

# EMC TEST REPORT

No. 1887 FR

Issue#2: 8<sup>th</sup> April 2020



Hursley

# FCC Part 15C, Industry Canada Certification Report

for

**Perpetuum Ltd**

**WSN1.5-G9**

**FCC ID: 2AIZP-W15**  
**IC ID: 25921-W15**

Project Engineer: R. Pennell

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**EU Notified Body, No 2635**  
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### Document History:

Issue#1: 25<sup>th</sup> February 2020 was withdrawn and replaced by Issue#2: 8<sup>th</sup> April 2020 updated with editorial correction.

## 1.0 DECLARATION

### 1.1 FCC Part 15C Statement and Industry Canada (IC) Statement

The Equipment Under Test (EUT), as described and reported within this document, complies with ISED RSS-Gen Issue 5 March 2019 and IC RSS-210 Issue 10 December 2019 and the parts 15.109, 15.209, 15.247 and 15.249 of the CFR 47:2015 FCC rules. The EUT operates at frequencies of 903 to 928 MHz and complies with part 15C emission requirements.

For emissions outside the 902 - 928MHz band the EUT, as described and reported within this document, complies with the parts 15.207 and 15.209 of the CFR 47 FCC rules in accordance with ANSI C63.10:2013 and ANSI C63.4:2014.

### 1.2 Related Submittal(s) Grants

This is an application for certification of a WSN1.5-G9 (transmitting at 903 to 927 MHz), described in this report.

The sections of FCC Part 15 that apply to the EUT are:

15.209 General requirements  
15.247 Operation within the band 902 to 928 MHz  
15.109 applied to the EUT in receive mode.

### 1.3 EUT Manufacturer

Trade name:	Perpetuum Ltd
Company name:	Perpetuum Ltd
Company address:	Unit 2 Strategic Park Comines Way Hedge End Southampton Hampshire SO30 4DA
	Tel: +44 (0) 23 8076 5888

Manufacturing address:	As above.
Company representative:	Chris Harden
	Tel: +44 (0) 23 8076 5888

## 2.0 EUT DESCRIPTION

### 2.1 Product Information

EUT: WSN1.5-G9

Serial numbers: PCB Assembly Serial numbers:

Unit 3 – S/N 08000397-2/CTP/06356/0003  
(Radiated continuous Tx)

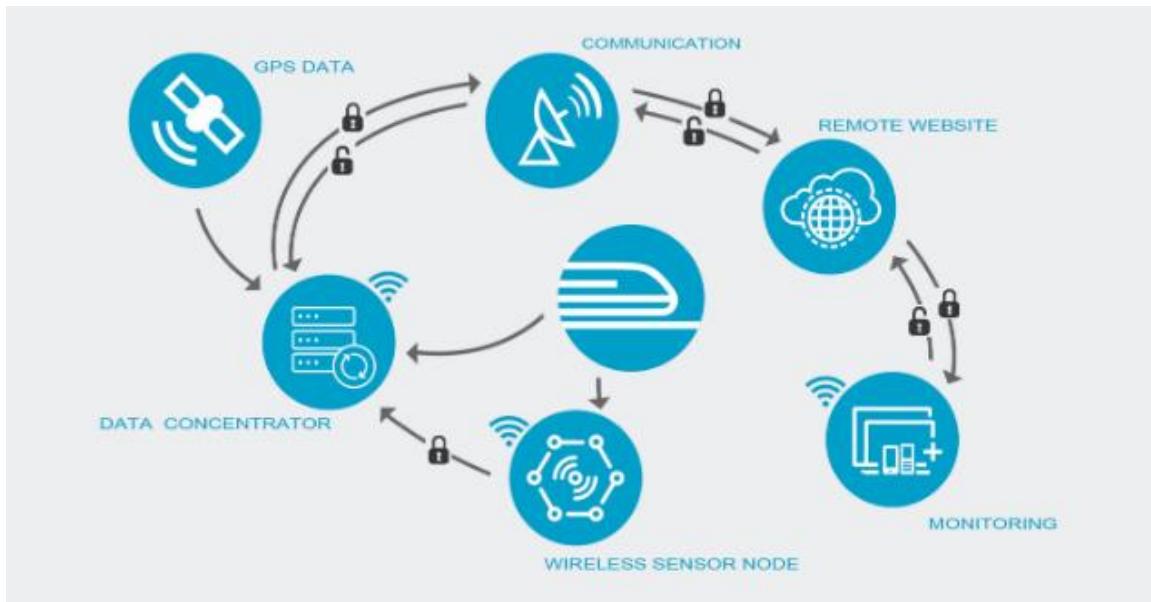
Unit 2 – S/N 08000397-2/CTP/06356/0002  
(Radiated normal operation and idle)

Unit 4 – S/N 08000397-2/CTP/06356/0004  
(Conducted measurements)

Sample build: Pre-Production

### 2.2 Product Operation

The Perpetuum Wireless Sensor Node (WSN) is a low power, vibration energy harvesting powered device for condition monitoring on rail vehicles. It utilises a low power UHF radio module in a transmit only mode to send sensor readings back to a Data Concentrator. It operates at a transmit frequencies of 903 to 927 MHz using Chirped Spread Spectrum (CSS) 'LoRa' modulation with a nominal 500kHz bandwidth.



## 2.3 Support Equipment

- Acer Aspire Laptop, Perpetuum Asset No. 248 (for configuration only via USB-Serial Adaptor)
- Tenma Bench Power Supply 72-10480, Perpetuum Asset No. 211

## 2.4 Exerciser Program

Acer Laptop running LPRS EasyRadio Companion Software.

The EUT was set to transmit continuously at the bottom, middle and top of the 902 to 928MHz radio operating range, this being 903, 915 and 927MHz respectively. Once transmitting the EUT was tested standalone in the semi-anechoic chamber.

# 3.0 MEASUREMENT PROCEDURE AND INSTRUMENTATION

## 3.1 EMI Site Address & Test Date

EMI Company Offices	Eurofins Hursley Trafalgar House, Trafalgar Close, Chandlers Ford, Hampshire
EMI Measurement Site	Eurofins Hursley UK Designation number: UK0006 Canada CAB Identifier: UK0005
Test Dates Eurofins Hursley Reference:	5 <sup>th</sup> January to 6 <sup>th</sup> February 2020 1887

## 3.2 General Operating Conditions

Testing was performed according to the procedures in accordance with ANSI C63.4:2014 and 63.10 2013. Final radiated testing was performed at a EUT to antenna distance of three metres. Instrumentation, including receiver and spectrum analyser bandwidth, comply with the requirements of ANSI C63.2:1996.

### 3.3 Uncertainty

The following measurement uncertainties have been calculated in accordance with ANSI C63.23, CISPR 16-4-2 and in line with other available guidance to provide a confidence level of 95% (coverage factor,  $k = 2$ ) in the reported measurements:

For radiated emissions below 1 GHz:

3 m measurement distance	30 MHz – 200 MHz	200 MHz – 1 GHz
Vertical polarisation	$\pm 3.7$ dB	$\pm 5.1$ dB
Horizontal polarisation	$\pm 3.9$ dB	$\pm 3.8$ dB

For radiated emissions below 1 GHz:

10 m measurement distance	30 MHz – 200 MHz	200 MHz – 1 GHz
Vertical polarisation	$\pm 4.4$ dB	$\pm 4.8$ dB
Horizontal polarisation	$\pm 4.5$ dB	$\pm 4.6$ dB

For radiated emissions above 1 GHz:

3 m measurement distance	1 GHz – 6 GHz	6 GHz - 18 GHz	18 GHz – 40 GHz
Both polarisations	$\pm 4.5$ dB	$\pm 4.4$ dB	$\pm 4.3$ dB

Band Edge tests	
Conducted (absolute measurements)	$\pm 2.3$ dB
Close coupled radiated (relative measurements)	$\pm 0.3$ dB

Occupied bandwidth tests	
RBW setting $\leq 100$ kHz	$\pm 0.62$ %
RBW setting $> 100$ kHz	$\pm 1.66$ %

### 3.4 Environmental Ambient

Test Type	Temperature	Humidity	Atmospheric Pressure
Radiated	20 to 22 degrees Celsius	38 to 40 % relative	1032 to 1035 millibars

## 3.5 Radiated Emissions

### Initial Scan

A radiated profile scan was taken at a three metre distance on eight azimuths of the system under test in both vertical and horizontal polarities of the antenna in a semi-anechoic chamber. Instrumentation used in the chamber as below:

#ID	CP	Manufacturer	Type	Serial No	Description	Calibration due date
053	1	HP	8449B	3008A01394	Pre-amplifier (1.0-26.5GHz)	17/10/2020
456	1	Rohde & Schwarz	ESCI7	1144573407	EMI Test Receiver	21/08/2020
466	3	Schwarzbeck	BBHA 9120 571	571	1-10GHz Horn	28/02/2022
651	1	Rohde & Schwarz	ESIB 40 no.2	100262	40GHz receiver	27/11/2020
750	1	Global	CISPR16 chamber	1	11 x 7 x 6.2m	28/10/2020
762	3	Schwarzbeck	VULB9162	129	30-7000MHz	07/04/2020
762a	3	Schwarzbeck	DGA 9552N	0	6dB attenuator for #762	07/04/2020

CP = Interval period [year] prescribed for external calibrations

Note: ‘Calibration due date’ means that the instrument is certified with a UKAS or traceable calibration certificate.

‘Internal’ means internally calibrated using Eurofins Hursley procedures

The data obtained from the profile scan was used as a guide for the final measurements.

### Final Measurements

Final measurements of the system under test were also taken in the semi-anechoic chamber. The data obtained from the chamber profile-scan was used as a guide. Above 30 MHz, each emission identified from the EUT was maximised by revolving the system on the turntable and moving the antennae in height and azimuth. The worst-case data is presented in this report. Test instrumentation used for final measurements is unchanged from the initial scan.

## 4.0 TEST DATA

### 4.1 Radiated Emissions 30MHz to 1GHz

A search was made of the frequency spectrum from 30 MHz to 10 GHz and the measurements reported are the highest emissions relative to the:

‘FCC CFR 47 Section 15.209 and 15.249 Limits’ at a measuring distance of three metres.

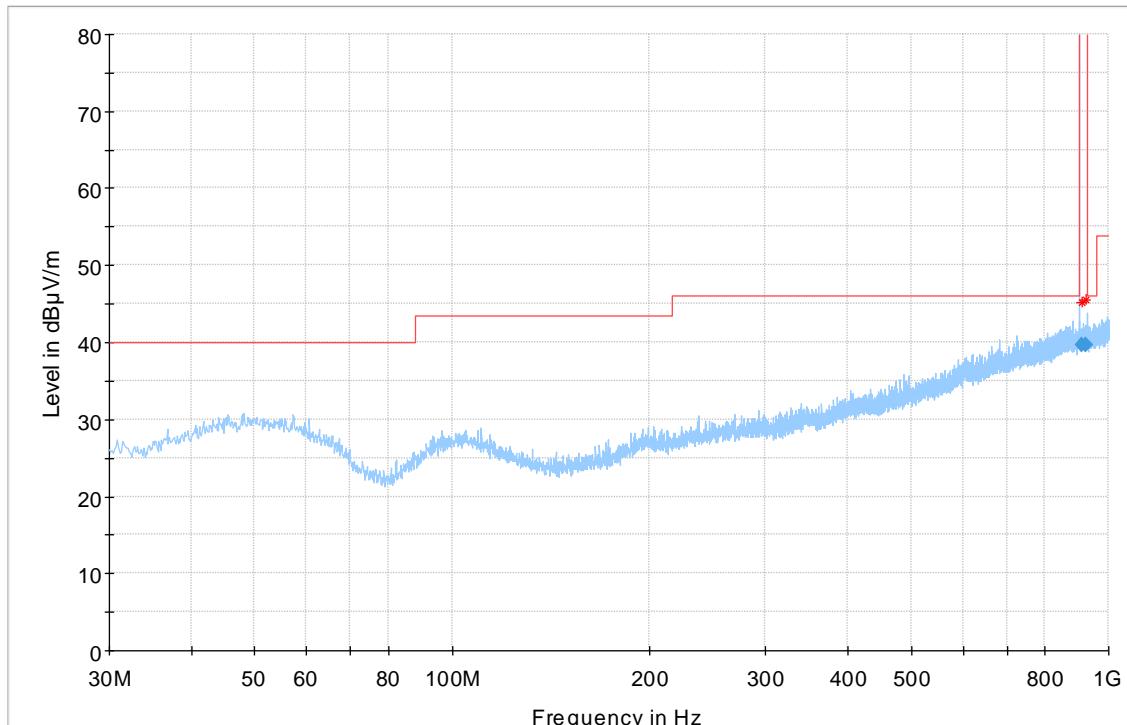
‘ISED RSS-210 issue 10 Annex B section B10’

Testing was performed with the EUT at the top, bottom and middle transmitter operating frequencies. Below 1 GHz a quasi-peak detector was used (bandwidth 120 kHz), above 1 GHz a peak and average detector was used (bandwidth 1 MHz). The worst-case results from all tests are presented here.

#### 4.1.1 Data, WSN1.5-G9; (Transmitting) Bottom Channel

Frequency	Quasi Peak	Specified Limit	Margin	Height	Pol	Azimuth	Corr	
MHz	dB $\mu$ V/m	dB $\mu$ V/m	dB	cm	H/V	Deg	dB/m	Status
908.836943	39.62	94.00	54.38	268.0	V	239.0	31.4	Pass
921.566827	39.73	94.00	54.27	259.0	H	296.0	31.5	Pass

#### 4.1.2 Profile; WSN1.5-G9; (Transmitting) Bottom Channel

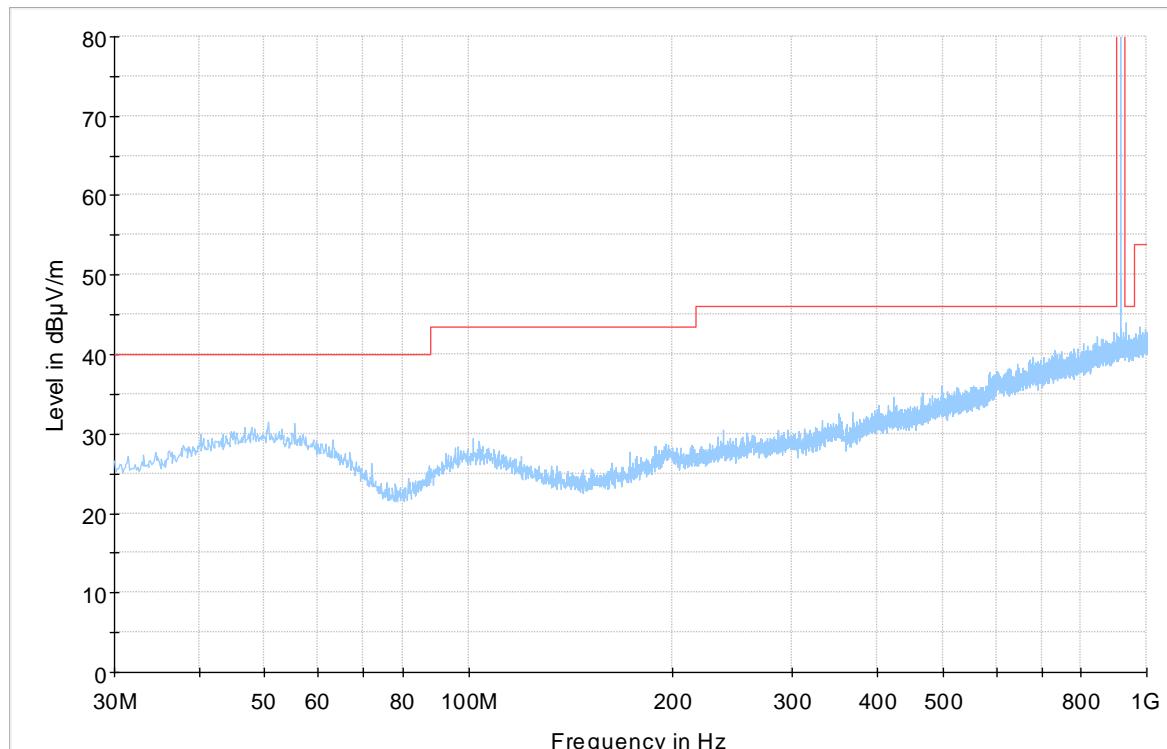


#### 4.1.3 Data; WSN1.5-G9; (Transmitting) Middle Channel

Frequency	Quasi Peak	Specified Limit	Margin	Height	Pol	Azimuth	Corr	
MHz	dB $\mu$ V/m	dB $\mu$ V/m	dB	cm	H/V	Deg	dB/m	Status
No Significant Peaks Were Found								Pass

\*Transmitter frequency

#### 4.1.4 Profile; WSN1.5-G9; (Transmitting) Middle Channel

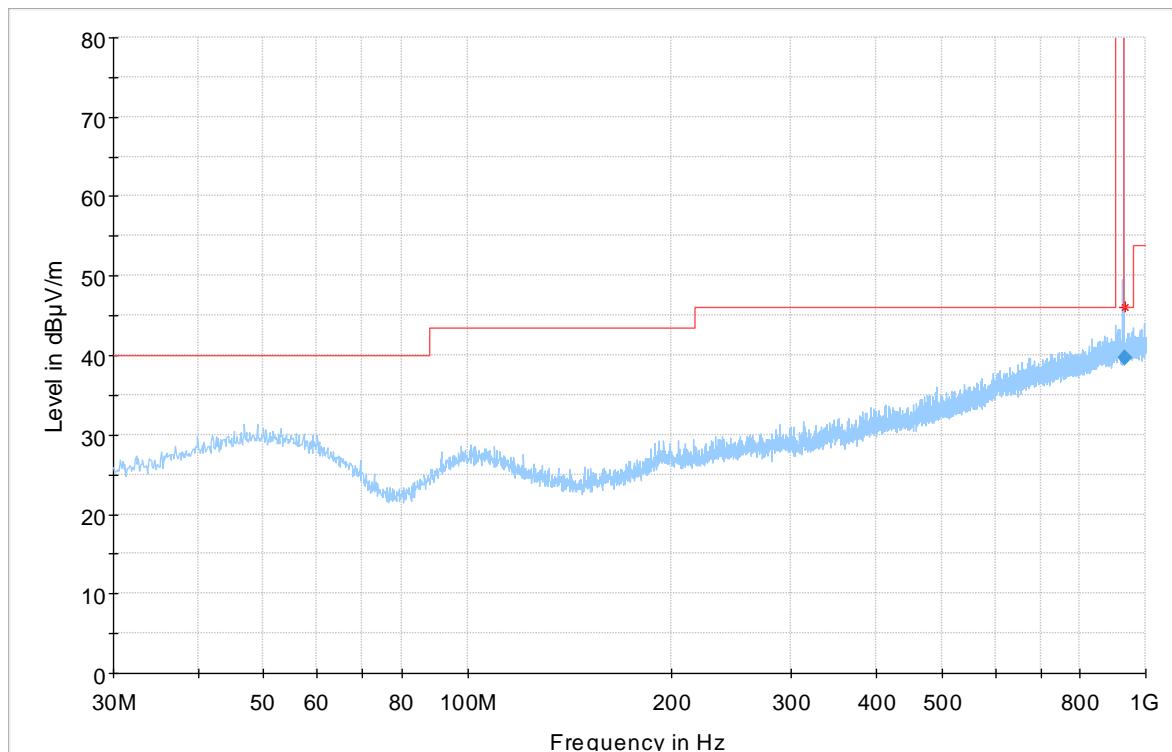


#### 4.1.5 Data; WSN1.5-G9; (Transmitting) Top Channel

Frequency	Quasi Peak	Specified Limit	Margin	Height	Pol	Azimuth	Corr	
MHz	$\text{dB}\mu\text{V/m}$	$\text{dB}\mu\text{V/m}$	dB	cm	H/V	Deg	$\text{dB}/\text{m}$	Status
931.891995	39.73	46.00	6.27	154.0	H	172.0	31.4	Pass

\*Transmitter frequency

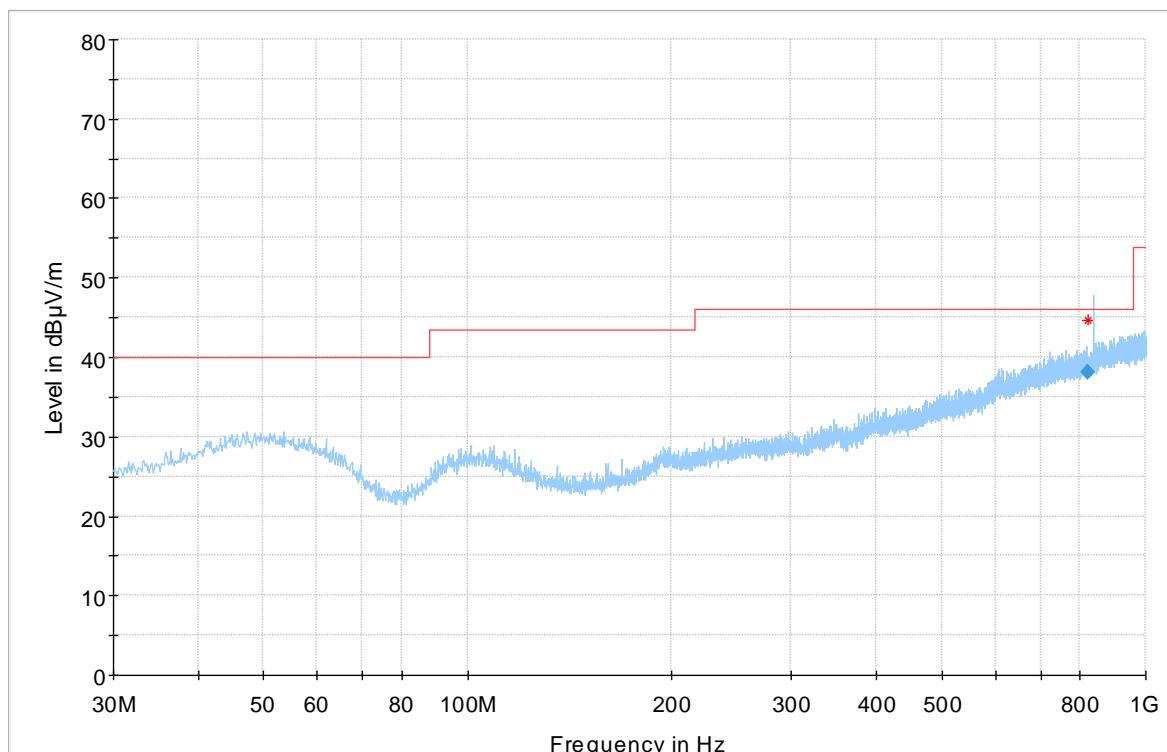
#### 4.1.6 Profile; WSN1.5-G9; (Transmitting) Top Channel



#### 4.1.7 Data; WSN1.5-G9; Idle Mode

Frequency	Quasi Peak	Specified Limit	Margin	Height	Pol	Azimuth	Corr	
MHz	dB $\mu$ V/m	dB $\mu$ V/m	dB	cm	H/V	Deg	dB/m	Status
822.337008	38.06	46.00	7.94	256.0	V	18.0	29.9	Pass

#### 4.1.8 Profile; WSN1.5-G9; Idle Mode

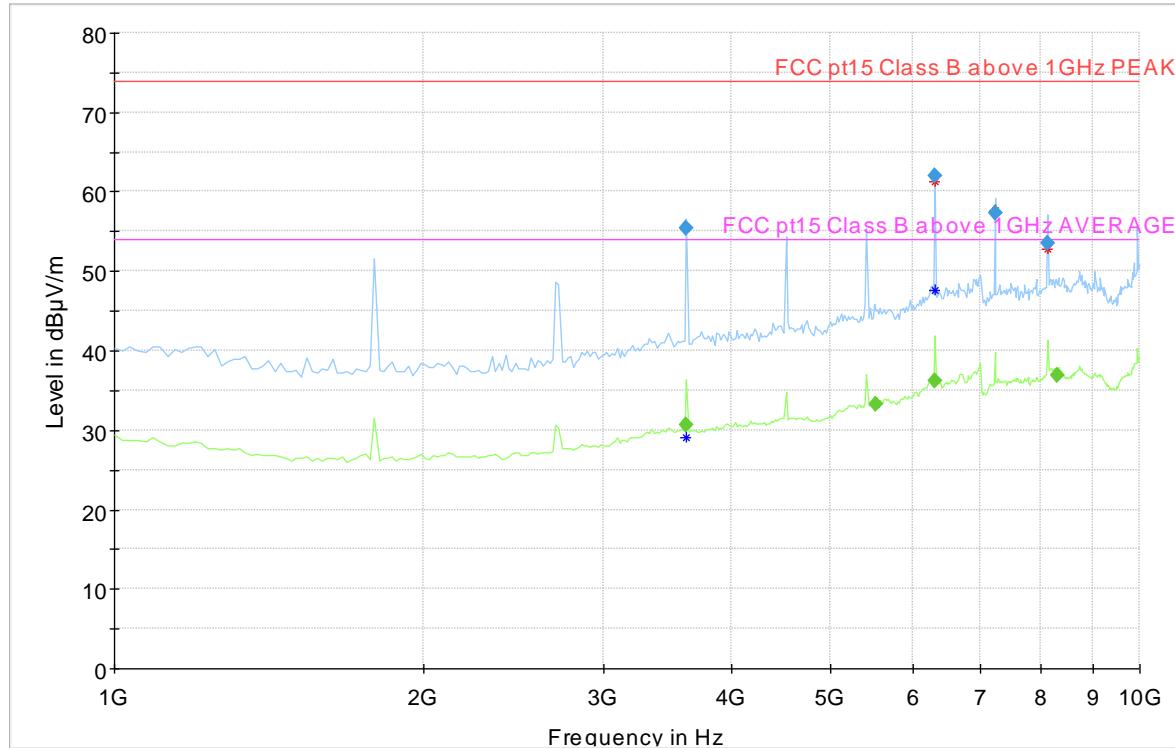


## 4.2 Radiated Emissions 1 to 10 GHz

### 4.2.1 Data; WSN1.5-G9; (Transmitting) Bottom Channel

Frequency	Peak	Average	Limit	Margin	Height	Pol	Azimuth	Corr.	
MHz	dB $\mu$ V/m	dB $\mu$ V/m	dB $\mu$ V/m	dB	cm	H/V	Deg	dB/m	Status
3612.542886	55.46	---	74.00	18.54	274.0	V	270.0	-2.7	Pass
3612.542886	---	30.69	54.00	23.31	169.0	V	41.0	-2.7	Pass
5533.363227	---	33.16	54.00	20.84	400.0	V	187.0	0.7	Pass
6320.683317	---	36.22	54.00	17.78	310.0	V	82.0	1.6	Pass
6321.950050	61.96	---	74.00	12.04	129.0	V	231.0	1.6	Pass
7224.361924	57.23	---	74.00	16.77	217.0	H	93.0	2.7	Pass
8124.964178	53.49	---	74.00	20.51	248.0	H	323.0	3.9	Pass
8308.188126	---	36.93	54.00	17.07	100.0	H	76.0	4.1	Pass

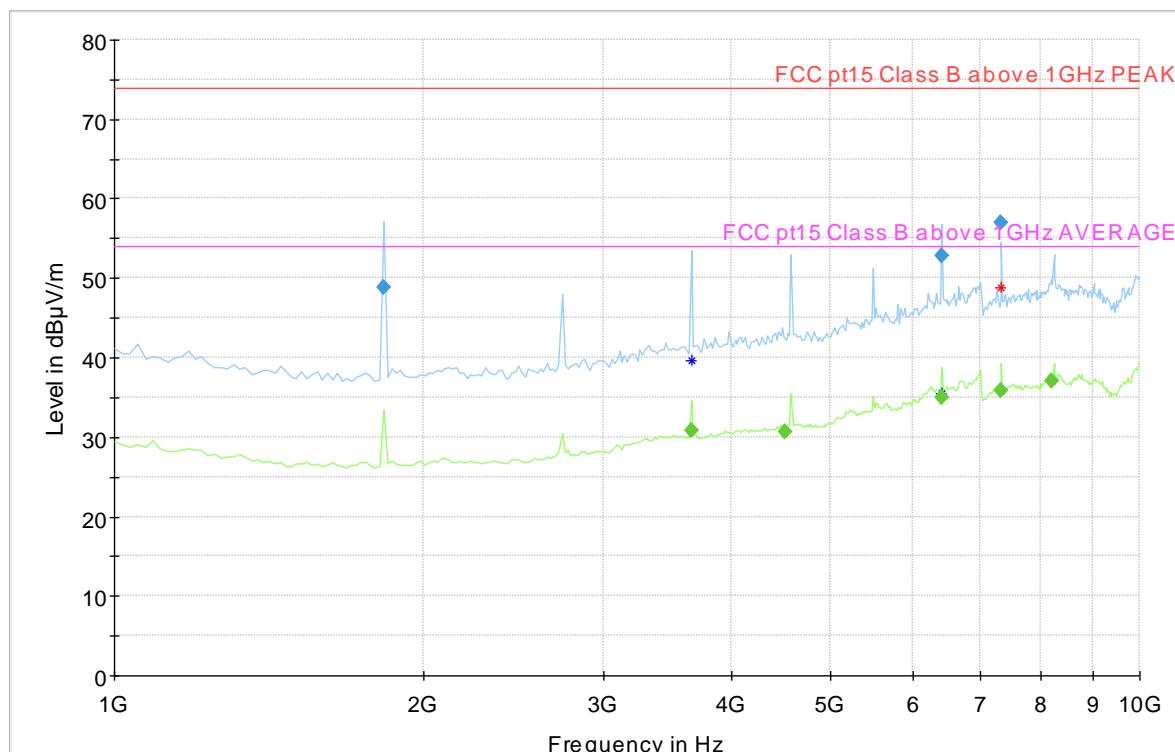
### 4.2.2 Profile; WSN 1.5; (Transmitting) Bottom Channel



#### 4.2.3 Data; WSN1.5-G9; (Transmitting) Middle Channel

Frequency	Peak	Average	Limit	Margin	Height	Pol	Azimuth	Corr.	
MHz	dB $\mu$ V/	dB $\mu$ V/m	dB $\mu$ V/m	dB	cm	H/V	Deg	dB/m	Status
1829.934318	48.78	---	74.00	25.22	337.0	H	128.0	-8.0	Pass
3660.266217	---	30.87	54.00	23.13	149.0	V	182.0	-2.6	Pass
4510.453302	---	30.74	54.00	23.26	287.0	V	221.0	-1.1	Pass
6405.361526	---	34.90	54.00	19.10	218.0	V	347.0	1.7	Pass
6406.646259	52.75	---	74.00	21.25	109.0	V	354.0	1.7	Pass
7318.541494	---	35.85	54.00	18.15	261.0	H	272.0	2.8	Pass
7320.745100	56.99	---	74.00	17.01	156.0	H	355.0	2.8	Pass
8195.525225	---	37.04	54.00	16.96	199.0	V	302.0	3.9	Pass

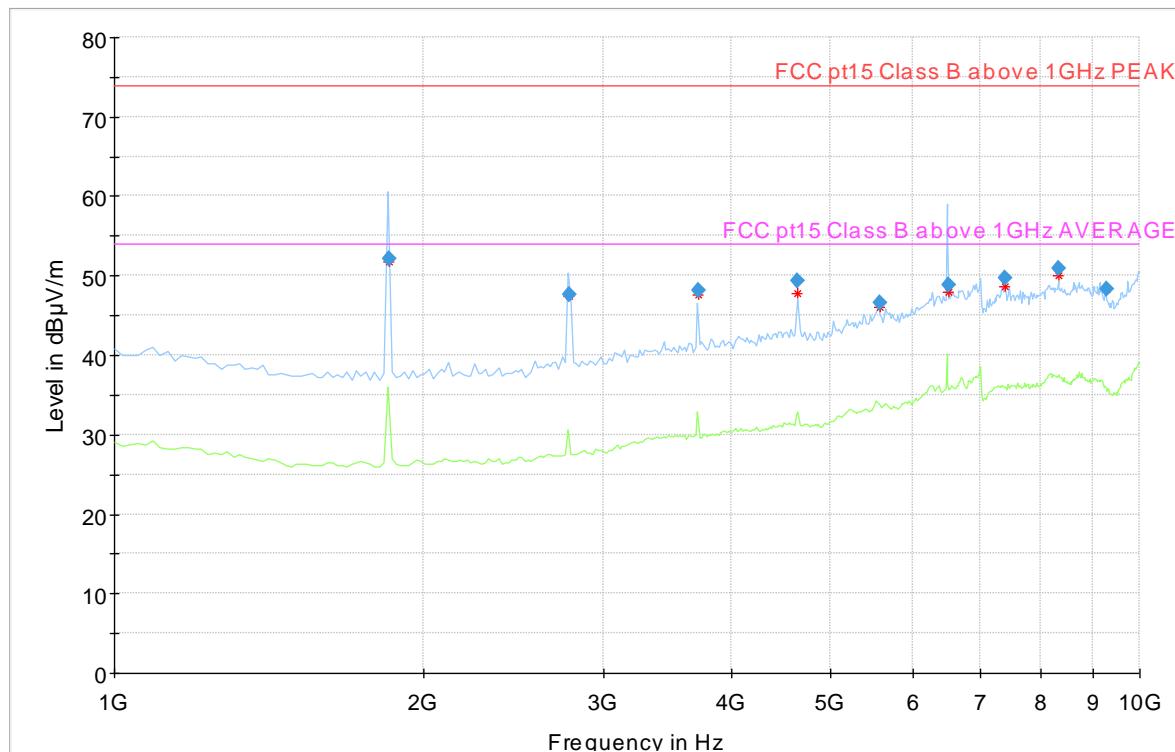
#### 4.2.4 Profile; WSN 1.5; (Transmitting) Middle Channel



#### 4.2.5 Data; WSN1.5-G9; (Transmitting) Top Channel

Frequency	Peak	Average	Limit	Margin	Height	Pol	Azimuth	Corr.	
MHz	dB $\mu$ V/m	dB $\mu$ V/m	dB $\mu$ V/m	dB	cm	H/V	Deg	dB/m	Status
1854.3901	52.18	---	74.00	21.82	292.0	V	93.0	-8.0	Pass
2781.7523	47.54	---	74.00	26.46	128.0	H	153.0	-5.9	Pass
3708.5573	48.11	---	74.00	25.89	169.0	H	169.0	-2.5	Pass
4633.5602	49.44	---	74.00	24.56	169.0	H	0.0	-0.9	Pass
5588.6953	46.50	---	74.00	27.50	141.0	V	128.0	0.7	Pass
6510.5216	48.89	---	74.00	25.11	341.0	V	215.0	1.9	Pass
7379.0686	49.65	---	74.00	24.35	297.0	V	13.0	2.9	Pass
8324.8594	50.95	---	74.00	23.05	367.0	H	271.0	4.1	Pass
9295.1720	48.32	---	74.00	25.68	218.0	H	3.0	3.0	Pass

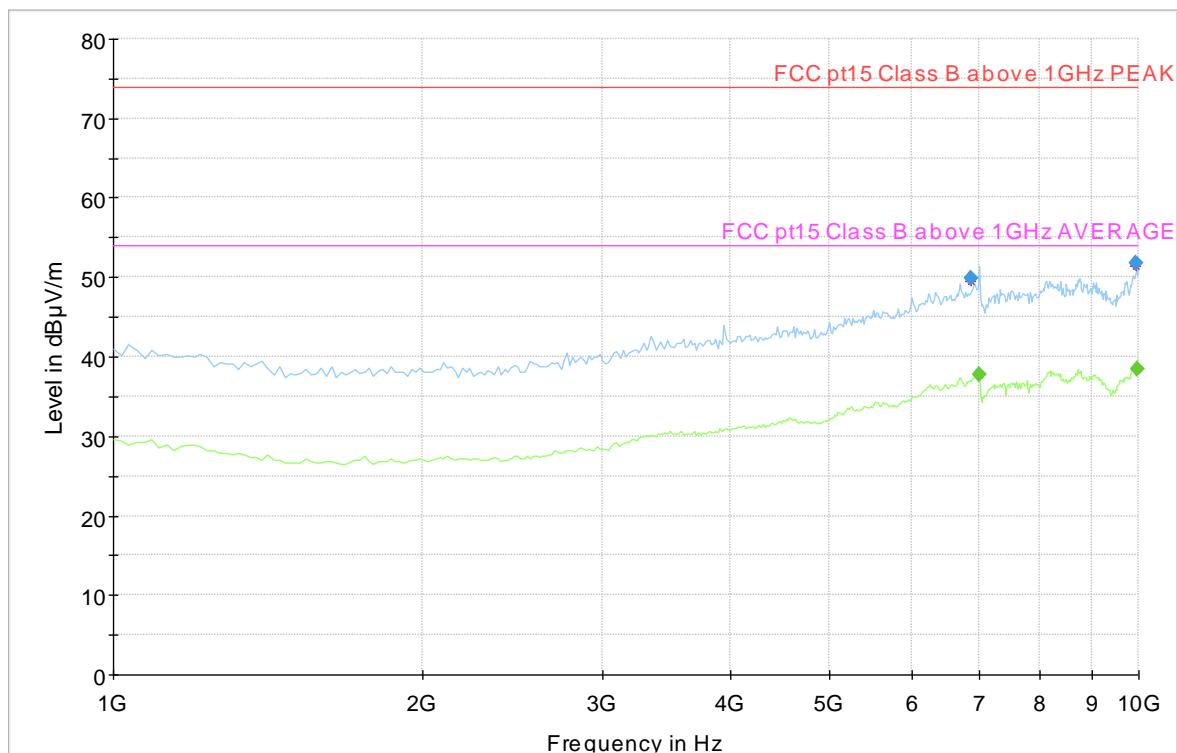
#### 4.2.6 Profile; WSN1.5-G9; (Transmitting) Top Channel



#### 4.2.7 Data; WSN1.5-G9; Idle Mode

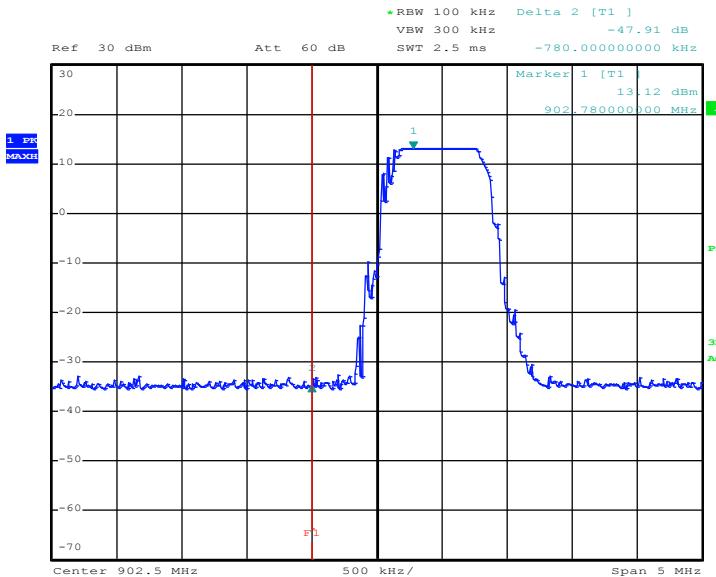
Frequency	Peak	Average	Limit	Margin	Height	Pol	Azimuth	Corr.	
MHz	dB $\mu$ V/m	dB $\mu$ V/m	dB $\mu$ V/m	dB	cm	H/V	Deg	dB/m	Status
6858.089149	49.82	---	74.00	24.18	400.0	V	251.0	2.3	Pass
6991.827043	---	37.67	54.00	16.33	263.0	H	46.0	2.4	Pass
9945.137608	51.71	---	74.00	22.29	223.0	H	280.0	5.4	Pass
9983.376479	---	38.47	54.00	15.53	305.0	V	310.0	5.7	Pass

#### 4.2.8 Profile; WSN1.5-G9 Idle Mode

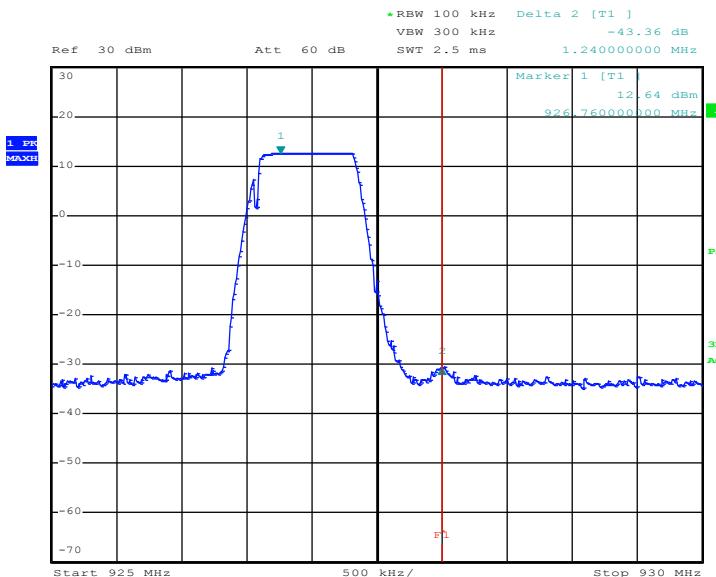


### 4.3 Band Edge 63.10 section 6.10, 15.2479d (Conducted Measurement)

Channel	Carrier power (dBm)	Delta (dB)	Limit (CFR 15.247 (d))	Pass / Fail
Bottom (903MHz)	13.05	-47.91	-20dBc	Pass
Top (927MHz)	12.59	-43.36	-20dBc	Pass



Date: 6.FEB.2020 15:46:38



Date: 6.FEB.2020 15:44:09

## 4.4 Occupied Bandwidth (Conducted Measurement)

Test instrumentation used was as follows:

#ID	CP	Manufacturer	Type	Serial No	Description	Calibration due date
456	1	Rohde & Schwarz	ESCI7	1144573407	EMI Test Receiver	21/08/2020

### 4.4.1 Test method

#### 4.4.1.1 Occupied Bandwidth (IC)

RSS-GEN Section 6.6

The output from the EUT was fed into the input of the ESCI7 spectrum analyser/receiver. The bandwidth of the transmitter was measured with an ESCI7 analyser set to 99% Occupied Bandwidth with a peak detector on max hold. The resolution bandwidth, span and video bandwidth are indicated on the occupied bandwidth plot (modulated) included with this report.

#### 4.4.1.2 Occupied Bandwidth (FCC)

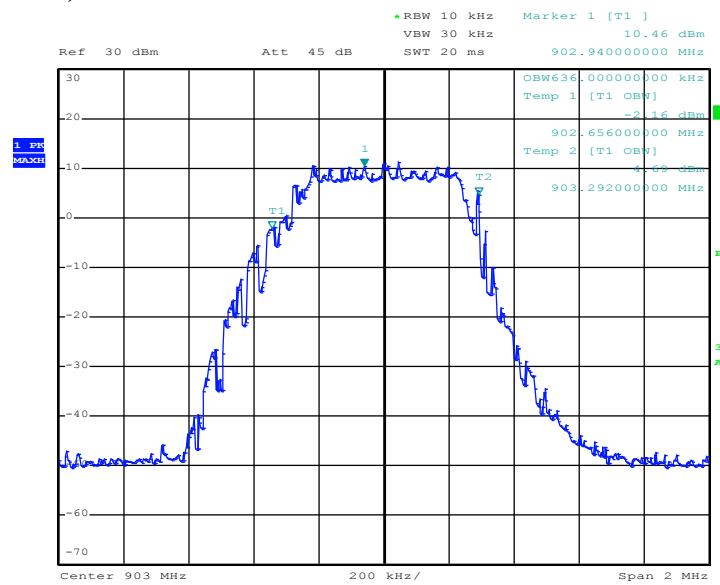
FCC 15.215 (c) / Ansi C63.10 Section 6.9

The output from the EUT was fed into the input of the ESCI7 spectrum analyser/receiver. The bandwidth of the transmitter was measured 20dB down either side of the peak. The ESCI7 analyser was set to peak detector on max hold. The resolution bandwidth, span and video bandwidth are indicated on the occupied bandwidth plot (modulated) included with this report.

## 4.4.2 Test Plots

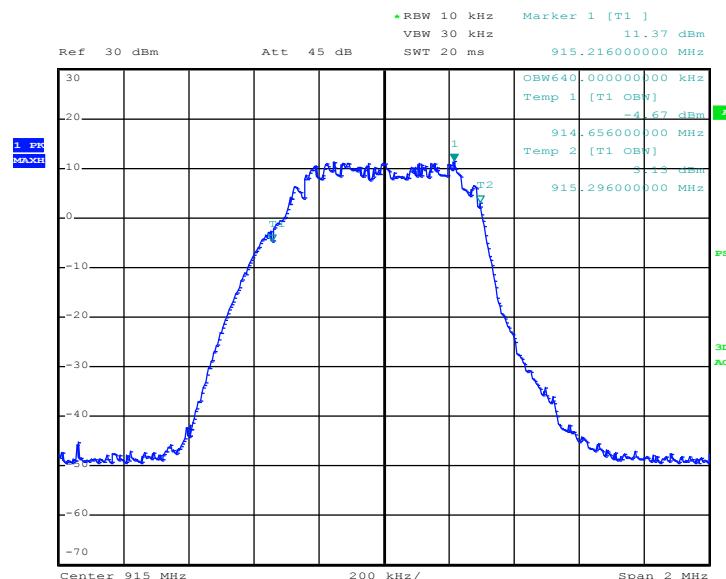
### 4.4.2.1 99% Bandwidth Plots (IC)

(903MHz - Bottom) 99% bandwidth measured as 636kHz



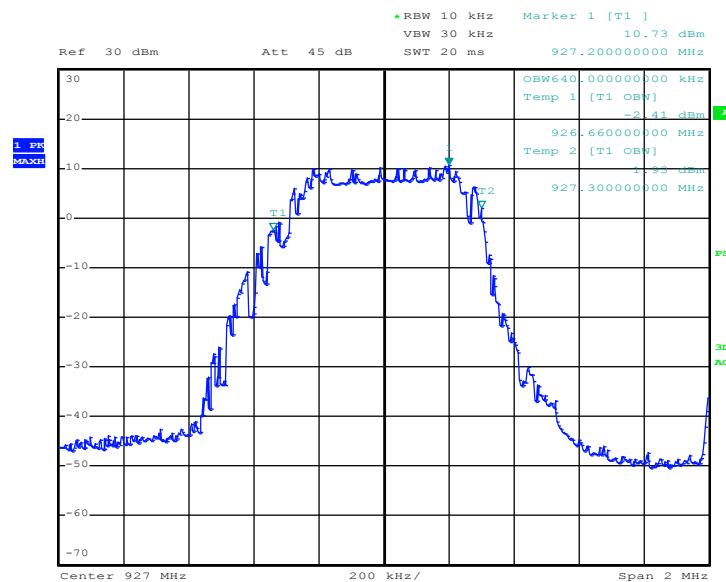
Date: 6.FEB.2020 14:49:16

(915MHz - Middle) 99% bandwidth measured as 640kHz



Date: 6.FEB.2020 14:40:46

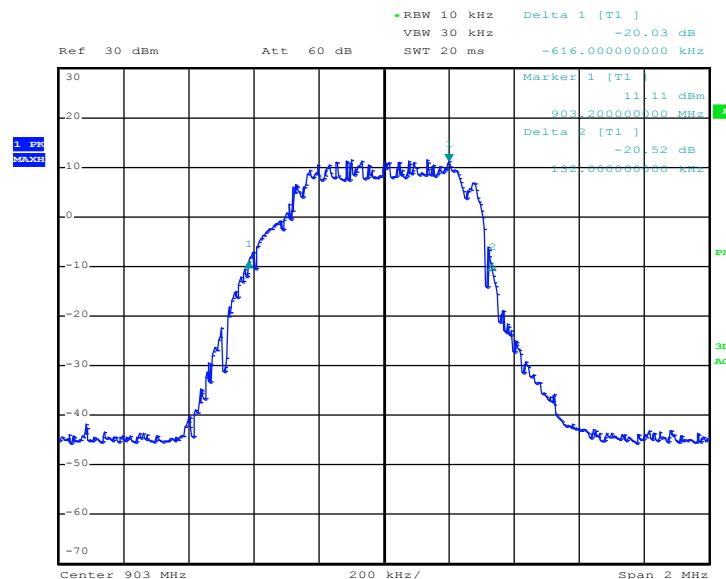
(927MHz - Top) 99% bandwidth measured as 184kHz



Date: 6.FEB.2020 14:50:19

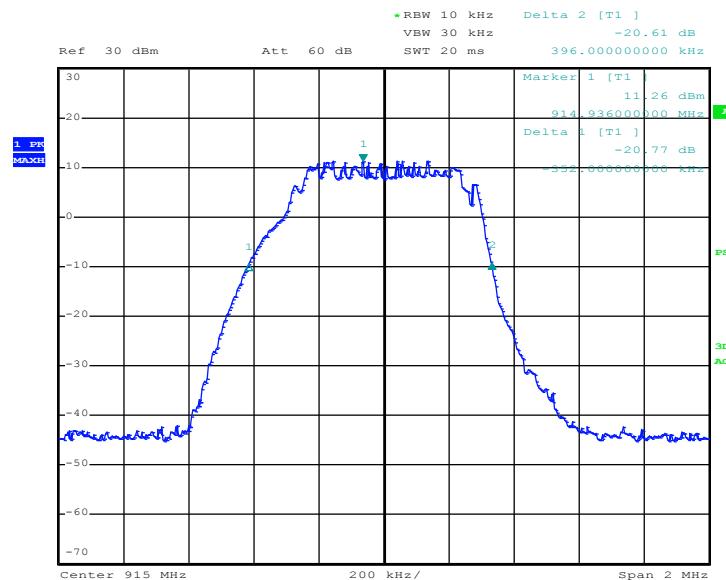
#### 4.4.3 20dB Bandwidth Plots (FCC) 63.10 section 6.9

(903MHz - Bottom) 20dB bandwidth measured as 748kHz



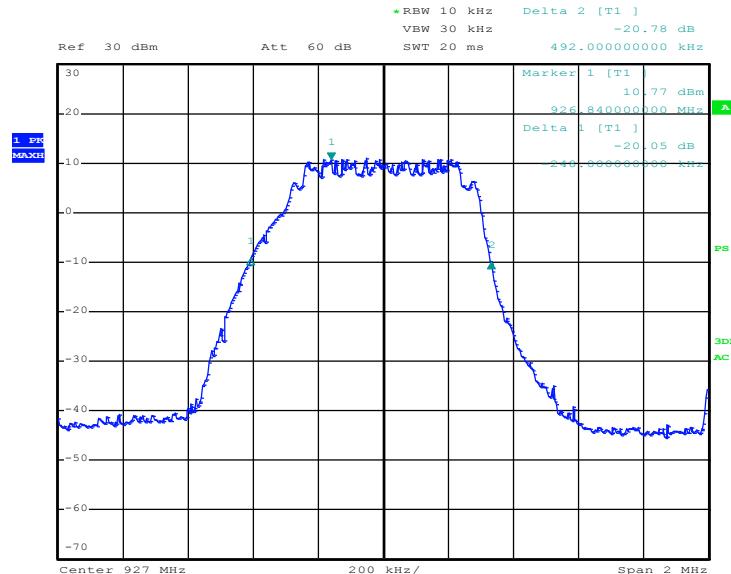
Date: 6.FEB.2020 14:46:13

(915MHz - Middle) 20dB bandwidth measured as 748kHz



Date: 6.FEB.2020 14:44:11

(927MHz -Top) 20dB bandwidth measured as 740kHz

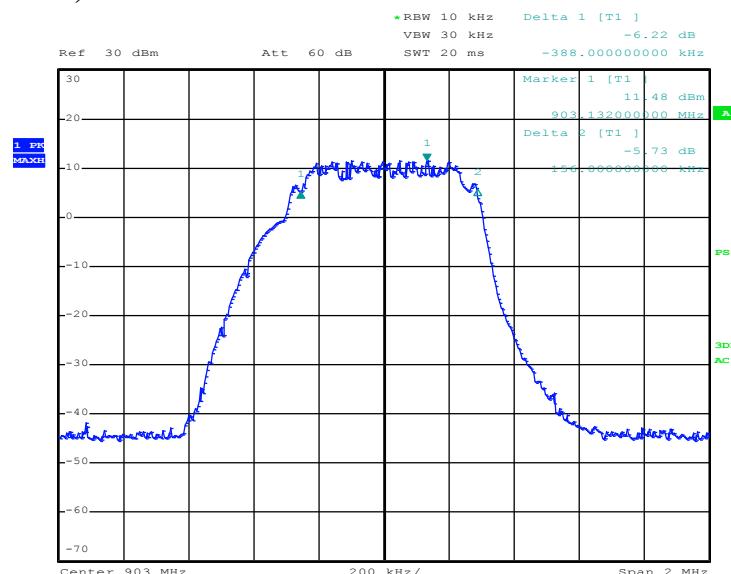


Date: 6.FEB.2020 14:54:05

#### 4.4.4 6dB Bandwidth Plots (FCC) 15.247 a2

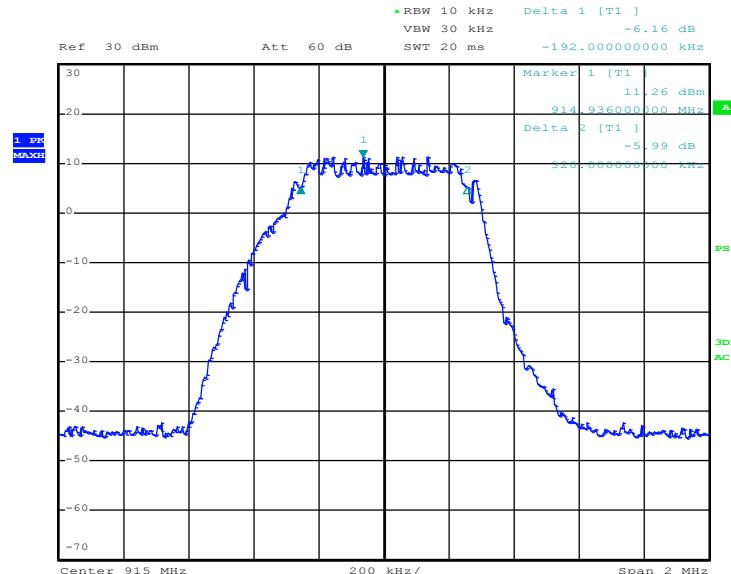
Channel	Measured	Limit	Pass / Fail
Bottom (903MHz)	544kHz	>500kHz	Pass
Middle (915MHz)	512kHz	>500kHz	Pass
Top (927MHz)	544kHz	>500kHz	Pass

(903MHz - Bottom) 6dB bandwidth measured as 544kHz



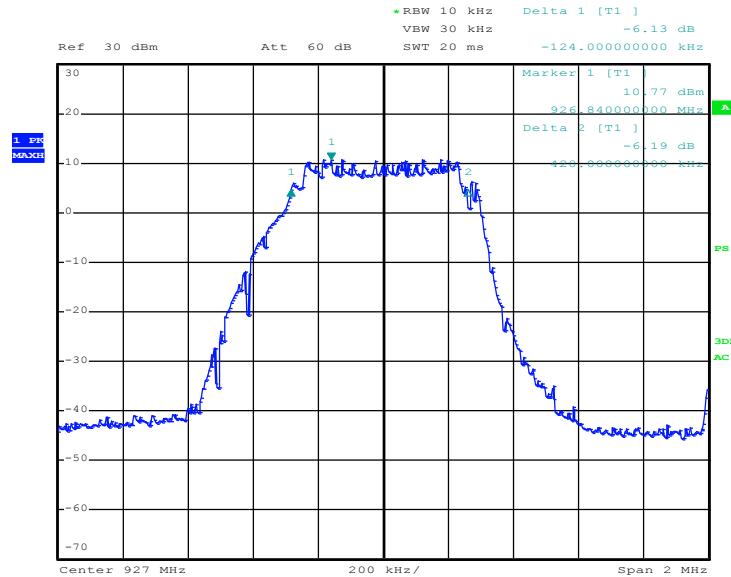
Date: 6.FEB.2020 14:48:15

(915MHz - Middle) 6dB bandwidth measured as 512kHz



Date: 6.FEB.2020 14:43:20

(927MHz - Top) 6dB bandwidth measured as 544kHz



Date: 6.FEB.2020 14:52:43

## 4.5 Power Spectral density 15.247 e (Conducted Measurement)

Test instrumentation used was as follows:

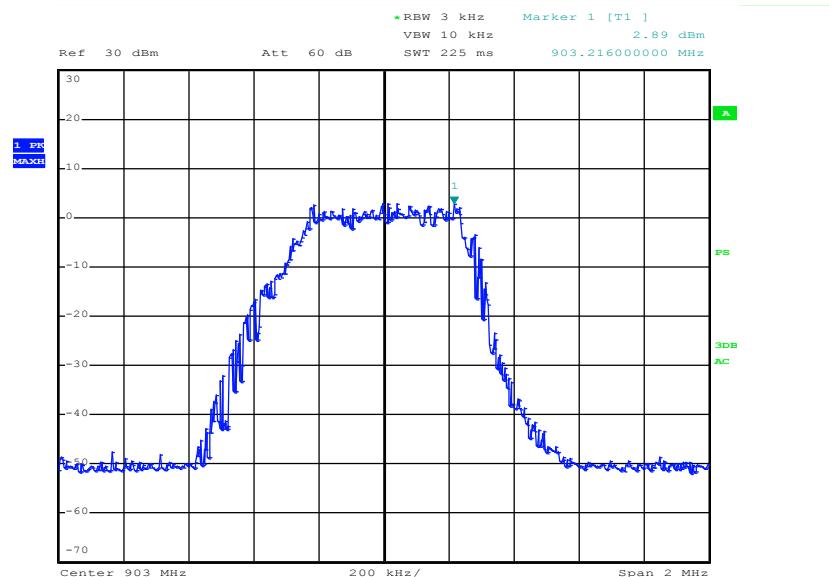
#ID	CP	Manufacturer	Type	Serial No	Description	Calibration due date
456	1	Rohde & Schwarz	ESCI7	1144573407	EMI Test Receiver	21/08/2020

### 4.5.1 Test results

Channel	Measured (3kHz B/W)	PSD Limit	Pass / Fail
Bottom (903MHz)	2.89dBm	8dBm	Pass
Middle (915MHz)	3.42dBm	8dBm	Pass
Top (927MHz)	2.30dBm	8dBm	Pass

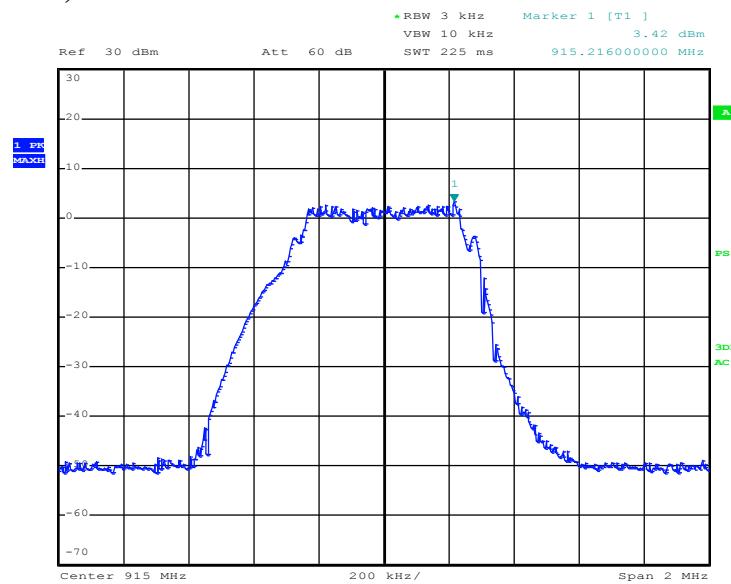
### 4.5.2 Test plots

(903MHz - Bottom) 2.89dBm



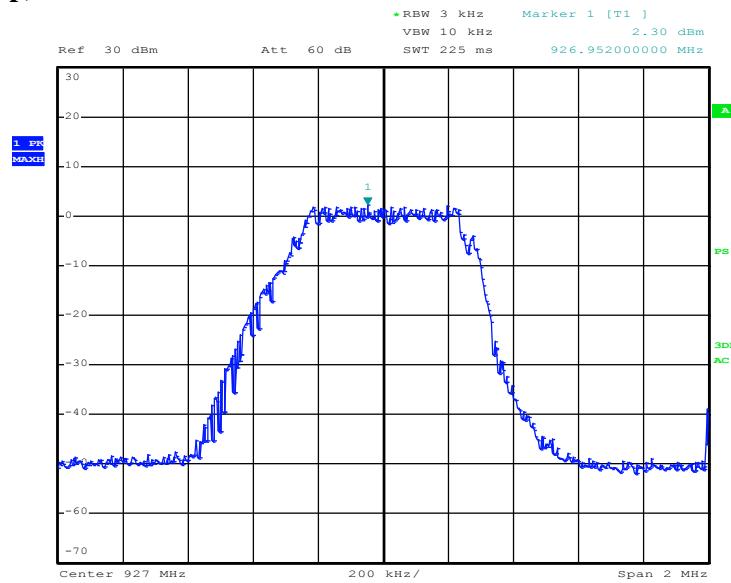
Date: 6.FEB.2020 15:22:38

**(915MHz - Middle) 3.42dBm**



Date: 6.FEB.2020 15:20:59

**(927MHz - Top) 2.30dBm**



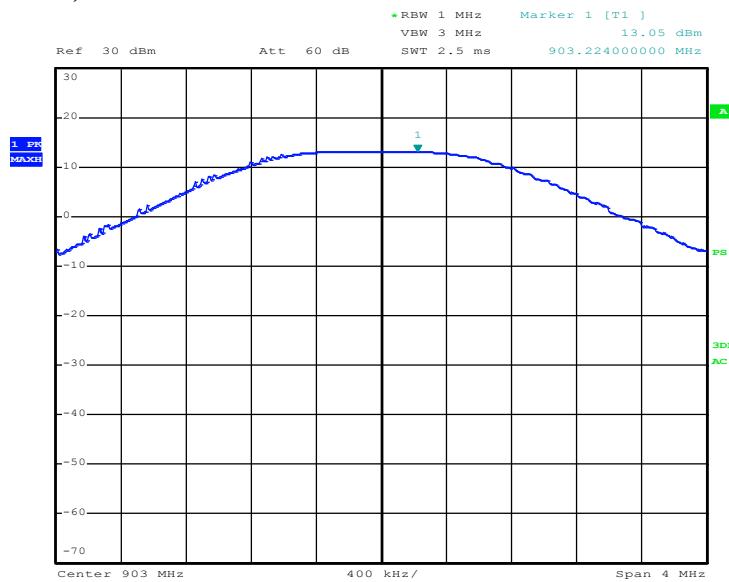
Date: 6.FEB.2020 15:27:18

## 4.6 RF Carrier Power 15.247 b3 (Conducted Measurement)

Channel	Measured	Limit	Pass / Fail
Bottom (903MHz)	13.05dBm	30dBm (1Watt)	Pass
Middle (915MHz)	12.83dBm	30dBm (1Watt)	Pass
Top (927MHz)	12.59dBm	30dBm (1Watt)	Pass

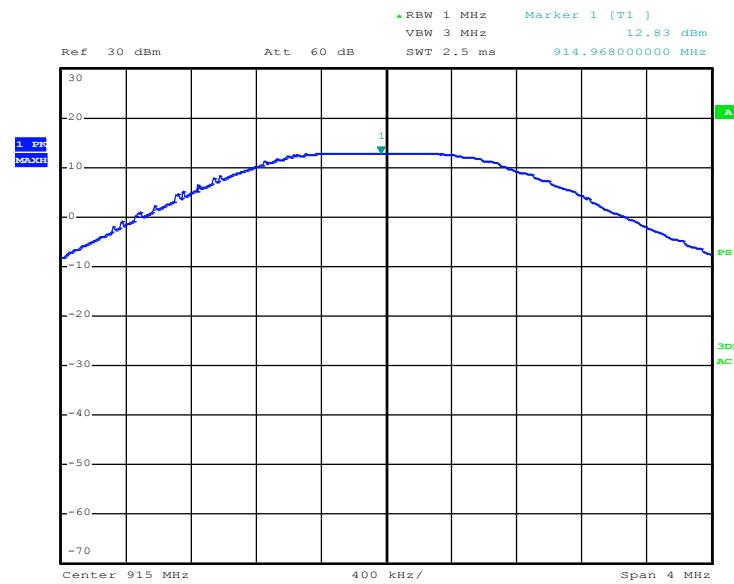
### 4.6.1 Test plots

(903MHz - Bottom) 13.05dBm



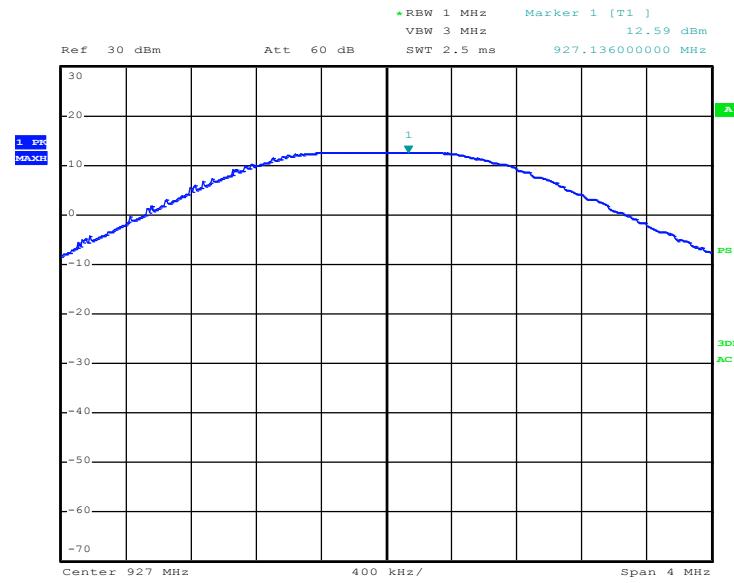
Date: 6.FEB.2020 15:06:18

(915MHz - Middle) 12.83dBm



Date: 6.FEB.2020 15:07:07

**(927MHz - Top) 12.59dBm**

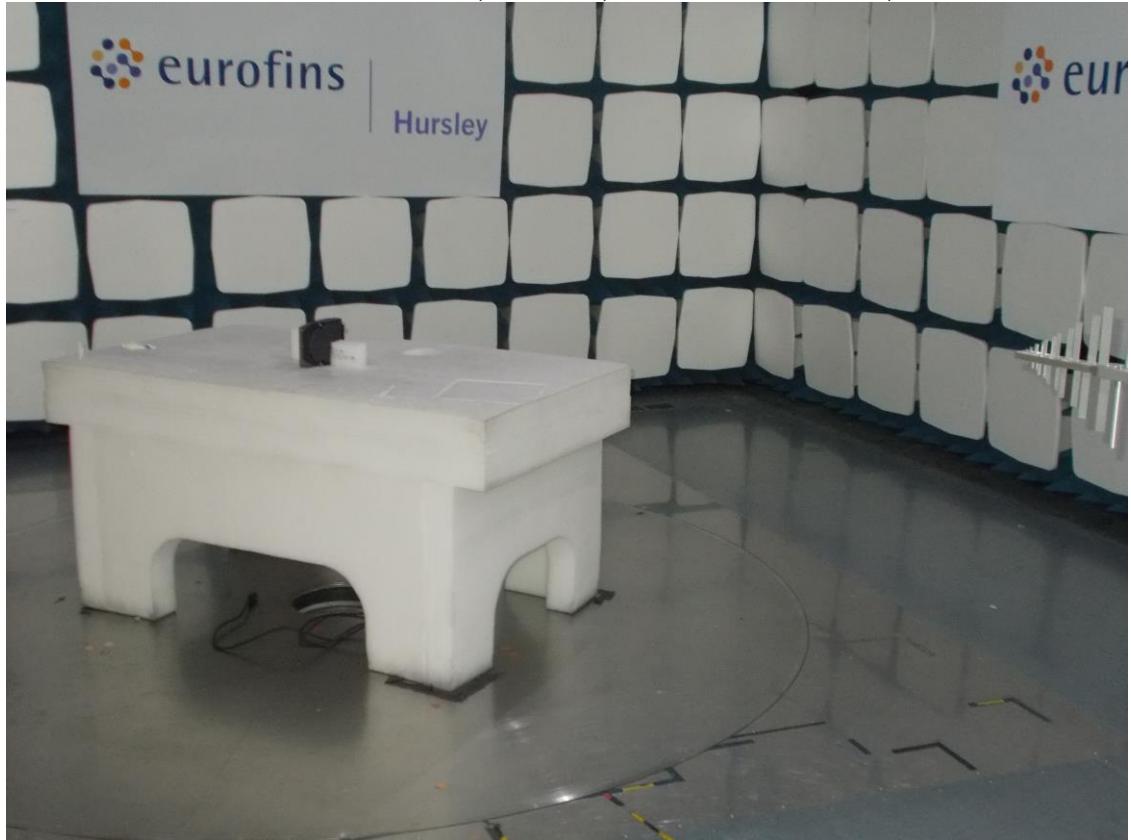


Date: 6.FEB.2020 15:04:11

## 5.0 PHOTO LOG

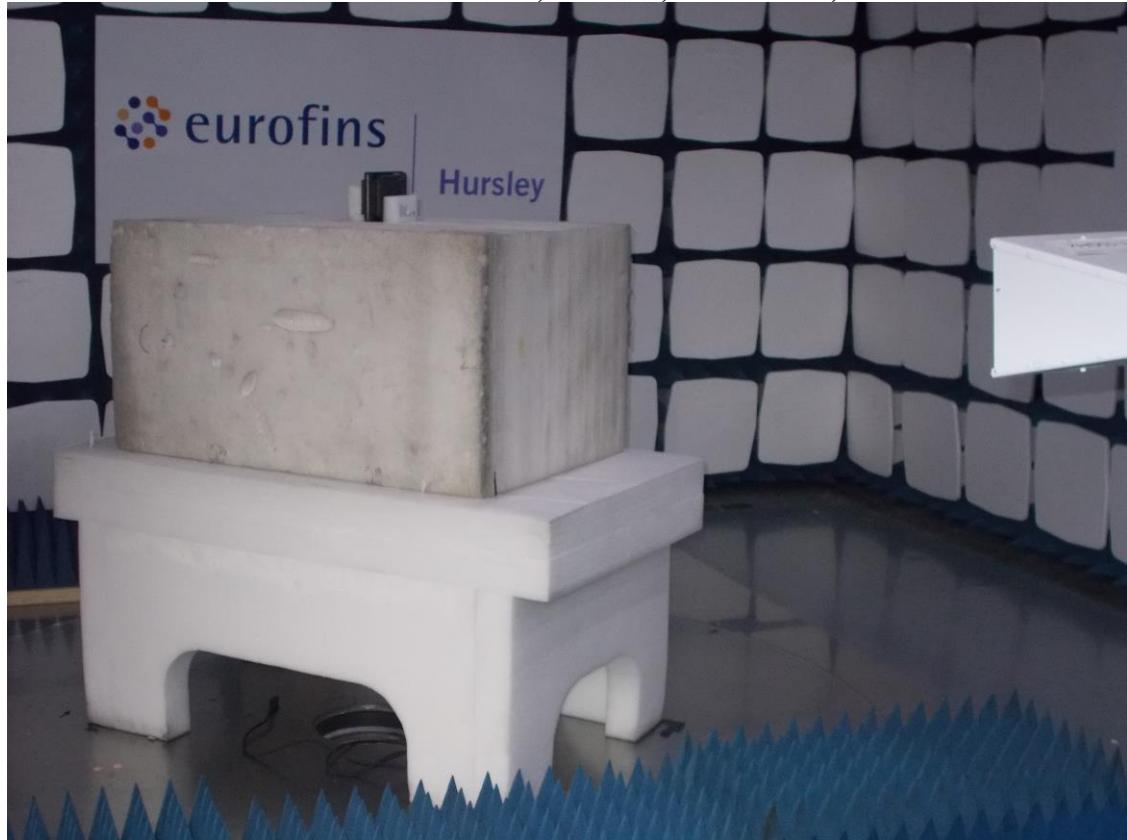
### Emissions:

**Radiated emissions, Pre-scan, 30 MHz to 1000 MHz;**



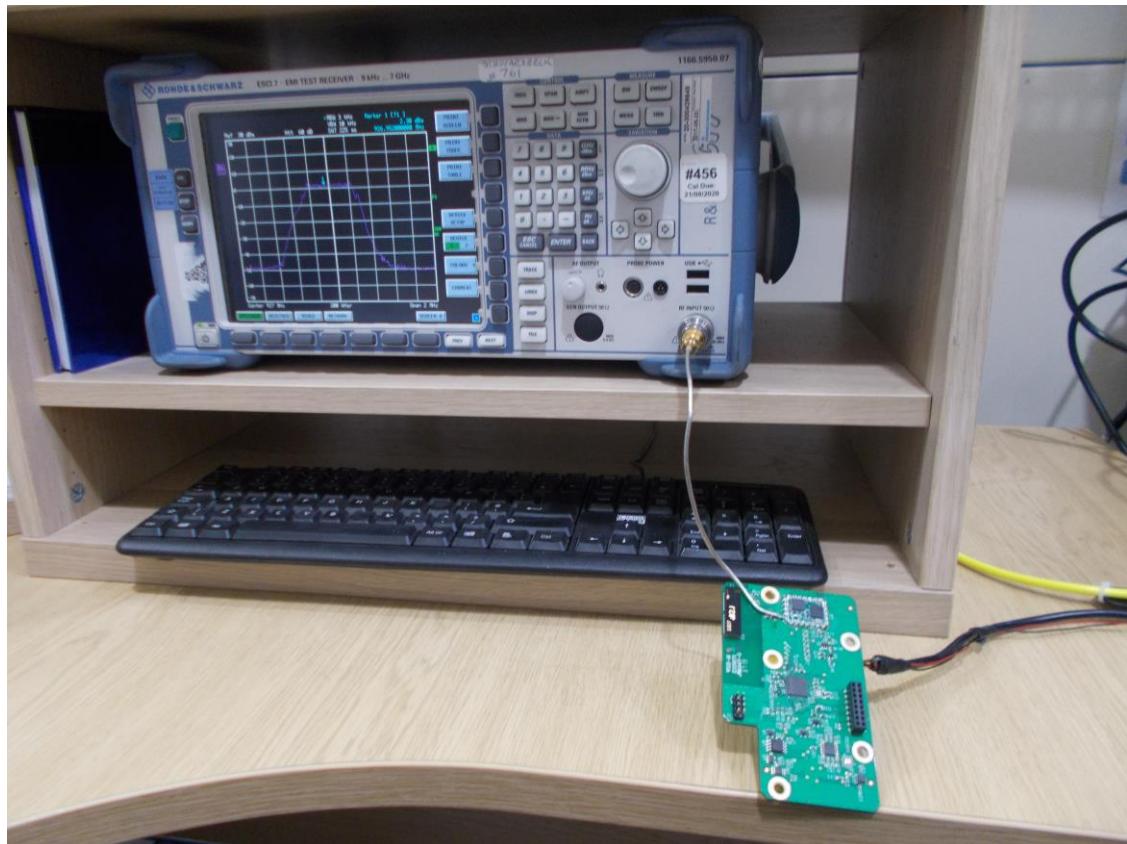
**Photo Log (continued)**

**Radiated emissions, Pre-scan, > 1000 MHz;**



**Photo Log (continued)**

**Conducted Measurements**



## 6.0 MEASUREMENT UNCERTAINTIES

### Emissions tests

For all emissions tests, measurement uncertainties have been calculated in line with the requirements of CISPR 16-4-2 to give a confidence level of greater than 95%. In all cases the laboratories calculated uncertainty values (known as  $U_{lab}$ ) are equal to or are less than the expected uncertainty values contained in CISPR 16-4-2 (known as  $U_{cisp}$ ). Below is a list of the laboratories calculated measurement uncertainties:

#### *Conducted emissions:*

Via AMN/LISN:	$\pm 3.27$ dB (9 kHz – 150 kHz), $\pm 3.28$ dB (150 kHz – 30 MHz)
Via AAN/ISN:	$\pm 4.99$ dB (150 kHz – 30 MHz)
Via CVP:	$\pm 3.47$ dB (150 kHz – 30 MHz)
Via CP:	$\pm 2.69$ dB (150 kHz – 30 MHz)
Via $100\ \Omega$ :	$\pm 2.69$ dB (150 kHz – 30 MHz)
Clicks:	$\pm 3.34$ dB (150 kHz – 30 MHz)
Harmonics:	$\pm 5.82$ % (100 Hz – 2 kHz)
Flicker:	$\pm 3.78$ % (worst case for all parameters)

#### *Radiated emissions:*

H-Field:	$\pm 2.73$ dB (9 kHz – 3 MHz), $\pm 2.88$ dB (3 MHz – 30 MHz)
D = 3.0 m (Horizontal):	$\pm 3.95$ dB (30 MHz – 200 MHz), $\pm 3.78$ dB (200 MHz – 1 GHz)
D = 3.0 m (Vertical):	$\pm 3.74$ dB (30 MHz – 200 MHz), $\pm 5.06$ dB (200 MHz – 1 GHz)
D = 3.0 m:	$\pm 4.50$ dB (1 GHz – 6 GHz), $\pm 4.04$ dB (6 GHz – 18 GHz), $\pm 4.27$ dB (18 GHz – 40 GHz)
D = 10.0 m (Horizontal):	$\pm 4.53$ dB (30 MHz – 200 MHz), $\pm 4.61$ dB (200 MHz – 1 GHz)
D = 10.0 m (Vertical):	$\pm 4.41$ dB (30 MHz – 200 MHz), $\pm 4.77$ dB (200 MHz – 1 GHz)

### Immunity tests

*For IEC 61000-4-2, IEC 61000-4-4, IEC 61000-4-5, IEC 61000-4-8, IEC 61000-4-9, IEC 61000-4-11 tests, the following applies:*

Measurement uncertainty has been calculated or calibrated for the various required parameters to provide a confidence level of 95% ( $k=2$ ). These parameters have been compared to the basic standard tolerance requirements for each of the various parameters.

In all cases the calculated or calibrated uncertainty meets the basic standard requirements.

*For IEC 61000-4-3, IEC 61000-4-6 tests, the following applies:*

Measurement uncertainty has been calculated to provide a confidence level of 95%, or  $k=2$ , but this has not been applied to the applied test level, therefore the applied test level has an uncertainty of  $\pm 50\%$ . This is in accordance with Cenelec and other international guidance.

In the case of Maritime equipment tested to IEC 60945, there is a specific requirement that the applied test level be increased by the calculated measurement uncertainty. This is done by applying a coverage factor of  $k = 1.64$ , which provides a 95% confidence that the applied test level has been achieved.

*End of Document*