Report on the Radio Testing

For

Adeunis RF

on

Sigfox Demonstrator 915

Report no. TRA-030856-47-00-A

29th June 2016



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

Report Number: TRA-030856-47-00-A
Issue: A

# REPORT ON THE RADIO TESTING OF A
# Sigfox Demonstrator 915
# WITH RESPECT TO SPECIFICATION
# FCC 47CFR 15.247

TEST DATE: 1st March - 29th March 2016

Written by: S Hodgkinson

S Hodgkinson
Radio test engineer

Approved by: John Charters

Digitally signed by John Charters
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Date: 2016.06.29 13:34:53 +01'00'

J Charters
Department Manager - Radio

Date: 29th June 2016





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# 1 Revision Record

| *Issue Number* | *Issue Date* | *Revision History* |
|---|---|---|
| A | 29th June 2016 | Original |
| | | |

## 2 Summary

| | |
|---|---|
| TEST REPORT NUMBER: | TRA-030856-47-00-A |
| WORKS ORDER NUMBER | TRA-030856 |
| 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. |
| TEST SPECIFICATION(S): | 47CFR15.247 |
| EQUIPMENT UNDER TEST (EUT): | Sigfox Demonstrator 915 |
| FCC IDENTIFIER: | U3Z-ARF8075 |
| MANUFACTURER/AGENT: | Adeunis RF |
| ADDRESS: | 283 Rue Louis Néel<br>Parc Technologique Pré Roux<br>Crolles<br>38920<br>France |
| CLIENT CONTACT: | Pascal Saguin<br>☎ 0033 47692 0774<br>✉ p.saguin@adeunis-rf.com |
| ORDER NUMBER: | 20160303265 |
| TEST DATE: | 26/03/2016 |
| TESTED BY: | S Hodgkinson<br>Element |

## *2.1 Test Summary*

| *Test Method and Description* | *Requirement Clause* *47CFR15* | *Applicable to this equipment* | *Result / Note* |
|---|---|---|---|
| Radiated spurious emissions (restricted bands of operation and cabinet radiation) | 15.205 | ☒ | *Pass* |
| AC power line conducted emissions | 15.207 | ☒ | *Pass* |
| Carrier frequency separation | 15.247(a)(1) | ☒ | *Pass* |
| Number of hopping channels | 15.247(a)(1) (i), (ii) and (iii) | ☒ | *Pass* |
| Average time of occupancy | 15.247(a)(1) (i), (ii) and (iii) | ☒ | *Pass* |
| Maximum peak conducted output power | 15.247 (a)(1), (b)(1) and (b)(2) | ☒ | *Pass* |
| 20dB emission bandwidth | 15.247(a)(1) (i) and (ii) | ☒ | *Pass* |
| Unintentional radiation / receiver emissions | 15.109 | ☒ | *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-030856-47-00-A presents the results of the Radio testing on a Sigfox Demonstrator 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 Sigfox 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: Sigfox Demonstrator 915

## *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…
Transmitter operating on hopping channels selected by customer software

### *7.3.2 Reception*

The mode of operation for Rx tests was as follows…
EUT in receive mode.

## *7.4 EUT Radio Parameters*

### *7.4.1 General*

| | |
|---|---|
| ***Frequency of operation:*** | 902-929MHz |
| ***Modulation type(s):*** | BPSK @ 600bps |
| ***Occupied channel bandwidth(s):*** | 21.826kHz |
| ***Channel spacing:*** | 25kHz |
| ***Nominal Supply Voltage:*** | 3.7Vdc |
| ***Software version*** | V2.00e |
| ***Hardware version*** | B |

### *7.4.2 Antennas*

| | |
|---|---|
| ***Type:*** | Integral |
| ***Frequency range:*** | 902.928MHz |

### *7.4.3 Product specific declarations*

| | |
|---|---|
| ***Multiple antenna configuration(s), e.g. MIMO:*** | ***N/A*** |
| ***Fixed pt-pt operations (yes/no):*** | ***N/A*** |
| ***Installation manual advice on pt-pt operational restrictions (yes/no):*** | ***N/A*** |
| ***Fixed pt-mpt operations (yes/no):*** | ***N/A*** |

## ***7.5 EUT Description***

The EUT is a radio device that operates in the 902-928MHz band.
The main function of the radio is for the validation of applications like sensor networks, environment , intelligent buildings, metering, security, or M2M.

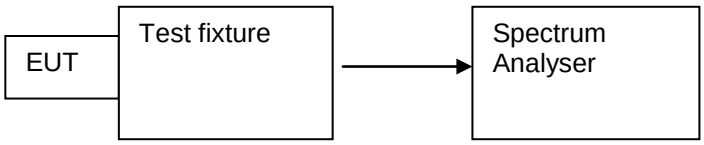
# 8 Modifications

No modifications were performed during this assessment.

# 9 EUT Test Setup

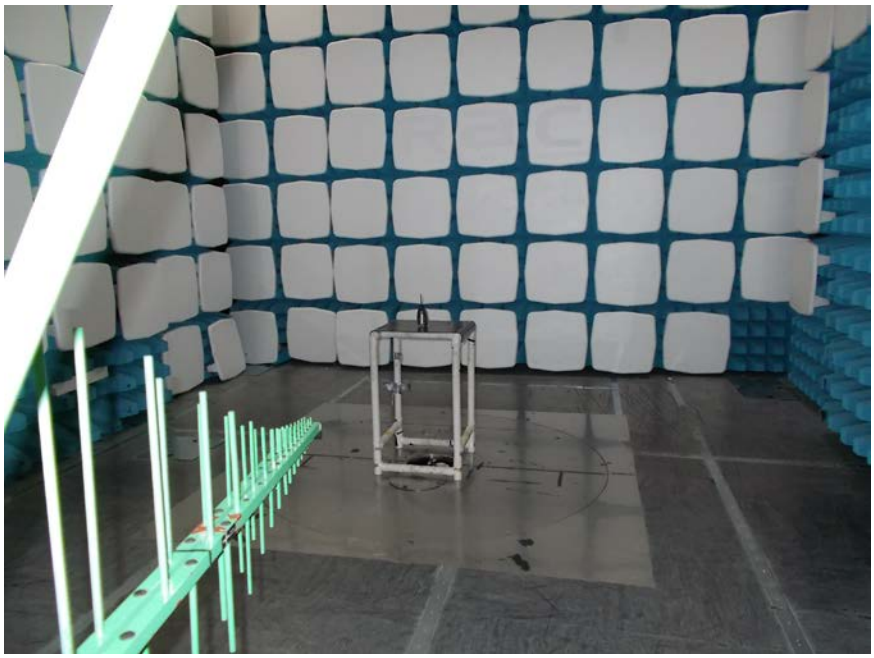
## *9.1 Block Diagram*

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. 3.7 V dc.

## *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 % |
| ☒ | 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 Chamnber |
| Test Standard and Clause: | ANSI C63.10-2013, Clause 6.5 and 6.6 |
| EUT Channels / Frequencies Measured: | Low High |
| EUT Channel Bandwidths: | 21.826kHz |
| Deviations From Standard: | None |
| Measurement BW: | 30 MHz to 1 GHz: 120 kHz<br>Above 1 GHz: 1 MHz |
| Measurement Detector: | Up to 1 GHz: quasi-peak<br>Above 1 GHz: RMS average and 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:3.7 Vdc | Via Battery (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:

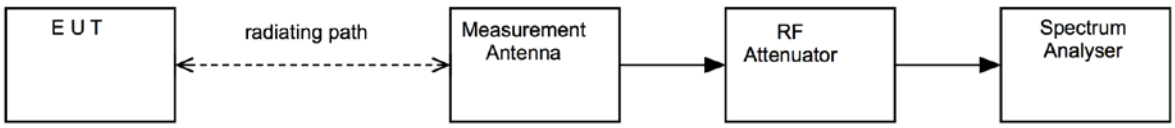
$$FS = PR + CL + AF – PA + DC – CF$$

Where,

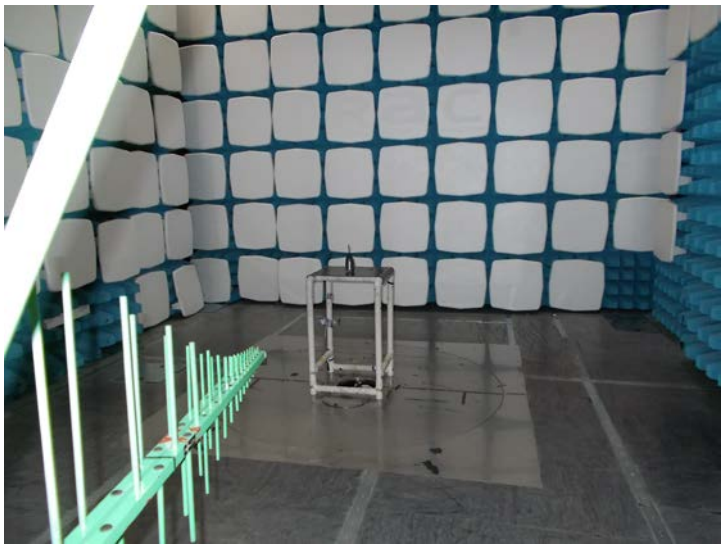
PR is the power recorded on the receiver / spectrum analyzer in dBµV;
CL is the cable loss in dB;
AF is the test antenna factor in dB/m;
PA is the pre-amplifier gain in dB (where used);
DC is the duty correction factor in dB (where used, e.g. harmonics of pulsed fundamental);
CF is the distance factor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

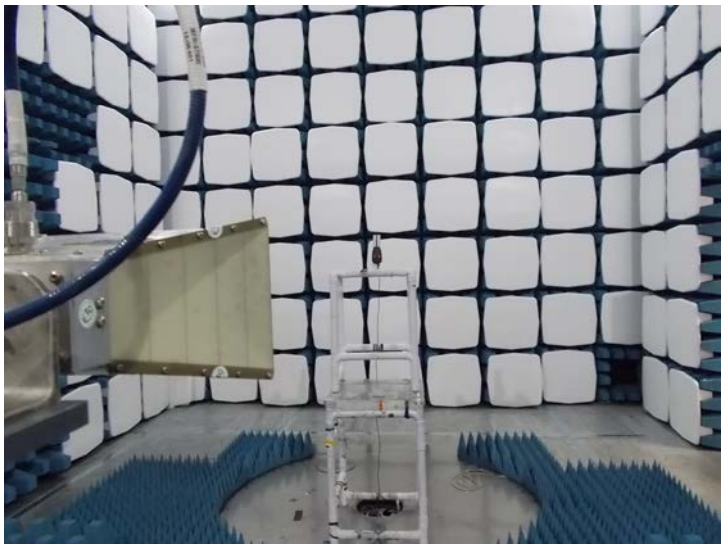
This field strength value is then compared with the regulatory limit.

**Figure i Test Setup**



### *11.5 Test Set-up Photograph*



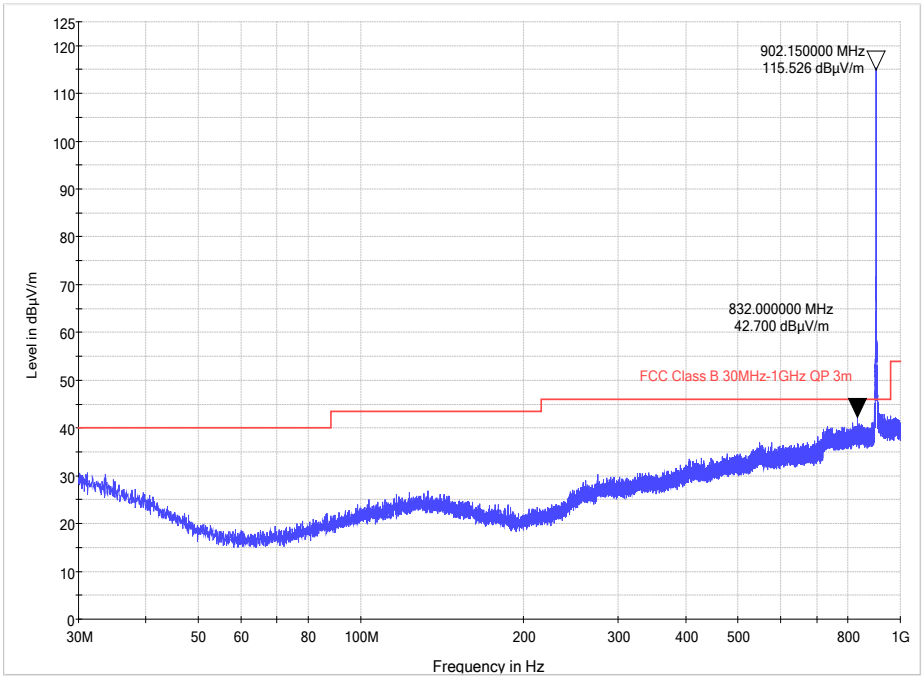


### *11.6 Test Equipment*

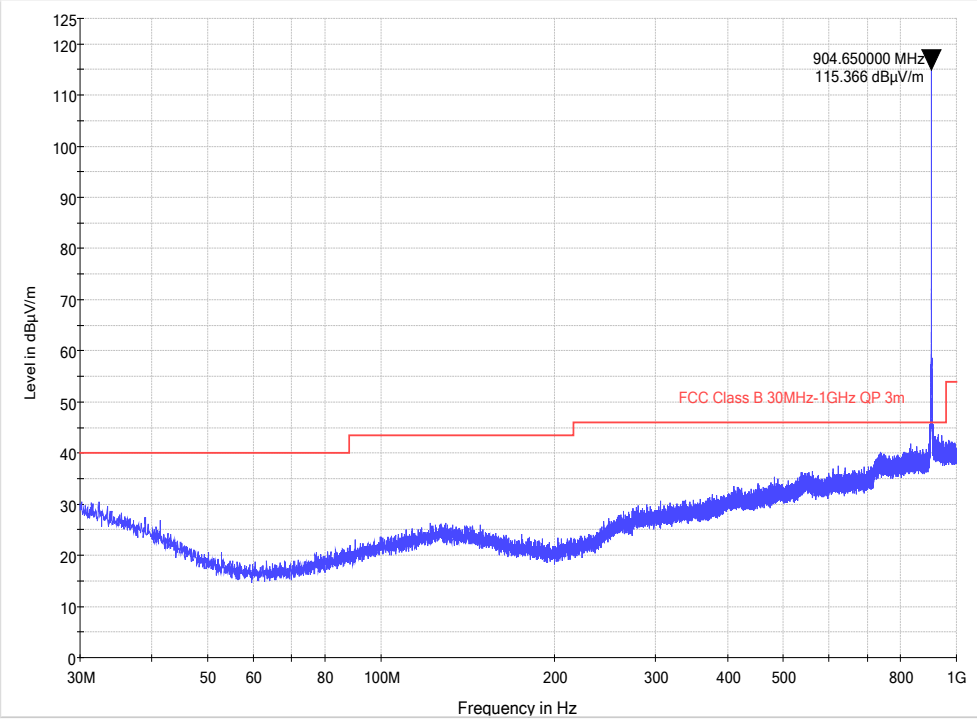
| Equipment Type | Manufacturer | Equipment Description | Element No | Due For Calibration |
|---|---|---|---|---|
| CBL6112B | Chase | Bilog | U093 | 17/06/2017 |
| ESVS10 | R&S | Receiver | L352 | 07/08/2016 |
| ATS | Rainford EMC | Radio Chamber - PP | REF940 | 08/09/2016 |
| 3115 | EMCO | 1-18GHz Horn | L139 | 25/09/2017 |
| FSU46 | R&S | Spectrum Analyser | U281 | 24/04/2016 |
| 8449B | Agilent | Pre Amp | L572 | 16/02/2017 |
| SH4141 | BSC | High Pass Filter | REF977 | 25/02/2017 |

## *11.7 Test Results*

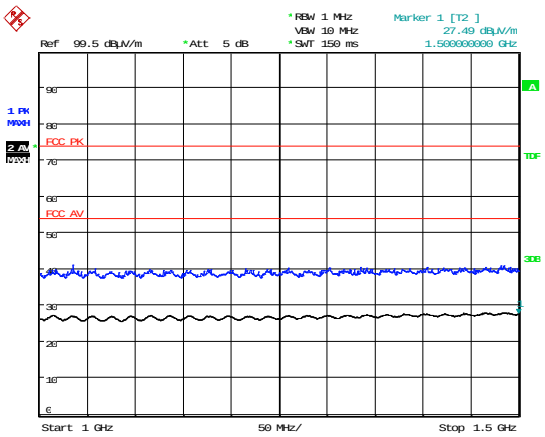
Tx bottom 30MHz-1GHz




Tx Top 30MHz-1GHz

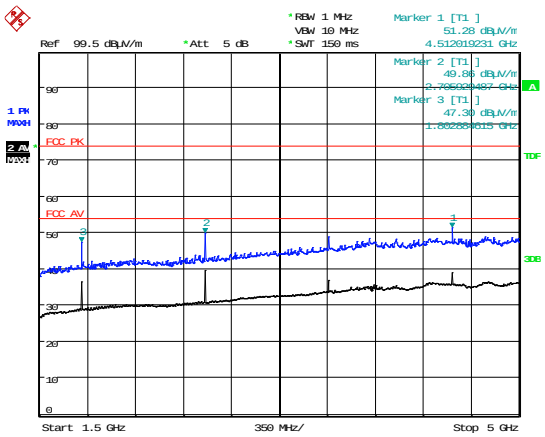


Bottom 1-1.5GHz




Date: 1.APR.2016 10:30:11

Bottom 1.5 - 5GHz

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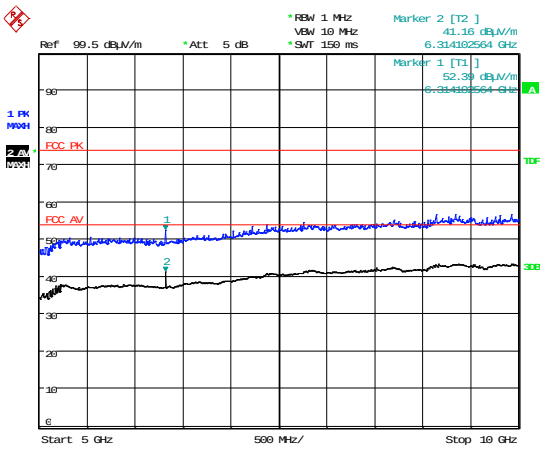


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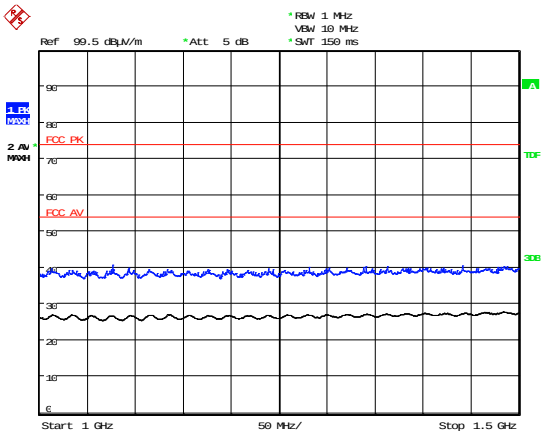
Bottom 5-10GHz

Top 1-1.5GHz

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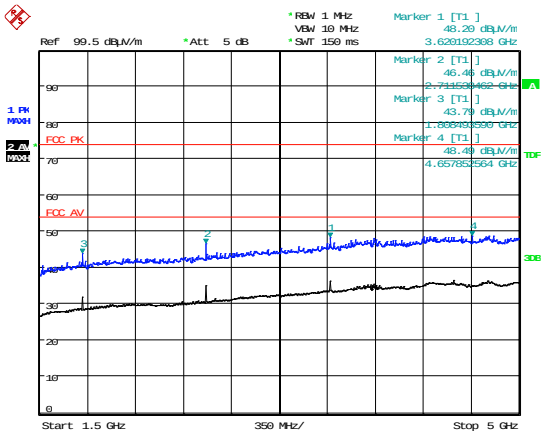
Top 1.5-5GHz

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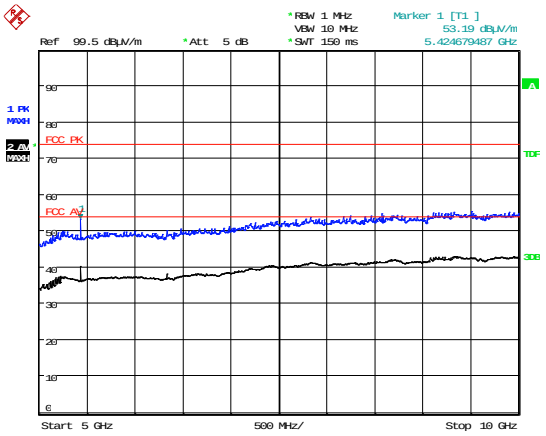


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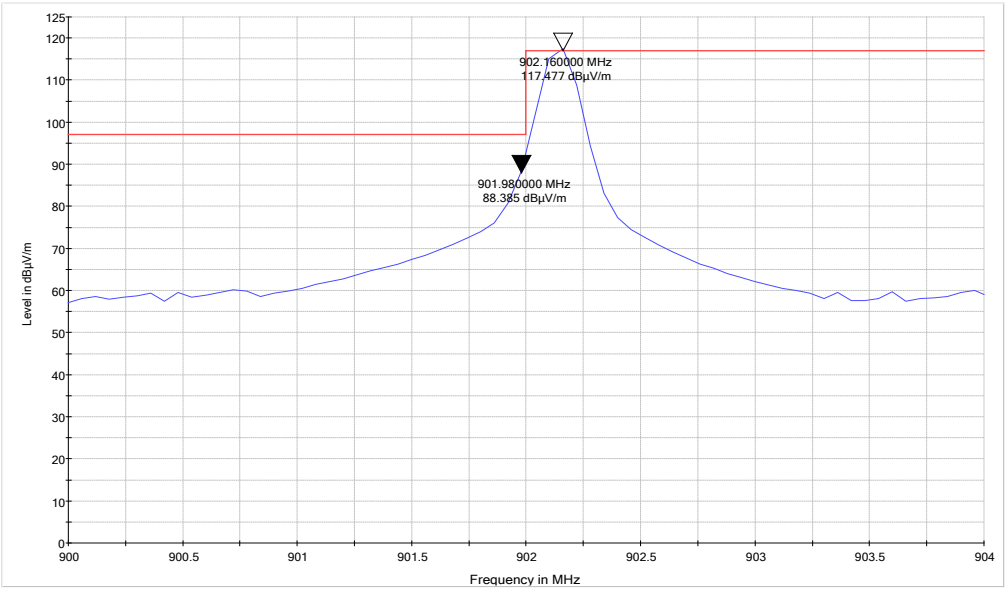
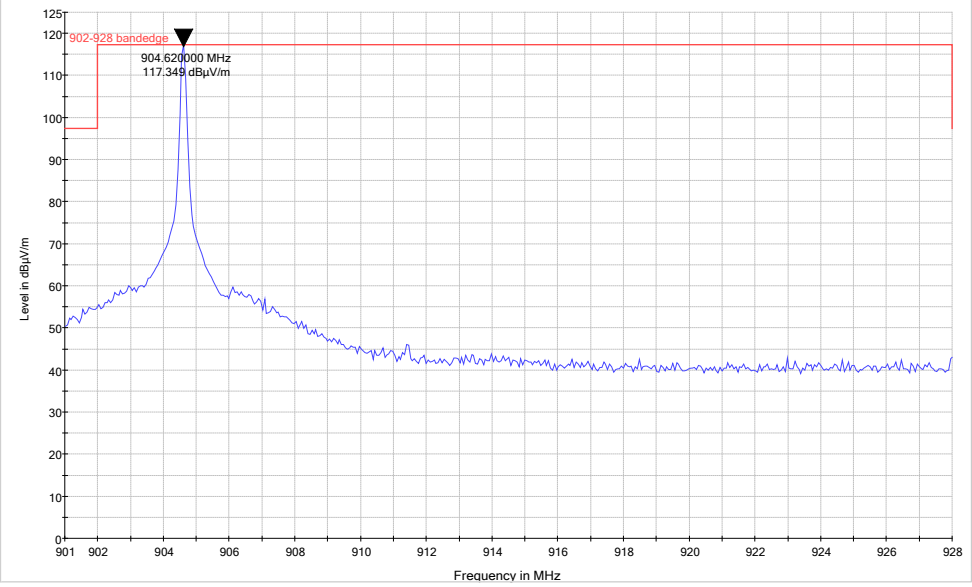
Top 5-10GHz

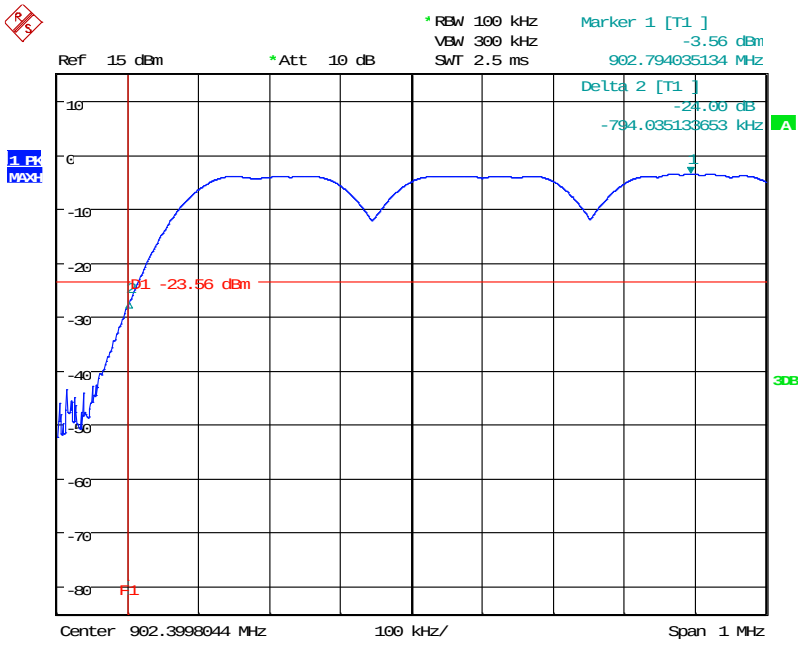
Lower bandedge Hopping mode disabled




Upper bandedge hopping mode disabled



## Lower Bandedge Hopping

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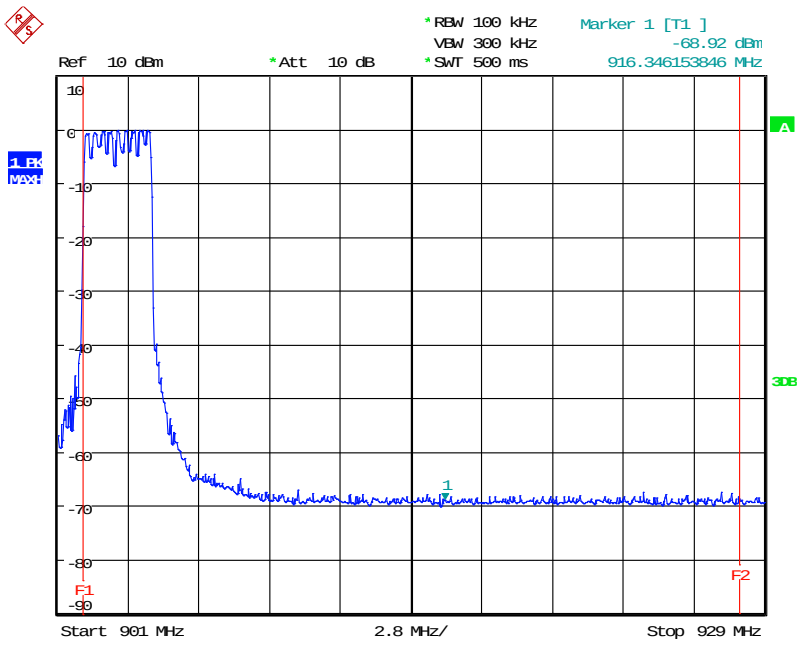
## Upper Bandedge Hopping

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| MaxPower; low 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 | 2706.420 | 56.46 | 3.2 | 28.9 | 36.1 | N/A | N/A | 53.90 | 495.45 | 5011 |
| Av | 2706.420 | 50.65 | 3.2 | 28.9 | 36.1 | N/A | N/A | 48.09 | 253.80 | 500 |
| Pk | 3608.525 | 53.19 | 3.7 | 31.5 | 35.7 | N/A | N/A | 53.15 | 454.46 | 5011 |
| Av | 3608.525 | 45.60 | 3.7 | 31.5 | 35.7 | N/A | N/A | 45.56 | 189.67 | 500 |
| Pk | 4510.663 | 53.12 | 4.2 | 32.3 | 35.7 | N/A | N/A | 54.09 | 506.41 | 5011 |
| Av | 4510.663 | 46.19 | 4.2 | 32.3 | 35.7 | N/A | N/A | 47.16 | 228.03 | 500 |
| Pk | 5412.792 | 49.95 | 4.6 | 34.4 | 35.9 | N/A | N/A | 53.45 | 470.44 | 5011 |
| Av | 5412.792 | 39.27 | 4.6 | 34.4 | 35.9 | N/A | N/A | 42.77 | 137.56 | 500 |
| Pk | 8119.26 | 49.41 | 5.9 | 37.1 | 5.9 | N/A | N/A | 56.55 | 672.20 | 5011 |
| Av | 8119.26 | 36.69 | 5.9 | 37.1 | 5.9 | N/A | N/A | 43.83 | 155.42 | 500 |
| Pk | 9021.366 | 327 | 6.2 | 37.7 | 36.4 | N/A | N/A | 57.47 | 747.31 | 5011 |
| Av | 9021.366 | 327 | 6.2 | 37.7 | 36.4 | N/A | N/A | 44.22 | 162.55 | 500 |

| Max Power top 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 | 2713.998 | 53.24 | 3.2 | 28.9 | 36.1 | N/A | N/A | 50.58 | 338.06 | 5011 |
| Av | 2713.998 | 45.69 | 3.2 | 28.9 | 36.1 | N/A | N/A | 43.03 | 141.74 | 500 |
| Pk | 3618.613 | 58.30 | 3.7 | 31.6 | 35.7 | N/A | N/A | 58.36 | 827.94 | 5011 |
| Av | 3618.613 | 52.92 | 3.7 | 31.6 | 35.7 | N/A | N/A | 52.98 | 445.66 | 500 |
| Pk | 4523.28 | 49.74 | 4.2 | 32.3 | 35.7 | N/A | N/A | 50.71 | 343.16 | 5011 |
| Av | 4523.28 | 39.12 | 4.2 | 32.3 | 35.7 | N/A | N/A | 40.09 | 101.04 | 500 |
| Pk | 5427.99 | 53.77 | 4.6 | 34.4 | 35.9 | N/A | N/A | 57.27 | 730.30 | 5011 |
| Av | 5427.99 | 46.28 | 4.6 | 34.4 | 35.9 | N/A | N/A | 49.78 | 308.32 | 500 |
| Pk | 8141.84 | 49.27 | 5.8 | 37.1 | 36.3 | N/A | N/A | 56.31 | 653.88 | 5011 |
| Av | 8141.84 | 37.71 | 5.8 | 37.1 | 36.3 | N/A | N/A | 44.75 | 172.78 | 500 |
| Pk | 9046.55 | 49.99 | 6.1 | 37.8 | 36.4 | N/A | N/A | 57.98 | 792.50 | 5011 |
| Av | 9046.55 | 38.09 | 6.1 | 37.8 | 36.4 | N/A | N/A | 46.08 | 201.37 | 500 |

# 12 AC power-line conducted emissions

## *12.1 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.

## *12.2 Test Parameters*

| | |
|---|---|
| Test Location: | Element Skelmersdale |
| Test Standard and Clause: | ANSI C63.10-2013, Clause 6.2 |
| EUT Channels / Frequencies Measured: | Mid |
| EUT Channel Bandwidths: | 21.826kHz |
| EUT Modulation: | BPSK |
| Deviations From Standard: | None |
| Measurement BW: | 10kHz |
| Measurement Detectors: | Quasi-Peak and Average, |

**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: 3.7V dc | Via battery (as declared) |

**Test Limit**

A radio apparatus that is designed to be connected 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.

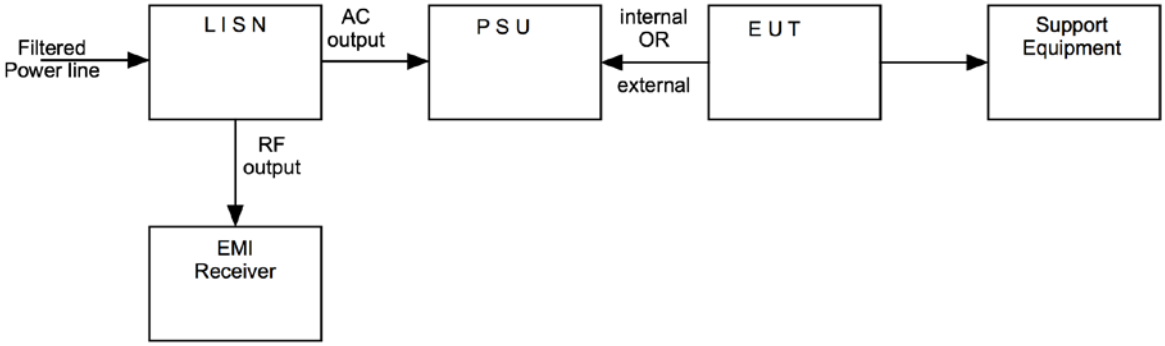
### *12.3 Test Method*

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**



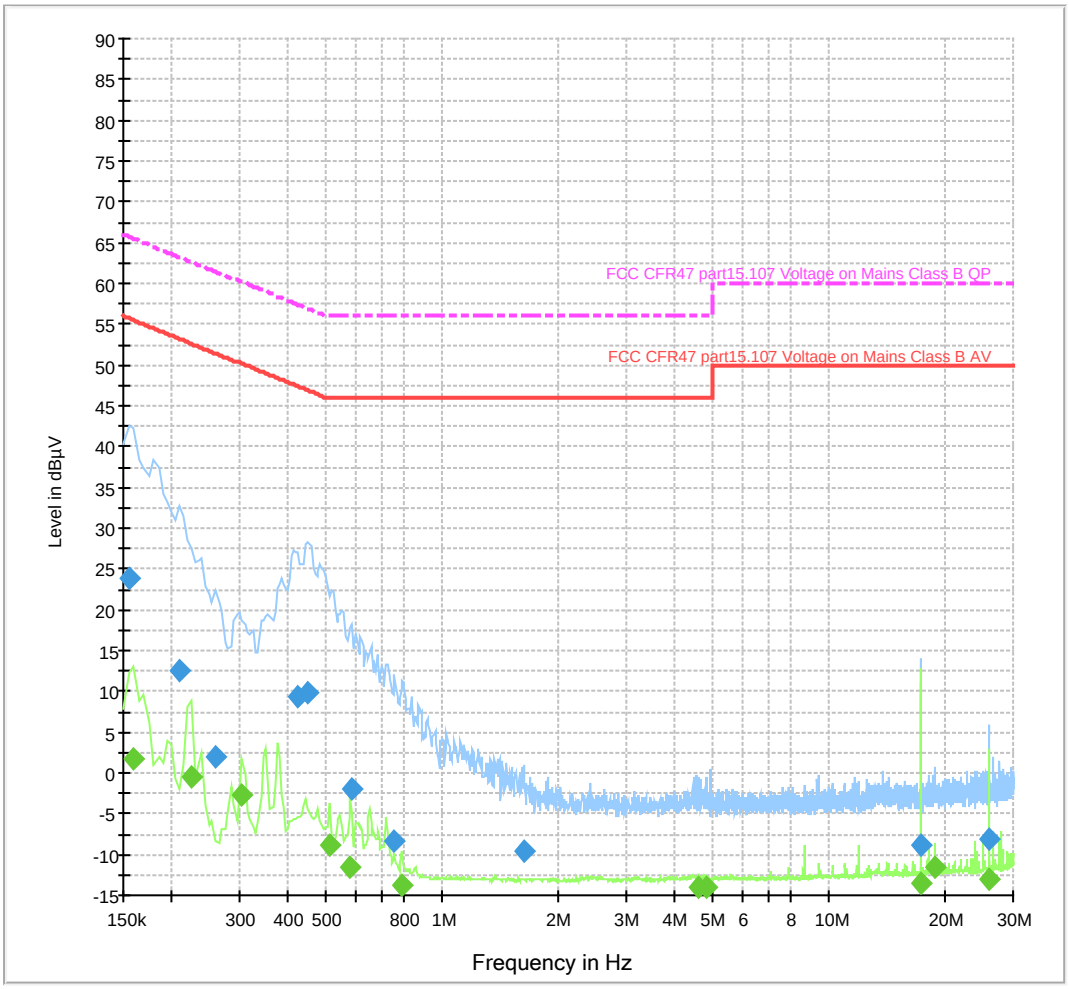

### *12.4 Test Set-up Photograph*

### *12.5 Test Equipment*

| Equipment Type | Manufacturer | Equipment Description | Element No | Due For Calibration |
|---|---|---|---|---|
| ENV216 | R&S | Lisn | UH396 | 01/07/2016 |
| ESHS10 | R&S | Receiver | U187 | 29/10/2016 |

## *12.6 Test Results*

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



| Frequency (MHz) | QuasiPeak (dBµV) | Meas. Time (ms) | Bandwidth (kHz) | Line | Corr. (dB) | Margin (dB) | Limit (dBµV) | Comment |
|---|---|---|---|---|---|---|---|---|
| 0.155000 | 23.9 | 5000.0 | 10.000 | N | 0.0 | 31.9 | 55.7 | Pass |
| 0.210000 | 12.5 | 5000.0 | 10.000 | N | 0.0 | 40.7 | 53.2 | Pass |
| 0.260000 | 2.1 | 5000.0 | 10.000 | N | 0.0 | 49.4 | 51.4 | Pass |
| 0.425000 | 9.3 | 5000.0 | 10.000 | N | 0.0 | 38.1 | 47.3 | Pass |
| 0.450000 | 10.0 | 5000.0 | 10.000 | N | 0.0 | 36.9 | 46.9 | Pass |
| 0.585000 | -1.9 | 5000.0 | 10.000 | N | 0.1 | 47.9 | 46.0 | Pass |
| 0.755000 | -8.4 | 5000.0 | 10.000 | N | 0.1 | 54.4 | 46.0 | Pass |
| 0.960000 | -15.9 | 5000.0 | 10.000 | N | 0.1 | 61.9 | 46.0 | Pass |
| 1.270000 | -18.0 | 5000.0 | 10.000 | N | 0.1 | 64.0 | 46.0 | Pass |
| 1.630000 | -9.6 | 5000.0 | 10.000 | L1 | 9.6 | 55.6 | 46.0 | Pass |
| 4.570000 | -18.7 | 5000.0 | 10.000 | N | 0.1 | 64.7 | 46.0 | Pass |
| 4.930000 | -19.2 | 5000.0 | 10.000 | N | 0.1 | 65.2 | 46.0 | Pass |
| 17.255000 | -18.4 | 5000.0 | 10.000 | N | 0.3 | 68.4 | 50.0 | Pass |
| 17.275000 | -8.8 | 5000.0 | 10.000 | L1 | 9.9 | 58.8 | 50.0 | Pass |
| 25.885000 | -8.1 | 5000.0 | 10.000 | L1 | 9.9 | 58.1 | 50.0 | Pass |

| Frequency (MHz) | Average (dBµV) | Meas. Time (ms) | Bandwidth (kHz) | Line | Corr. (dB) | Margin (dB) | Limit (dBµV) | Comment |
|---|---|---|---|---|---|---|---|---|
| 0.160000 | 1.8 | 5000.0 | 10.000 | N | 0.0 | 63.7 | 65.5 | Pass |
| 0.225000 | -0.5 | 5000.0 | 10.000 | N | 0.0 | 63.1 | 62.6 | Pass |
| 0.305000 | -2.8 | 5000.0 | 10.000 | L1 | 9.6 | 62.9 | 60.1 | Pass |
| 0.350000 | -18.8 | 5000.0 | 10.000 | N | 0.0 | 77.7 | 59.0 | Pass |
| 0.375000 | -17.4 | 5000.0 | 10.000 | N | 0.0 | 75.8 | 58.4 | Pass |
| 0.510000 | -8.9 | 5000.0 | 10.000 | L1 | 9.6 | 64.9 | 56.0 | Pass |
| 0.580000 | -11.6 | 5000.0 | 10.000 | L1 | 9.6 | 67.6 | 56.0 | Pass |
| 0.785000 | -13.7 | 5000.0 | 10.000 | L1 | 9.6 | 69.7 | 56.0 | Pass |
| 1.045000 | -23.9 | 5000.0 | 10.000 | N | 0.1 | 79.9 | 56.0 | Pass |
| 4.635000 | -13.9 | 5000.0 | 10.000 | L1 | 9.7 | 69.9 | 56.0 | Pass |
| 4.820000 | -14.1 | 5000.0 | 10.000 | L1 | 9.7 | 70.1 | 56.0 | Pass |
| 17.255000 | -23.3 | 5000.0 | 10.000 | N | 0.3 | 83.3 | 60.0 | Pass |
| 17.275000 | -13.6 | 5000.0 | 10.000 | L1 | 9.9 | 73.6 | 60.0 | Pass |
| 18.870000 | -11.6 | 5000.0 | 10.000 | L1 | 9.9 | 71.6 | 60.0 | Pass |
| 25.885000 | -12.9 | 5000.0 | 10.000 | L1 | 9.9 | 72.9 | 60.0 | Pass |

# 13 Carrier frequency separation

## *13.1 Definition*

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

## *13.2 Test Parameters*

| | |
|---|---|
| Test Location: | Element Skelmersdale |
| Test Chamber: | Radio Lab |
| Test Standard and Clause: | ANSI C63.10-2013, Clause 7.8.2 |
| EUT 20dB Bandwidth: | 21.826kHz |
| EUT Test Modulations: | Internal pattern generation – hopping enabled |
| Deviations From Standard: | None |
| Measurement BW: | 1kHz |
| Measurement Detector: | Peak |

**Environmental Conditions (Normal Environment)**

| | |
|---|---|
| Temperature: 24 °C | +15 ºC to +35 ºC (as declared) |
| Humidity: 36 % RH | 20 % RH to 75 % RH (as declared) |
| Supply: 3.7V dc | Via battery (as declared) |

## *13.3 Test Limit*

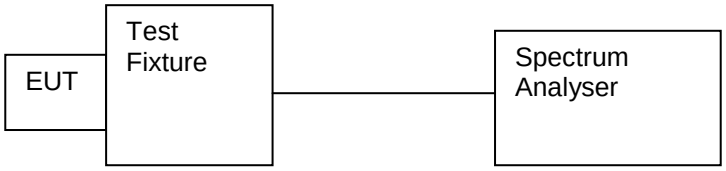
Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the -20 dB bandwidth of the hopping channel, whichever is greater. Alternatively, frequency hopping systems operating in the band 2400 to 2483.5 MHz may have hopping channel carrier frequencies 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.

### *13.4 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**

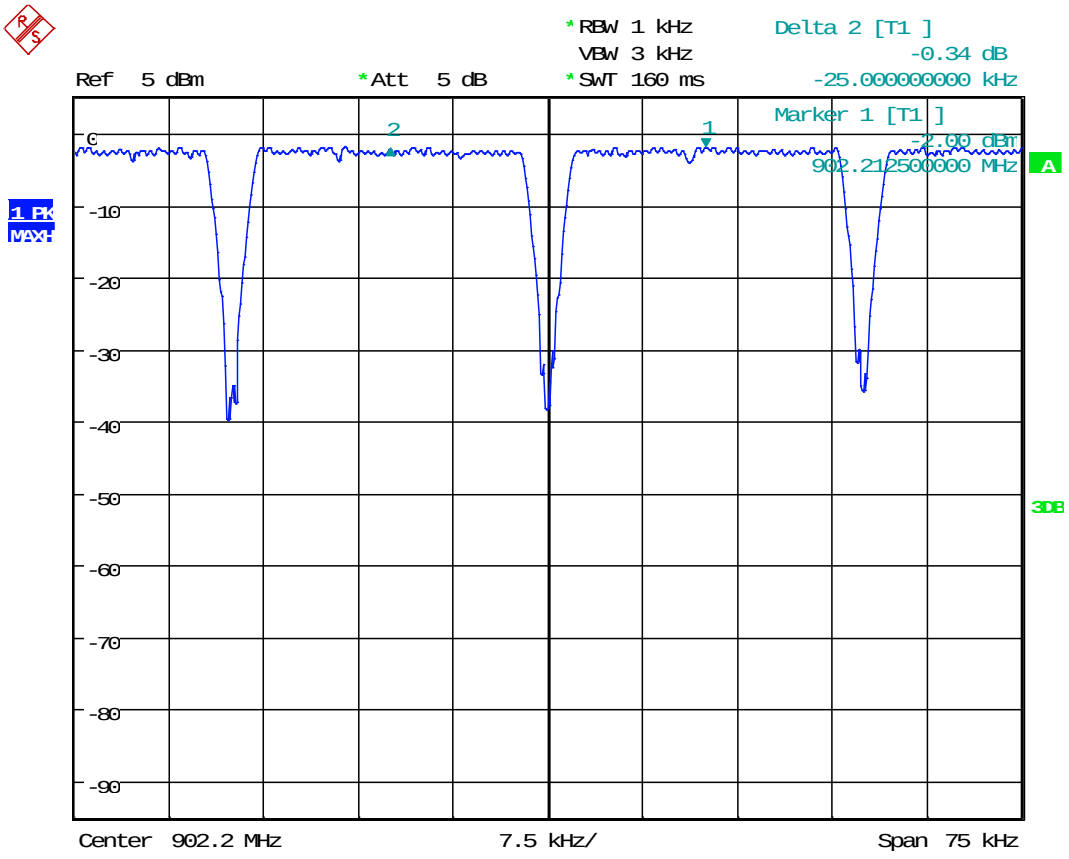



### *13.5 Test Equipment*

| Equipment Type | Manufacturer | Equipment Description | Element No | Due For Calibration |
|---|---|---|---|---|
| FSU46 | R&S | Spectrum Analyser | U281 | 24/04/2016 |

### *13.6 Test Results*

| ***Channel #: xx; Modulation: xx; Power setting: xx*** | | | | |
|---|---|---|---|---|
| ***Data Rate*** | ***$F1_c$ (MHz)*** | ***$F2_c$ (MHz)*** | ***Channel Separation, $F2_c - F1_c$ (kHz)*** | ***Result*** |
| 600bps | 902.2125 | 902.1875 | 25kHz | PASS |

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# 14 Number of hopping frequencies

## *14.1 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.

## *14.2 Test Parameters*

| | |
|---|---|
| Test Location: | Element Skelmersdale |
| Test Chamber: | Radio Lab |
| Test Standard and Clause: | ANSI C63.10-2013, Clause 7.8.3 |
| EUT Channels / Frequencies Measured: | All; 902 – 928MHz |
| EUT 20dB Bandwidth: | 21.62kHz |
| EUT Test Modulations: | Internal pattern generation – hopping enabled |
| Deviations From Standard: | None |
| Measurement BW: | 10kHz/1kHz |
| Measurement Detector: | Peak |

**Environmental Conditions (Normal Environment)**

| | |
|---|---|
| Temperature: 23 °C | +15 ºC to +35 ºC (as declared) |
| Humidity: 36 % RH | 20 % RH to 75 % RH (as declared) |
| Supply: 3.7V dc | Via battery (as declared) |

## *14.3 Test Limit*

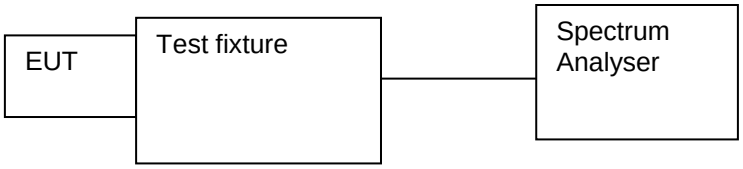
- For frequency hopping systems in the band 902 to 928 MHz: if the -20 dB bandwidth of the hopping channel is less than 250 kHz, the system shall use at least 50 hopping channels; If the -20 dB bandwidth of the hopping channel is 250 kHz or greater, the system shall use at least 25 hopping channels;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

### *14.4 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**




### *14.5*

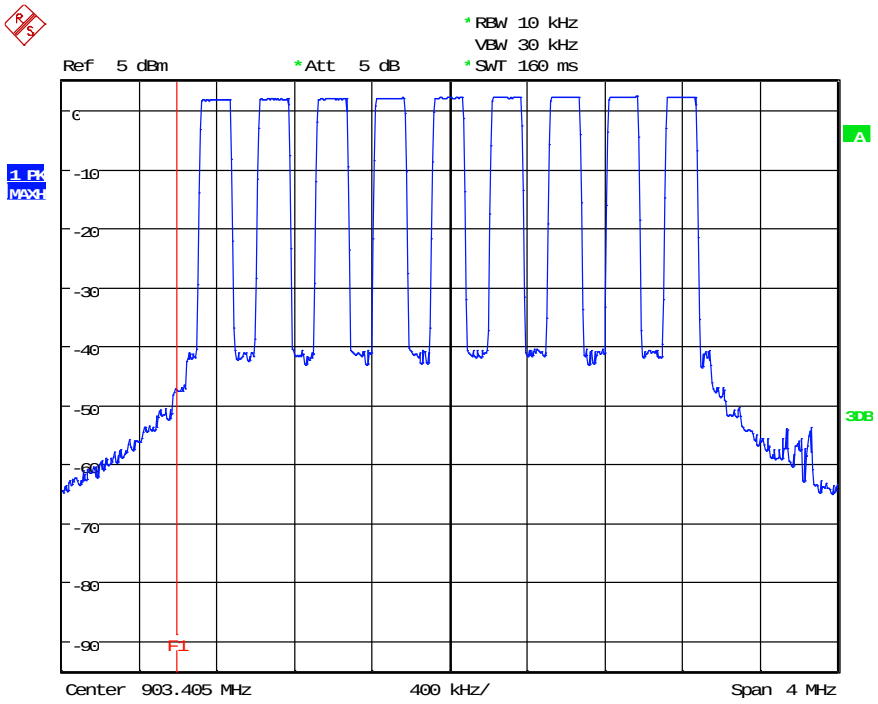
### *14.6*

### *14.7 Test Equipment*

| Equipment Type | Manufacturer | Equipment Description | Element No | Due For Calibration |
|---|---|---|---|---|
| FSU46 | R&S | Spectrum Analyser | U281 | 24/04/2016 |

### *14.8 Test Results*

| ***Lowest channel, $F_{CL}$ (MHz)*** | ***Highest channel, $F_{CH}$ (MHz)*** | ***Number of channels observed*** | ***Result*** |
|---|---|---|---|
| 902.1375 | 904.6625 | 54 | PASS |

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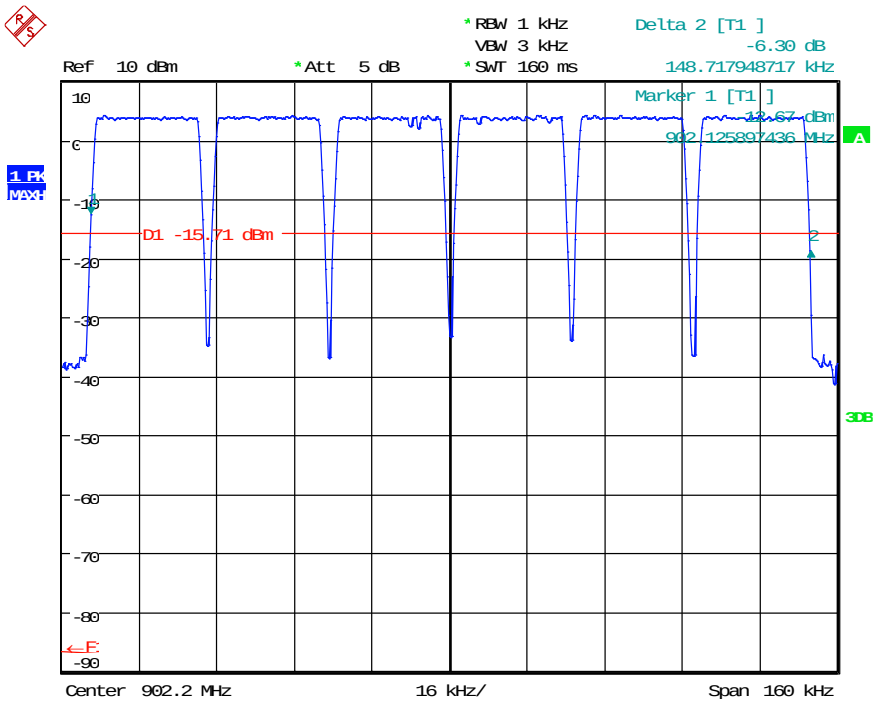
6 micro channels

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# 15 Average channel occupancy

## *15.1 Definition*

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

## *15.2 Test Parameters*

| | |
|---|---|
| Test Location: | Element Skelmersdale |
| Test Chamber: | Radio Lab |
| Test Standard and Clause: | ANSI C63.10-2013, Clause 7.8.4 |
| EUT Channels / Frequencies Measured: | Mid |
| EUT 20dB bandwidth: | 21.826kHz |
| EUT Number of hopping channels: | 54 |
| EUT Test Modulations: | Internal pattern generation – hopping enabled |
| Deviations From Standard: | None |
| Measurement Detector: | Peak |

**Environmental Conditions (Normal Environment)**

| | |
|---|---|
| Temperature: 24 °C | +15 ºC to +35 ºC (as declared) |
| Humidity: 36 % RH | 20 % RH to 75 % RH (as declared) |
| Supply: 3.7V dc | Via battery (as declared) |

## *15.3 Test Limit*

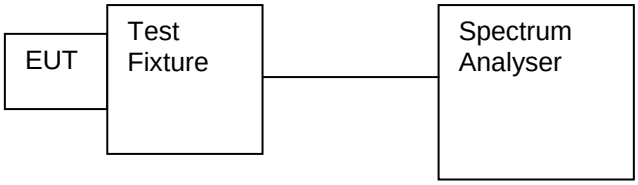
- For frequency hopping systems in the band 902 to 928 MHz: if the -20 dB bandwidth of the hopping channel is less than 250 kHz, the average time of occupancy on any channel shall not be greater than 0.4 seconds within a 20 second period;
  If the -20 dB bandwidth of the hopping channel is 250 kHz or 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.

### *15.4 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**

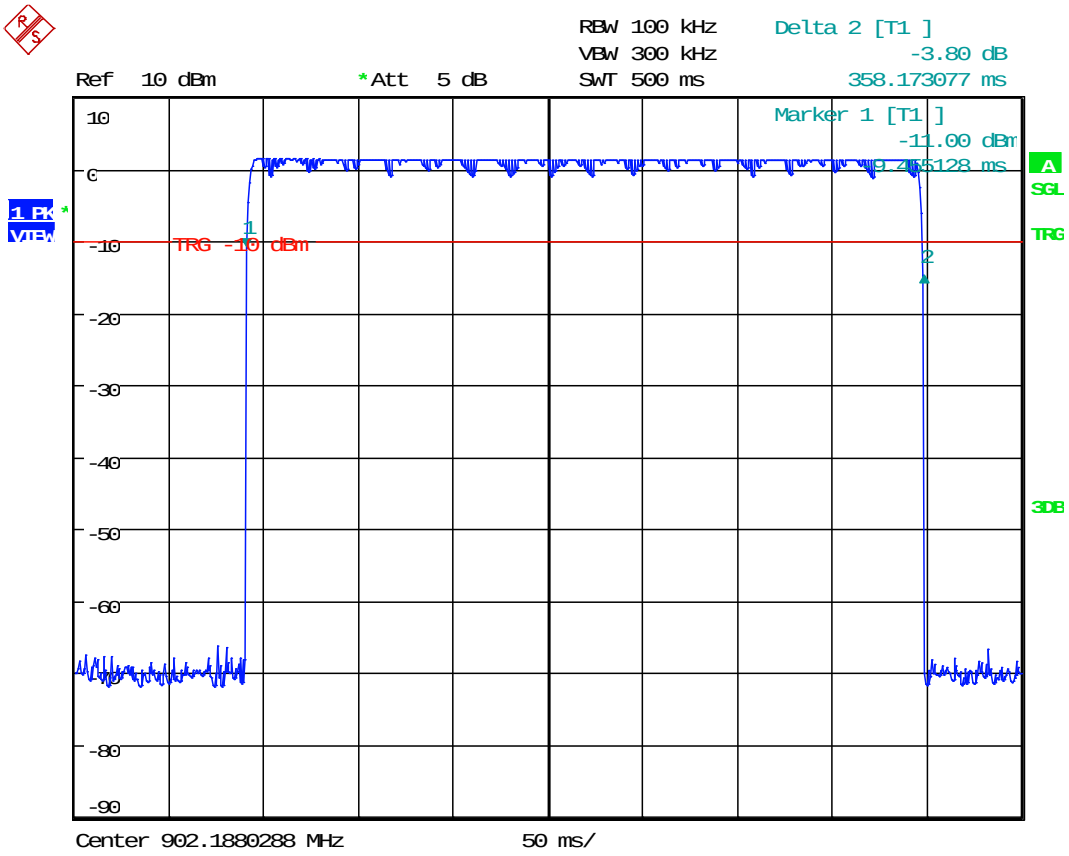



### *15.5 Test Equipment*

| Equipment Type | Manufacturer | Equipment Description | Element No | Due For Calibration |
|---|---|---|---|---|
| FSU46 | R&S | Spectrum Analyser | U281 | 24/04/2016 |

### *15.6 Test Results*

| ***Modulation BPSK ; Power setting: Max*** | | | | | |
|---|---|---|---|---|---|
| ***Data Rate*** | ***Individual occupancy time (ms)*** | ***Observation period (s)*** | ***Number of hops observed*** | ***Average time of occupancy (ms)*** | ***Result*** |
| 600 | 358.17 | 20 | 1 | 358.17 | PASS |

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# 16 Maximum peak conducted output power

## *16.1 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.

## *16.2 Test Parameters*

| | |
|---|---|
| Test Location: | Element Skelmersdale / Element Hull |
| Test Chamber: | Radio Lab |
| Test Standard and Clause: | ANSI C63.10-2013, Clause 7.8.5 |
| EUT Channels / Frequencies Measured: | Low / High – hopping disabled. |
| EUT Channel Bandwidths: | 21.826MHz |
| Deviations From Standard: | None |
| Measurement BW: | 100kHz |
| Spectrum Analyzer Video BW: | N/A |
| Measurement Detector: | Peak |
| Voltage Extreme Environment Test Range: | Mains Power = 85 % and 115 % of Nominal (FCC only requirement);<br>Battery Power = new battery. |

**Environmental Conditions (Normal Environment)**

| | |
|---|---|
| Temperature: 24 °C | +15 ºC to +35 ºC (as declared) |
| Humidity: 36 % RH | 20 % RH to 75 % RH (as declared) |

## *16.3 Test Limit*

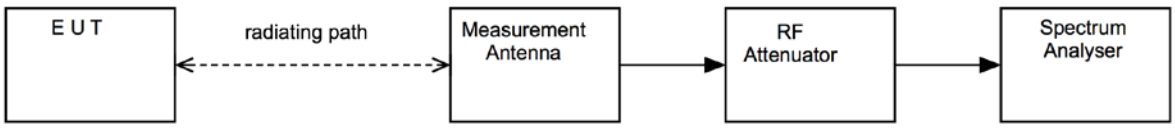
- For frequency hopping systems operating in the band 902 to 928 MHz, the maximum peak conducted output power shall not exceed 1 W, and the e.i.r.p. shall not exceed 4 W, if the hopset uses 50 or more hopping channels;
  the maximum peak conducted output power shall not exceed 0.25 W, and the e.i.r.p. 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
  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.

### *16.4 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**




### *16.5 Test Equipment*

| Equipment Type | Manufacturer | Equipment Description | Element No | Due For Calibration |
|---|---|---|---|---|
| CBL6112B | Chase | Bilog | U093 | 17/06/2017 |
| ESVS10 | R&S | Receiver | L317 | 11/03/2017 |
| ATS | Rainford EMC | Radio Chamber - PP | REF940 | 08/09/2016 |

### *16.6 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.

| ***Modulation: bpsk; Data rate: 600; Power setting: Max*** | | | | | | | |
|---|---|---|---|---|---|---|---|
| ***Channel Frequency (MHz)*** | ***Peak Field Strength (dBµV/m)*** | ***Peak Field Strength (V/m)*** | ***Distance (m)*** | ***Antenna Gain ()*** | ***E.I.R.P. (W)*** | ***Maximum output power (W)*** | ***Result*** |
| 902.1375 | 120.1 | 1.011579 | 3 | 0 | .306902 | 4 | PASS |
| 904.6625 | 119.0 | 0.891250 | 3 | 0 | .238297 | 4 | PASS |

# 17 Occupied Bandwidth

## *17.1 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.

## *17.2 Test Parameters*

| | |
|---|---|
| Test Location: | Element Skelmersdale |
| Test Chamber: | Radio Lab |
| Test Standard and Clause: | ANSI C63.10-2013, Clause 6.9 |
| EUT Channels / Frequencies Measured: | 902.2125MHz |
| EUT Channel Bandwidths: | 21.826kHz |
| Deviations From Standard: | None |
| Measurement BW:<br>(requirement: 1 % to 5 % OBW) | 300Hz |
| Spectrum Analyzer Video BW:<br>(requirement at least 3x RBW) | 1kHz |
| Measurement Span:<br>(requirement 2 to 5 times OBW) | See note 1 |
| Measurement Detector: | Peak |

**Environmental Conditions (Normal Environment)**

| | |
|---|---|
| Temperature: 24 °C | +15 ºC to +35 ºC (as declared) |
| Humidity: 36 % RH | 20 % RH to 75 % RH (as declared) |
| Supply: 3.7V dc | Via battery (as declared) |

## *17.3 Test Limit*

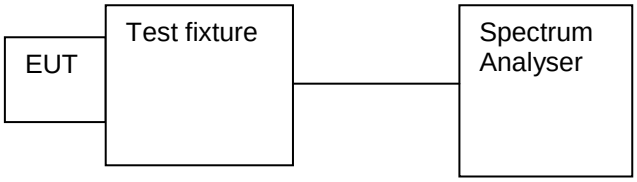
- For frequency hopping systems in the band 902 to 928 MHz: The maximum allowed -20 dB bandwidth of the hopping channel is 500 kHz.
- Frequency hopping systems operating in the band 5725 to 5850 MHz: The maximum -20 dB bandwidth of the hopping channel shall be 1 MHz

### *17.4 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**

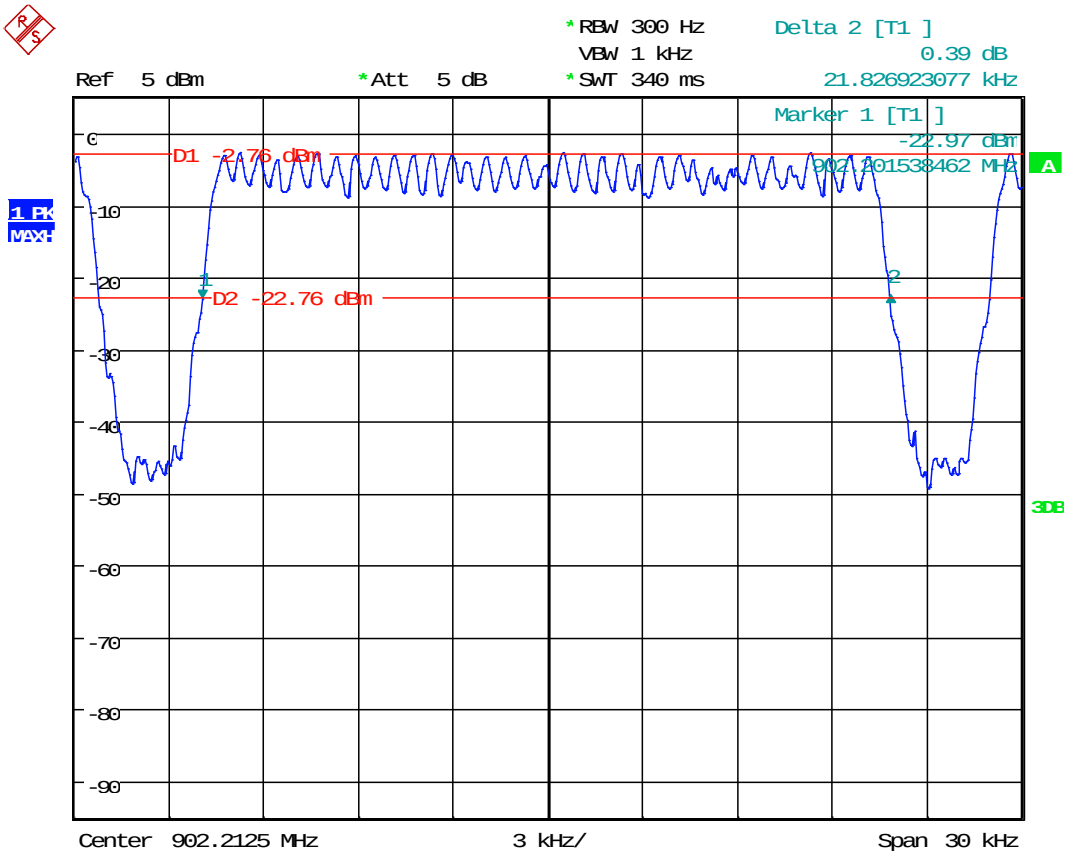



### *17.5 Test Equipment*

| Equipment Type | Manufacturer | Equipment Description | Element No | Due For Calibration |
|---|---|---|---|---|
| FSU46 | R&S | Spectrum Analyser | U281 | 24/04/2016 |

### *17.6 Test Results*

| ***Modulation: D-BPSK; Data rate: 600BPS; Power setting: Max*** | | | | |
|---|---|---|---|---|
| ***Channel Frequency (MHz)*** | ***$F_L$ (MHz)*** | ***$F_H$ (MHz)*** | ***20dB Bandwidth (kHz)*** | ***Result*** |
| 902.201500 | 902.201538 | 902.223364 | 21.826 | PASS |

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# 18 Radiated emissions – unintentional radiation / receiver emissions

## *18.1 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.

## *18.2 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: | Low / Mid / High |
| EUT Channel Bandwidths: | 21.826kHz |
| Deviations From Standard: | None |
| Measurement BW: | 30 MHz to 1 GHz: 120 kHz<br>Above 1 GHz: 1 MHz |
| Measurement Detector: | Up to 1 GHz: quasi-peak<br>Above 1 GHz: Peak |

**Environmental Conditions (Normal Environment)**

| | |
|---|---|
| Temperature: 23 °C | +15 ºC to +35 ºC (as declared) |
| Humidity: 37 % RH | 20 % RH to 75 % RH (as declared) |
| Supply: 3.7 Vdc | 230 V ac ±10 % (as declared) |

## *18.3 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**

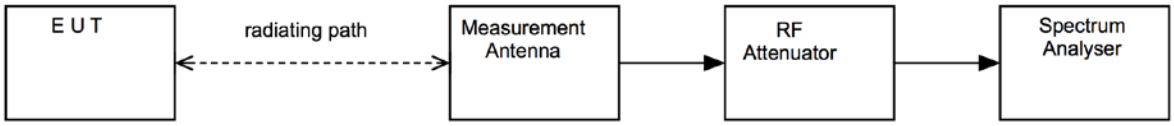
| ***Frequency (MHz)*** | ***Field Strength (µV/m at 3 m)*** |
|---|---|
| 30 to 88 | 100 |
| 88 to 216 | 150 |
| 216 to 960 | 200 |
| Above 960 | 500 |

### *18.4 Test Method*

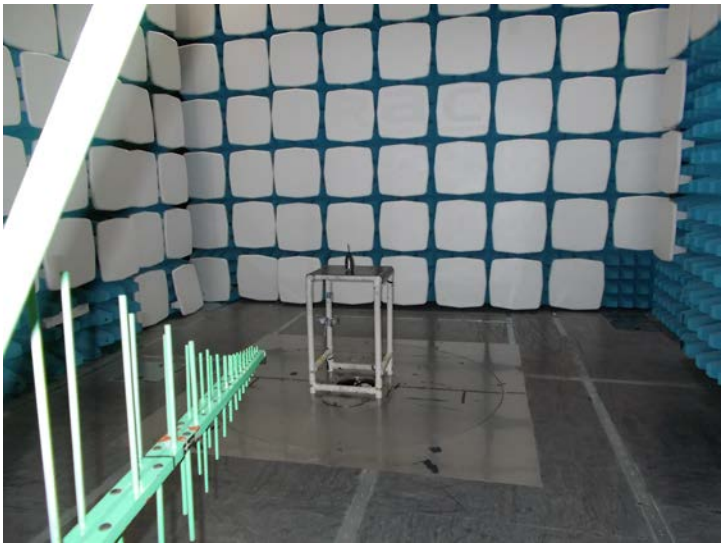
With the EUT setup as per section 9 of this report and connected as per Figure viii, the emissions from the EUT were measured on a spectrum analyzer / EMI receiver. The EUT was rotated in three orthogonal planes and the measurement antenna height scanned (below 1 GHz, from 1 to 4 m; above 1 GHz as necessary)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

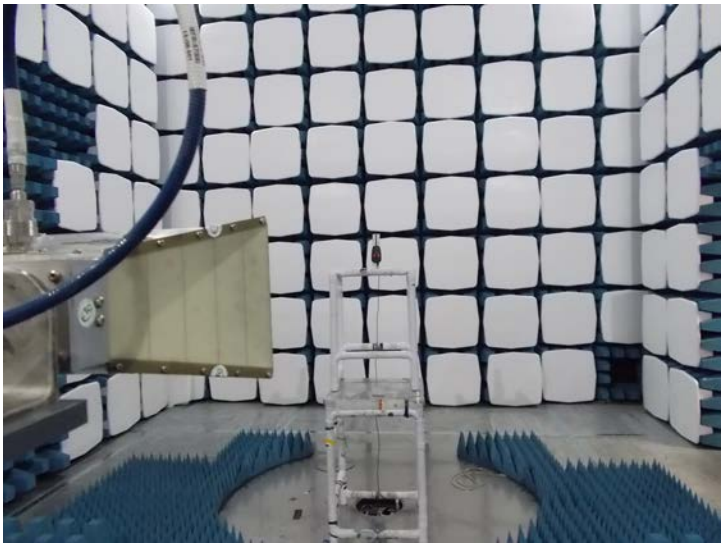
The measurements were performed with EUT set at its maximum duty. All modulation schemes, data rates and power settings were used to observe the worst-case configuration at each frequency. Pre-scan plots are shown with a peak detector and 100 kHz RBW.

**Figure viii Test Setup**




### *18.5 Test Set-up Photograph*



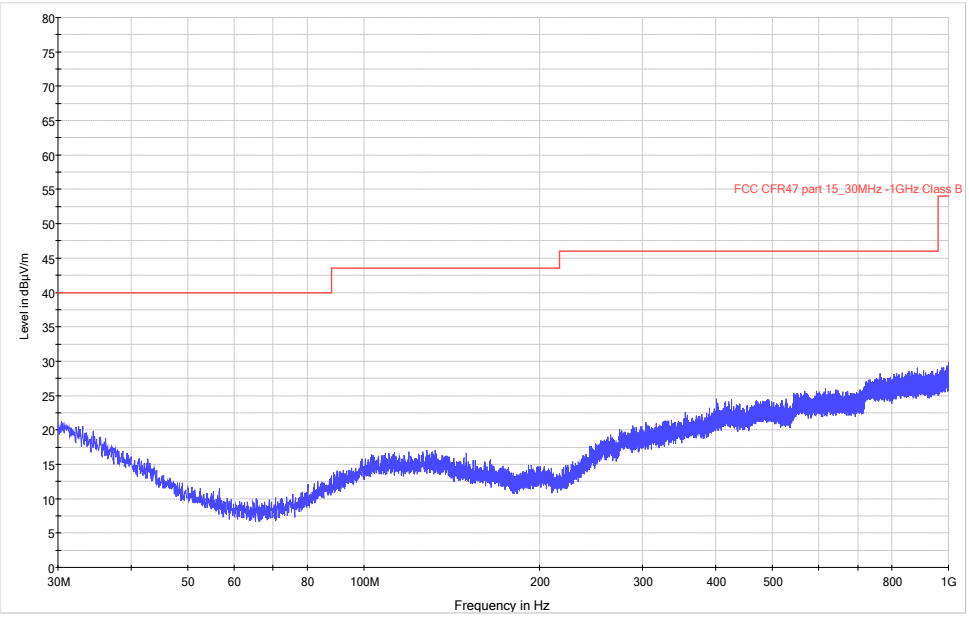


### *18.6 Test Equipment*

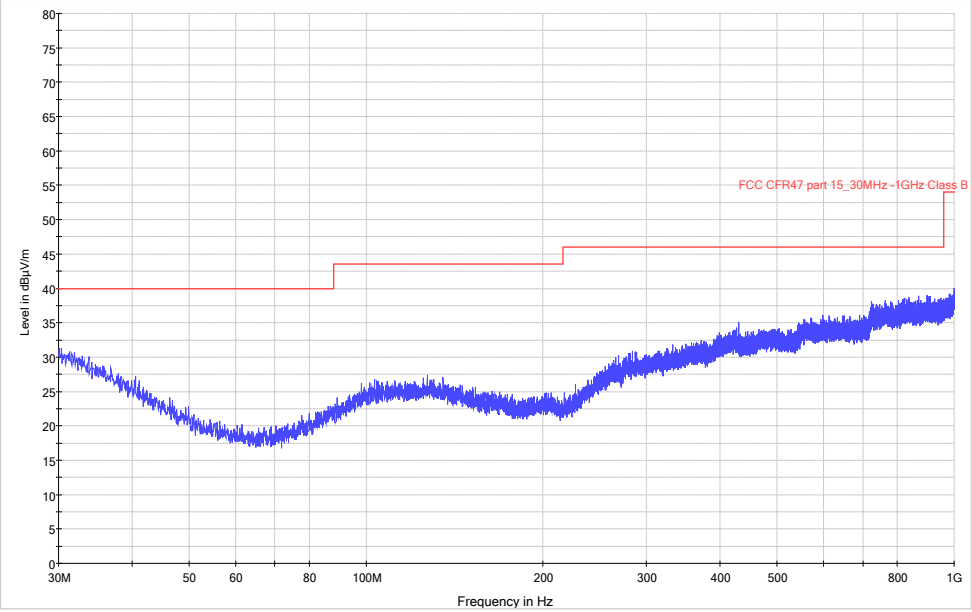
| Equipment Type | Manufacturer | Equipment Description | Element No | Due For Calibration |
|---|---|---|---|---|
| CBL6112B | Chase | Bilog | U093 | 17/06/2017 |
| ESVS10 | R&S | Receiver | L352 | 07/08/2016 |
| ATS | Rainford EMC | Radio Chamber - PP | REF940 | 08/09/2016 |
| 3115 | EMCO | 1-18GHz Horn | L139 | 25/09/2017 |
| FSU46 | R&S | Spectrum Analyser | U281 | 24/04/2016 |
| 8449B | Agilent | Pre Amp | L572 | 16/02/2017 |
| SH4141 | BSC | High Pass Filter | REF977 | 25/02/2017 |

### *18.7 Test Results*

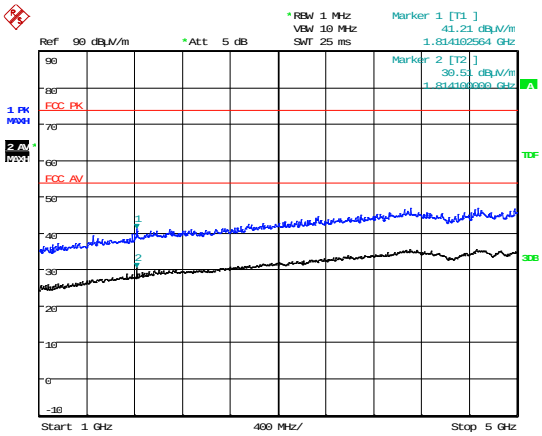
Rx bottom channel 30MHz -1GHz




Rx top channel 30MHz -1GHz

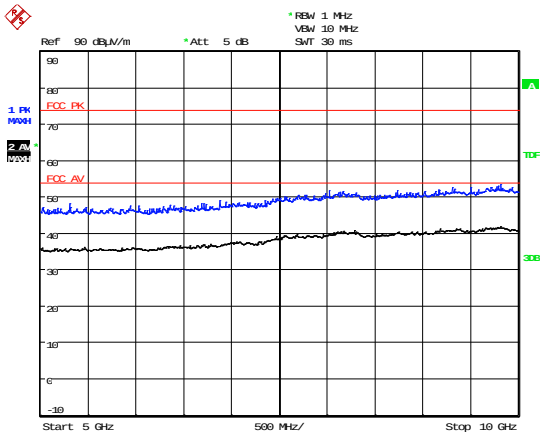


## Rx bottom 1-5GHz



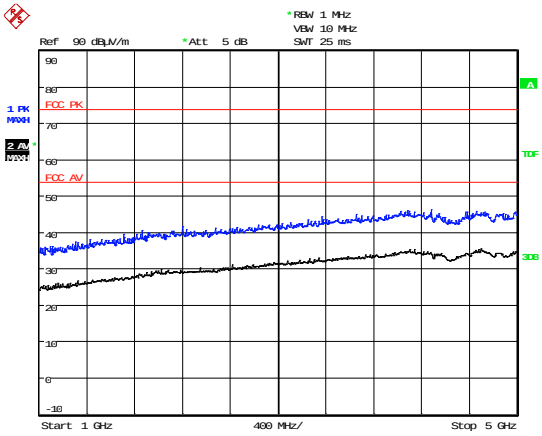

Date: 16.FEB.2016 10:21:38

## Rx bottom 5-10GHz



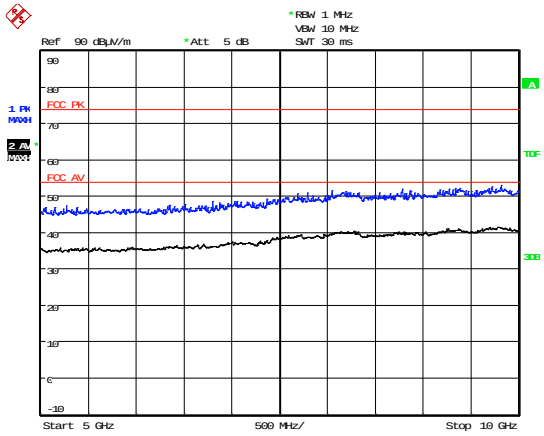

Date: 16.FEB.2016 10:23:40

## Rx top 1-5GHz




Date: 16.FEB.2016 10:40:28

## Rx top 5-10GHz




Date: 16.FEB.2016 10:41:27

| *Rx bottom channel* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ***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)*** |
| No Significant emissions | | | | | | | | | |

| *Rx top channel* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ***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)*** |
| No Significant emissions | | | | | | | | | |

# 19 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 %**