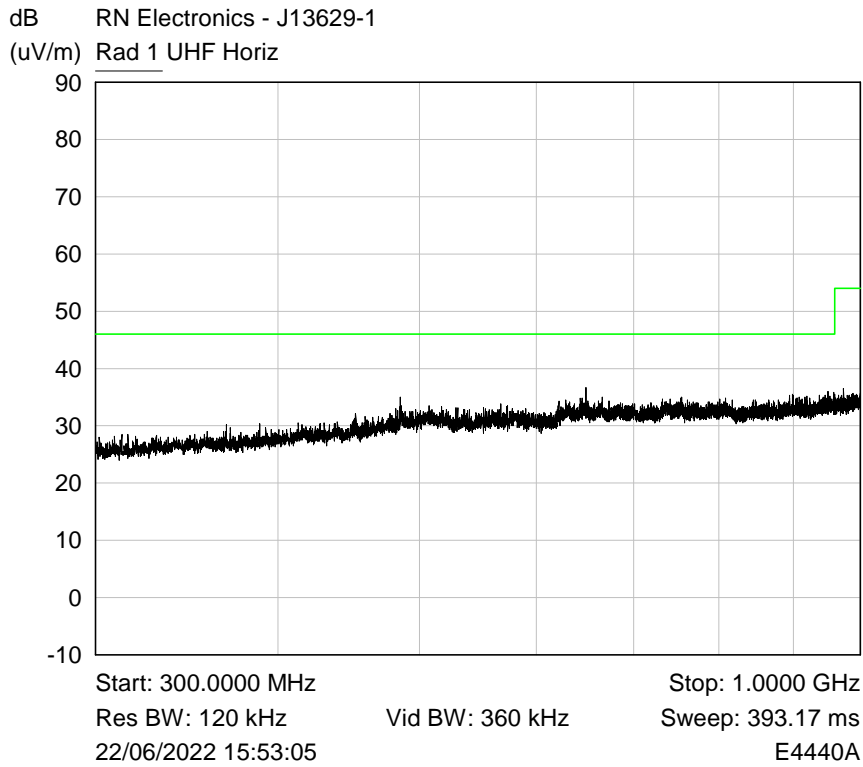
RF Parameters: Band 13.11-14.01 MHz, Power Maximum, Channel Spacing Single Channel, Modulation ASK, Channel 13.56 MHz



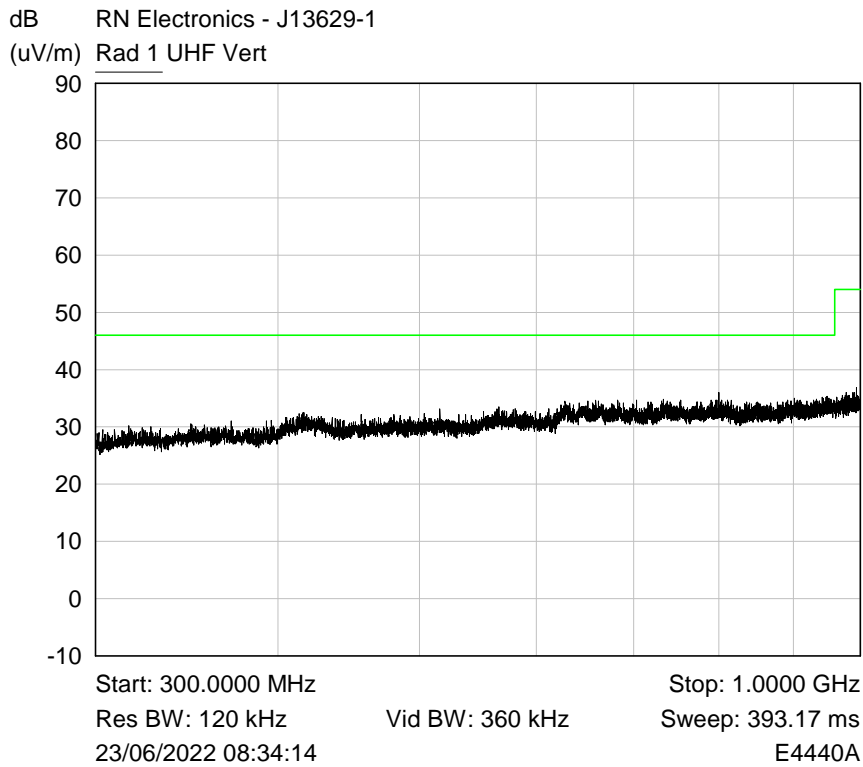
Plot of Peak emissions for VHF Horizontal against the QP limit line.



Plot of Peak emissions for VHF Vertical against the QP limit line.



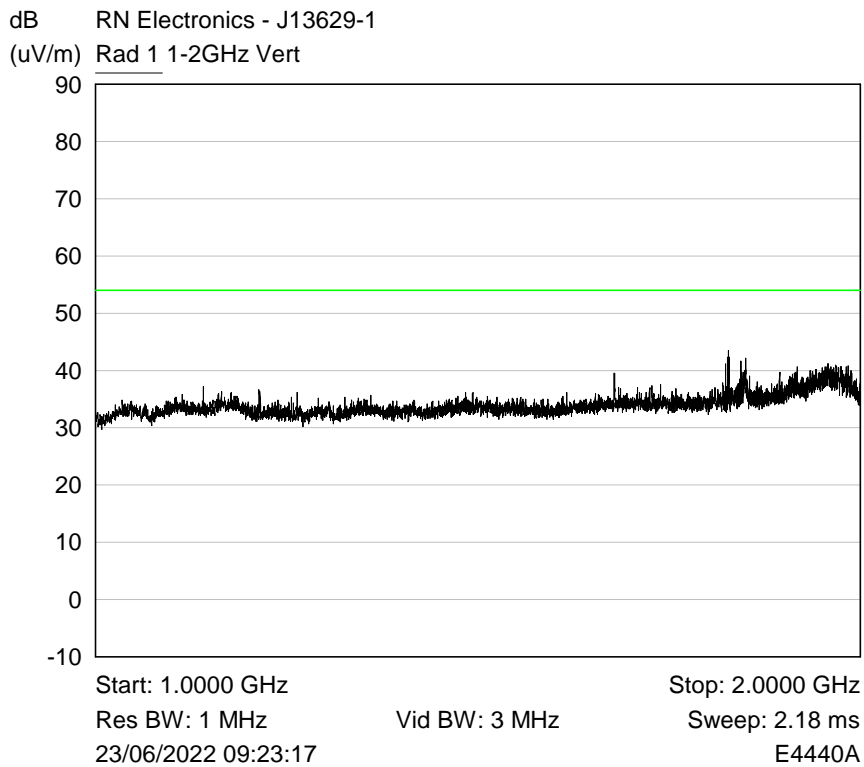
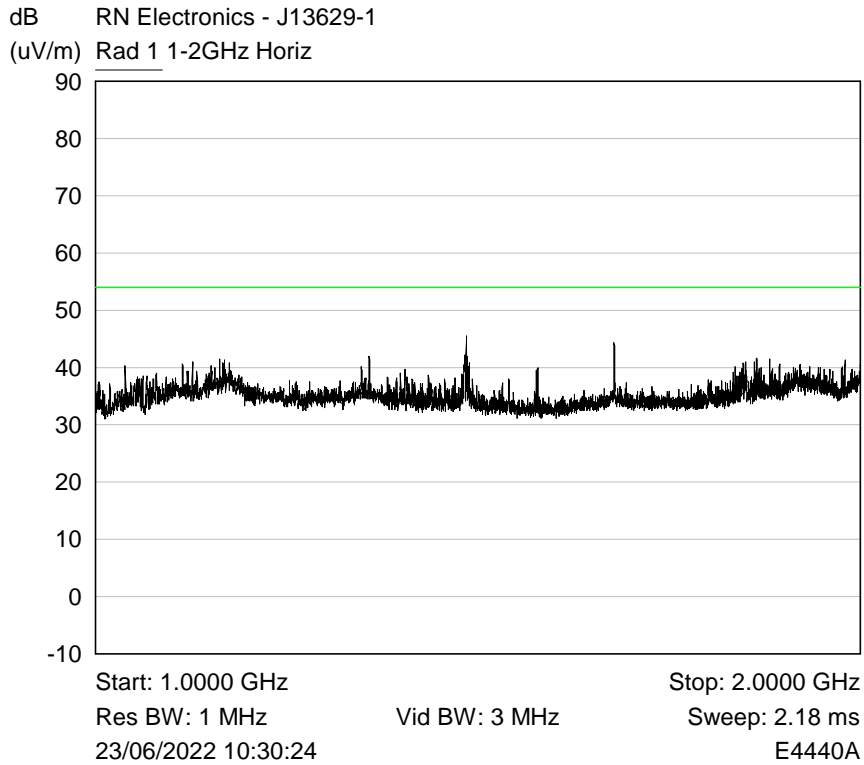
Plot of Peak emissions for UHF Horizontal against the QP limit line.

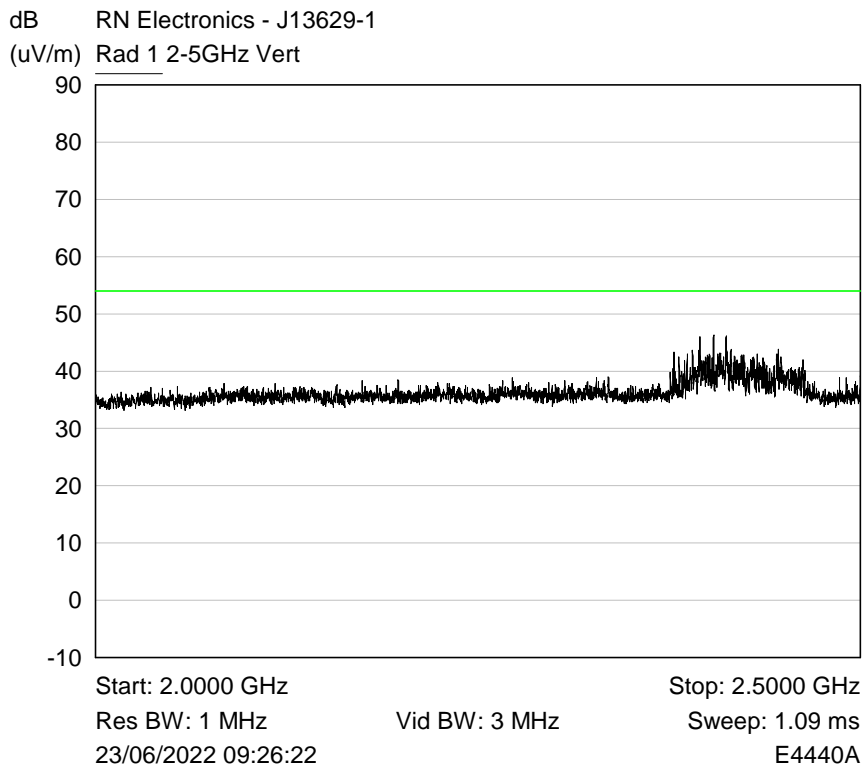
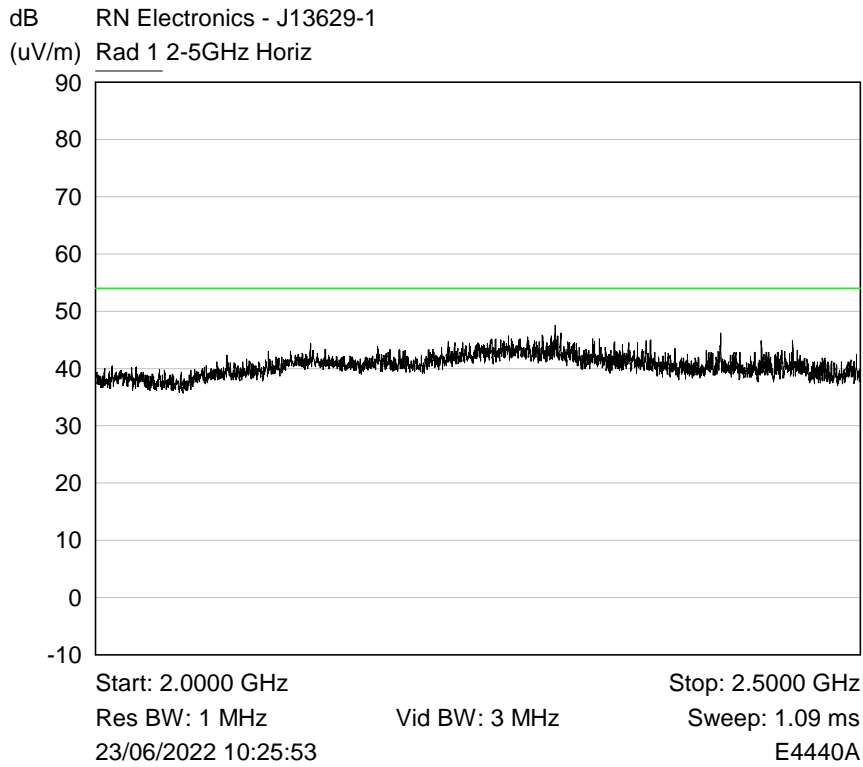


Plot of Peak emissions for UHF Vertical against the QP limit line.

6.5 Radiated emissions above 1 GHz

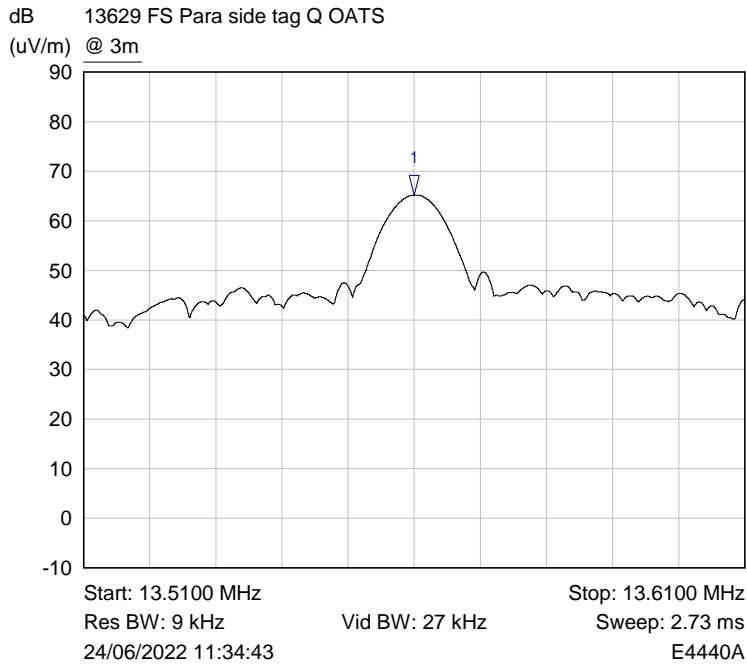
RF Parameters: Band 13.11-14.01 MHz, Power Maximum, Channel Spacing Single Channel,
Modulation ASK, Channel 13.56 MHz





6.6 Intentional radiator field strength

RF Parameters: Band 13.11-14.01 MHz, Power Maximum, Channel Spacing Single Channel,
 Modulation ASK, Channel 13.56 MHz

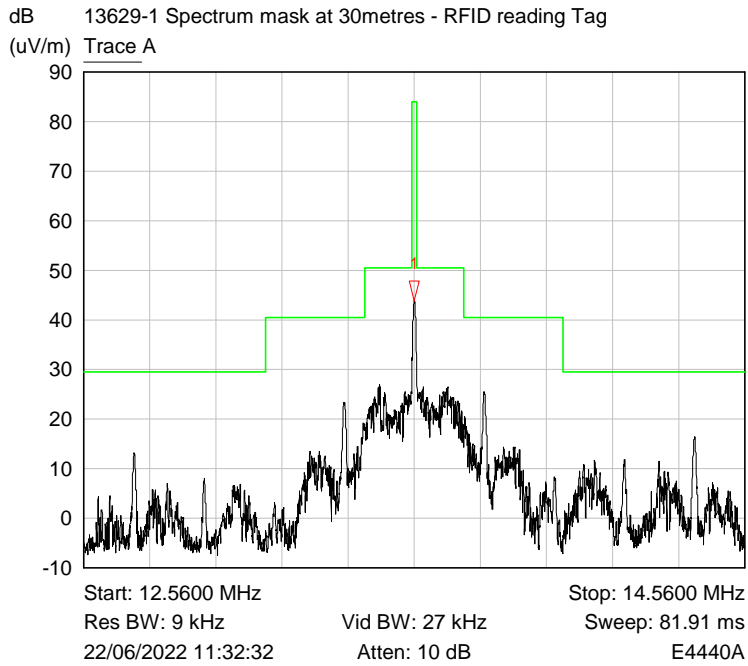


Mkr	Trace	X-Axis	Value	Notes
1 ▾	@ 3m	13.5601 MHz	65.25 dB(uV/m)	

Plot of parallel polarisation and EUT in side position

6.7 Spectrum mask

RF Parameters: Band 13.11-14.01 MHz, Power Maximum, Channel Spacing Single Channel,
 Modulation ASK, Channel 13.56 MHz

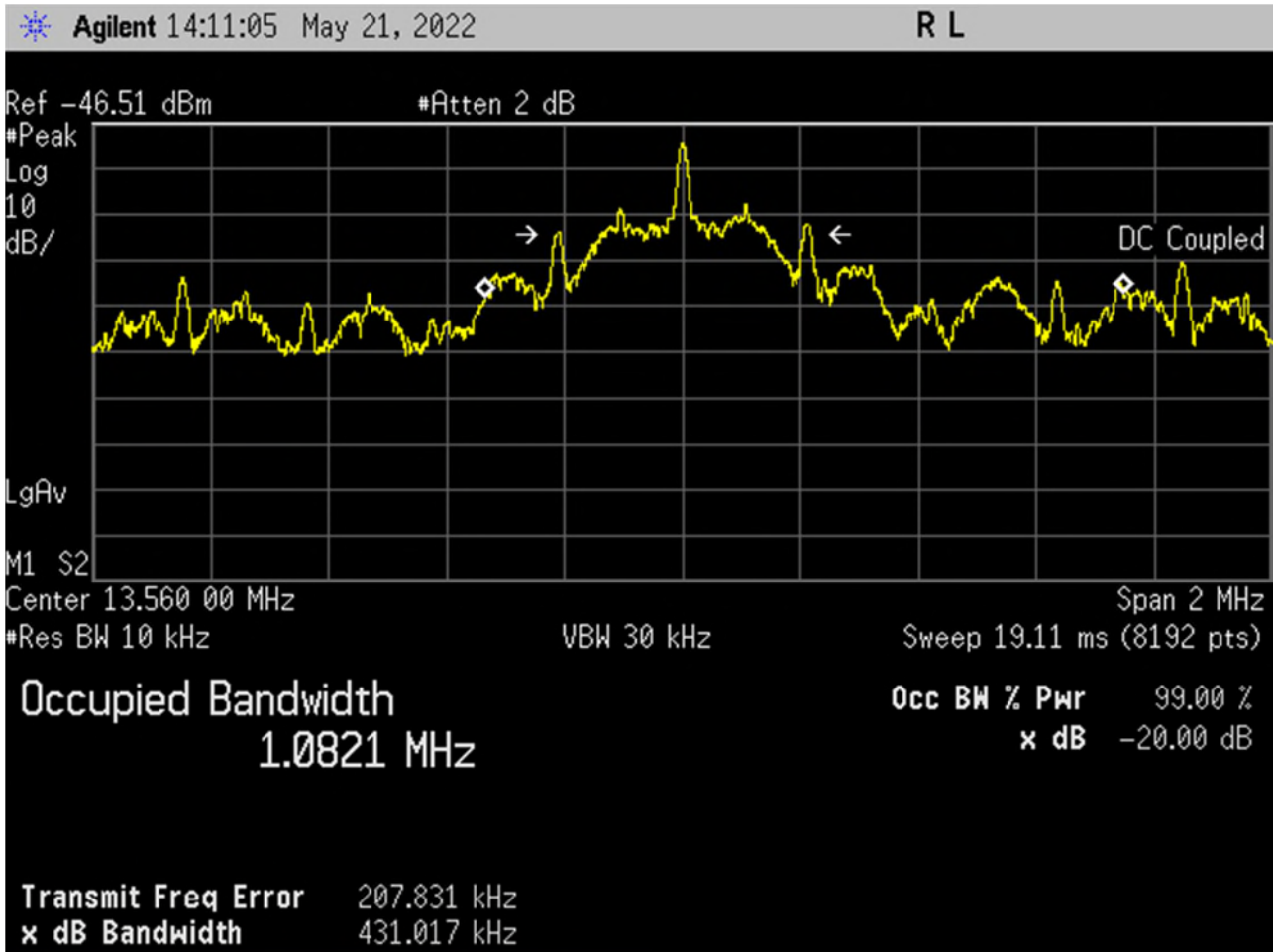


Mkr	Trace	X-Axis	Value	Notes
1 ▾	Trace A	13.5606 MHz	43.90 dB(uV/m)	

Nominal Temperature, Nominal Voltage

6.8 Occupied Bandwidth

RF Parameters: Band 13.11-14.01 MHz, Power Maximum, Channel Spacing Single Channel,
Modulation ASK, Channel 13.56 MHz



Plot of Occupied Bandwidth

7 Explanatory Notes

7.1 Explanation of Table of Signals Measured

Measurements are made as required by the standard. These measurements are made and recorded using detectors, either peak, quasi peak or average dependant on the test. A table of results has been given following the relevant plots. This table looks similar to the one illustrated below dependant on the measurements required by the test: -

Signal No.	Freq (MHz)	Peak Amp (dB μ V)	Pk – Lim 1 (dB)	QP Amp (dB μ V)	QP - Lim1 (dB)	Av Amp (dB μ V)	Av - Lim1 (dB)
1	12345	54.9	-10.5	48	-12.6	37.6	-14.4

Column One - Labelled Signal No. is an incremental number that the receiver has given to each signal that has been measured.

Column Two - Labelled Freq (MHz) is the approximate frequency of the signal received.

Column Three - Labelled Peak Amp (dB μ V) is the level of received signal that was measured in dB above 1 μ V using the peak detector.

Column Four - Labelled Pk - Lim1 (dB) is the difference in level from the peak signal given to the active limit line. If this column appears in the table the peak detector measurement is required by the standard for this test. The results entered in this column indicate the signal level relative to the compliance limit required. Negative numbers indicate that the product is compliant.

Column Five - Labelled QP Amp (dB μ V) is the level of received signal that was measured in dB above 1 μ V using the quasi-peak detector.

Column Six - Labelled QP - Lim1 (dB) is the difference in level from the quasi-peak signal given to the active limit line. If this column appears in the table the quasi-peak detector measurement is required by the standard for this test. The results entered in this column indicate the signal level relative to the compliance limit required. Negative numbers indicate that the product is compliant.

Column Seven - Labelled Av Amp (dB μ V) is the level of received signal that was measured in dB above 1 μ V using the average detector.

Column Eight - Labelled Av - Lim1 (dB) is the difference in level from the average signal given to the active limit line. If this column appears in the table the average detector measurement is required by the standard for this test. The results entered in this column indicate the signal level relative to the compliance limit required. Negative numbers indicate that the product is compliant.

Only signals highlighted in red are deemed to exceed the limit of the detector required.

7.2 Explanation of limit line calculations for radiated measurements

The limits given in the test standard are normally expressed as absolute values (e.g. in $\mu\text{V}/\text{m}$ at a specified distance), whereas the measured values are expressed as peak, quasi peak or average values in $\text{dB}\mu\text{V}/\text{m}$ referenced to the measuring instrument inputs. RN Electronics calibrate the test set-up to account for any path losses, antenna gains, etc. so that the value read at the receiver relates directly to the absolute value required, except that it is expressed in dB relative to one microVolt and may need to take account of any alternative measuring distance used. Examples:

(a) limit of $500 \mu\text{V}/\text{m}$ equates to $20.\log(500) = 54 \text{ dB } \mu\text{V}/\text{m}$.

(b) limit of $300 \mu\text{V}/\text{m}$ at 10m equates to $20.\log(300 \cdot 10/3) = 60 \text{ dB } \mu\text{V}/\text{m}$ at 3m

(c) limit of $30 \mu\text{V}/\text{m}$ at 30m, but below 30MHz, equates to $20.\log(30) + 40.\log(30/3) = 69.5 \text{ dB}\mu\text{V}/\text{m}$ at 3m, as extrapolation factor below 30MHz is 40dB/decade per 15.31(f)(2).

The measurement receiver used for emissions testing, performs the field strength (FS) calculations automatically. The receiver combines the signal amplitude (RA), Antenna Factor (AF) and Cable Loss (CL) factors for the frequency to be measured.

Example calculation: - FS = RA + AF + CL.

Receiver amplitude (RA)	Antenna factor (3m) (AF)	Cable loss (CL)	Field strength result (3m) (FS)
20dBuV	25 dB	3 dB	48dBuV/m

Additional calculation examples per ANSI C63.10 clause 9.4 – 9.6 equations 21, 22, 25 & 26:

Equation 21: $E_{\text{Linear}} = 10^{((E_{\text{Log}} - 120)/20)}$

And therefore equation 21 transposed is: $E_{\text{Log}} = 20 \times \text{Log}(E_{\text{Linear}}) + 120$

Where:

E_{Linear} is the field strength of the emission in V/m

E_{Log} is the field strength of the emissions in $\text{dB}\mu\text{V}/\text{m}$

Equation 22: $\text{EIRP} = E_{\text{Meas}} + 20\log(d_{\text{Meas}}) - 104.7$

Where:

EIRP is equivalent isotropically radiated power in dBm

E_{Meas} is the field strength of the emission at the measurement distance in $\text{dB}\mu\text{V}/\text{m}$

d_{Meas} is the measurement distance in metres

Equation 25: $\text{PD} = \text{EIRP}_{\text{Linear}} / 4\pi d^2$

And therefore equation 25 transposed is: $\text{EIRP}_{\text{Linear}} = \text{PD} \times 4\pi d^2$

Where:

PD is the power density at distance specified by the limit, in W/m^2

$\text{EIRP}_{\text{Linear}}$ is the equivalent isotropically radiated power in Watts

d is the distance at which the power density limit is specified in metres

Equation 26: $\text{PD} = E_{\text{Spec limit}}^2 / 377$

And therefore equation 26 transposed is: $E_{\text{Spec limit}} = \sqrt{(\text{PD} \times 377)}$

Where:

PD is the power density at distance specified by the limit, in W/m^2

$E_{\text{spec limit}}$ is the field strength at the distance specified by the limit in V/m

Example:

Radiated spurious emissions limit at 3metres of $90pW/cm^2$

$$90pW/cm^2 \times 100^2 = 0.9 \mu W/m^2 = (\text{EIRP Linear})$$

$$\text{Equation 25 transposed: } 0.9 \times 10^{-6} \times 4 \times \pi \times 3^2 = 0.0001017876 \text{ W}$$

And

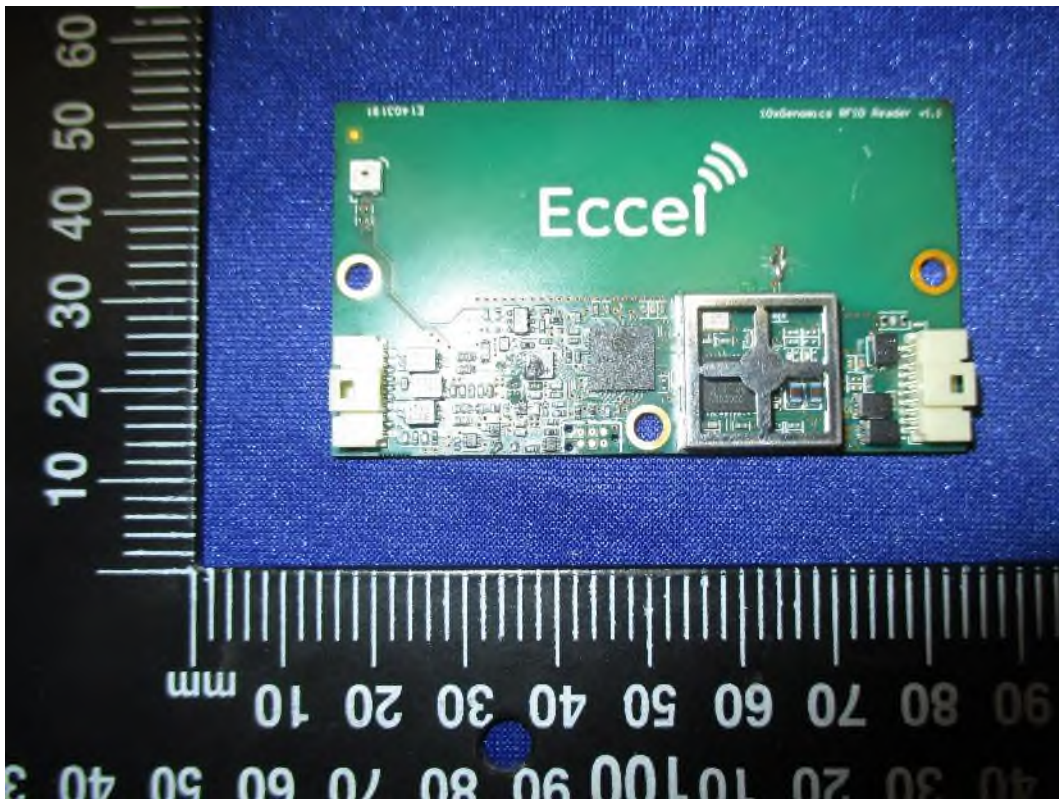
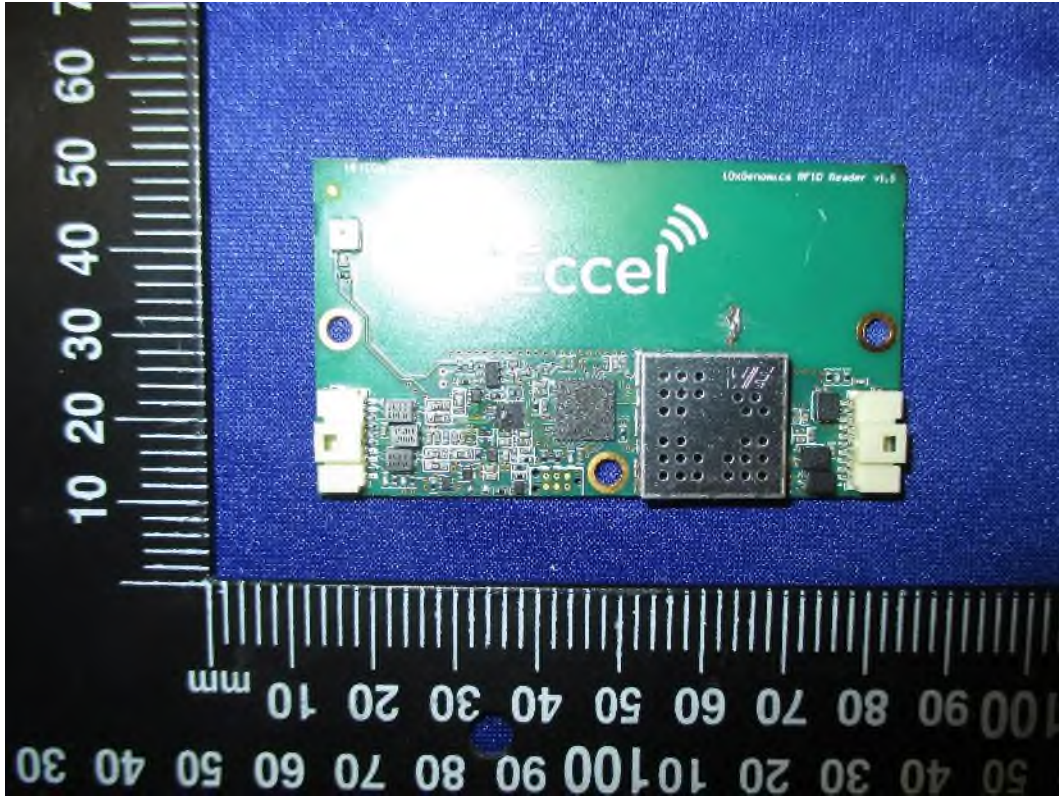
$$\text{Equation 26 transposed: } E_{\text{spec limit}} = \sqrt{(0.9 \times 10^{-6} \times 377)} = 0.01842 \text{ V/m.}$$

And

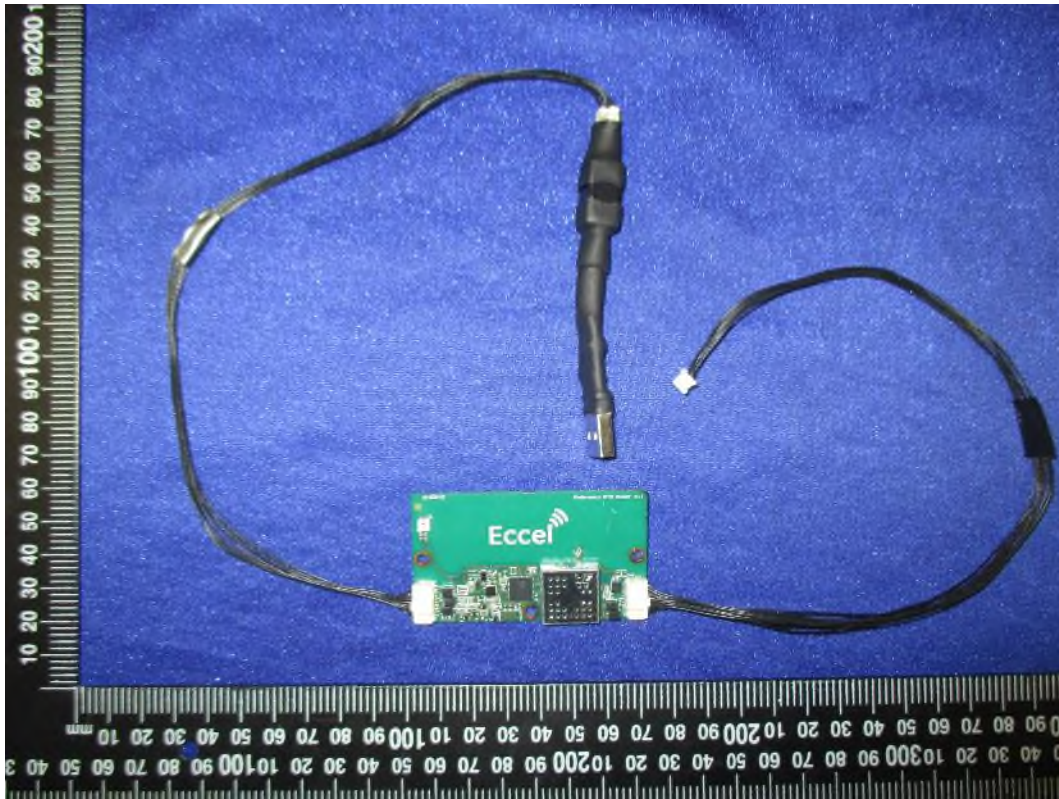
$$\text{Equation 21 transposed: } E_{\text{Log}} = 20\text{Log}(0.01842) + 120 = 85.3\text{dB}\mu\text{V/m @ 3m.}$$

8 Photographs

8.1 EUT Front View

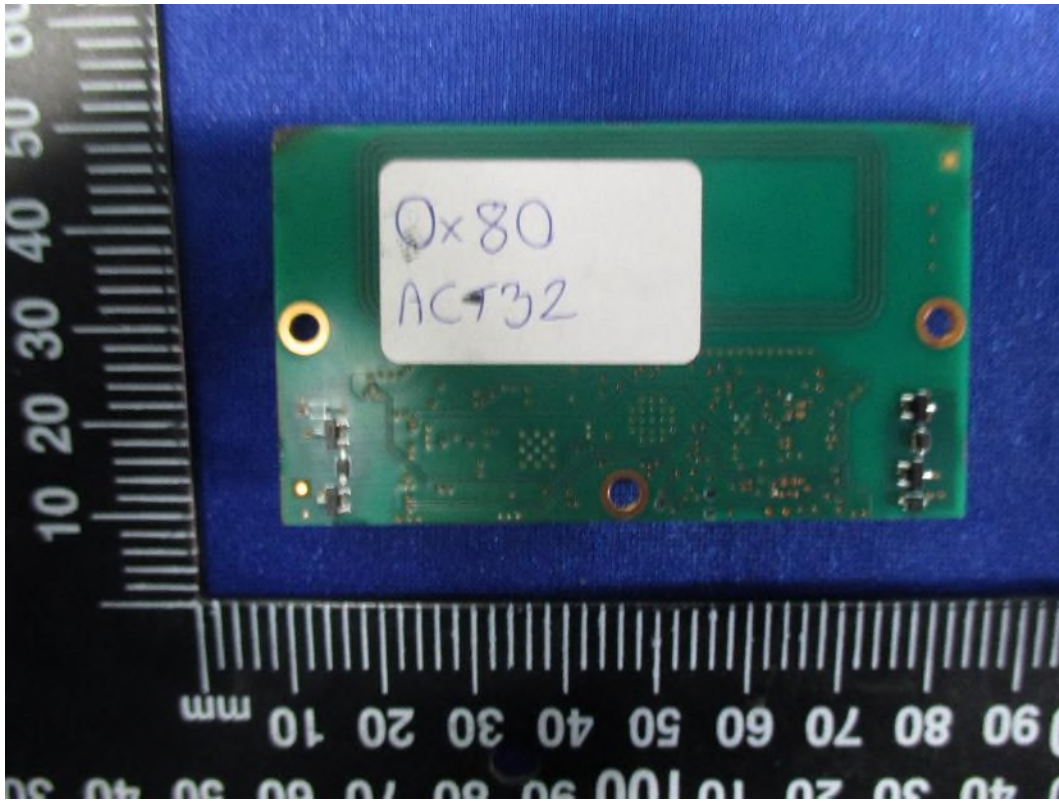


RF Can lid removed

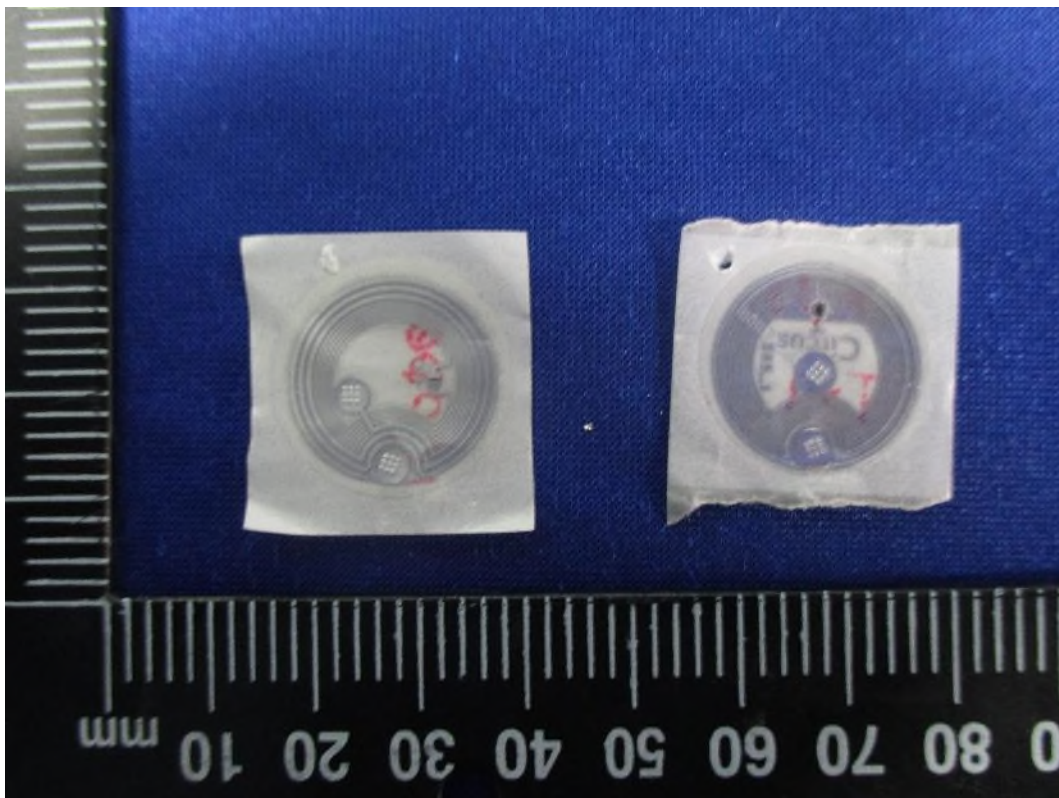


Supplied input and output cables

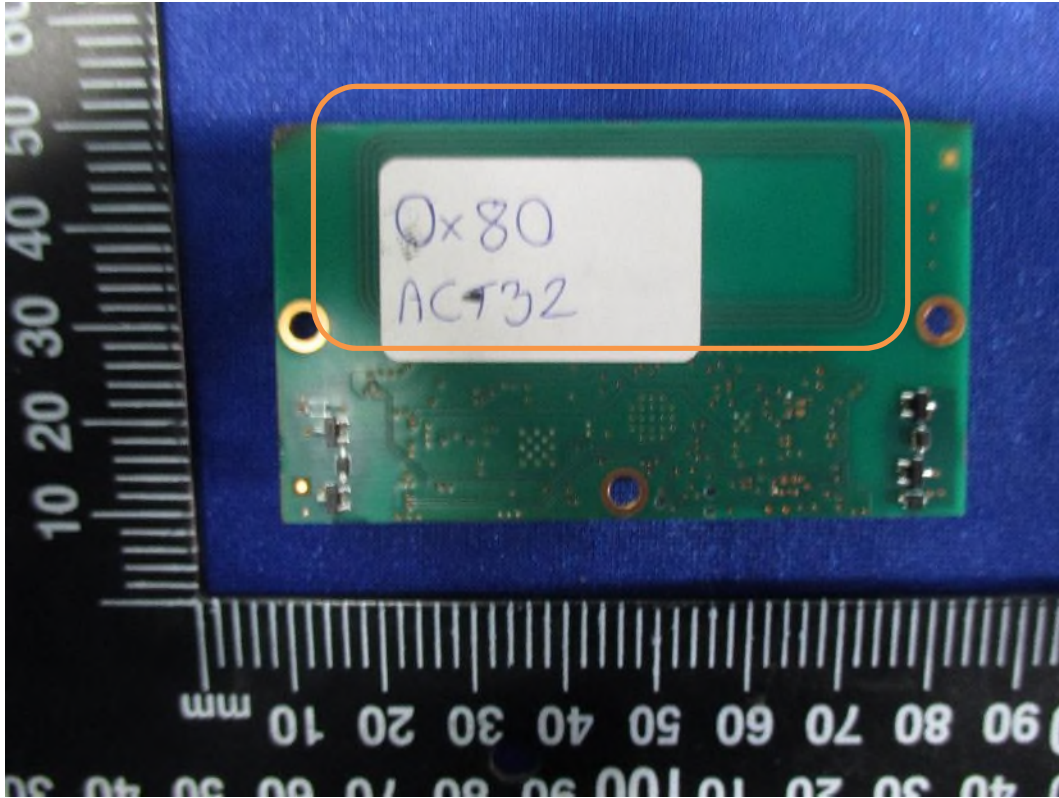
8.2 EUT Reverse Angle



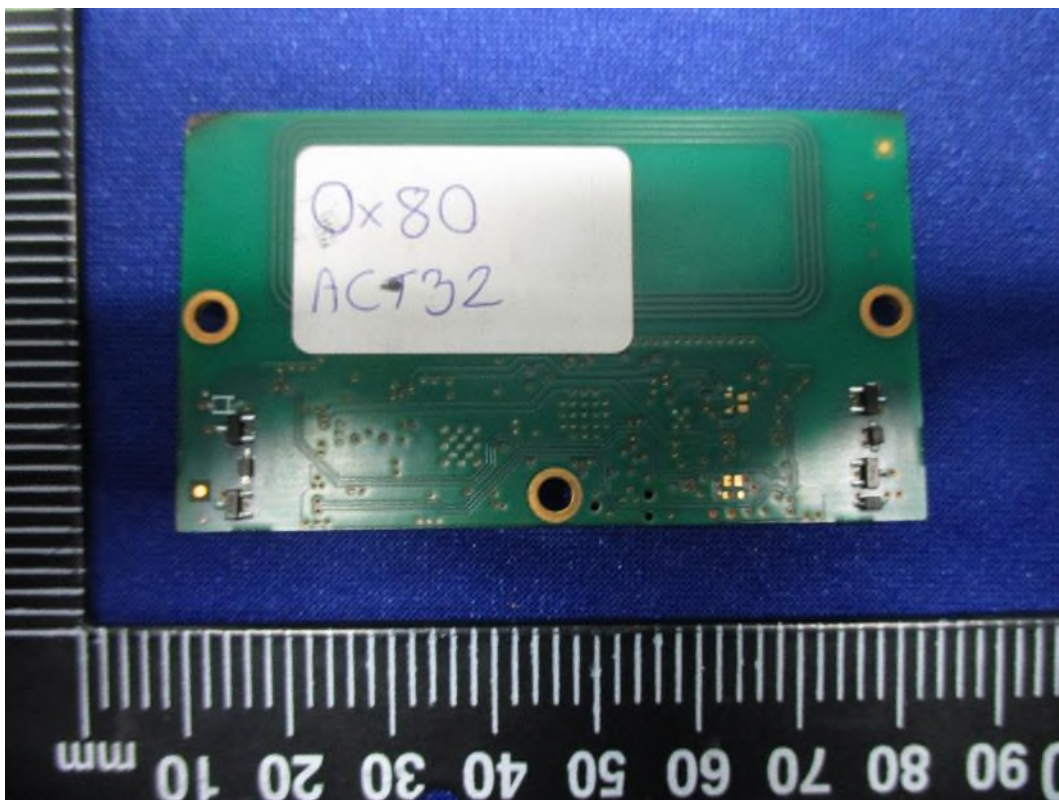
8.3 EUT Ancillary Tags



8.4 EUT Antenna Port



8.5 EUT ID Label

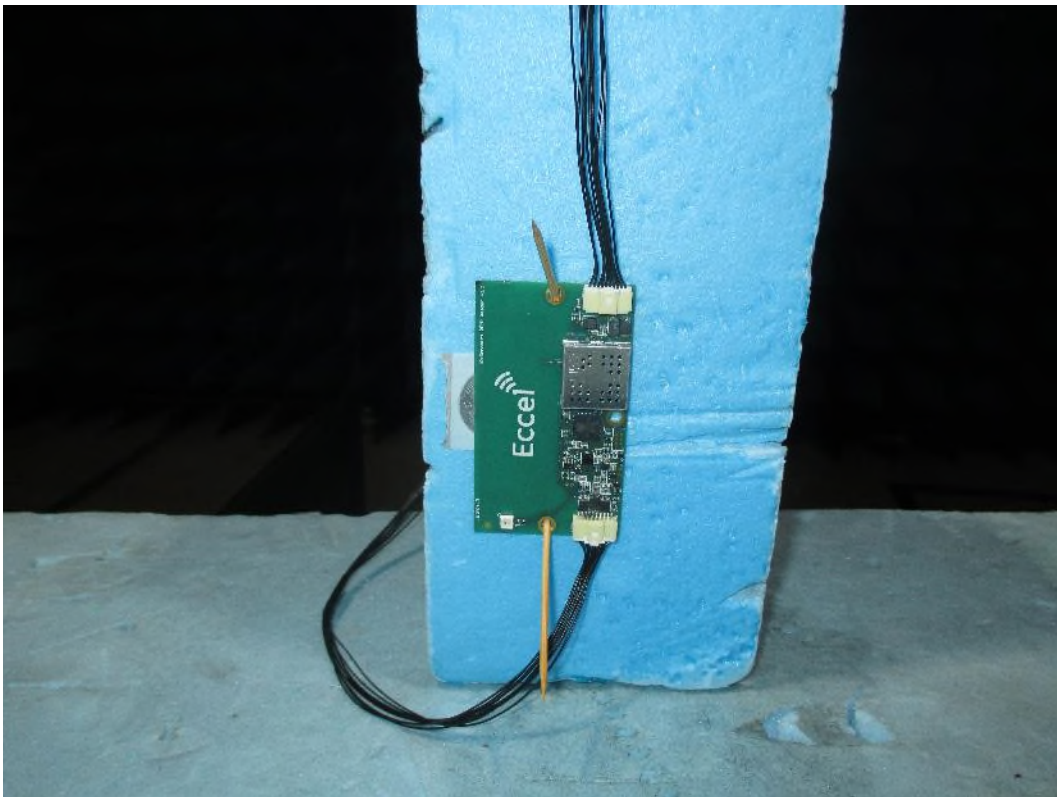
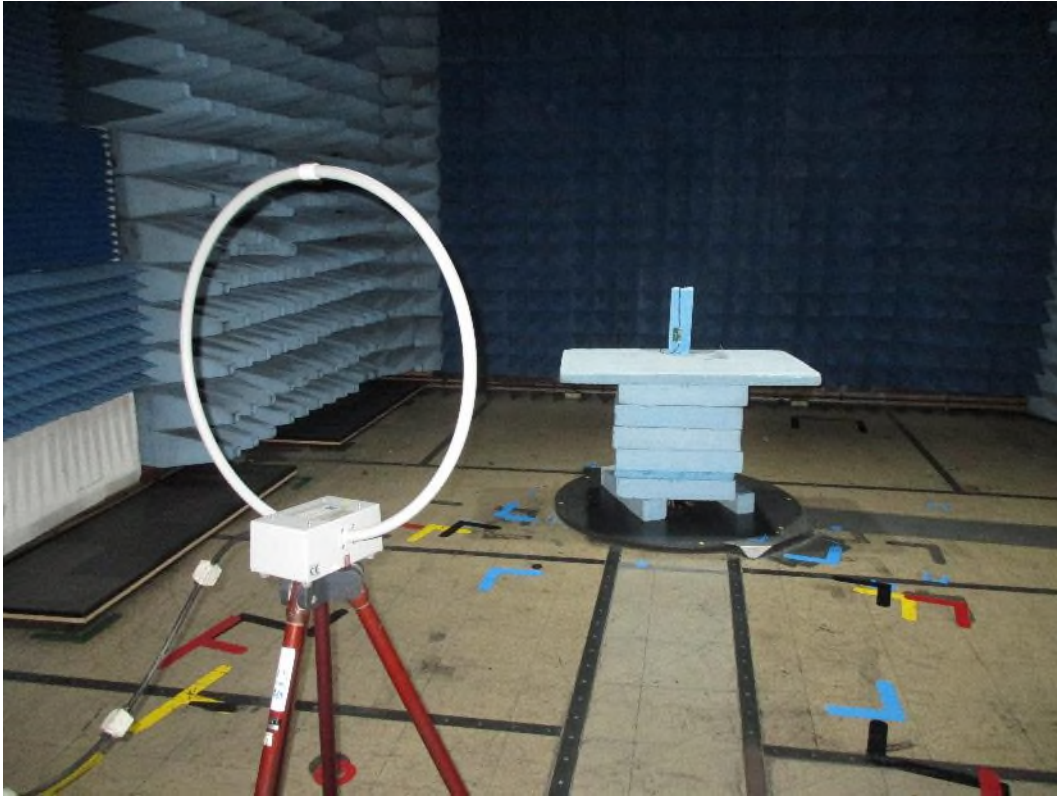


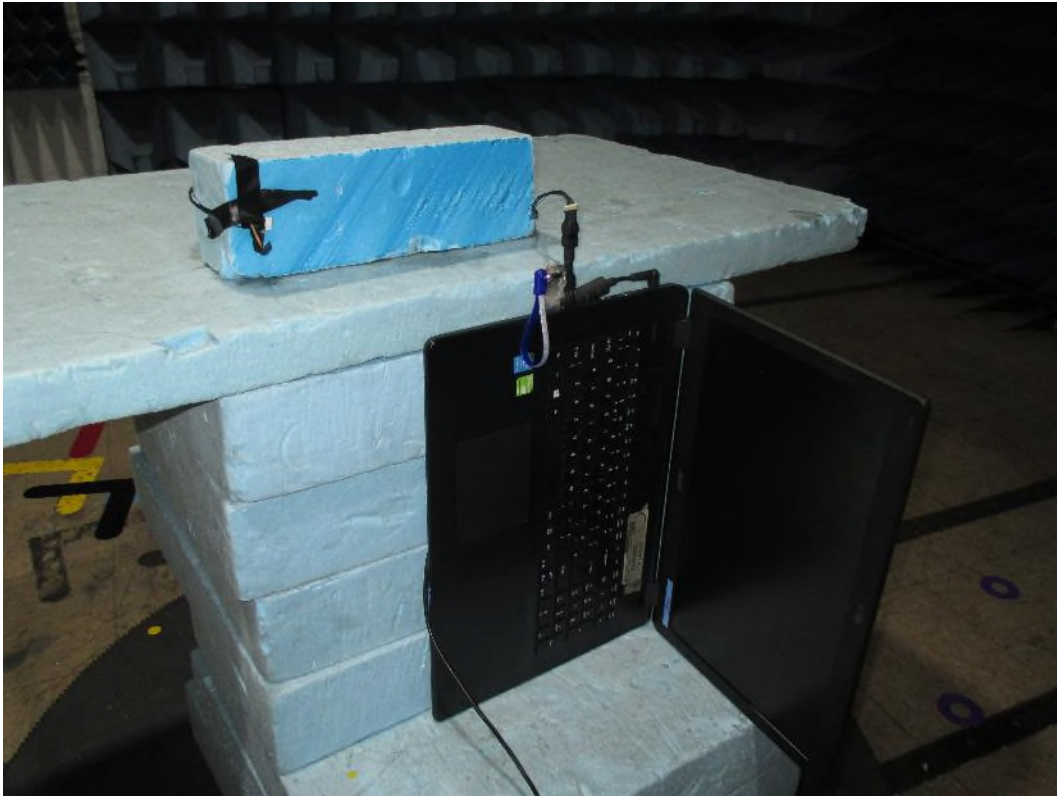
8.6 AC power line conducted emissions



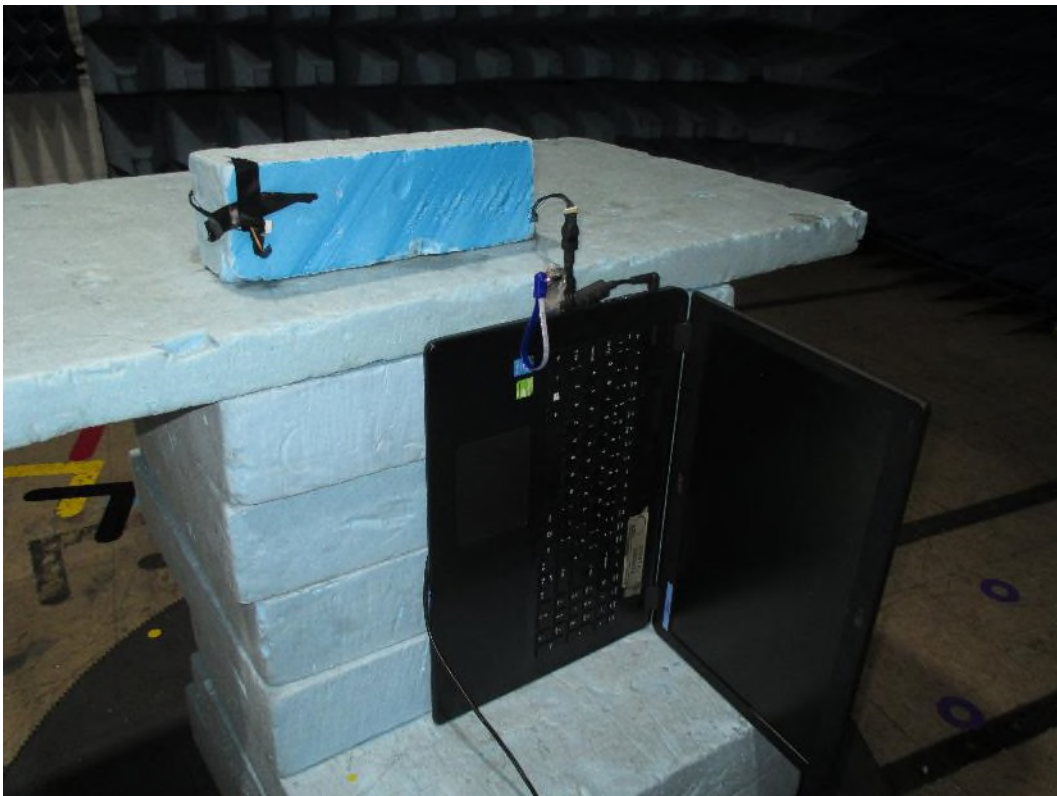


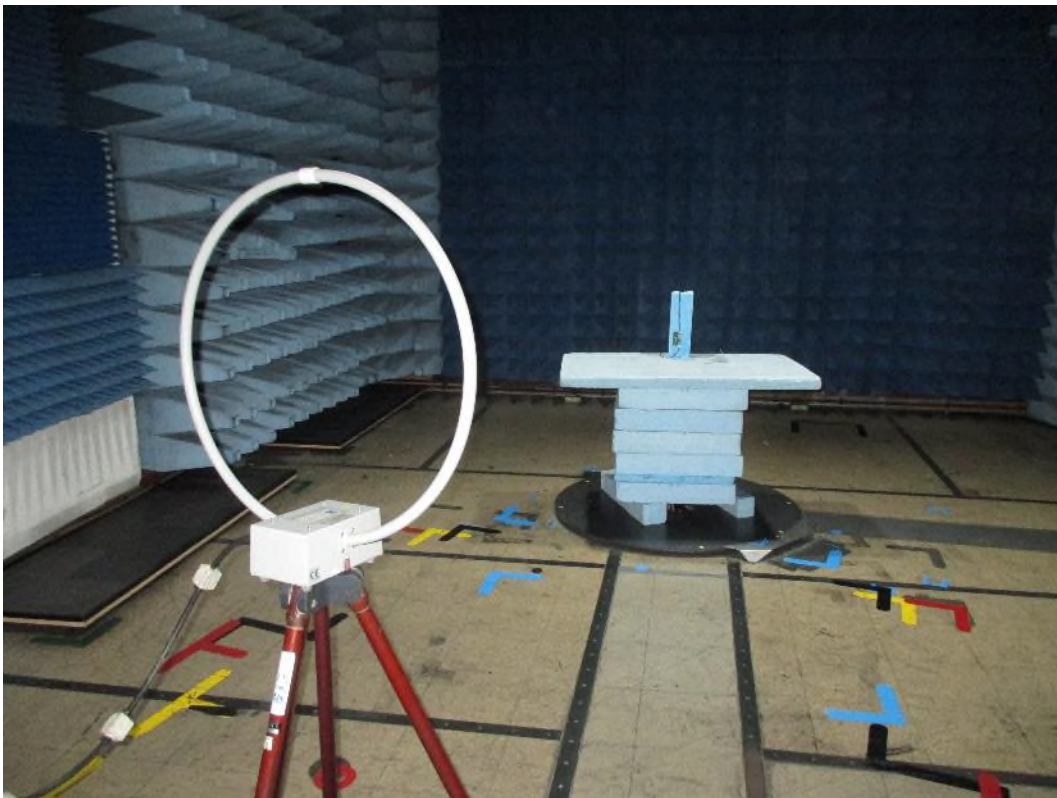
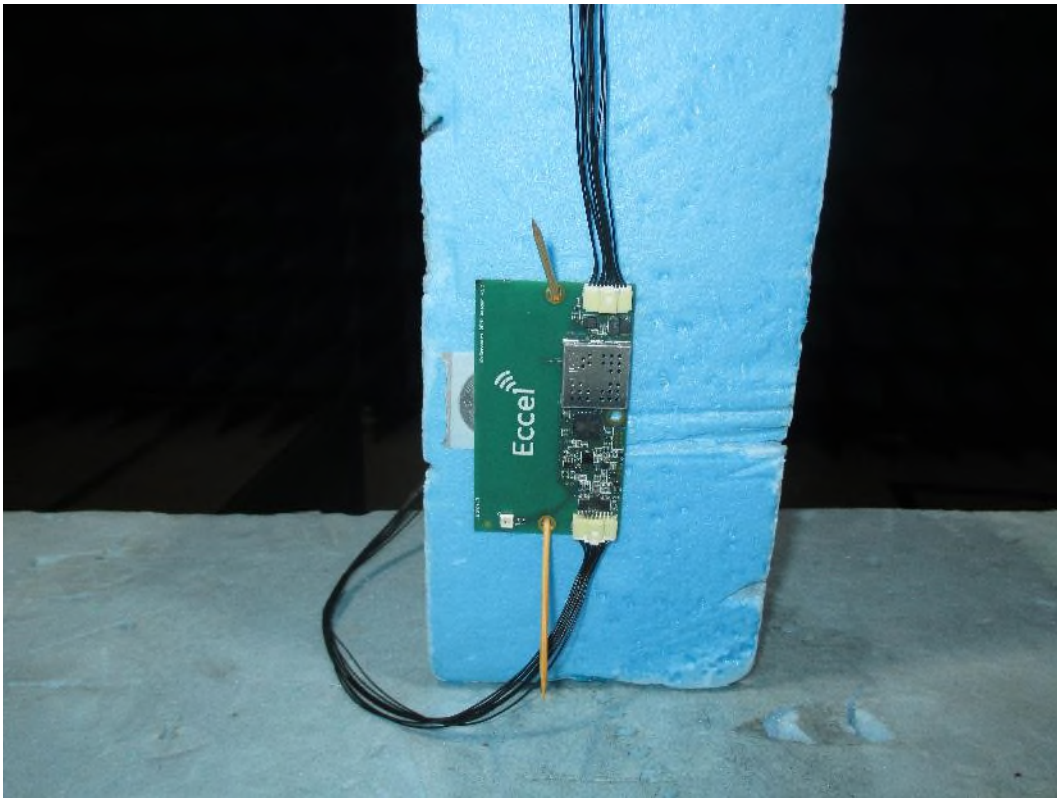
8.7 Radiated emissions 9 - 150 kHz





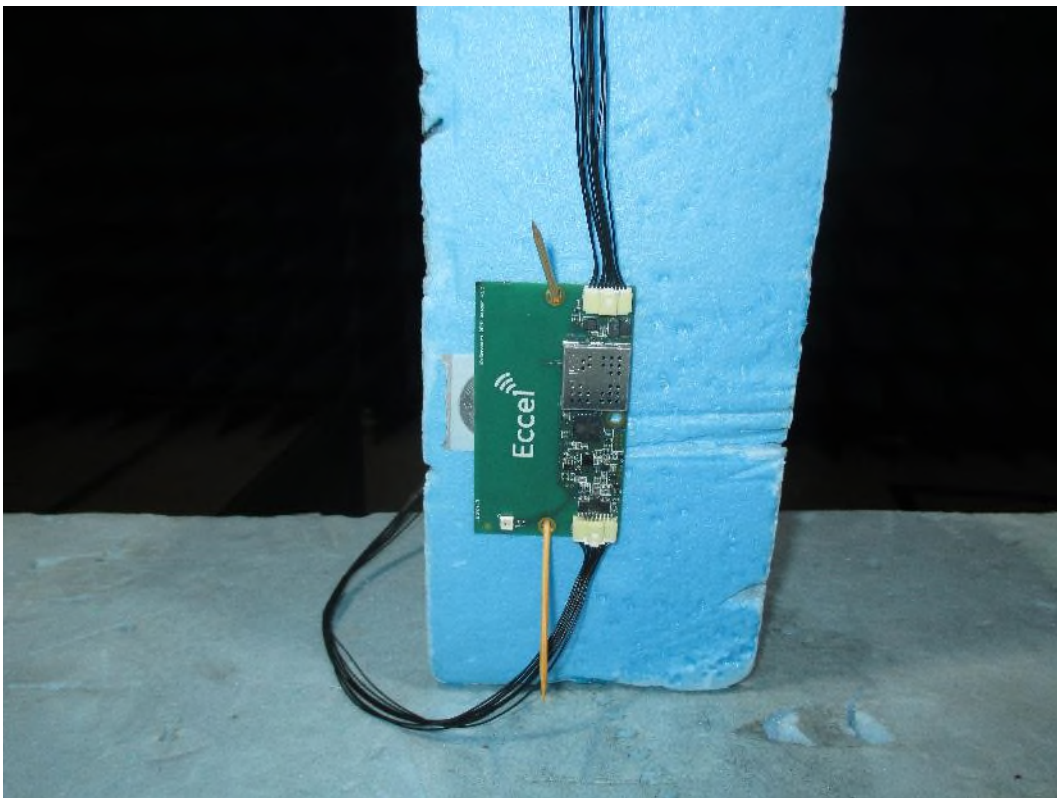
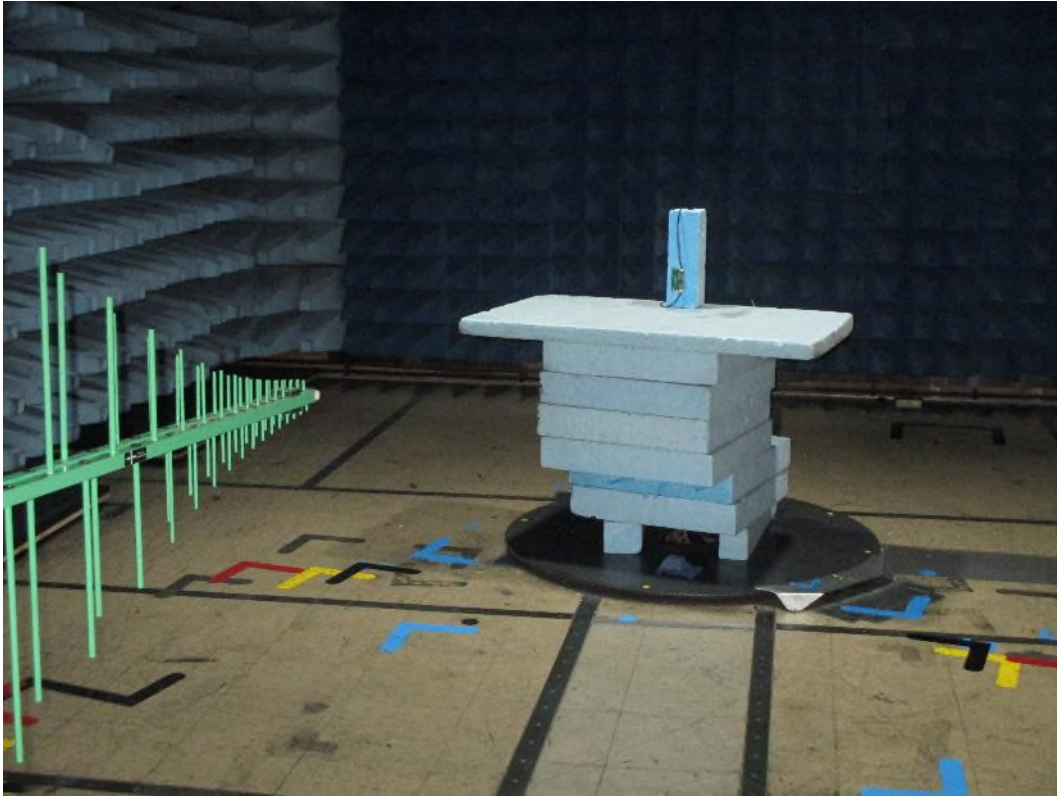
8.8 Radiated emissions 150 kHz - 30 MHz



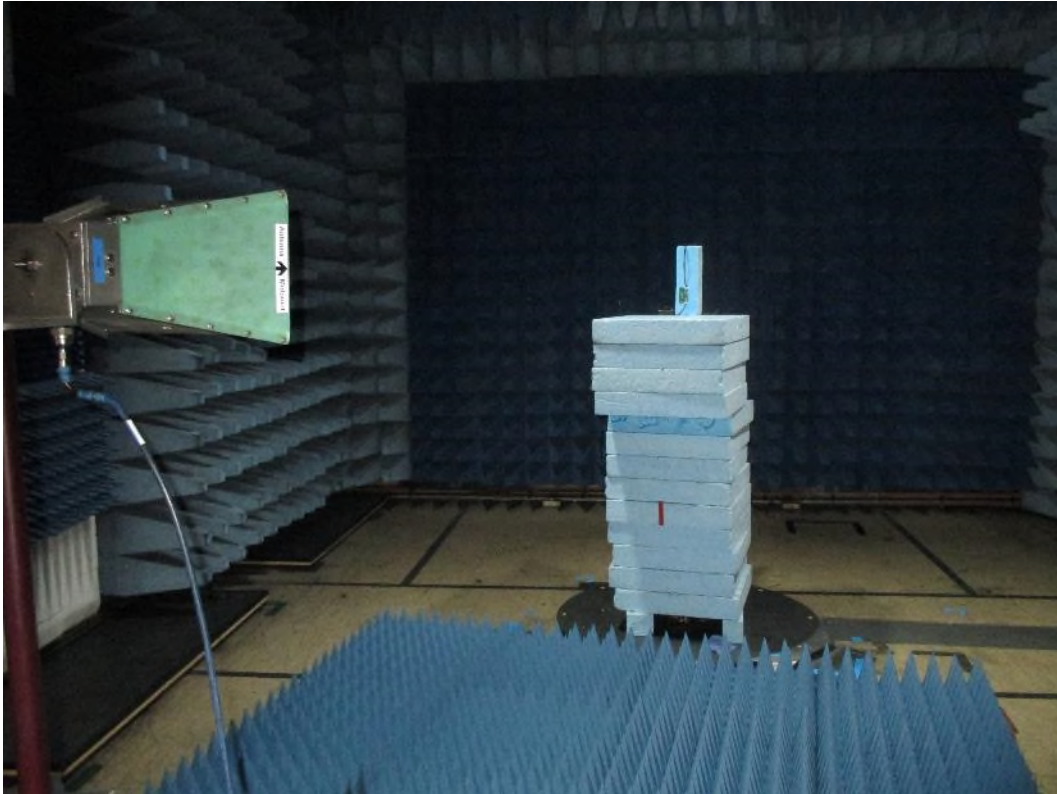




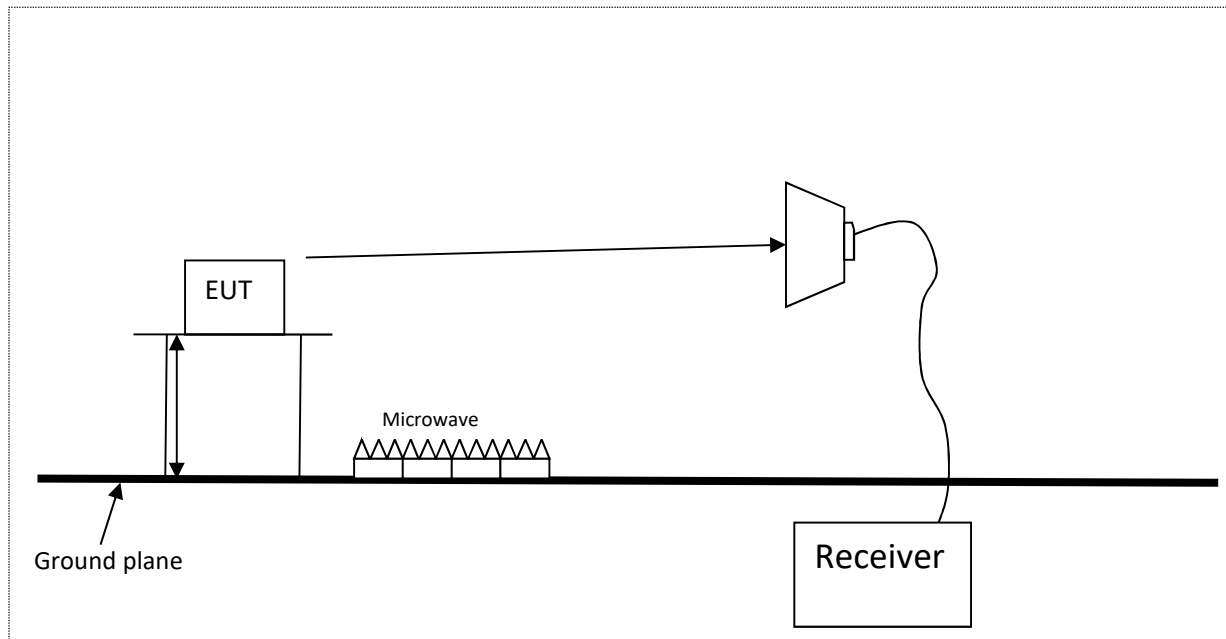
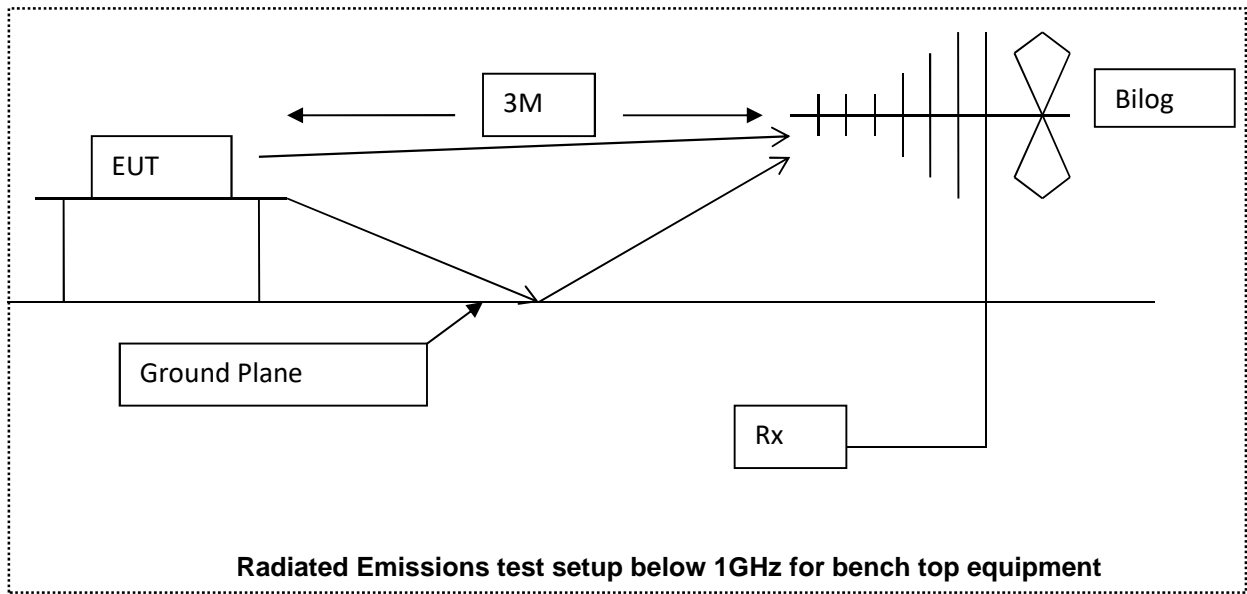
8.9 Radiated emissions 30 MHz -1 GHz



8.10 Radiated emissions above 1 GHz



8.11 Radiated emission diagrams



8.12 AC powerline conducted emission diagram

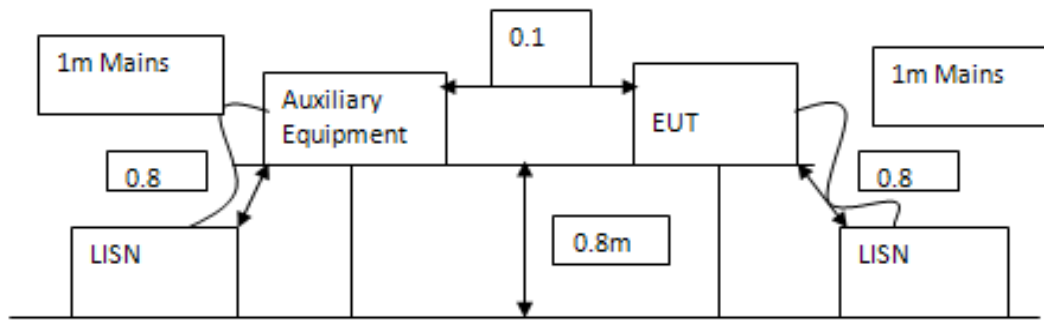


Diagram of the AC conducted emissions test setup

9 Test equipment calibration list

The following is a list of the test equipment used by R.N. Electronics Ltd to test the unit detailed within this report. In line with our procedures, the equipment was within calibration for the period during which testing was carried out.

RN No.	Model No.	Description	Manufacturer	Calibration date	Cal period
E035	11947A	Transient Limiter 9kHz - 200MHz	Hewlett Packard	14-Dec-2021	12 months
E136	3105	Horn Antenna 1 - 12.5 GHz	EMCO	02-Apr-2022	12 months
E150	MN2050	LISN 13A	Chase	25-Apr-2022	12 months
E411	N9039A	9 kHz - 1 GHz RF Filter Section	Agilent Technologies	08-Jul-2021	12 months
E555	CMV 5E-1	Variac 5A	Carroll & Meynell Ltd	04-Aug-2021	12 months
E623	72-7715	Thermometer	Tenma	05-Apr-2022	12 months
E624	E4440A	PSA 3 Hz - 26.5 GHz	Agilent Technologies	08-Jul-2021	24 months
E743	2017 4/2dB	Attenuator 4/2dB 30-1000MHz	RN Electronics	10-Mar-2022	12 months
E807	10MHz OCXO	Frequency Standard 10MHz OCXO	BG7TBL	17-Mar-2022	12 months
E843	G3RUH	10 MHz GPS Disciplined Oscillator	G3RUH - James Miller	21-Oct-2021	12 months
E932	N5181A	Signal Generator 100kHz to 6GHz	Agilent Technologies	08-Jun-2022	12 months
H071	N9010B	EXA Signal Analyser 10 Hz to 44 GHz	Keysight Technologies		24 months
LPE364	CBL6112A	Antenna BiLog 30MHz - 2GHz	Chase Electronics Ltd	28-Mar-2022	24 months
N607	HSGDW-50B	Environmental Oven	Shanghai Hasuc Instrument		months
NSA-M	NSA - M	NSA - Site M	RN Electronics	29-Nov-2021	36 months
TMS57	PM2534	Digital Multimeter	Philips	13-Apr-2022	12 months
TMS81	6502	Antenna Active Loop	EMCO	22-Jul-2021	24 months
TMS82	8449B	Pre-Amplifier 1GHz - 26.5GHz	Agilent Technologies	16-Dec-2021	12 months
VSWR-M	VSWR	VSWR 1-18GHz	RN Electronics	24-Nov-2021	36 months
ZSW1	V2.5.2	Measurement Software Suite	RN Electronics	Not Applicable	

10 Auxiliary and peripheral equipment

10.1 Customer supplied equipment

Item No.	Model No.	Description	Manufacturer	Serial No.
1	Not Specified	RFID NTAG Tag	Not Specified	Not Specified
2	Not Specified	RFID ICODE Tag	Not Specified	Not Specified

10.2 RN Electronics supplied equipment

RN No.	Model No.	Description	Manufacturer	Serial No
1218	ZYW	Laptop	Acer	NXV9WEK0014380846B7600

11 Condition of the equipment tested

In order for the EUT to produce the results shown within this report the following modifications, if any, were implemented.

11.1 Modifications before test

No modifications were made before test by RN Electronics Ltd.

11.2 Modifications during test

No modifications were made during test by RN Electronics Ltd.

12 Description of test sites

Site A	Radio Laboratory and Anechoic Chamber
Site B	Semi-Anechoic Chamber and Control Room FCC Registration No. 293246, ISED Registration No. 5612A-4
Site C	Transient Laboratory
Site D	Screened Room (Conducted Immunity)
Site E	Screened Room (Control Room for Site D)
Site F	Screened Room (Conducted Emissions)
Site G	Screened Room (Control Room for Site H)
Site H	3m Semi-Anechoic Chamber (indoor OATS) FCC Registration No. 293246, ISED Registration No. 5612A-2, VCCI Registration No. 4065
Site J	Transient Laboratory
Site K	Screened Room (Control Room for Site M)
Site M	3m Semi-Anechoic Chamber (indoor OATS) FCC Registration No. 293246, ISED Registration No. 5612A-3
Site N	Radio Laboratory
Site Q	Fully-Anechoic Chamber
Site OATS	3m and 10m Open Area Test Site FCC Registration No. 293246, ISED Registration No. 5612A-1
Site R	Screened Room (Conducted Immunity)
Site S	Safety Laboratory
Site T	Transient Laboratory

RN Electronics CAB identifier as issued by Innovation, Science and Economic Development Canada is UK0002

RN Electronics CAB identifier as issued by FCC is UK0015

13 Abbreviations and units

%	Percent	dB μ V	decibel relative to 1 μ V
λ	Wavelength	dB μ V/m	decibel relative to 1 μ V/m
μ A/m	microAmps per metre	dBc	decibel relative to Carrier
μ V	microVolts	dBd	decibel relative to dipole gain
μ W	microWatts	dBi	decibel relative to isotropic gain
AC	Alternating Current	dBm	decibel relative to 1mW
ACK	ACKnowledgement	dB	decibel relative to a maximum value
ACP	Adjacent Channel Power	dBW	decibel relative to 1W
AFA	Adaptive Frequency Agility	DC	Direct Current
ALSE	Absorber Lined Screened Enclosure	DFS	Dynamic Frequency Selection
AM	Amplitude Modulation	DMO	Dynamic Modulation Order
Amb	Ambient	DSSS	Direct Sequence Spread Spectrum
ANSI	American National Standards Institute	DTA	Digital Transmission Analyser
ATPC	Automatic Transmit Power Control	EIRP	Equivalent Isotropic Radiated Power
AVG	Average	emf	electromotive force
AWGN	Additive White Gaussian Noise	ERC	European Radiocommunications Committee
BER	Bit Error Rate	ERP	Effective Radiated Power
BPSK	Binary Phase Shift Keying	ETSI	European Telecommunications Standards Institute
BT	BlueTooth	EU	European Union
BLE	BlueTooth Low Energy	EUT	Equipment Under Test
BW	Bandwidth	FCC	Federal Communications Commission
$^{\circ}$ C	Degrees Celsius	FER	Frame Error Rate
C/I	Carrier / Interferer	FHSS	Frequency Hopping Spread Spectrum
CAC	Channel Availability Check	FM	Frequency Modulation
CCA	Clear Channel Assessment	FSK	Frequency Shift Keying
CEPT	European Conference of Postal and Telecommunications Administrations	FSS	Fixed Satellite Service
CFR	Code of Federal Regulations	g	Grams
CISPR	Comité International Spécial des Perturbations Radioélectriques	GHz	GigaHertz
cm	centimetre	GNSS	Global Navigation Satellite System
COFDM	Coherent OFDM	GPS	Global Positioning System
COT	Channel Occupancy Time	Hz	Hertz
CS	Channel Spacing	IEEE	Institute of Electrical and Electronics Engineers
CW	Continuous Wave	IF	Intermediate Frequency
DAA	Detect And Avoid	ISED	Innovation Science and Economic Development
dB	decibel	ITU	International Telecommunications Union
dB μ A/m	decibel relative to 1 μ A/m	KDB	Knowledge DataBase

kg	kilogram	pW	picoWatts
kHz	kiloHertz	QAM	Quadrature Amplitude Modulation
kPa	Kilopascal	QP	Quasi Peak
LBT	Listen Before Talk	QPSK	Quadrature Phase Shift Keying
LISN	Line Impedance Stabilisation Network	RBW	Resolution Band Width
LNA	Low Noise Amplifier	RED	Radio Equipment Directive
LNB	Low Noise Block	R&TTE	Radio and Telecommunication Terminal Equipment
LO	Local Oscillator	Ref	Reference
m	metre	RF	Radio Frequency
mA	milliAmps	RFC	Remote Frequency Control
max	maximum	RFID	Radio Frequency IDentification
Mbit/s	MegaBits per second	RLAN	Radio Local Area Network
MCS	Modulation and Coding Scheme	RMS	Root Mean Square
MHz	MegaHertz	RNSS	Radio Navigation Satellite Service
mic	Microphone	RSL	Received Signal Level
MIMO	Multiple Input, Multiple Output	RSSI	Received Signal Strength Indicator
min	minimum	RTP	Room Temperature and Pressure
mm	millimetres	RTPC	Remote Transmit Power Control
ms	milliseconds	Rx	Receiver
mW	milliWatts	s	Seconds
NA	Not Applicable	SINAD	Signal to Noise And Distortion
NFC	Near Field Communications	SRD	Short Range Device
nom	Nominal	Tx	Transmitter
nW	nanoWatt	UKAS	United Kingdom Accreditation Service
OATS	Open Area Test Site	UKCA	United Kingdom Conformity Assessed
OBW	Occupied Band Width	UKRER	United Kingdom Radio Equipment Regulations
OCW	Occupied Channel Width	UHF	Ultra High Frequency
OFDM	Orthogonal Frequency Division Multiplexing	U-NII	Unlicensed National Information Infrastructure
OOB	Out Of Band	USB	Universal Serial Bus
ppm	Parts per million	UWB	Ultra Wide Band
PER	Packet Error Rate	V	Volts
PK	Peak	V/m	Volts per metre
PMR	Private Mobile Radio	VBW	Video Band Width
PRBS	Pseudo Random Bit Sequence	VHF	Very High Frequency
PRF	Pulse Repetition Frequency	VSAT	Very Small Aperture Terminal
PSD	Power Spectral Density	W	Watts
PSU	Power Supply Unit		

===== END OF TEST REPORT =====