Report on the Radio Testing

For

Harvard Engineering plc.

on

WMVRB-915USA

Report no. TRA-025316-47-02A

24th May 2016

Report Number: TRA-025316-47-02A
Issue: A

REPORT ON THE RADIO TESTING OF A
Harvard Engineering plc.
WMVRB-915USA
WITH RESPECT TO SPECIFICATION
FCC 47CFR 15.247 & IC RSS-247

TEST DATE: 04-05-2016 to 09-05-2016

Written by: D Winstanley

D Winstanley
Radio Senior Test Engineer

Approved by: John Charters

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John Charters
Department Manager- Radio

Date: 24th May 2016

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

1 Revision Record

Issue Number	*Issue Date*	*Revision History*
A	24th May 2016	Original

2 Summary

TEST REPORT NUMBER:	TRA-025316-47-02A
WORKS ORDER NUMBER	TRA-025316-04
PURPOSE OF TEST:	USA: Testing of radio frequency equipment per the relevant authorization procedure of chapter 47 of CFR (code of federal regulations) Part 2, subpart J. Canada: Testing of radio apparatus for TAC (technical acceptance certificate) per subsections 4(2) of the Radio communication Act and 21(1) of the Radio communication Regulations.
TEST SPECIFICATION(S):	47CFR15.247 & RSS-247
EQUIPMENT UNDER TEST (EUT):	WMVRB-915USA
FCC IDENTIFIER:	2AGAAWMVRB-915
IC IDENTIFIER:	11286A-WMVRB915
EUT SERIAL NUMBER:	not applicable
MANUFACTURER/AGENT:	Harvard Engineering plc.
ADDRESS:	Tyler Close Normanton Wakefield West Yorkshire WF6 1RL United Kingdom
CLIENT CONTACT:	Trever Parrett ☎ 0113 383 1059 ✉ treverparrett@harvardeng.com
ORDER NUMBER:	Not applicable
TEST DATE:	04-05-2016 to 09-05-2016
TESTED BY:	D Winstanley Element

2.1 Test Summary

Test Method and Description	*Requirement Clause*		*Applicable to this equipment*	*Result / Note*
	RSS	*47CFR15*		
Radiated spurious emissions (restricted bands of operation and cabinet radiation) Receiver emissions	Gen, 8.10	15.205 15.109	☒	*Pass*
AC power line conducted emissions	Gen, 8.8	15.207	☒	*Pass*
Carrier frequency separation	247, 5.1 (2)	15.247(a)(1)	☒	*Pass*
Number of hopping channels	247, 5.1 (3), (4) and (5)	15.247(a)(1) (i), (ii) and (iii)	☒	*Pass*
Average time of occupancy	247, 5.1 (3), (4) and (5)	15.247(a)(1) (i), (ii) and (iii)	☒	*Pass*
Maximum peak conducted output power	247, 5.4 (1), (2) and (3)	15.247 (a)(1), (b)(1) and (b)(2)	☒	*Pass*
20dB emission bandwidth	247, 5.1 (1)	15.247(a)(1) (i) and (ii)	☒	*Pass*
Out-of-band emissions	247, 5.5	15.247(d)	☒	*Pass*

Notes:

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

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

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

3 Contents

4 Introduction

This report TRA-025316-47-02A presents the results of the Radio testing on a Harvard Engineering plc., WMVRB-915USA to specification 47CFR15 Radio Frequency Devices and RSS-247 Licence-exempt Radio Apparatus (All Frequency Bands): Category I Equipment.

The testing was carried out for Harvard Engineering plc. by Element, at the address(es) detailed below.

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

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

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

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

Throughout this report EUT denotes equipment under test.

FCC Site Listing:
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.
- 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.
- Industry Canada RSS-247, Issue 1, May 2015 – Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and Licence-Exempt Local Area Network (LE-LAN) Devices
- Industry Canada RSS-Gen, Issue 4, November 2014 – General Requirements for Compliance of Radio Apparatus.

5.2 Deviations from Test Standards

There were no deviations from the test standard.

6 Glossary of Terms

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

7 Equipment Under Test

7.1 EUT Identification

- Name: WMVRB-915USA
- Serial Number: not applicable
- Model Number: WMUN3-10A-UNI-915USA-M4-I /E/N7
- Software Revision: 53
- Build Level / Revision Number: Not Applicable

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.

Not Applicable – No support/monitoring equipment required.

7.3 EUT Mode of Operation

7.3.1 Transmission

The mode of operation for Tx tests was as follows: the module was transmitting continuously on 905.2 MHz, 910.5 MHz and 915.91MHz. Normal transmitting mode with the normal hopping operation.

7.3.2 Reception

The mode of operation for Rx tests was as follows: the module was place on a testing board receiving continuously on 905.2 MHz, 910.5 MHz and 915.91MHz.

7.4 EUT Radio Parameters

7.4.1 General

Frequency of operation:	905.2 MHz to 915.91 MHz
Modulation type(s):	FHSS
Occupied channel bandwidth(s):	16.4 kHz
Channel spacing:	170 kHz
ITU emission designator(s):	16K4FID
Declared output power(s):	17 dBm
Warning against use of alternative antennas in user manual (yes/no):	No
Nominal Supply Voltage:	5 V dc
Location of notice for license exempt use:	Label / user manual / both.
Duty cycle:	0.5%

7.4.2 Product specific declarations

Multiple antenna configuration(s), e.g. MIMO:	No
Fixed pt-pt operations (yes/no):	No
Installation manual advice on pt-pt operational restrictions (yes/no):	No
Fixed pt-mpt operations (yes/no):	No
Simultaneous tx (yes/no):	No

7.5 EUT Description

The EUT is a module transmiting in the 902 MHz to 928 MHz band.

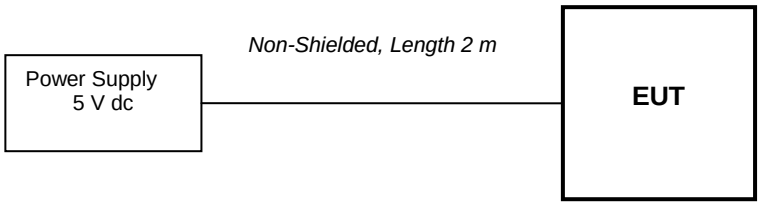
8 Modifications

No modifications were performed during this assessment.

9 EUT Test Setup

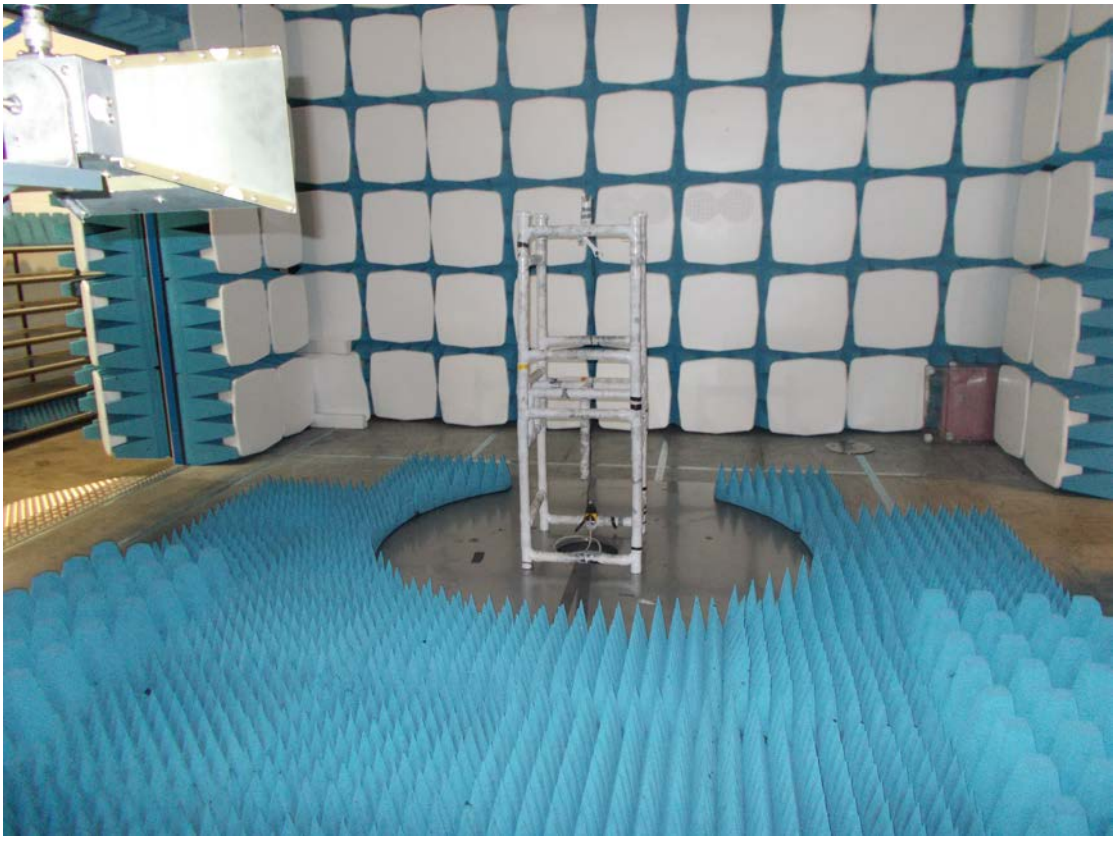
9.1 Block Diagram

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



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 approx. 5 V dc from the adaptor/ power supply.

10.2 Varying Test Conditions

There are no specific frequency stability requirements for the type of device. The results contained in this report demonstrate that the occupied bandwidth is contained within the authorised band and the manufacturer has declared sufficient frequency stability (refer to section 7.4).

Variation of supply voltage is required to ensure stability of the declared output power. During carrier power testing the following variations were made:

	Category	***Nominal***	***Variation***
☐	Mains	110 V ac +/-2 %	85 % and 115 %
☒	DC Via mains PSU	+5vdc	85 % and 115 %
☐	Battery	New battery	N/A

11 Radiated emissions

11.1 Definitions

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

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

11.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Radio Chamber
Test Standard and Clause:	ANSI C63.10-2013, Clause 6.5 and 6.6
EUT Channels / Frequencies Measured:	905.2 MHz / 910.47 MHz / 915.91 MHz
Deviations From Standard:	None
Measurement BW:	30 MHz to 1 GHz: 120 kHz Above 1 GHz: 1 MHz
Measurement Detector:	Up to 1 GHz: quasi-peak Above 1 GHz: RMS average and Peak

Environmental Conditions (Normal Environment)

Temperature: 24 °C	+15 ºC to +35 ºC (as declared)
Humidity: 27 % RH	20 % RH to 75 % RH (as declared)
Supply: 5 V dc	5 V dc ±10 % (as declared)

11.3 Test Limit

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

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

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

11.4 Test Method

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

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

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

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

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

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

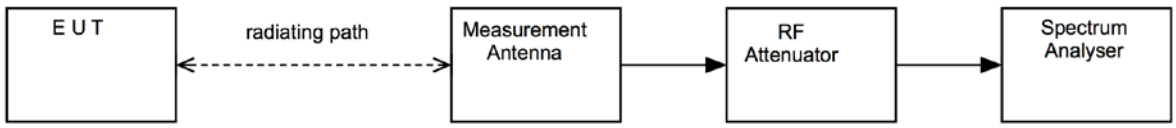
$$FS = PR + CL + AF – PA + DC – CF$$

Where,

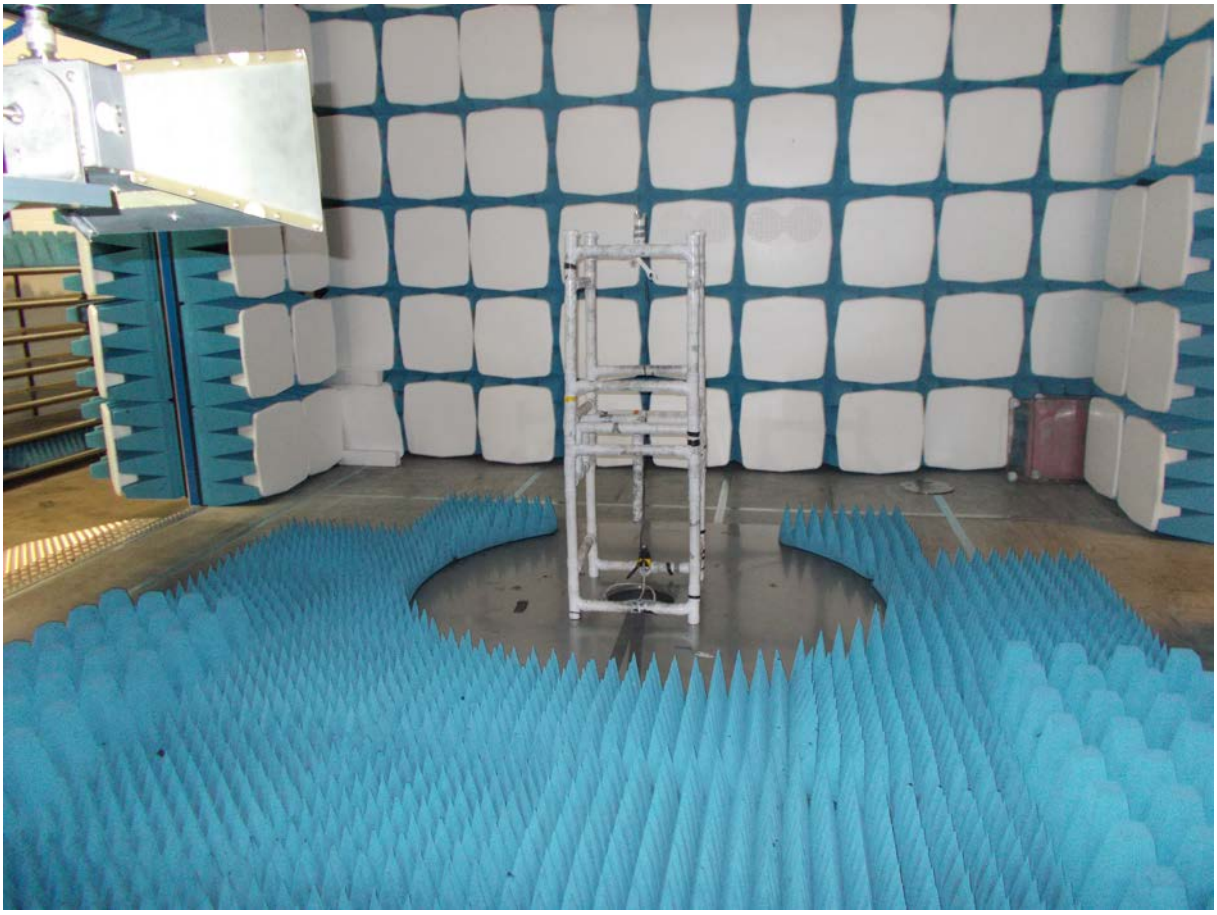
PR is the power recorded on the receiver / spectrum analyzer in dBµV;
CL is the cable loss in dB;
AF is the test antenna factor in dB/m;
PA is the pre-amplifier gain in dB (where used);
DC is the duty correction factor in dB (where used, e.g. harmonics of pulsed fundamental);
CF is the distance factor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

Type of Equipment	*Maker/Supplier*	*Model Number*	*Element Number*	*Calibration Due Date*	*Calibration Interval*
Bilog	Chase	CBL611/A	UH191	26/02/2017	24
ESVS10	R&S	ESVS10	L352	07/08/2016	12
Spectrum analyser	R&S	FSU50	U544	16/03/2017	12
Horn Antenna	EMCO	3115	TRL139	25/09/2017	24
Pre-Amplifier	Agilent	8449B	TRL572	16/02/2017	12

11.7 Test Results

Integral antenna bottom channel plots

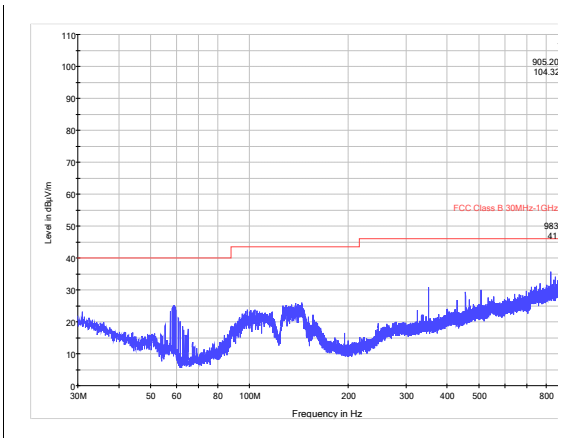


Figure 1 – Radiated Emissions Plot (30 MHz to 1 GHz).

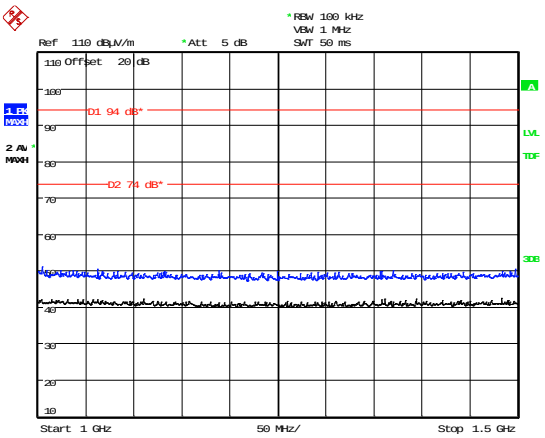


Figure 2 – Radiated Emissions Plot (1 GHz to 1.5 GHz).

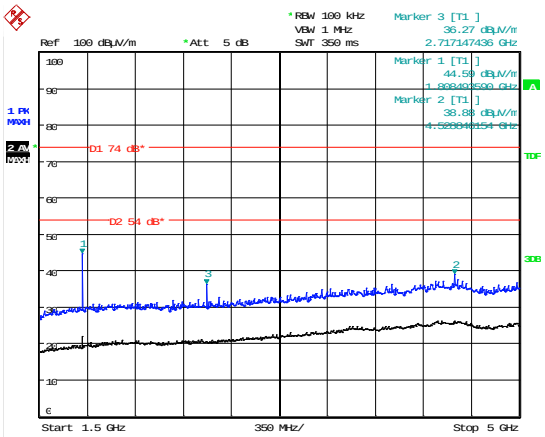


Figure 3 – Radiated Emissions Plot (1.5 GHz to 5 GHz).

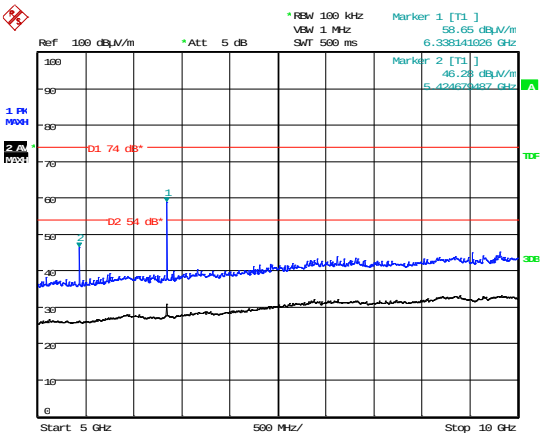


Figure 4 – Radiated Emissions Plot (5 GHz to 10 GHz).

High Power; Channel: 905.2 MHz										
Detector	***Freq. (MHz)***	***Meas'd Emission (dBµV)***	***Cable Loss (dB)***	***Antenna Factor (dB/m)***	***Pre-amp Gain (dB)***	***Duty Cycle Corr'n (dB)***	***Distance Extrap'n Factor (dB)***	***Field Strength (dBµV/m)***	***Field Strength (µV/m)***	***Limit (µV/m)***
Pk	2715.57	52.54	3.60	28.90	36.06	0.00	0.00	48.98	281.19	5012
Av	2715.57	46.47	3.60	28.90	36.06	0.00	0.00	42.91	139.80	500
Pk	4528.85	49.87	5.30	32.40	35.74	0.00	0.00	51.83	390.39	5012
Av	4528.85	38.38	5.30	32.40	35.74	0.00	0.00	40.34	103.99	500
Pk	5431.24	51.53	6.20	34.40	35.90	0.00	0.00	56.23	647.89	5012
Av	5431.24	45.94	6.20	34.40	35.90	0.00	0.00	50.64	340.41	500
Pk	8146.75	48.00	9.70	37.10	36.26	0.00	0.00	58.54	845.28	5012
Av	8146.75	36.00	9.70	37.10	36.26	0.00	0.00	46.54	212.32	500

Integral antenna middle channel plots

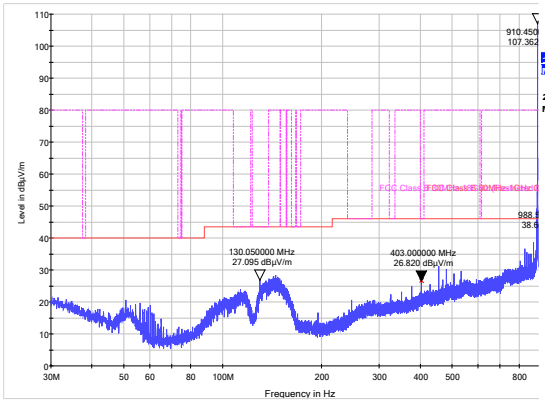


Figure 1 – Radiated Emissions Plot (30 MHz to 1 GHz).

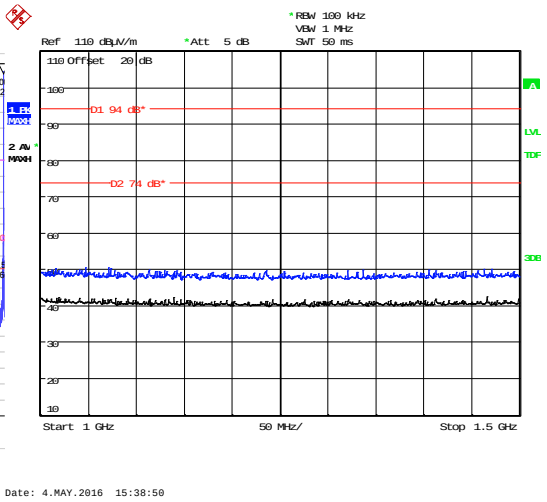


Figure 2 – Radiated Emissions Plot (1 GHz to 1.5 GHz).

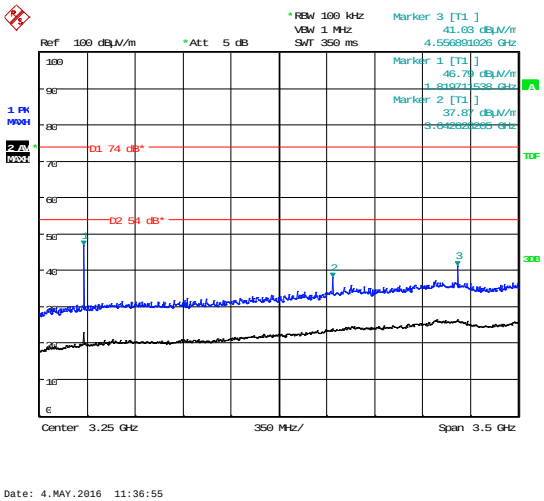


Figure 3 – Radiated Emissions Plot (1.5 GHz to 5 GHz).

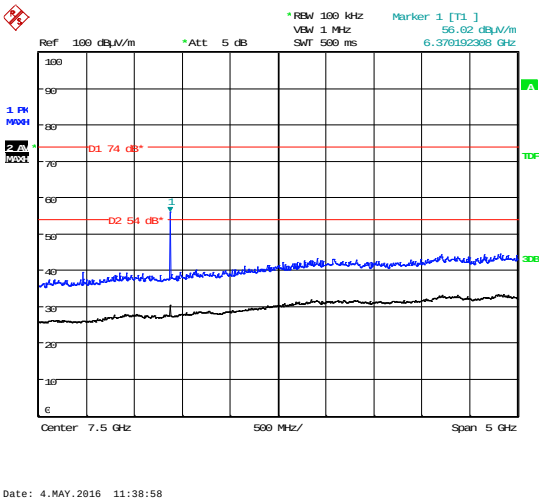


Figure 4 – Radiated Emissions Plot 5 GHz to 10 GHz).

High Power; Channel: 910.47 MHz										
Detector	***Freq. (MHz)***	***Meas'd Emission (dBµV)***	***Cable Loss (dB)***	***Antenna Factor (dB/m)***	***Pre-amp Gain (dB)***	***Duty Cycle Corr'n (dB)***	***Distance Extrap'n Factor (dB)***	***Field Strength (dBµV/m)***	***Field Strength (µV/m)***	***Limit (µV/m)***
Pk	4552.25	50.00	5.40	32.40	35.75	0.00	0.00	52.05	400.41	5012
Av	4552.25	39.85	5.40	32.40	35.75	0.00	0.00	41.90	124.45	500
Pk	7283.65	49.10	8.60	36.30	36.05	0.00	0.00	57.95	789.77	5012
Av	7283.65	39.66	8.60	36.30	36.05	0.00	0.00	48.51	266.38	500
Pk	8194.17	48.58	9.70	37.20	36.27	0.00	0.00	59.21	913.06	5012
Av	8194.17	37.00	9.70	37.20	36.27	0.00	0.00	47.63	240.71	500

Integral antenna top channel plots

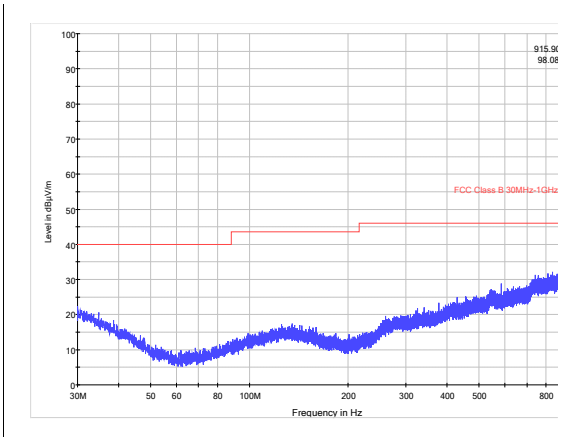


Figure 1 – Radiated Emissions Plot (30 MHz to 1 GHz).

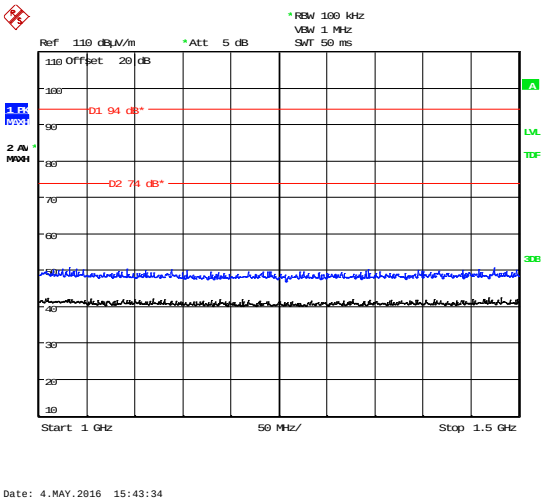


Figure 2 – Radiated Emissions Plot (1 GHz to 1.5 GHz).

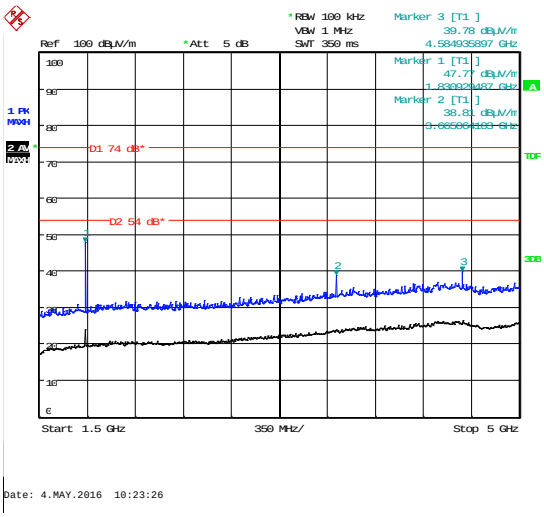


Figure 3 – Radiated Emissions Plot (1.5 GHz to 5 GHz).

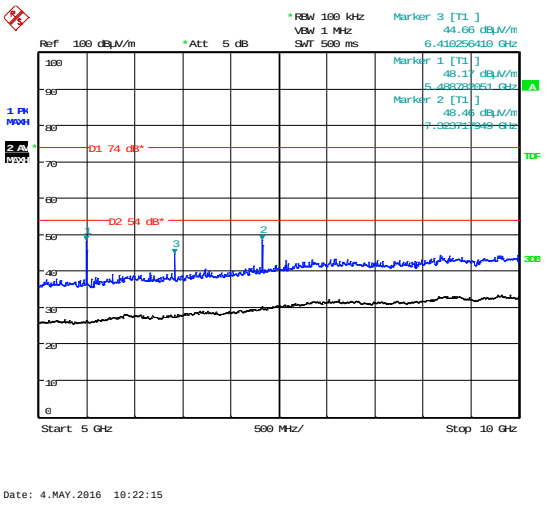


Figure 4 – Radiated Emissions Plot (5 GHz to 10 GHz).

High Power; Channel: 915.91 MHz										
Detector	***Freq. (MHz)***	***Meas'd Emission (dBµV)***	***Cable Loss (dB)***	***Antenna Factor (dB/m)***	***Pre-amp Gain (dB)***	***Duty Cycle Corr'n (dB)***	***Distance Extrap'n Factor (dB)***	***Field Strength (dBµV/m)***	***Field Strength (µV/m)***	***Limit (µV/m)***
Pk	3663.67	49.41	4.30	31.70	35.71	0.00	0.00	49.70	305.49	5012
Av	3663.67	39.06	4.30	31.70	35.71	0.00	0.00	39.35	92.79	500
Pk	4579.55	49.82	5.40	32.50	35.76	0.00	0.00	51.96	396.28	5012
Av	4579.55	39.16	5.40	32.50	35.76	0.00	0.00	41.30	116.14	500
Pk	7327.28	51.19	8.80	36.40	36.06	0.00	0.00	60.33	1038.72	5012
Av	7327.28	44.51	8.80	36.40	36.06	0.00	0.00	53.65	481.39	500
Pk	8243.14	48.56	9.60	37.20	36.28	0.00	0.00	59.08	899.50	5012
Av	8243.14	35.47	9.60	37.20	36.28	0.00	0.00	45.99	199.30	500

12 Radiated emissions – unintentional radiation / receiver emissions

12.1 Definitions

Receiver spurious emissions
The radio frequency signals generated within the receiver, which may cause interference to other equipment. This includes the period during which the equipment is scanning or switching channels.

Unintentional radiator
A device that generates RF energy which is not intended to be radiated for reception by a radio receiver.

12.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Radio Chamber
Test Standard and Clause:	ANSI C63.10-2013, Clause 6.5 and 6.6
EUT Channels / Frequencies Measured:	905.2 MHz / 910.47 MHz / 915.91 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: Peak

Environmental Conditions (Normal Environment)

Temperature: 24 °C	+15 ºC to +35 ºC (as declared)
Humidity: 31 % RH	20 % RH to 75 % RH (as declared)
Supply: 5 V dc	5 V dc ±10 % (as declared)

12.3 Test Limit

Note:

Only radio communication receivers operating in stand-alone mode within the band 30 to 960 MHz, as well as scanner receivers, are subject to requirements, as described above. All other receivers are exempted from any certification, testing, labelling and reporting requirements.

However, all receivers in all frequency bands shall comply with the limits set forth in FCC 47CFR15B / IC RSS-Gen even in cases where testing, reporting and/or certification are not required.

Receiver Radiated Limits

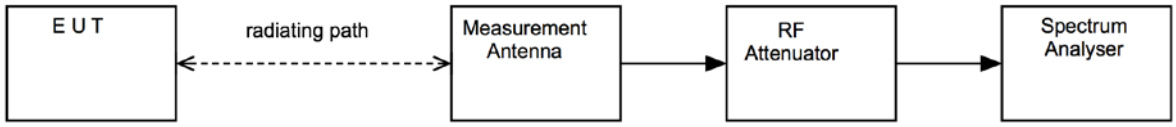
Frequency (MHz)	***Field Strength (µV/m at 3 m)***
30 to 88	100
88 to 216	150
216 to 960	200
Above 960	500

12.4 Test Method

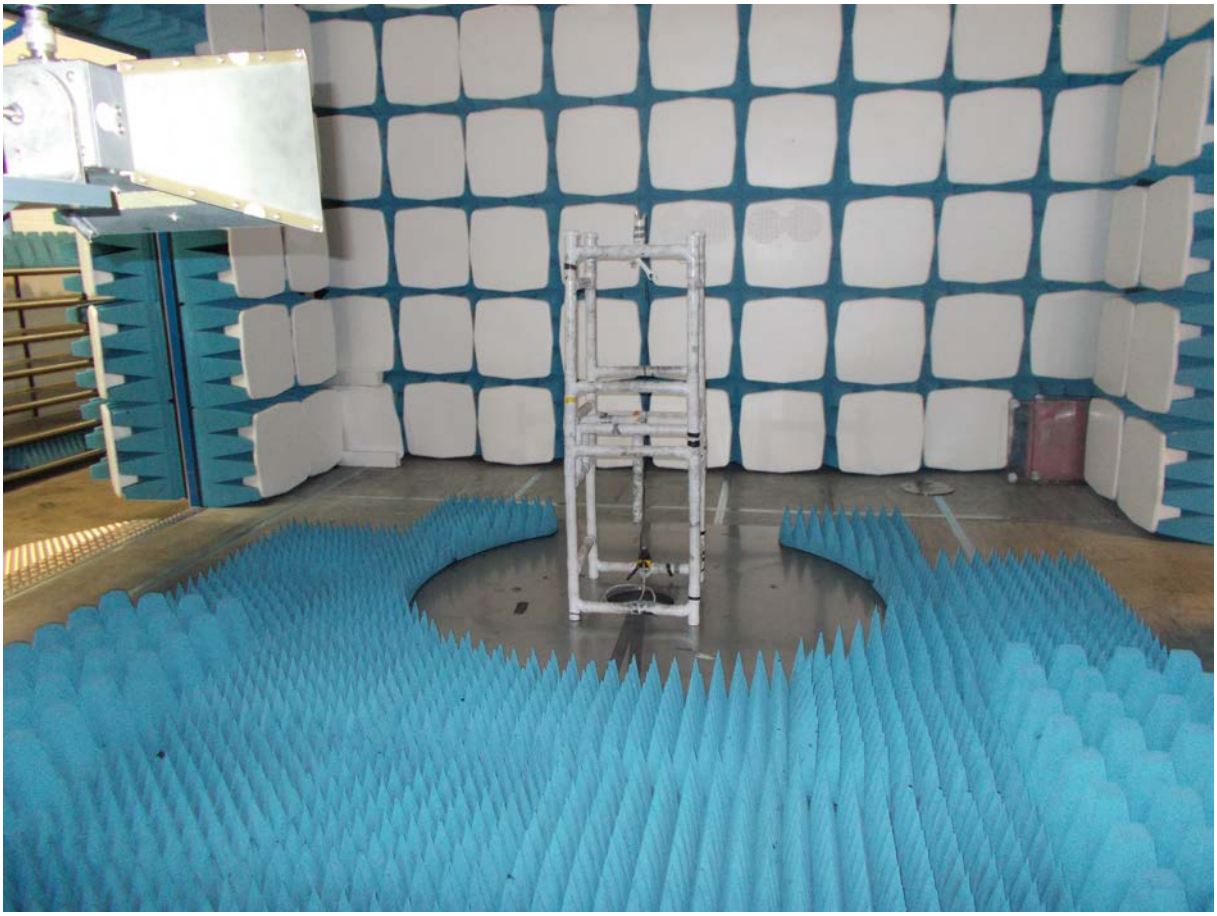
With the EUT setup as per section 9 of this report and connected as per Figure viii, the emissions from the EUT were measured on a spectrum analyzer / EMI receiver. The EUT was rotated in three orthogonal planes and the measurement antenna height scanned (below 1 GHz, from 1 to 4 m; above 1 GHz as necessary) in order to maximise emissions.

The measurements were performed with EUT set at its maximum duty. All modulation schemes, data rates and power settings were used to observe the worst-case configuration at each frequency.
Pre-scan plots are shown with a peak detector and 100 kHz RBW.

Figure viii Test Setup



12.5 Test Set-up Photograph



12.6 Test Equipment

Type of Equipment	*Maker/Supplier*	*Model Number*	*Element Number*	*Calibration Due Date*	*Calibration Interval*
Bilog	Chase	CBL611/A	UH191	26/02/2017	24
ESVS10	R&S	ESVS10	L352	07/08/2016	12
Spectrum analyser	R&S	FSU50	U544	16/03/2017	12
Horn Antenna	EMCO	3115	TRL139	25/09/2017	24
Pre-Amplifier	Agilent	8449B	TRL572	16/02/2017	12

12.7 Test Results

Receive mode – Bottom channel

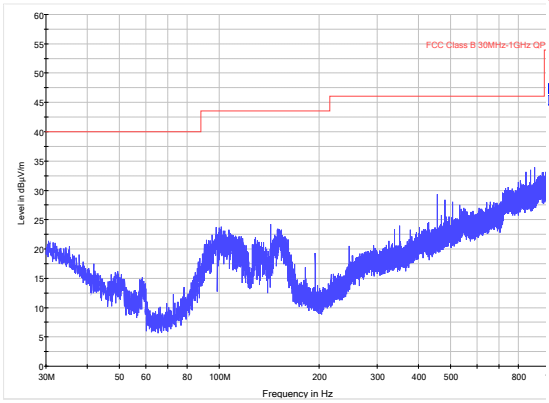


Figure 1 – Radiated Emissions Plot (30 MHz to 1 GHz).

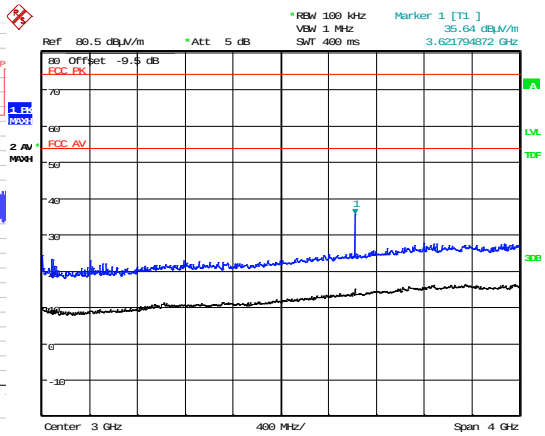


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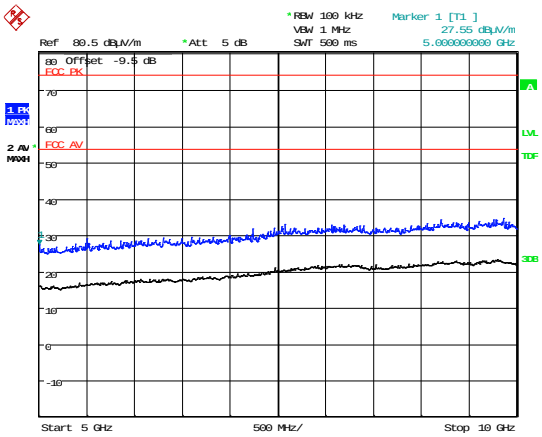
Figure 2 – Radiated Emissions Plot (1 GHz to 5 GHz).



Date: 4.MAY.2016 16:28:35

Figure 3 – Radiated Emissions Plot (5 GHz to 10 GHz).

High Power; Channel: 905.2 MHz									
Detector	***Freq. (MHz)***	***Measured Emission (dBµV/m)***	***Cable Loss (dB)***	***Antenna Factor (dB/m)***	***Pre-amp Gain (dB)***	***Field Strength (dBµV/m)***	***Extrap'n Factor (dB)***	***Field Strength (µV/m)***	***Limit (µV/m)***
Pk	3619.14	52.06	3.70	31.60	35.74	0.00	-9.54	42.08	127.02
Av	3619.14	45.95	3.70	31.60	35.74	0.00	-9.54	35.97	62.86

Receive mode – Middle channel

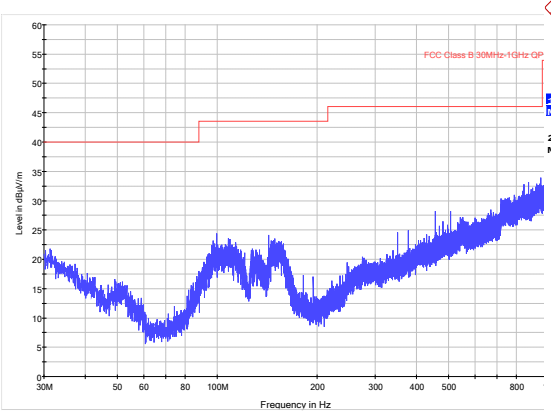


Figure 1 – Radiated Emissions Plot (30 MHz to 1 GHz).

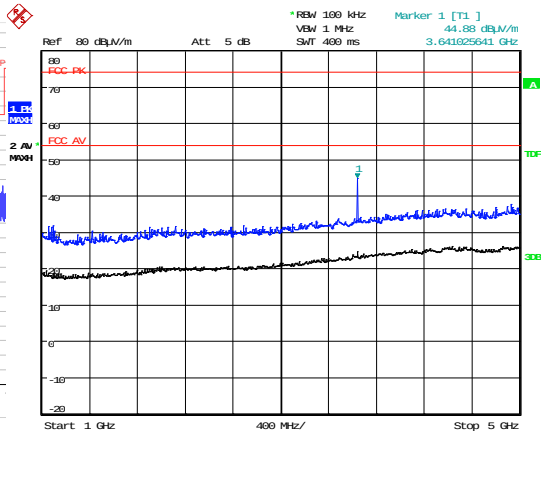


Figure 2 – Radiated Emissions Plot (1 GHz to 5 GHz).

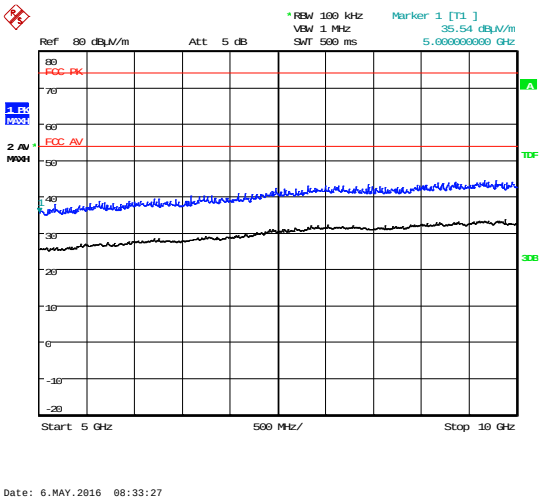


Figure 3 – Radiated Emissions Plot (5 GHz to 10 GHz).

High Power; Channel: 910.5 MHz									
Detector	***Freq. (MHz)***	***Measured Emission (dBµV/m)***	***Cable Loss (dB)***	***Antenna Factor (dB/m)***	***Pre-amp Gain (dB)***	***Field Strength (dBµV/m)***	***Extrap'n Factor (dB)***	***Field Strength (µV/m)***	***Limit (µV/m)***
Pk	3640.25	53.03	4.30	31.60	35.72	0.00	0.00	53.21	457.61
Av	3640.25	46.95	4.30	31.60	35.72	0.00	0.00	47.13	227.25

Receive mode – Top channel

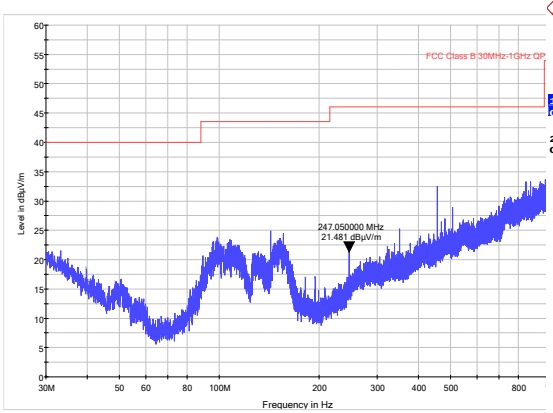


Figure 1 – Radiated Emissions Plot (30 MHz to 1 GHz).

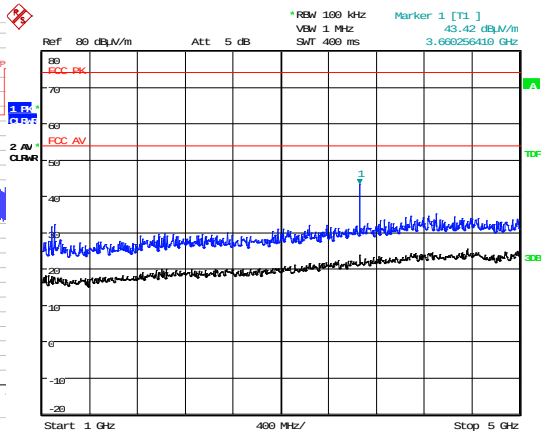


Figure 2 – Radiated Emissions Plot (1 GHz to 5 GHz).

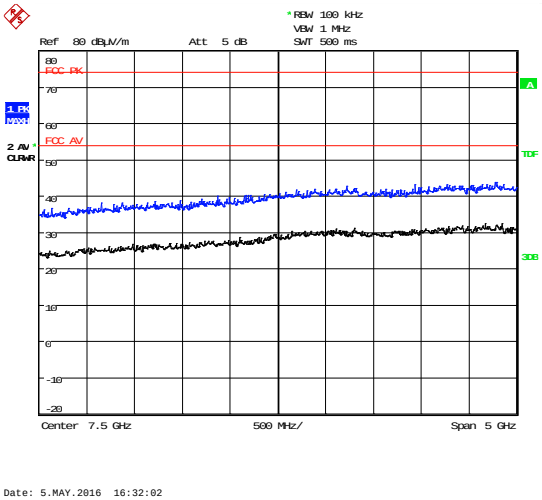


Figure 3 – Radiated Emissions Plot (5 GHz to 10 GHz).

High Power; Channel: 915.91 MHz									
Detector	***Freq. (MHz)***	***Measured Emission (dBµV/m)***	***Cable Loss (dB)***	***Antenna Factor (dB/m)***	***Pre-amp Gain (dB)***	***Field Strength (dBµV/m)***	***Extrap'n Factor (dB)***	***Field Strength (µV/m)***	***Limit (uV/m)***
Pk	3660.25	46.24	4.30	31.70	35.71	0.00	0.00	46.53	212.08
Av	3660.25	44.17	4.30	31.70	35.71	0.00	0.00	44.46	167.11

13 AC power-line conducted emissions

13.1 Definition

Line-to-ground radio-noise voltage that is conducted from all of the EUT current-carrying power input terminals that are directly (or indirectly via separate transformers or power supplies) connected to a public power network.

13.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Transient Laboratory
Test Standard and Clause:	ANSI C63.10-2013, Clause 6.2
EUT Channels / Frequencies Measured:	910.5 MHz
EUT Channel Bandwidths:	17 kHz
Deviations From Standard:	None
Measurement Detectors:	Quasi-Peak and Average, RMS

Environmental Conditions (Normal Environment)

Temperature: 24 °C	+15 ºC to +35 ºC (as declared)
Humidity: 30 % RH	20 % RH to 75 % RH (as declared)
Supply: 5 V dc	5 V dc ±10 % (as declared)

Test Limit

A radio apparatus that is designed to be connected indirectly to the public utility (AC) power line shall ensure that the radio frequency voltage, which is conducted back onto the AC power line on any frequency or frequencies within the band 150 kHz to 30 MHz, shall not exceed the limits in Table 3.

Table 3 – AC Power Line Conducted Emission Limits

Frequency (MHz)	***Conducted limit (dBµV)***	
	Quasi-Peak	***Average*** **
0.15 to 0.5	66 to 56*	56 to 46*
0.5 to 5	56	46
5 to 30	60	50

*The level decreases linearly with the logarithm of the frequency.
**A linear average detector is required.

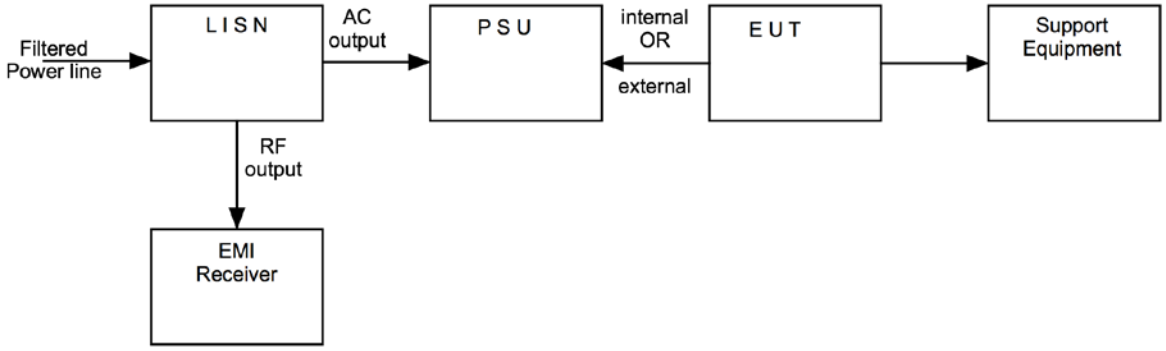
13.3 Test Method

With the EUT setup in a screened room, as per section 9 of this report and connected as per Figure ii, the power line emissions were measured on a spectrum analyzer / EMI receiver.

AC power line conducted emissions from the EUT are checked first by preview scans with peak and average detectors covering both live and neutral lines. A spectrum analyzer is used to determine if any periodic emissions are present.

Formal measurements using the correct detector(s) and bandwidth are made on frequencies identified from the preview scans. Final measurements were performed with EUT set at its maximum duty in transmit and receive modes.

Figure ii Test Setup



13.4 Test Set-up Photograph

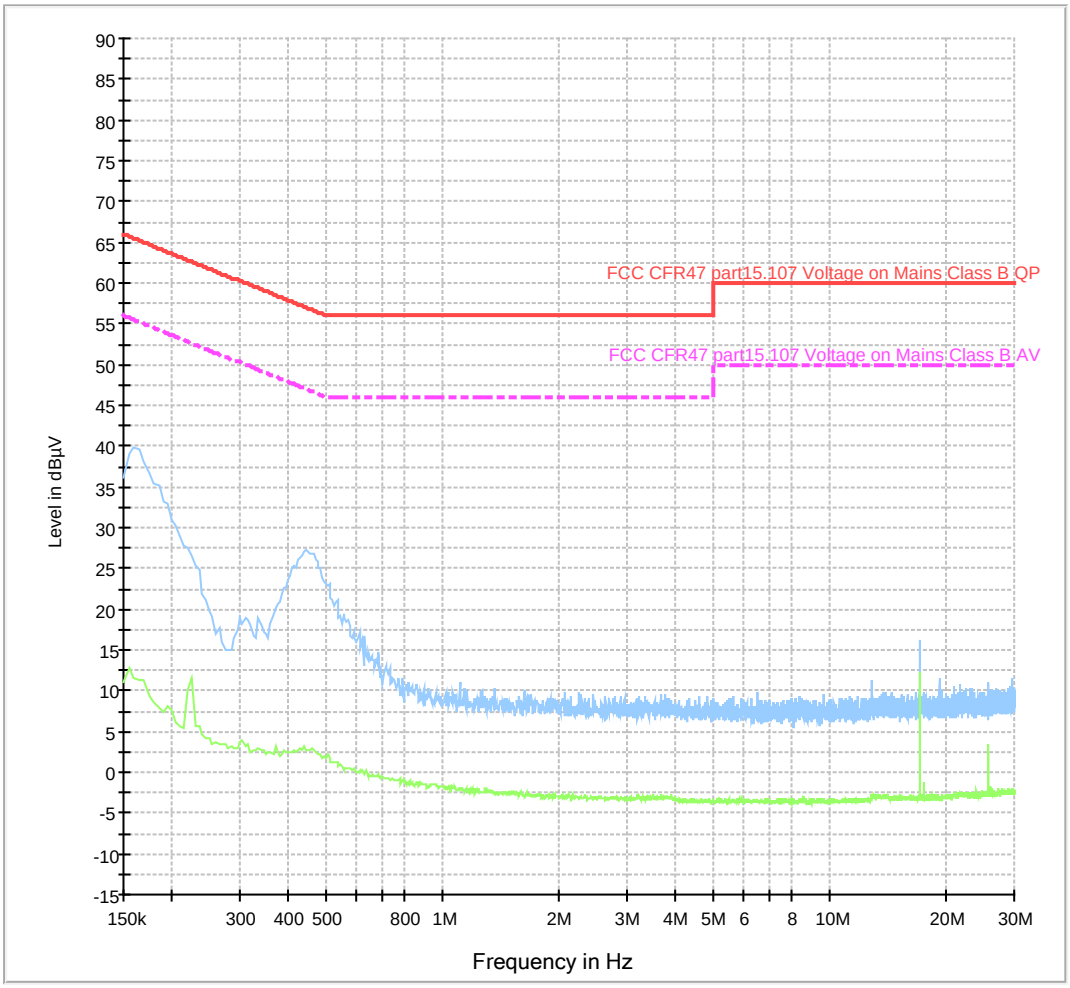
13.5 Test Equipment

Type of Equipment	*Maker/Supplier*	*Model Number*	*Element Number*	*Calibration Due Date*
LISN	R&S	ESH3-Z5.831.5	U195	04/06/2016
EMI Receiver	R&S	ESHS10	U003	25/06/2016

13.6 Test Results

Tx mode

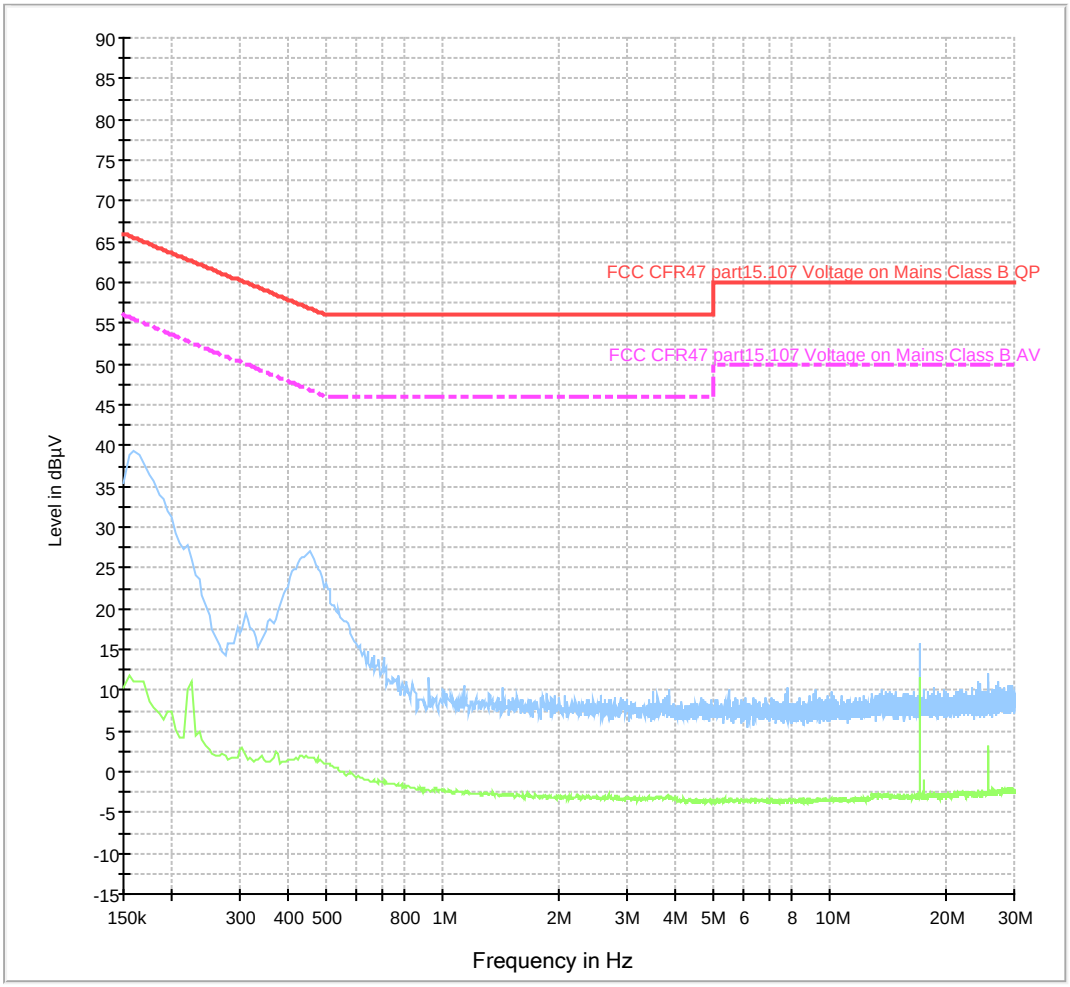
Conducted emissions on Mains 9kHz-30MHz ESHS10 + UH396



No emission within 20 dB of the limit.

Rx mode

Conducted emissions on Mains 9kHz-30MHz ESHS10 + UH396



No emissions found within 20 dB of the limit.

14 Carrier frequency separation

14.1 Definition

The carrier frequency separation is the frequency separation between two adjacent hopping frequencies.

14.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Radio Laboratory
Test Standard and Clause:	ANSI C63.10-2013, Clause 7.8.2
EUT Channels / Frequencies Measured:	All; 905.2 to 915.91 MHz
EUT 20dB Bandwidth:	17 kHz
EUT Test Modulations:	Internal pattern generation – hopping enabled
Deviations From Standard:	None
Measurement BW:	50 kHz
Measurement Detector:	Peak

Environmental Conditions (Normal Environment)

Temperature: 23 °C	+15 ºC to +35 ºC (as declared)
Humidity: 32 % RH	20 % RH to 75 % RH (as declared)
Supply: 5 V dc	5 V dc ±10 % (as declared)

14.3 Test Limit

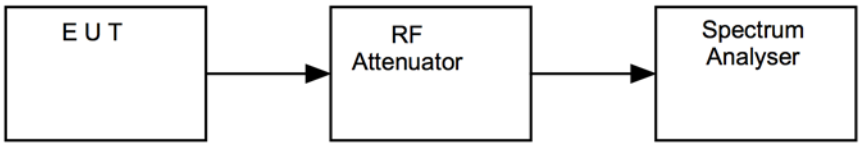
Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the -20 dB bandwidth of the hopping channel, whichever is greater. Alternatively, frequency hopping systems operating in the band 2400 to 2483.5 MHz may have hopping channel carrier frequencies that are separated by 25 kHz or two-thirds of the -20 dB bandwidth of the hopping channel, whichever is greater, provided that the systems operate with an output power no greater than 0.125 W.

14.4 Test Method

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

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

Figure iii Test Setup

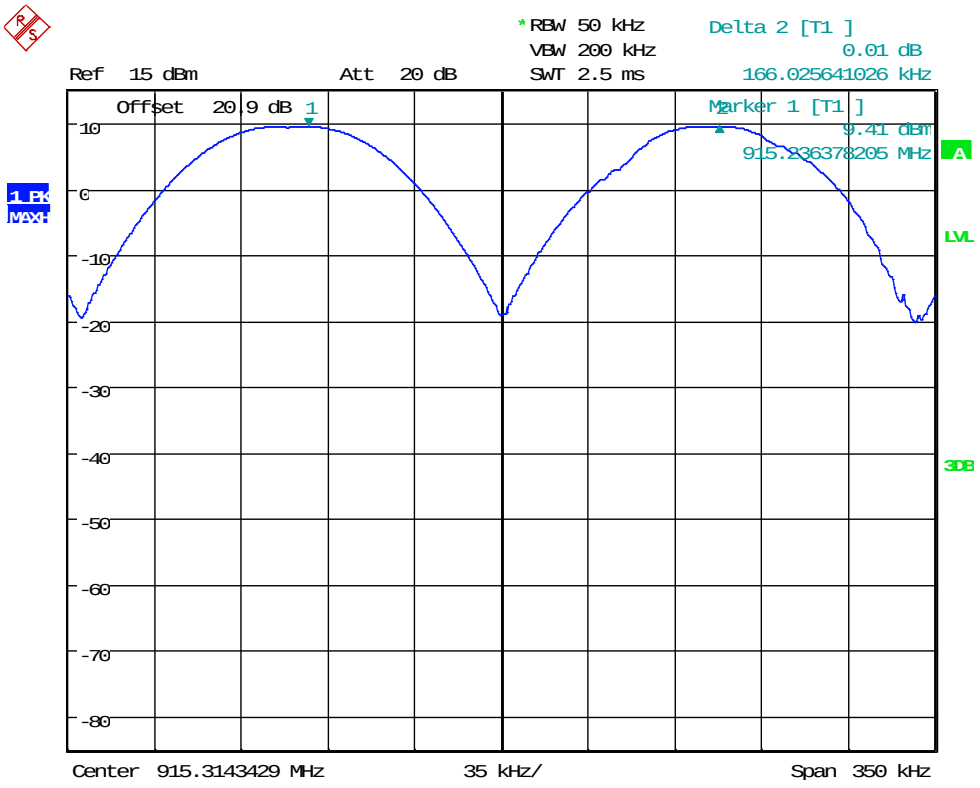


14.5 Test Equipment

Type of Equipment	*Maker/Supplier*	*Model Number*	*Element Number*	*Calibration Due Date*	*Calibration Interval*
Spectrum analyser	R&S	FSU50	U544	16/03/2017	12

14.6 Test Results

$F1_c$ (MHz)	*$F2_c$ (MHz)*	*Channel Separation, $F2_c - F1_c$ (kHz)*	*Result*
915.236378205	915.4024038	166.025641026	PASS



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15 Number of hopping frequencies

15.1 Definition

The total number of hopping frequencies (the centre frequencies defined within the hopping sequence of a FHSS equipment) which are randomly sequenced in order to spread the transmission.

15.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Radio Laboratory
Test Standard and Clause:	ANSI C63.10-2013, Clause 7.8.3
EUT Channels / Frequencies Measured:	All; 905.2 – 915.91 MHz
EUT 20dB Bandwidth:	17 kHz
EUT Test Modulations:	Internal pattern generation – hopping enabled
Deviations From Standard:	None
Measurement BW:	100 kHz
Measurement Detector:	Peak

Environmental Conditions (Normal Environment)

Temperature: 24 °C	+15 ºC to +35 ºC (as declared)
Humidity: 32 % RH	20 % RH to 75 % RH (as declared)
Supply: 5 V dc	5 V dc ±10 % (as declared)

15.3 Test Limit

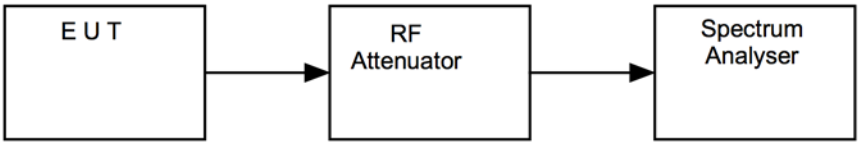
- For frequency hopping systems in the band 902 to 928 MHz: if the -20 dB bandwidth of the hopping channel is less than 250 kHz, the system shall use at least 50 hopping channels;
  If the -20 dB bandwidth of the hopping channel is 250 kHz or greater, the system shall use at least 25 hopping channels;
- Frequency hopping systems operating in the band 2400 to 2483.5 MHz shall use at least 15 hopping channels;
- Frequency hopping systems operating in the band 5725 to 5850 MHz shall use at least 75 hopping channels.

15.4 Test Method

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

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

Figure iv Test Setup

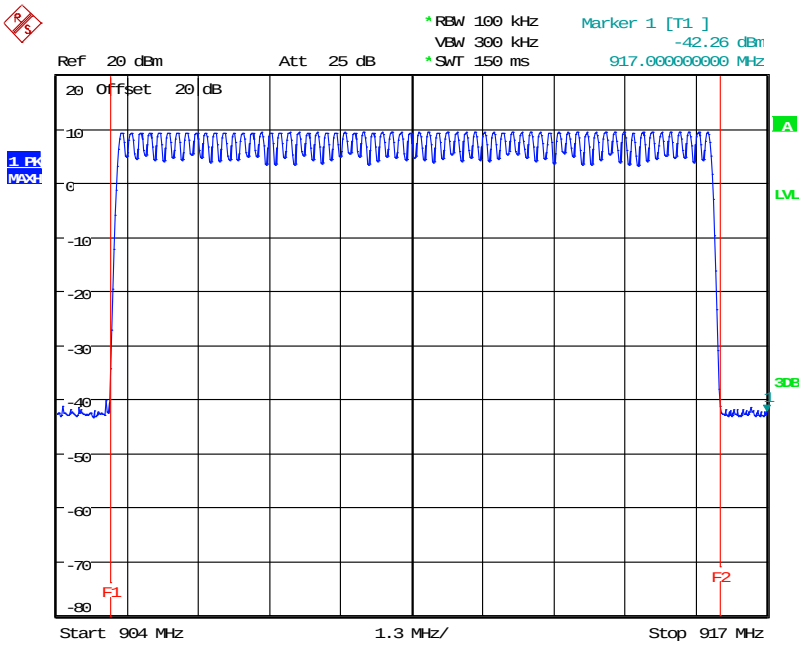


15.5 Test Equipment

Type of Equipment	*Maker/Supplier*	*Model Number*	*Element Number*	*Calibration Due Date*	*Calibration Interval*
Spectrum analyser	R&S	FSU50	U544	16/03/2017	12

15.6 Test Results

Lowest channel, F_{CL} (MHz)	*Highest channel, F_{CH} (MHz)*	*Number of channels observed*	*Result*
905.2	915.91	64	PASS



Date: 6.MAY.2016 11:17:30

16 Average channel occupancy

16.1 Definition

The channel occupancy is the total of the transmitter 'on' times, during an observation period, on a particular hopping frequency.

16.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Radio Laboratory
Test Standard and Clause:	ANSI C63.10-2013, Clause 7.8.4
EUT Channels / Frequencies Measured:	910.8 MHz
EUT 20dB bandwidth:	17 kHz
EUT Number of hopping channels:	64
EUT Test Modulations:	Internal pattern generation – hopping enabled
Deviations From Standard:	None
Measurement BW:	50 kHz
Measurement Detector:	Peak

Environmental Conditions (Normal Environment)

Temperature: 24 °C	+15 ºC to +35 ºC (as declared)
Humidity: 30 % RH	20 % RH to 75 % RH (as declared)
Supply: 5 V dc	5 V dc ±10 % (as declared)

16.3 Test Limit

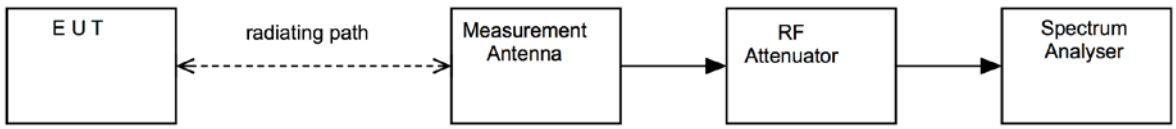
- For frequency hopping systems in the band 902 to 928 MHz: if the -20 dB bandwidth of the hopping channel is less than 250 kHz, the average time of occupancy on any channel shall not be greater than 0.4 seconds within a 20 second period;
  If the -20 dB bandwidth of the hopping channel is 250 kHz or greater, the average time of occupancy on any channel shall not be greater than 0.4 seconds within a 10 second period;
- Frequency hopping systems operating in the band 2400 to 2483.5 MHz: The average time of occupancy on any channel shall not be greater than 0.4 seconds within a period of 0.4 seconds, multiplied by the number of hopping channels employed;
- Frequency hopping systems operating in the band 5725 to 5850 MHz: The average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 30 second period.

16.4 Test Method

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

The measurements were performed with EUT set at its maximum duty. A number of hops were observed to confirm consistency of the dwell time / observe the worst case. All modulation schemes, data rates and power settings were used to observe the worst-case configuration.

Figure v Test Setup

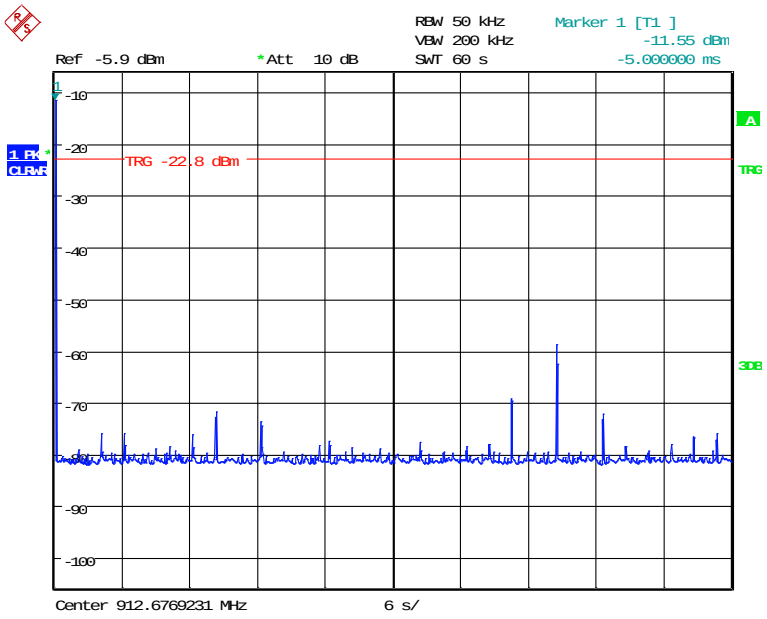


16.5 Test Equipment

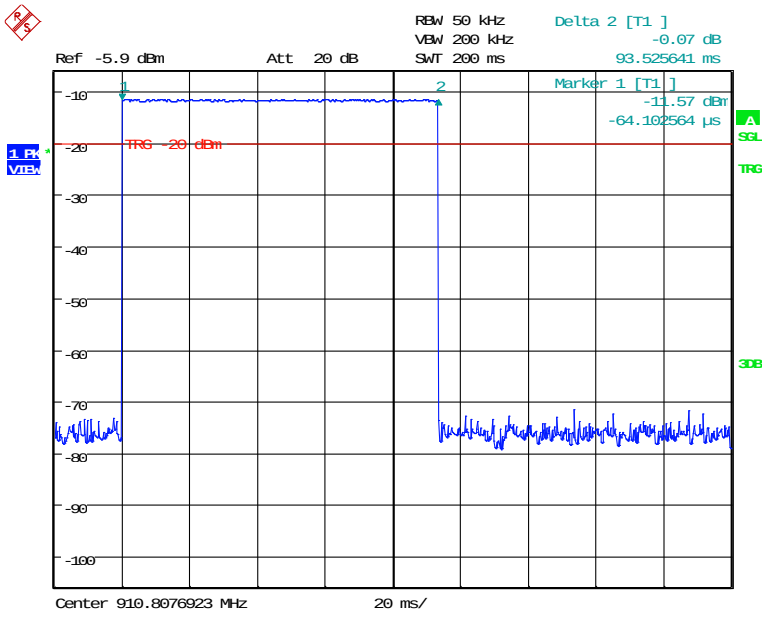
Type of Equipment	*Maker/Supplier*	*Model Number*	*Element Number*	*Calibration Due Date*	*Calibration Interval*
Spectrum analyser	R&S	FSU50	U544	16/03/2017	12

16.6 Test Results

Individual occupancy time (ms)	Observation period (s)	Number of hops observed	Average time of occupancy (s)	Result
93.525641	20	1	93.525641	PASS



Date: 9.MAY.2016 14:41:16



Date: 9.MAY.2016 13:06:04

17 Maximum peak conducted output power

17.1 Definition

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

17.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Radio Chamber
Test Standard and Clause:	ANSI C63.10-2013, Clause 7.8.5
EUT Channels / Frequencies Measured:	905.2 MHz / 910.47 MHz / 915.91 MHz– hopping disabled.
Deviations From Standard:	None
Measurement BW:	120 kHz
Measurement Detector:	Peak
Voltage Extreme Environment Test Range:	Mains Power = 85 % and 115 % of Nominal (FCC only requirement); Battery Power = new battery.

Environmental Conditions (Normal Environment)

Temperature: 24 °C	+15 ºC to +35 ºC (as declared)
Humidity: 30 % RH	20 % RH to 75 % RH (as declared)

17.3 Test Limit

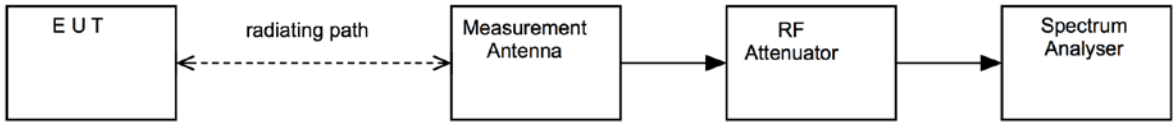
- For frequency hopping systems operating in the band 902 to 928 MHz, the maximum peak conducted output power shall not exceed 1 W, and the e.i.r.p. shall not exceed 4 W, if the hopset uses 50 or more hopping channels;
  the maximum peak conducted output power shall not exceed 0.25 W, and the e.i.r.p. shall not exceed 1 W, if the hopset uses less than 50 hopping channels.
- For frequency hopping systems operating in the band 2400 to 2483.5 MHz and employing at least 75 hopping channels, the maximum peak conducted output power shall not exceed 1 W;
  for all other frequency hopping systems in the band, the maximum peak conducted output power shall not exceed 0.125 W. The e.i.r.p. shall not exceed 4 W.
- For frequency hopping systems operating in the band 5725 to 5850 MHz, the maximum peak conducted output power shall not exceed 1 W. The e.i.r.p. shall not exceed 4 W.
- Point-to-point systems in the bands 2400-2483.5 MHz and 5725 to 5850 MHz are permitted to have an e.i.r.p. higher than 4 W provided that the higher e.i.r.p. is achieved by employing higher gain directional antennas and not higher transmitter output powers.

17.4 Test Method

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

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

Figure vi Test Setup



17.5 Test Equipment

Type of Equipment	*Maker/Supplier*	*Model Number*	*Element Number*	*Calibration Due Date*	*Calibration Interval*
Bilog	Chase	CBL611/A	UH191	26/02/2017	24
ESVS10	R&S	ESVS10	L352	07/08/2016	12

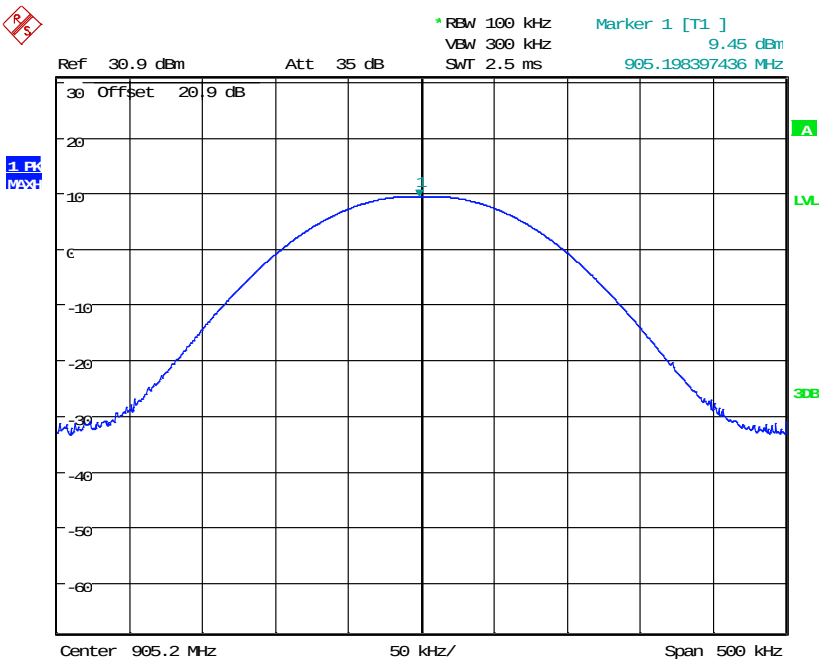
17.6 Test Results

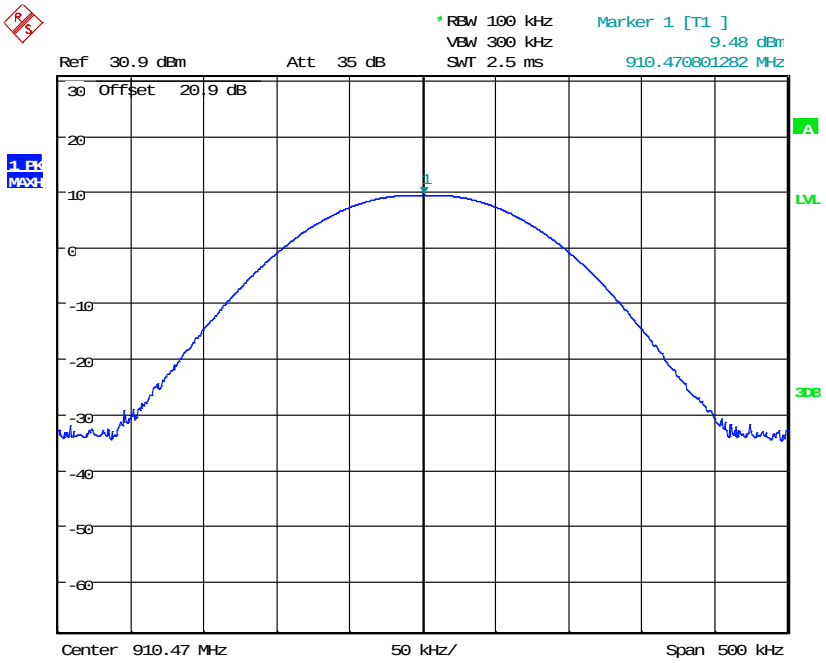
The following formula may be used to convert field strength (FS) in volts/metre to transmitter output power (TP) in watts:

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

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

Channel Frequency (MHz)	*Peak Field Strength (dBµV/m)*	*Peak Field Strength (V/m)*	*Distance (m)*	*Antenna Gain (dBi)*	*E.I.R.P. (W)*	*Maximum peak conducted output power (W)*	*Result*
905.2	106.42	0.208929613	3	1.72	0.008810489	0.005929253	PASS
910.5	107.58	0.239883292	3	2.89	0.00887156	0.004560369	PASS
915.91	103.80	0.154881662	3	-0.9	0.008851156	0.010889301	PASS





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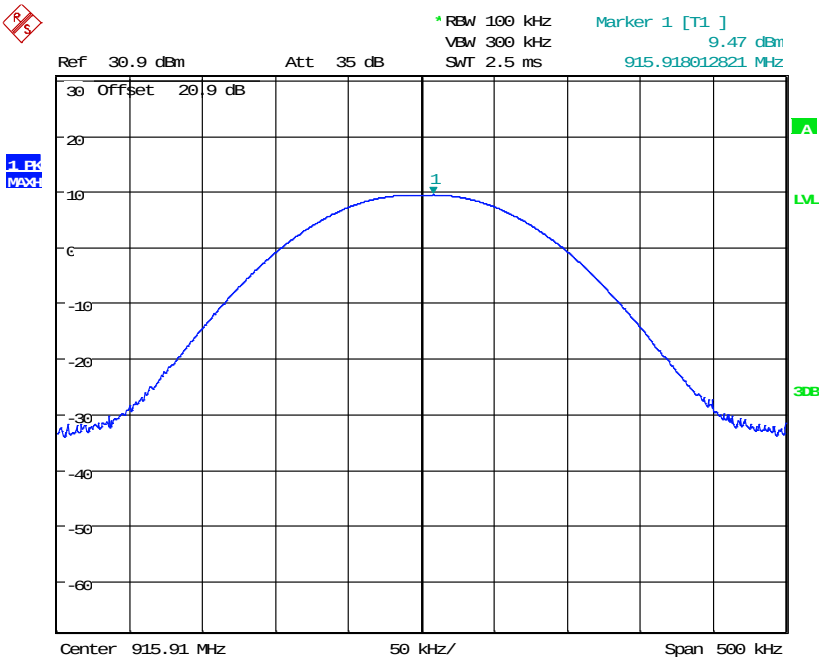


Date: 6.MAY.2016 14:06:32

18 Occupied Bandwidth

18.1 Definition

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

18.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Radio Laboratory
Test Standard and Clause:	ANSI C63.10-2013, Clause 6.9
EUT Channels / Frequencies Measured:	905.2 MHz / 910.47 MHz / 915.91 MHz – hopping stopped.
Deviations From Standard:	None
Measurement BW: (requirement: 1 % to 5 % OBW)	500 Hz
Spectrum Analyzer Video BW: (requirement at least 3x RBW)	2 kHz
Measurement Span: (requirement 2 to 5 times OBW)	50 kHz
Measurement Detector:	Peak

Environmental Conditions (Normal Environment)

Temperature: 24 °C	+15 ºC to +35 ºC (as declared)
Humidity: 30 % RH	20 % RH to 75 % RH (as declared)
Supply: 5 V dc	5 V dc ±10 % (as declared)

18.3 Test Limit

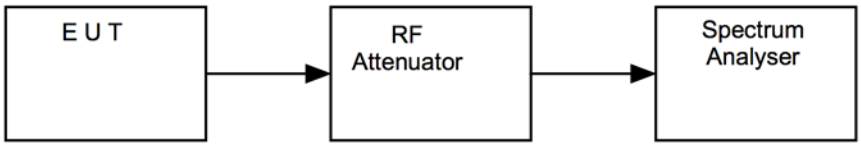
- For frequency hopping systems in the band 902 to 928 MHz: The maximum allowed -20 dB bandwidth of the hopping channel is 500 kHz.
- Frequency hopping systems operating in the band 5725 to 5850 MHz: The maximum -20 dB bandwidth of the hopping channel shall be 1 MHz

18.4 Test Method

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

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

Figure vii Test Setup

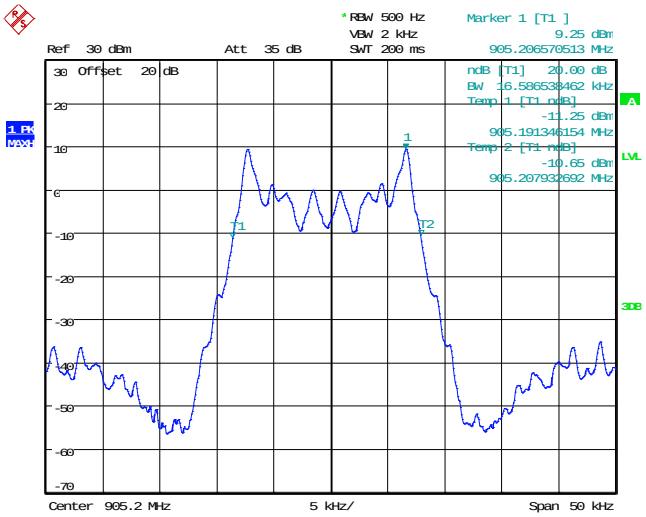


18.5 Test Equipment

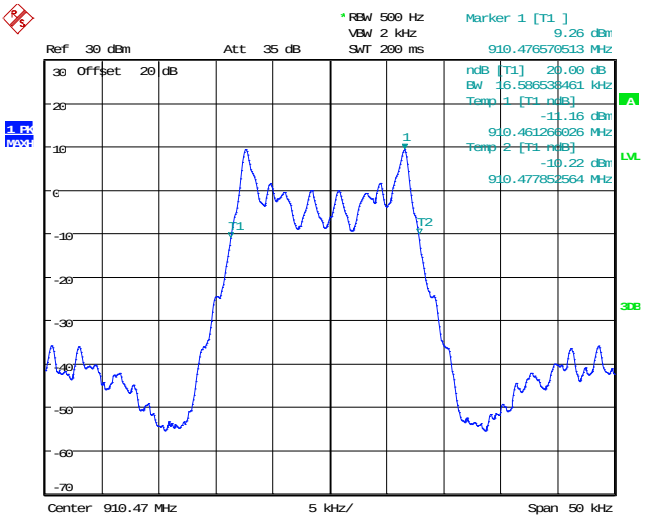
Type of Equipment	*Maker/Supplier*	*Model Number*	*Element Number*	*Calibration Due Date*	*Calibration Interval*
Spectrum analyser	R&S	FSU50	U544	16/03/2017	12

18.6 Test Results

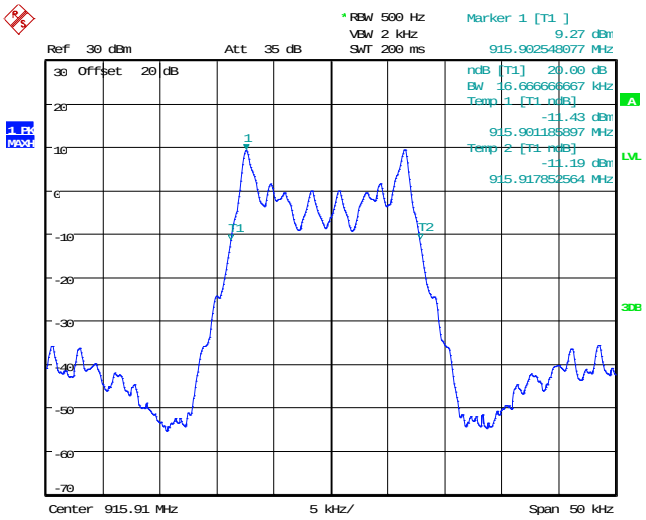
Channel Frequency (MHz)	*F_L (MHz)*	*F_H (MHz)*	*20dB Bandwidth (kHz)*	*Result*
905.2	905.1913526	905.2079391	16.586536	PASS
910.47	910.4612981	910.4778846	16.586515	PASS
915.91	915.901266	915.9178526	16.586538	PASS



Date: 6.MAY.2016 12:18:12



Date: 6.MAY.2016 12:15:59



Date: 6.MAY.2016 12:20:42

19 Out-of-band and conducted spurious emissions

19.1 Definition

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

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

19.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Radio Laboratory
Test Standard and Clause:	ANSI C63.10-2013, Clause 7.8.8
EUT Channels / Frequencies Measured:	905.2 MHz / 910.47 MHz / 915.91 MHz
Deviations From Standard:	None
Measurement BW:	100 kHz
Spectrum Analyzer Video BW: (requirement at least 3x RBW)	300 kHz
Measurement Detector:	Peak
Measurement Range:	150 kHz to 10 GHz

Environmental Conditions (Normal Environment)

Temperature: 24 °C	+15 ºC to +35 ºC (as declared)
Humidity: 29 % RH	20 % RH to 75 % RH (as declared)
Supply: 5 V dc	5 V dc ±10 % (as declared)

19.3 Test Limits

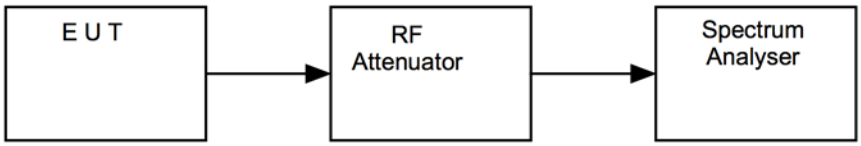
In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated device is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either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

19.4 Test Method

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

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

Figure viii Test Setup



19.5 Test Equipment

Type of Equipment	*Maker/Supplier*	*Model Number*	*Element Number*	*Calibration Due Date*	*Calibration Interval*
Spectrum analyser	R&S	FSU50	U544	16/03/2017	12

19.6 Test Results

Conducted spurious emissions bottom channel

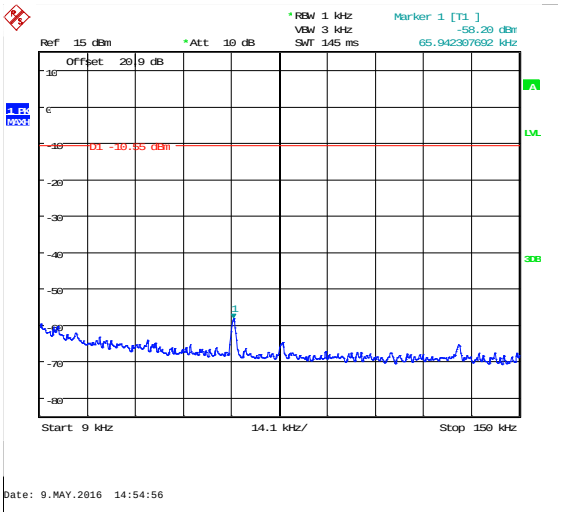


Figure 1 – Conducted Emissions Plot (9 kHz to 150 kHz).

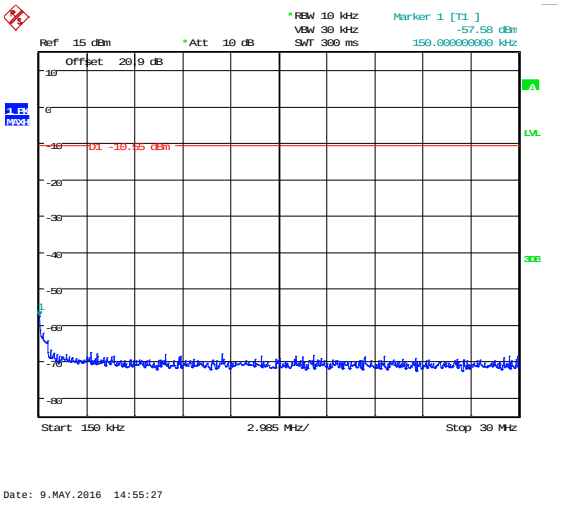


Figure 2 – Conducted Emissions Plot (150 kHz to 30 MHz).

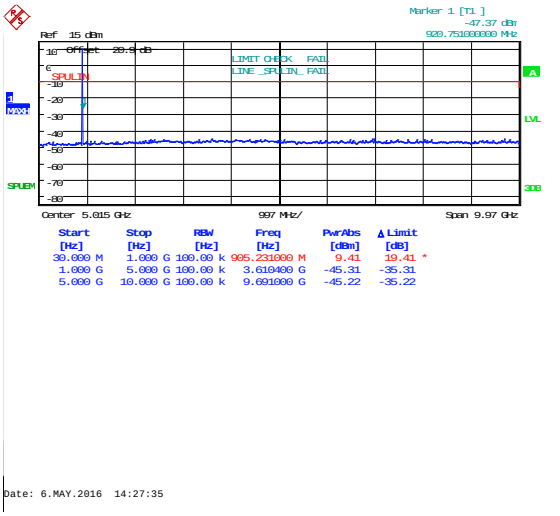


Figure 3 – Conducted Emissions Plot (30 MHz to 10 GHz).

No emission found within 20dB of the limit.

Conducted spurious emissions middle channel

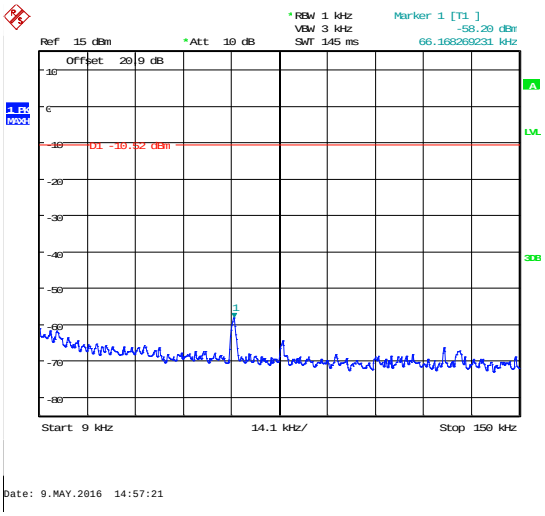


Figure 1 – Conducted Emissions Plot (9 kHz to 150 kHz).

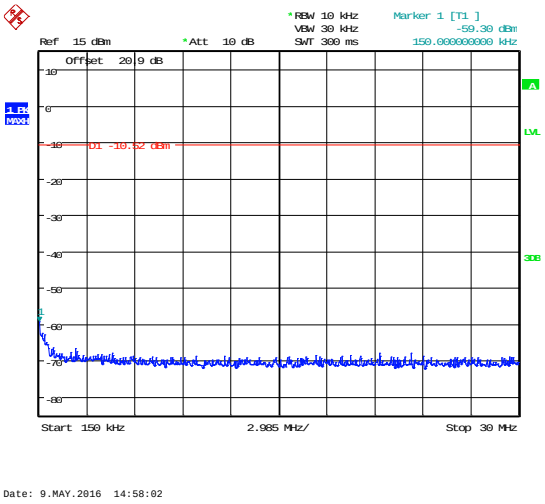


Figure 2 – Conducted Emissions Plot (150 kHz to 30 MHz).

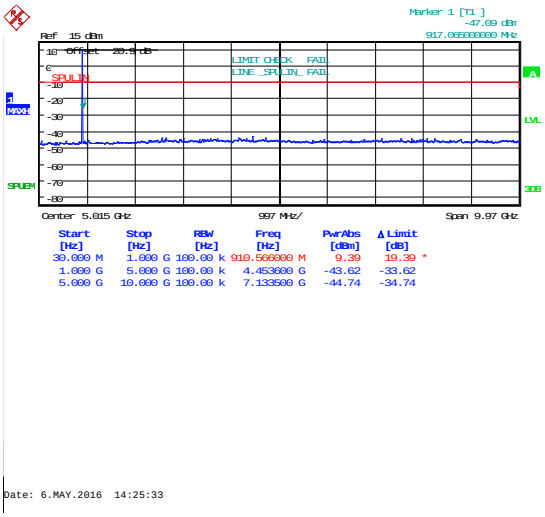


Figure 3 – Conducted Emissions Plot (30 MHz to 10 GHz).

No emission found within 20dB of the limit.

Conducted spurious emissions top channel

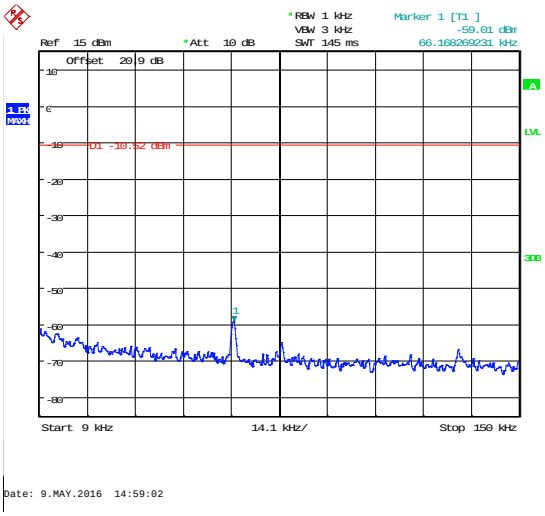


Figure 1 – Conducted Emissions Plot (9 kHz to 150 kHz).

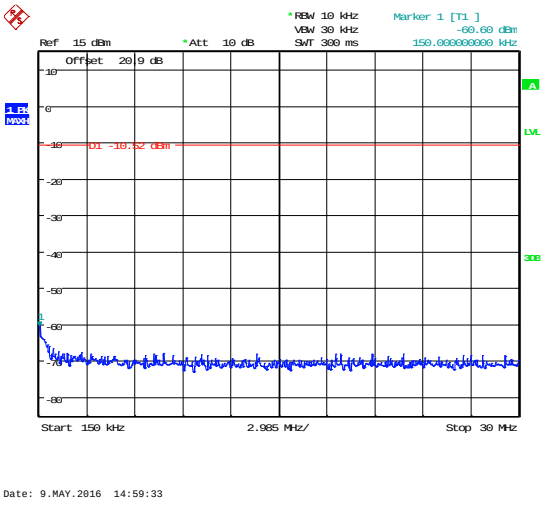


Figure 2 – Conducted Emissions Plot (150 kHz to 30 MHz).

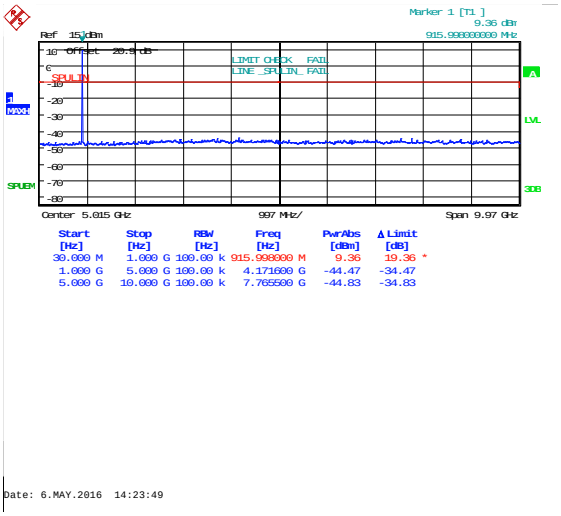


Figure 3 – Conducted Emissions Plot (30 MHz to 10 GHz).

No emission found within 20dB of the limit.

20 Measurement Uncertainty

Calculated Measurement Uncertainties

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

[1] Radiated spurious emissions

Uncertainty in test result (30 MHz to 1 GHz) = **4.6 dB**
Uncertainty in test result (1 GHz to 18 GHz) = **4.7 dB**

[2] AC power line conducted emissions

Uncertainty in test result = **3.4 dB**

[3] Occupied bandwidth

Uncertainty in test result = **15.5 %**

[4] Conducted carrier power

Uncertainty in test result (Power Meter) = **1.08 dB**

[5] Conducted / radiated RF power out-of-band

Uncertainty in test result – up to 8.1 GHz = **3.31 dB**
Uncertainty in test result – 8.1 GHz to 15.3 GHz = **4.43 dB**
Uncertainty in test result (30 MHz to 1 GHz) = **4.6 dB**
Uncertainty in test result (1 GHz to 18 GHz) = **4.7 dB**

[6] Frequency separation

Uncertainty in test result (Spectrum Analyser) = **3.6 kHz**

[7] Accumulated channel occupancy time

Uncertainty in test result = **7.98 %**