Report on the Radio Testing

For

Telecom Design S.A.

on

Modem for ITU Region 2

Report no. TRA-030878-47-00A

6th July 2016

Report Number: TRA-030878-47-00A
Issue: A

REPORT ON THE RADIO TESTING OF A
Telecom Design S.A.
Modem for ITU Region 2
WITH RESPECT TO SPECIFICATION
FCC 47CFR 15.247

TEST DATE: 14th April - 13th May 2016

Written by: D Winstanley

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D Winstanley
Radio Test Engineers

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J Charters
Department Manager - Radio

Date: 6th July 2016

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1 Revision Record

Issue Number	*Issue Date*	*Revision History*
A	6th July 2016	Original

2 Summary

TEST REPORT NUMBER:	TRA-030878-47-00A
WORKS ORDER NUMBER	TRA-030878-00
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):	Modem for ITU Region 2
FCC IDENTIFIER:	2AGMK-TD1508
EUT SERIAL NUMBER:	76214, 7622B, 761DC, 761FB
MANUFACTURER/AGENT:	Telecom Design S.A.
ADDRESS:	2 bis rue Nully de Harcourt 33610 CANEJAN FRANCE
CLIENT CONTACT:	Michel Stempin ☎ +33(0)557356386 ✉ mstempin@telecomdesign.fr
ORDER NUMBER:	Not Applicable
TEST DATE:	14th April - 13th May 2016
TESTED BY:	A Longley D Winstanley Element

2.1 Test Summary

Test Method and Description	*Requirement Clause m 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*
Out-of-band emissions	15.247(d)	☒	*Pass*
Unintentional Radiated Spurious Emissions	15.105	☒	*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-030878-47-00A presents the results of the Radio testing on a Telecom Design S.A.Modem for ITU Region 2 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 Telecom Design S.A.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.
- 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: Modem for ITU Region 2
- Serial Number: 76214, 7622B, 761DC, 761FB
- Model Number: TD1508
- Software Revision: SOFT1963
- Build Level / Revision Number: Production

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 EUT was programmed using command sequences sent via terminal program. Operating modes consisted of

CW – Fixed Frequency
Modulated Carrier - Fixed Frequency
Hopping over all channels
Hopping over a limited range of channels.

7.3.2 Reception

The mode of operation for Rx tests was as follows…

Permanent RX mode – Fixed Frequency

7.4 EUT Radio Parameters

7.4.1 General

Frequency of operation:	902.2 MHz – 904.6 MHz
Modulation type(s):	FHSS
Occupied channel bandwidth(s):	21.7 kHz
Channel spacing:	25 kHz
ITU emission designator(s):	Not Stated
Declared output power(s):	+25 dBm
Nominal Supply Voltage:	3.3 Vdc (regulated from USB)

7.4.2 Antennas

Type:	Dipole
Frequency range:	868 MHz
Impedance:	50 Ohm
SWR:	<= 2.0 @868 MHz
Gain:	2.0±0.7dBi @ 868 MHz
Polarisation:	Linear
Beam width:	Not Applicable
Connector type:	SMA Male
Environmental limits:	- 40 °C ~ + 65 °C
Mounting:	Screw on

7.4.3 Product specific declarations

Multiple antenna configuration(s), e.g. MIMO:	***N/A***
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 FHSS radio module operating in the 902 - 928 MHz band. The EUT is designed to utilise the Sigfox network.

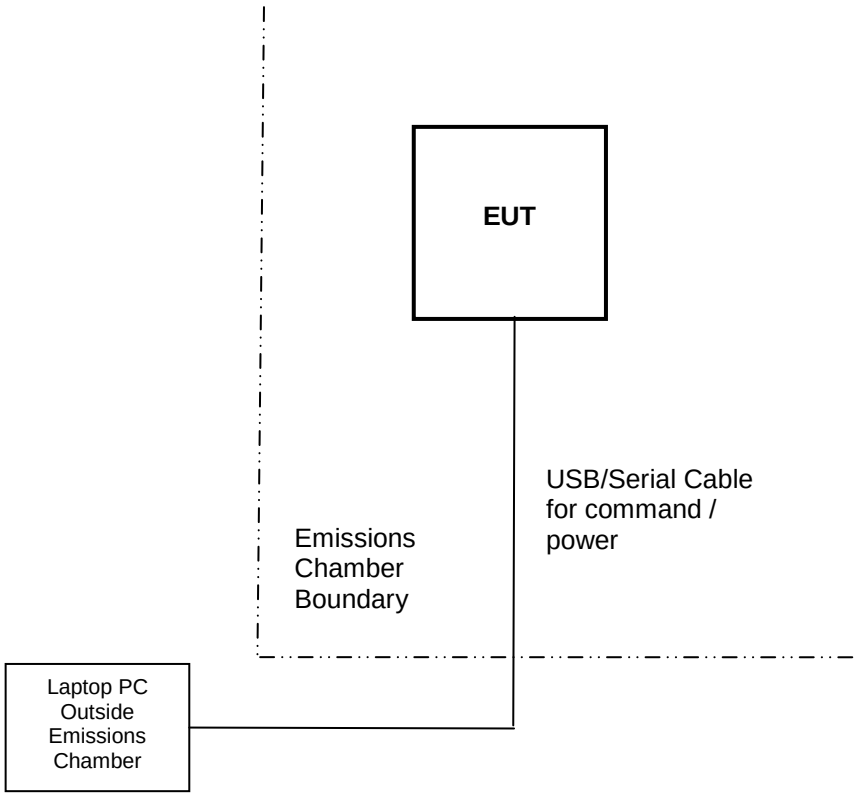
8 Modifications

No modifications were performed during this assessment.

9 EUT Test Setup

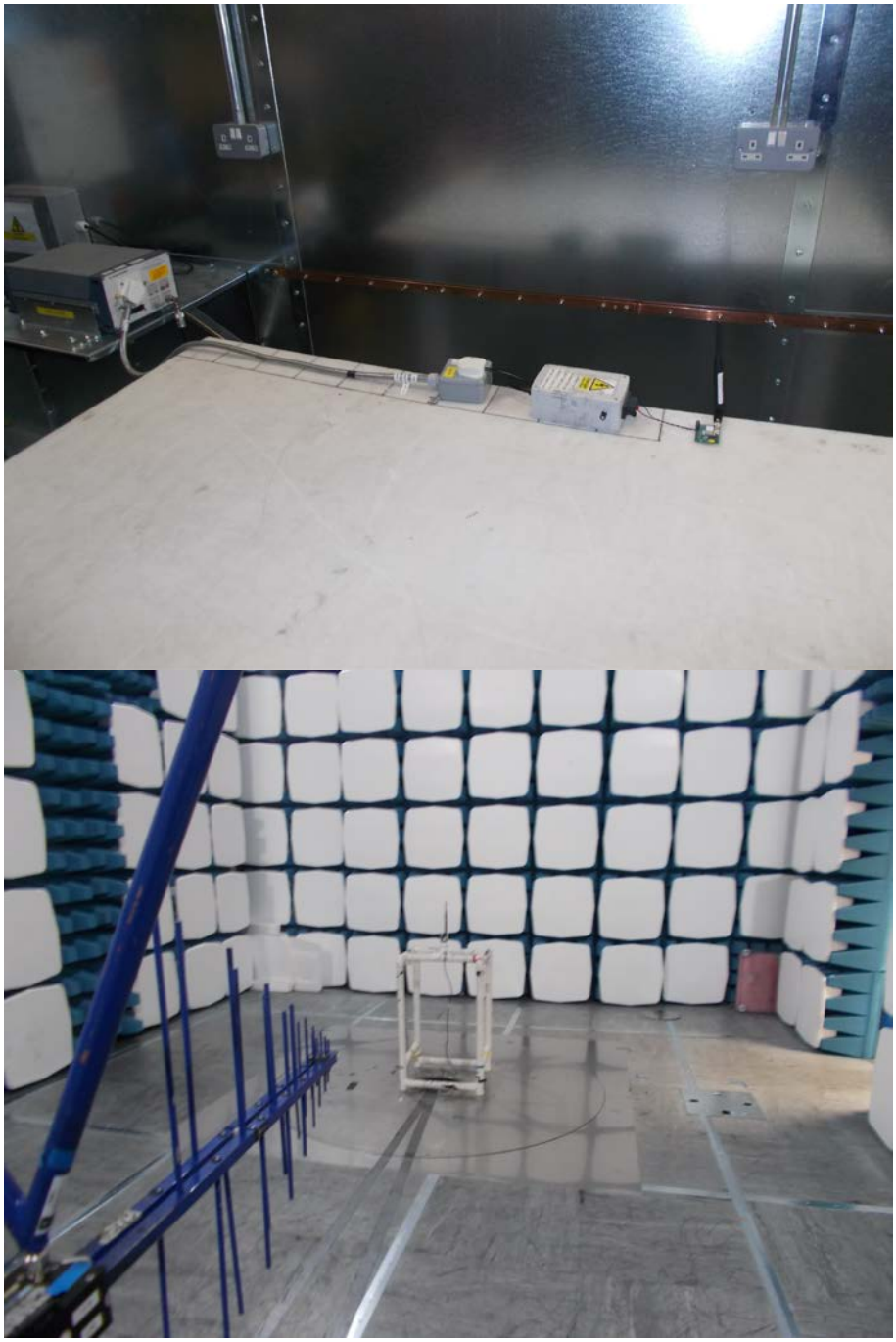
9.1 Block Diagram

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. 3.3 V dc from the adaptor from the mains.

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	N/A	85 % and 115 %
☒	Other	3.3 Vdc	85 % and 115 %

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:	Chamber 1
Test Standard and Clause:	ANSI C63.10-2013, Clause 6.5 and 6.6
EUT Channels / Frequencies Measured:	902.2 MHz / 904.6 MHz
EUT Channel Bandwidths:	25 kHz
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: 22 °C	+15 ºC to +35 ºC (as declared)
Humidity: 48 % RH	20 % RH to 75 % RH (as declared)
Supply: 3.3 V dc	3.3 V dc

11.3 Test Limit

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

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

Frequency (MHz)	***Field Strength (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:

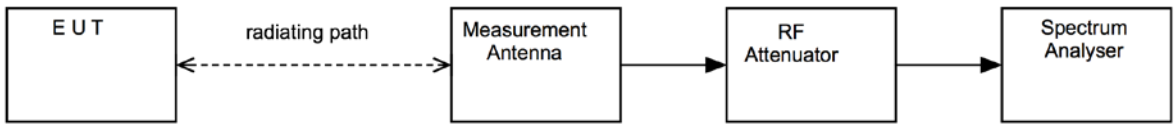
$$FS = PR + CL + AF – PA + DC – CF$$

Where,

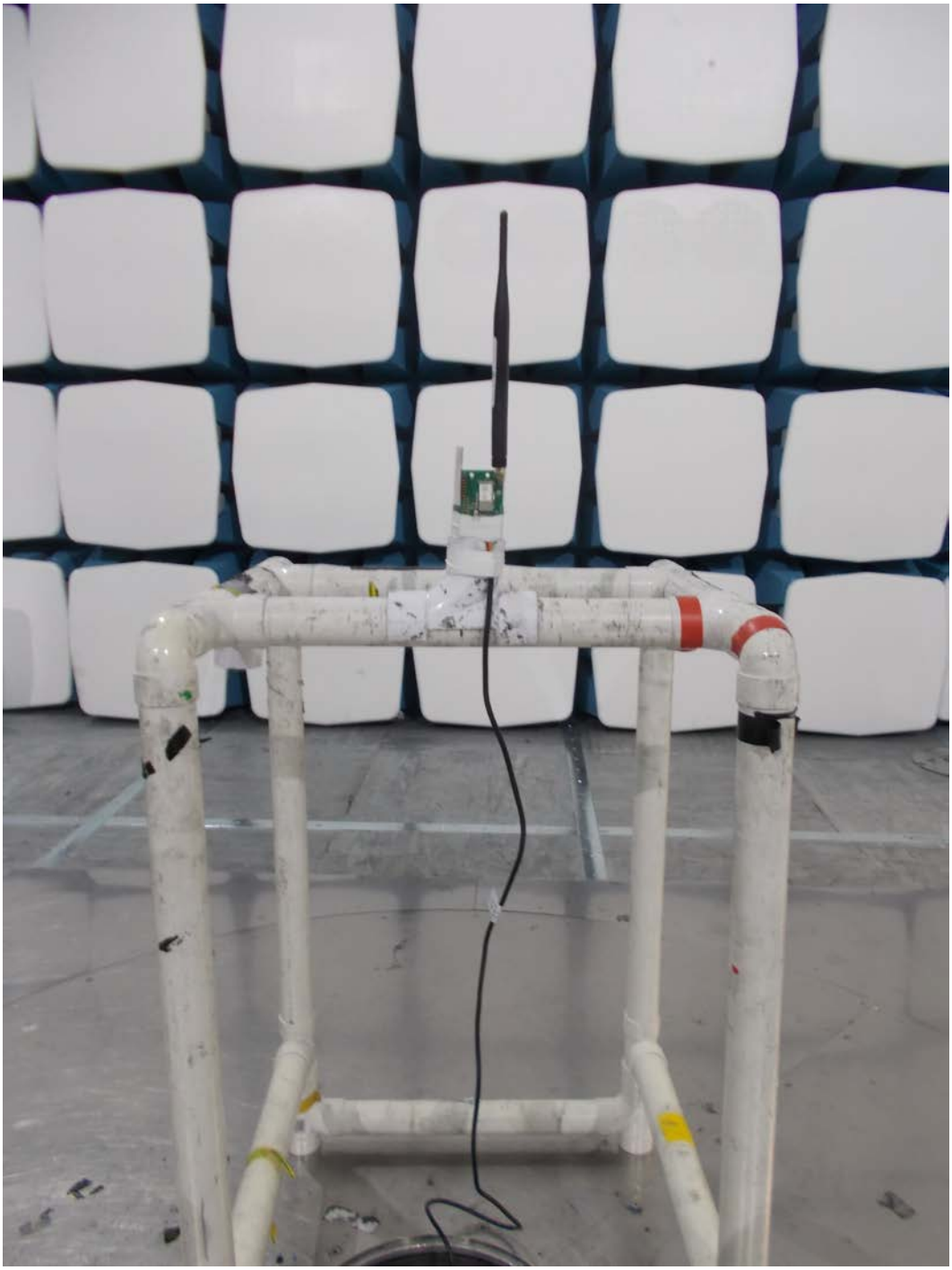
PR is the power recorded on the receiver / spectrum analyzer in dBµV;
CL is the cable loss in dB;
AF is the test antenna factor in dB/m;
PA is the pre-amplifier gain in dB (where used);
DC is the duty correction factor in dB (where used, e.g. harmonics of pulsed fundamental);
CF is the distance factor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

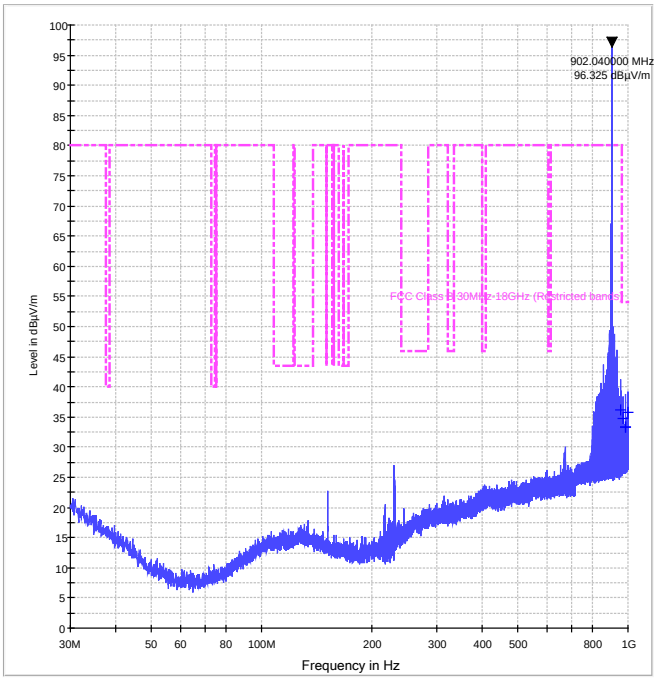


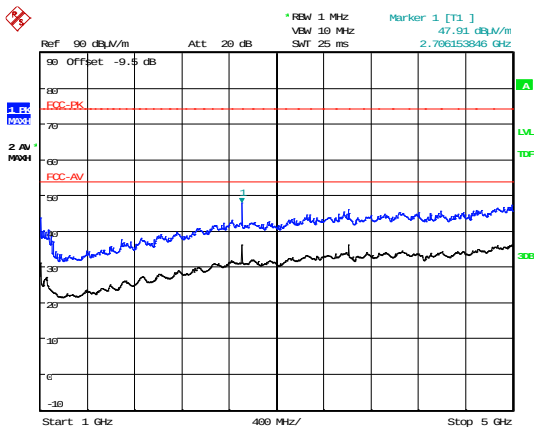
11.6 Test Equipment

Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration	Calibration Period
FSU26	R&S	Spectrum Analyser	REF909	26/04/2017	12
3115	EMCO	1-18GHz Horn	L138	13/04/2018	24
8449B	Agilent	Pre Amp	U457	18/08/2016	12
ESVS10	R&S	Receiver	L352	07/08/2016	12
CBL6112B	Chase	Bilog	U093	17/06/2017	24

11.7 Test Results

30MHz-1GHz ESVS10 + UH93 (Pre+Zoom)





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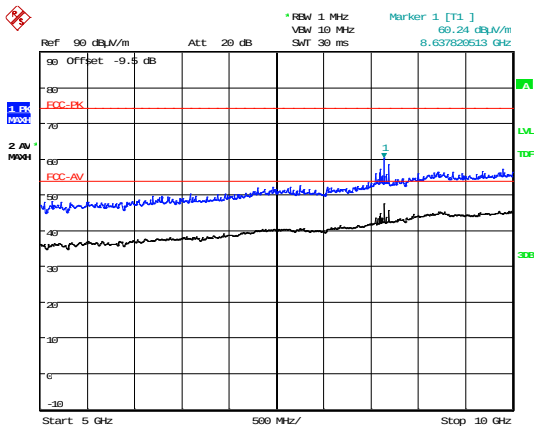
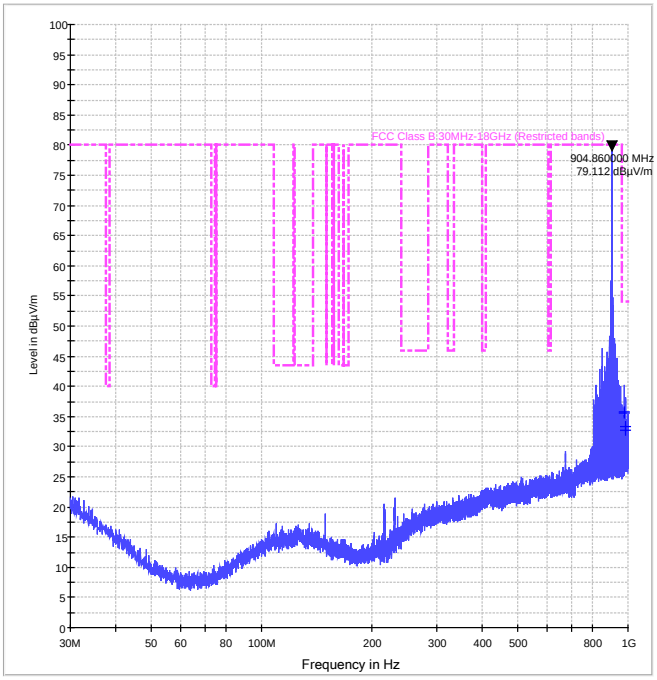
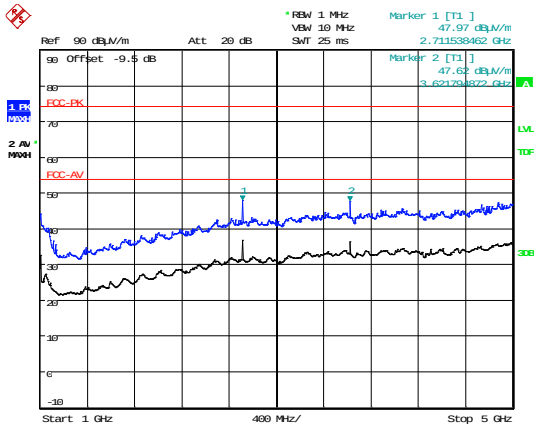


Date: 15.APR.2016 13:06:34

High Power; Channel: 902.2 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	2706.60	53.51	4.10	29.10	35.52	0.00	0.00	51.19	362.66	5012
Av	2706.60	48.47	4.10	29.10	35.52	0.00	0.00	46.15	203.00	500
Pk	3608.80	51.38	4.80	31.20	35.50	0.00	0.00	51.88	392.64	5012
Av	3608.80	46.06	4.80	31.20	35.50	0.00	0.00	46.56	212.81	500
Pk	5413.20	48.48	7.00	33.90	35.25	0.00	0.00	54.13	508.74	5012
Av	5413.20	41.42	7.00	33.90	35.25	0.00	0.00	47.07	225.68	500

30MHz-1GHz ESVS10 + UH93 (Pre+Zoom)





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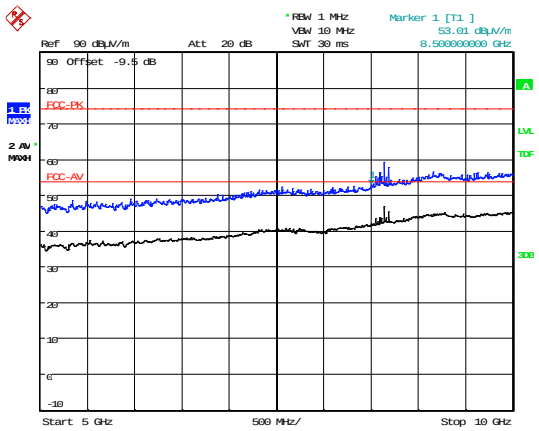


Date: 15.APR.2016 13:31:39

High Power; Channel: 904.6 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	2713.80	55.16	4.10	29.10	35.52	0.00	0.00	52.84	438.53	5012
Av	2713.80	51.55	4.10	29.10	35.52	0.00	0.00	49.23	289.40	500
Pk	3618.40	52.06	4.90	31.20	35.50	0.00	0.00	52.66	429.54	5012
Av	3618.40	46.56	4.90	31.20	35.50	0.00	0.00	47.16	228.03	500
Pk	5427.60	48.74	7.00	34.00	35.26	0.00	0.00	54.48	529.66	5012
Av	5427.60	41.46	7.00	34.00	35.26	0.00	0.00	47.20	229.09	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 Chamber:	UH404
Test Standard and Clause:	ANSI C63.10-2013, Clause 6.2
Deviations From Standard:	None
Measurement BW:	10 kHz
Measurement Detectors:	Quasi-Peak and Average, RMS

Environmental Conditions (Normal Environment)

Temperature: 22 °C	+15 ºC to +35 ºC (as declared)
Humidity: 28 % RH	20 % RH to 75 % RH (as declared)
Supply: 3.3 Vdc	3.3Vdc (regulated from a linear 110 Vac Supply)

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.

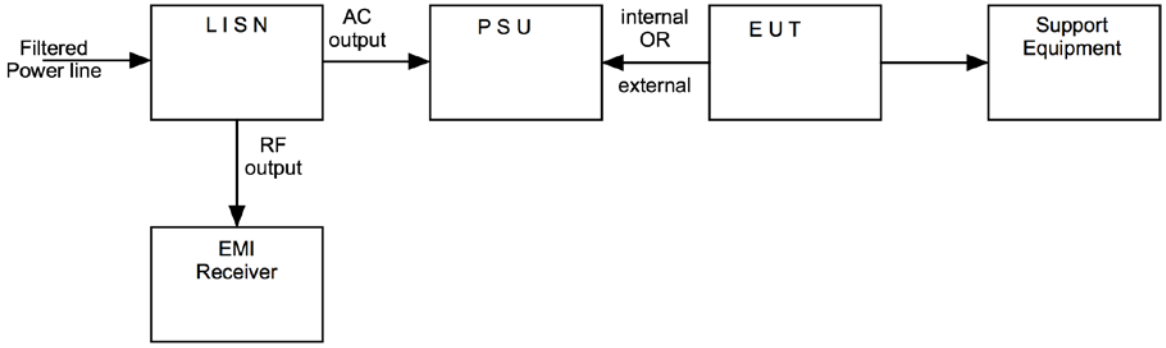
12.3 Test Method

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



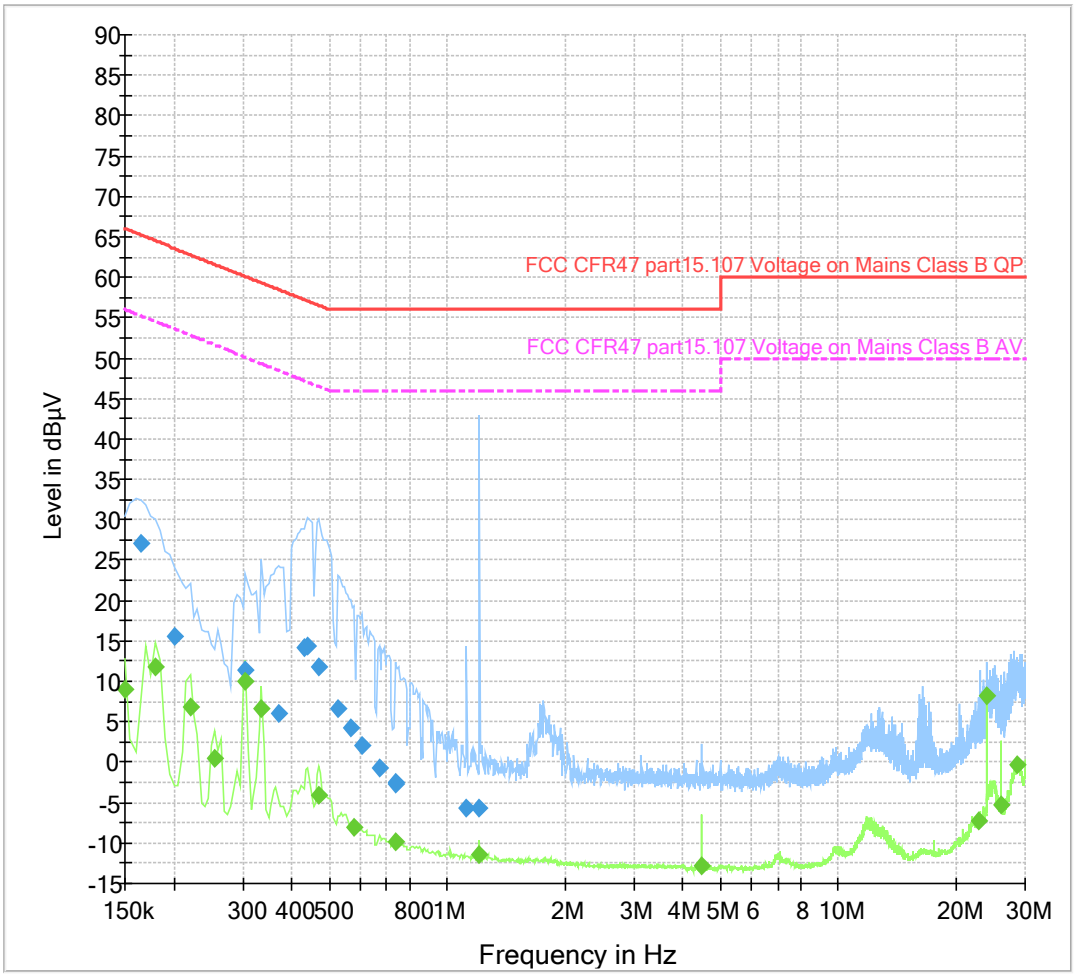
12.4 Test Set-up Photograph

12.5 Test Equipment

Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration	Calibration Period
ESHS10	R&S	Receiver	U187	29/10/2016	12
ESH3-Z5.831.5	R&S	Lisn	U195	04/06/2016	12

12.6 Test Results

Conducted emissions on Mains 9kHz-30MHz ESHS10 + UH195



Frequency (MHz)	QuasiPeak (dBµV)	Meas. Time (ms)	Bandwidth (kHz)	PE	Line	Corr. (dB)	Margin (dB)	Limit (dBµV)
0.165000	27.2	2000.0	10.000	GND	N	0.1	38.0	65.2
0.200000	15.5	2000.0	10.000	GND	N	0.1	48.1	63.6
0.305000	11.5	2000.0	10.000	GND	L1	0.1	48.6	60.1
0.430000	14.1	2000.0	10.000	GND	L1	0.1	43.1	57.3
0.440000	14.4	2000.0	10.000	GND	L1	0.1	42.7	57.1
0.470000	11.8	2000.0	10.000	GND	L1	0.1	44.7	56.5
0.525000	6.7	2000.0	10.000	GND	L1	0.1	49.3	56.0

Frequency (MHz)	Average (dBµV)	Meas. Time (ms)	Bandwidth (kHz)	PE	Line	Corr. (dB)	Margin (dB)	Limit (dBµV)
0.150000	9.0	2000.0	10.000	GND	L1	0.1	47.0	56.0
0.180000	11.8	2000.0	10.000	GND	L1	0.1	42.7	54.5
0.220000	6.9	2000.0	10.000	GND	L1	0.1	45.9	52.8
0.305000	10.1	2000.0	10.000	GND	L1	0.1	40.0	50.1
0.335000	6.6	2000.0	10.000	GND	L1	0.1	42.7	49.3
24.015000	8.3	2000.0	10.000	GND	N	1.6	41.7	50.0

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 Hull
Test Chamber:	Radio Lab
Test Standard and Clause:	ANSI C63.10-2013, Clause 7.8.2
EUT Channels / Frequencies Measured:	All; 902 MHz – 928 MHz
EUT 20dB Bandwidth:	21.7 kHz
EUT Test Modulations:	Internal pattern generation – hopping enabled
Deviations From Standard:	None
Measurement BW:	1 kHz
Measurement Detector:	Peak

Environmental Conditions (Normal Environment)

Temperature: 24 °C	+15 ºC to +35 ºC (as declared)
Humidity: 42 % RH	20 % RH to 75 % RH (as declared)
Supply: +3.3Vdc	+3.3Vdc (as declared)

13.3 Test Limit

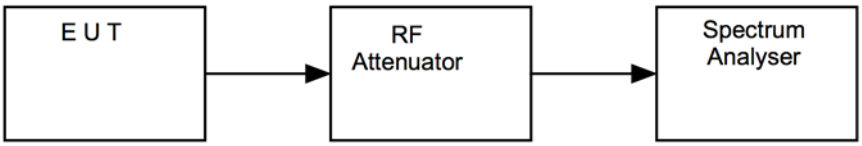
Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the -20 dB bandwidth of the hopping channel, whichever is greater. Alternatively, frequency hopping systems operating in the band 2400 to 2483.5 MHz may have hopping channel carrier frequencies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

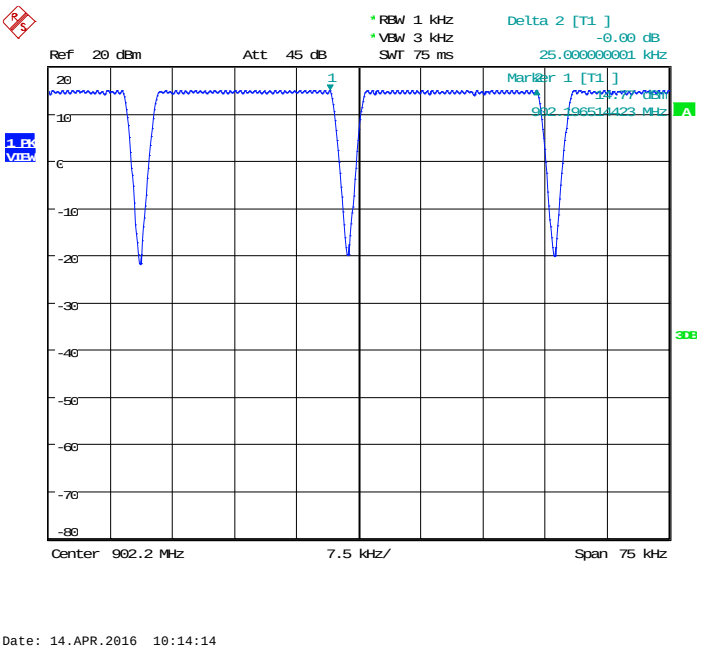


13.5 Test Equipment

Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration	Calibration Period
FSU46	R&S	Spectrum Analyser	REF910	28/05/2016	12

13.6 Test Results

$F1_c$ (MHz)	***$F2_c$ (MHz)***	***Channel Separation, $F2_c - F1_c$ (kHz)***	***Result***
902.1715144	902.1965	25 kHz	PASS



Date: 14.APR.2016 10:14:14

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 Hull
Test Chamber:	Lab 4
Test Standard and Clause:	ANSI C63.10-2013, Clause 7.8.3
EUT Channels / Frequencies Measured:	All; 902 - 928 MHz
EUT 20dB Bandwidth:	21.7 kHz
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: 42 % RH	20 % RH to 75 % RH (as declared)
Supply: +3.3Vdc	+3.3Vdc (as declared)

14.3 Test Limit

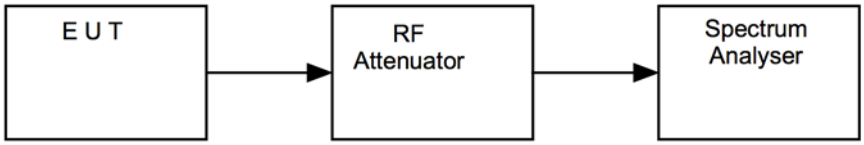
- For frequency hopping systems in the band 902 to 928 MHz: if the -20 dB bandwidth of the hopping channel is less than 250 kHz, the system shall use at least 50 hopping channels;
  If the -20 dB bandwidth of the hopping channel is 250 kHz or greater, the system shall use at least 25 hopping channels;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

Figure iv Test Setup

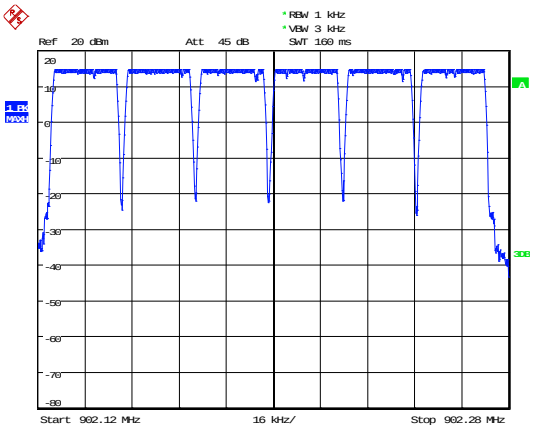


14.5 Test Equipment

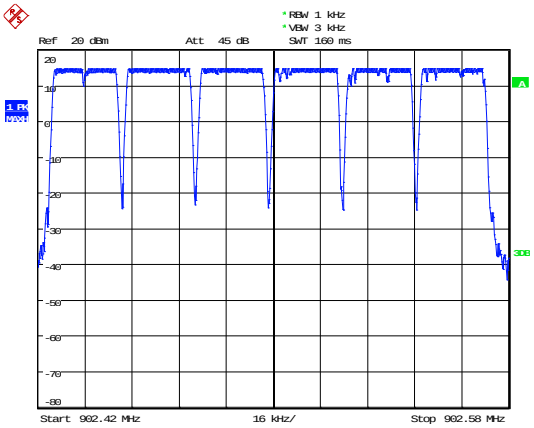
Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration	Calibration Period
FSU46	R&S	Spectrum Analyser	REF910	28/05/2016	12

14.6 Test Results

Lowest channel, F_{CL} (MHz)	***Highest channel, F_{CH} (MHz)***	***Number of channels observed***	***Result***
902.2	904.6	54	PASS



Date: 14.APR.2016 11:51:40



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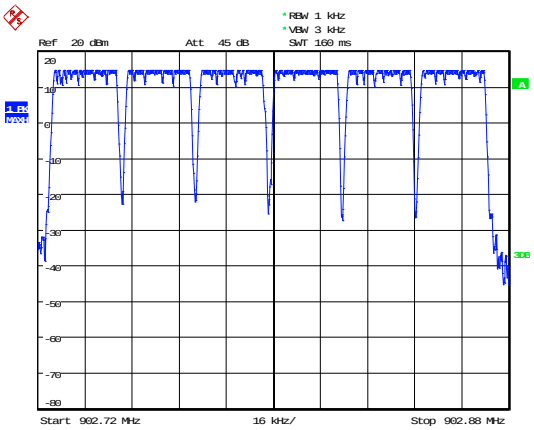

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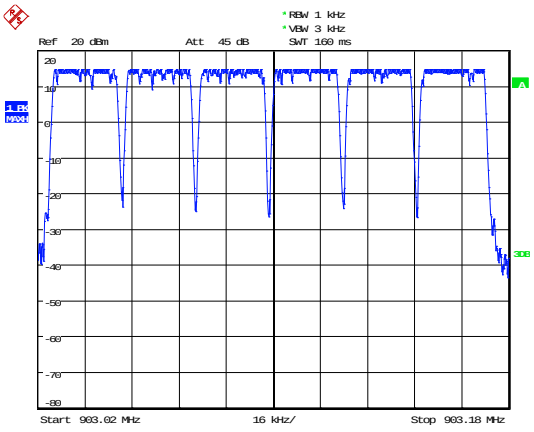

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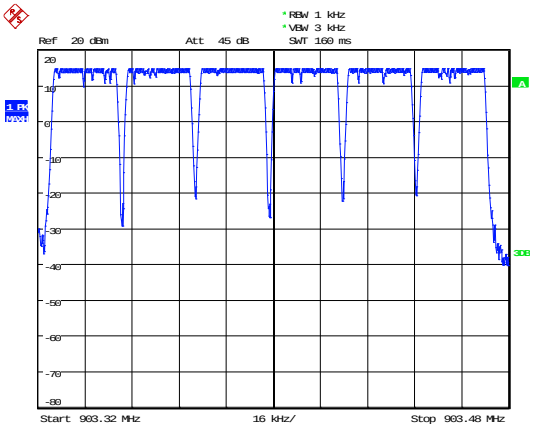
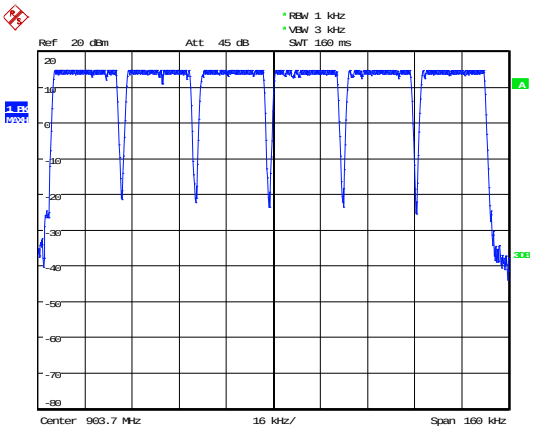


Date: 14.APR.2016 12:04:17



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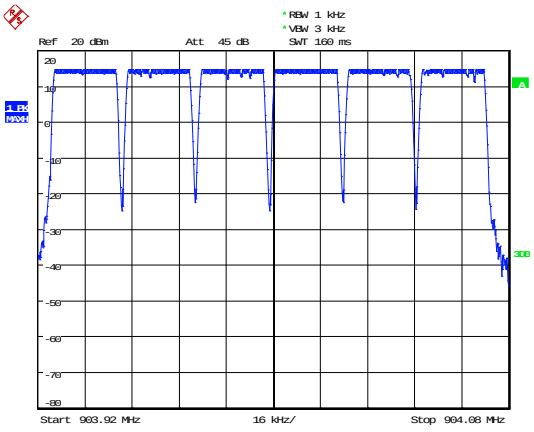
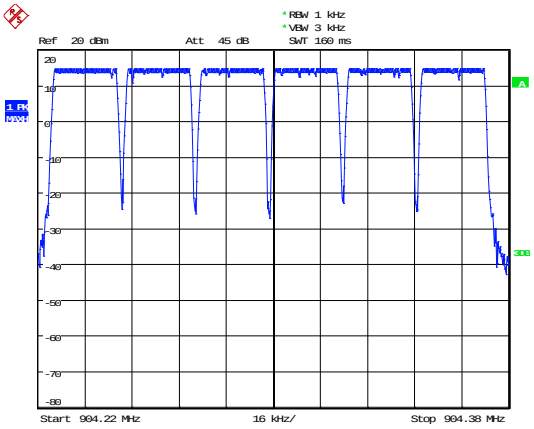
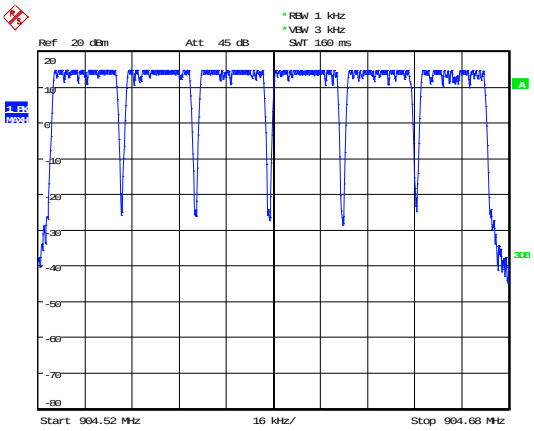


Date: 14.APR.2016 12:12:10



Date: 14.APR.2016 12:15:47



Date: 14.APR.2016 12:18:08

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 Hull
Test Chamber:	Lab 4
Test Standard and Clause:	ANSI C63.10-2013, Clause 7.8.4
EUT Channels / Frequencies Measured:	902 MHz
EUT 20dB bandwidth:	21.7 kHz
EUT Number of hopping channels:	54
EUT Test Modulations:	Internal pattern generation – hopping enabled
Deviations From Standard:	None
Measurement BW:	10 kHz
Measurement Detector:	Peak

Environmental Conditions (Normal Environment)

Temperature: 24 °C	+15 ºC to +35 ºC (as declared)
Humidity: 42 % RH	20 % RH to 75 % RH (as declared)
Supply: +3.3Vdc	+3.3Vdc (as declared)

15.3 Test Limit

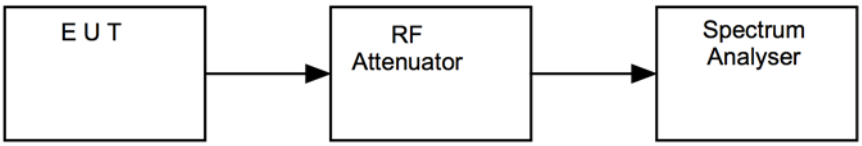
- For frequency hopping systems in the band 902 to 928 MHz: if the -20 dB bandwidth of the hopping channel is less than 250 kHz, the average time of occupancy on any channel shall not be greater than 0.4 seconds within a 20 second period;
  If the -20 dB bandwidth of the hopping channel is 250 kHz or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

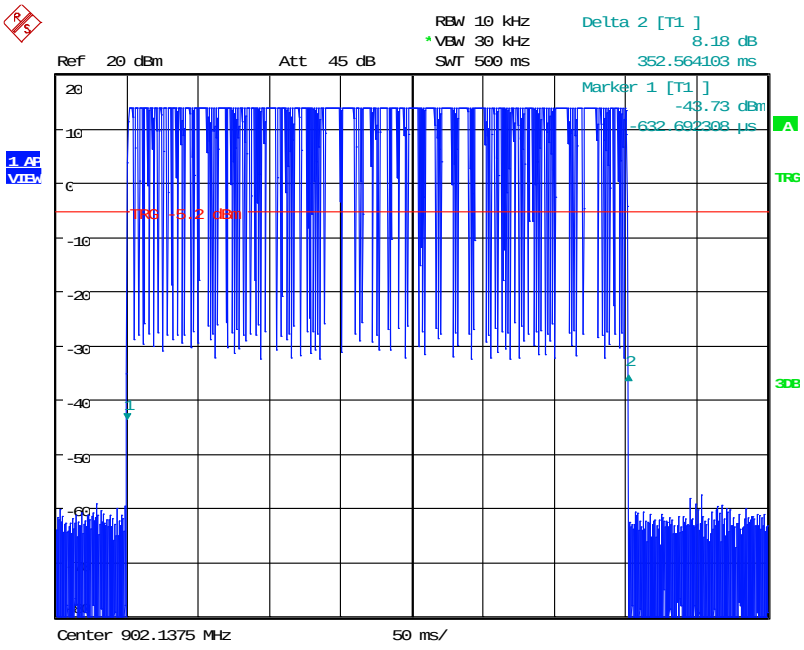


15.5 Test Equipment

Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration	Calibration Period
FSU46	R&S	Spectrum Analyser	REF910	28/05/2016	12

15.6 Test Results

Individual occupancy time (ms)	***Observation period (s)***	***Number of hops observed***	***Average time of occupancy (s)***	***Result***
352.56	20	1	0.35256	PASS



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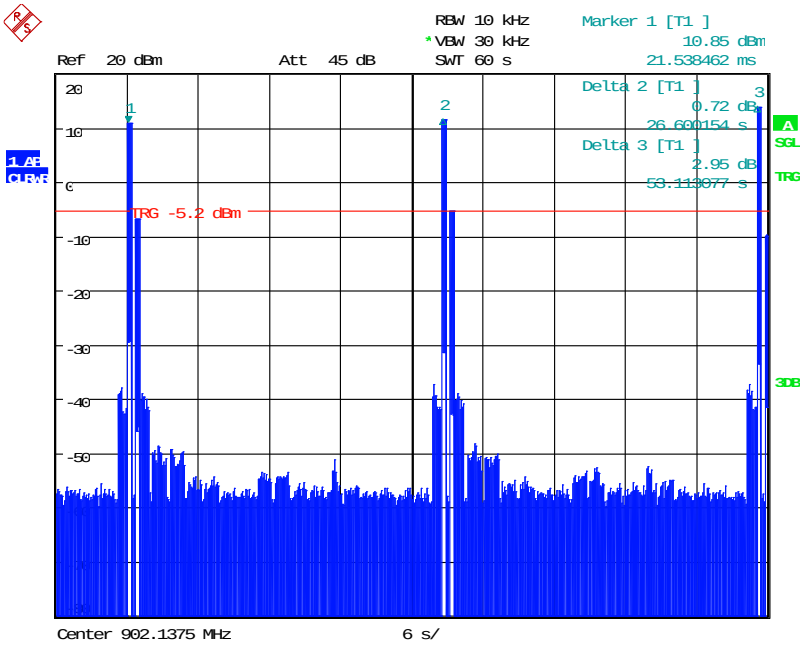


Date: 14.APR.2016 12:38:34

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 Hull
Test Chamber:	Lab 4
Test Standard and Clause:	ANSI C63.10-2013, Clause 7.8.5
EUT Channels / Frequencies Measured:	902.2 MHz / 903.4 MHz / 904.6 MHz – hopping disabled.
EUT Channel Bandwidths:	25 kHz
Deviations From Standard:	None
Measurement BW:	100 kHz
Spectrum Analyzer Video BW:	300 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: 22 °C	+15 ºC to +35 ºC (as declared)
Humidity: 45 % RH	20 % RH to 75 % RH (as declared)

16.3 Test Limit

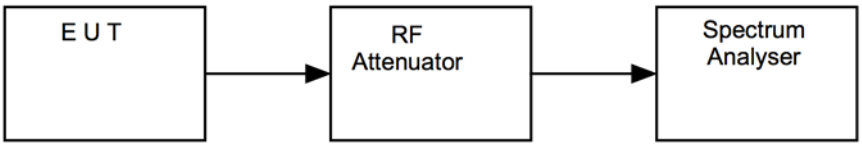
- For frequency hopping systems operating in the band 902 to 928 MHz, the maximum peak conducted output power shall not exceed 1 W, and the e.i.r.p. shall not exceed 4 W, if the hopset uses 50 or more hopping channels;
  the maximum peak conducted output power shall not exceed 0.25 W, and the e.i.r.p.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

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	Calibration Period
FSU46	R&S	Spectrum Analyser	REF910	28/05/2016	12

16.6 Test Results

Channel Frequency (MHz)	*Analyzer Level (dBm)*	*Cable loss (dB)*	*Attenuator loss (dB)*	*Maximum peak conducted output power (dBm)*	*Maximum peak conducted output power (mW)*	*Antenna gain (dBi)*	*E.I.R.P. (mW)*	*Result*
902.2	14.77	0.45	10	25.22	332.66	2.7	619.44	PASS
903.4	14.88	0.45	10	25.33	341.19	2.7	635.33	PASS
904.6	14.75	0.45	10	25.20	331.13	2.7	616.60	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 Hull
Test Chamber:	Lab 4
Test Standard and Clause:	ANSI C63.10-2013, Clause 6.9
EUT Channels / Frequencies Measured:	Low / Mid / High – hopping stopped.
EUT Channel Bandwidths:	902.2 MHz / 903.4 MHz / 904.6 MHz – hopping disabled.
EUT Test Modulations:	FHSS
Deviations From Standard:	None
Measurement BW: (requirement: 1 % to 5 % OBW)	300 Hz
Spectrum Analyzer Video BW: (requirement at least 3x RBW)	1 kHz
Measurement Span: (requirement 2 to 5 times OBW)	30 kHz
Measurement Detector:	Peak

Environmental Conditions (Normal Environment)

Temperature: 24 °C	+15 ºC to +35 ºC (as declared)
Humidity: 42 % RH	20 % RH to 75 % RH (as declared)
Supply: +5Vdc	+5Vdc (as declared)

17.3 Test Limit

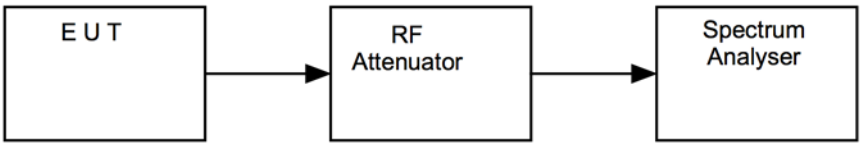
- For frequency hopping systems in the band 902 to 928 MHz: The maximum allowed -20 dB bandwidth of the hopping channel is 500 kHz.
- Frequency hopping systems operating in the band 5725 to 5850 MHz: The maximum -20 dB bandwidth of the hopping channel shall be 1 MHz

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

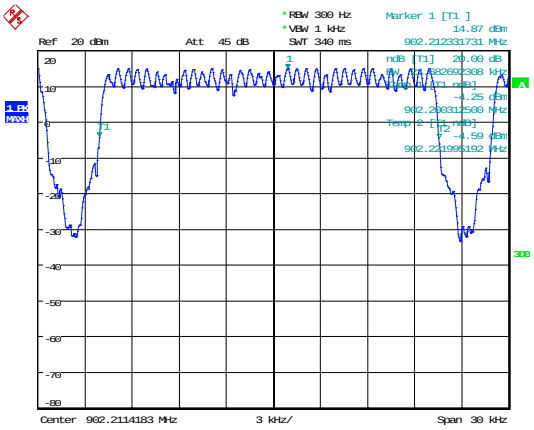


17.5 Test Equipment

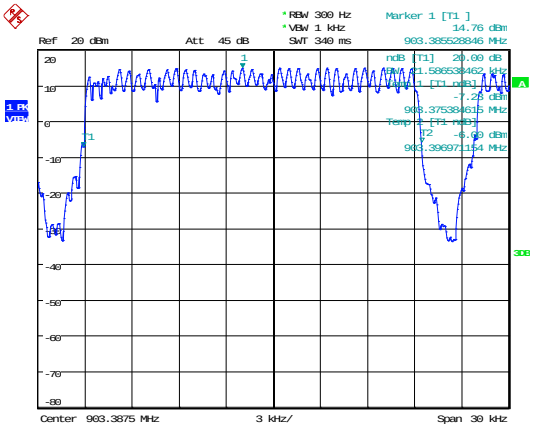
Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration	Calibration Period
FSU46	R&S	Spectrum Analyser	REF910	28/05/2016	12

17.6 Test Results

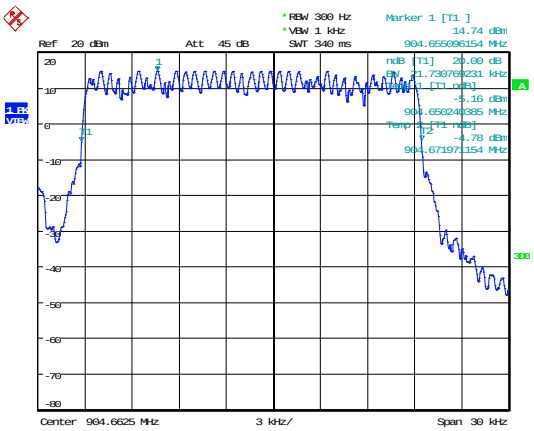
Channel Frequency (MHz)	***F_L (MHz)***	***F_H (MHz)***	***20dB Bandwidth (kHz)***	***Result***
902.2	902.2003125	902.2219952	21.682692	PASS
903.4	903.3753846	903.3969712	21.586539	PASS
904.6	904.6502404	904.6719712	21.730769	PASS



Date: 14.APR.2016 10:56:36



Date: 14.APR.2016 11:13:48



Date: 14.APR.2016 11:06:47

18 Out-of-band and conducted spurious emissions

18.1 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.

18.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Radio Lab
Test Standard and Clause:	ANSI C63.10-2013, Clause 7.8.8
EUT Channels / Frequencies Measured:	Low / Mid / High
EUT Channel Bandwidths:	25 kHz
Deviations From Standard:	None
Measurement BW:	100 kHz
Spectrum Analyzer Video BW: (requirement at least 3x RBW)	300 kHz
Measurement Detector:	Peak
Measurement Range:	30 MHz to 26.5 GHz

Environmental Conditions (Normal Environment)

Temperature: 24 °C	+15 ºC to +35 ºC (as declared)
Humidity: 44 % RH	20 % RH to 75 % RH (as declared)
Supply: +3.3Vdc	+3.3Vdc (as declared)

18.3 Test Limits

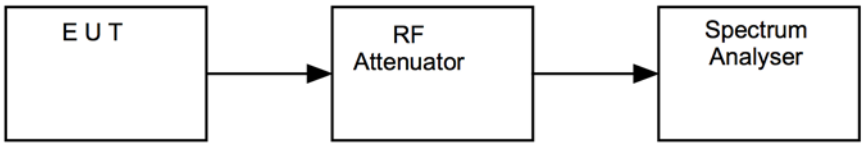
In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated device is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either 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.

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 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.

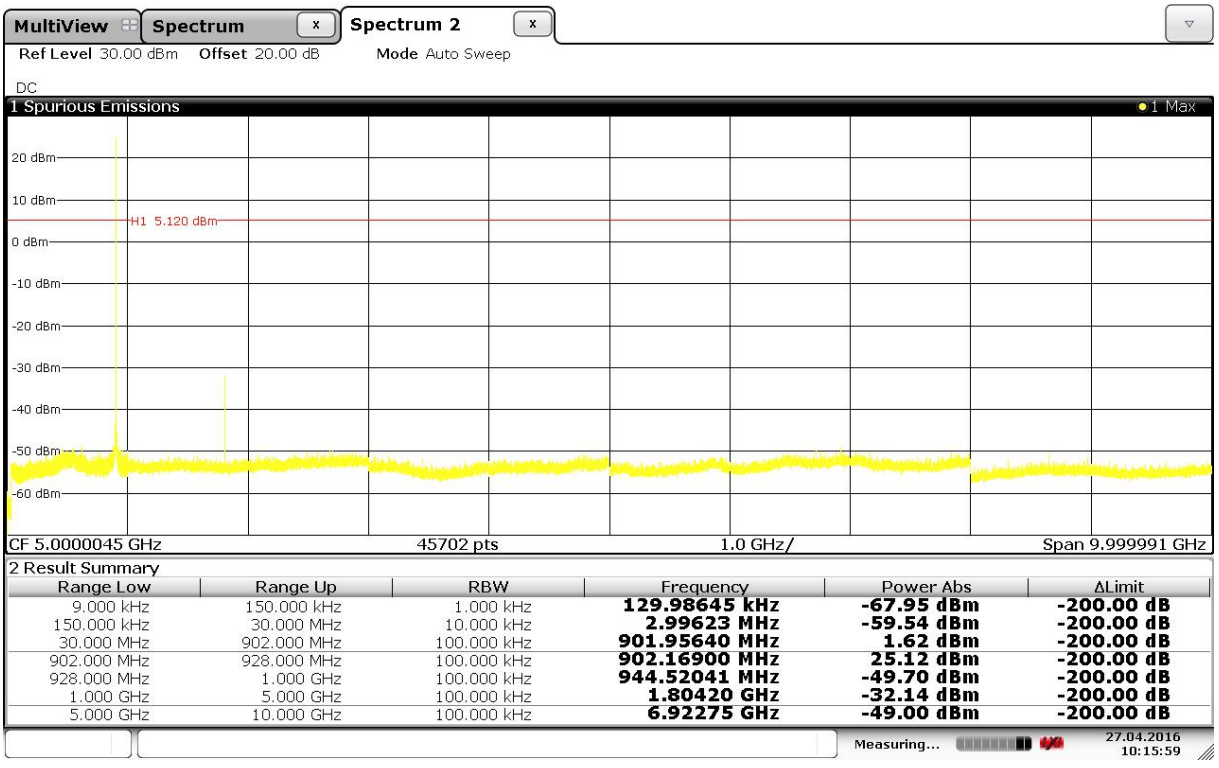
Figure viii Test Setup



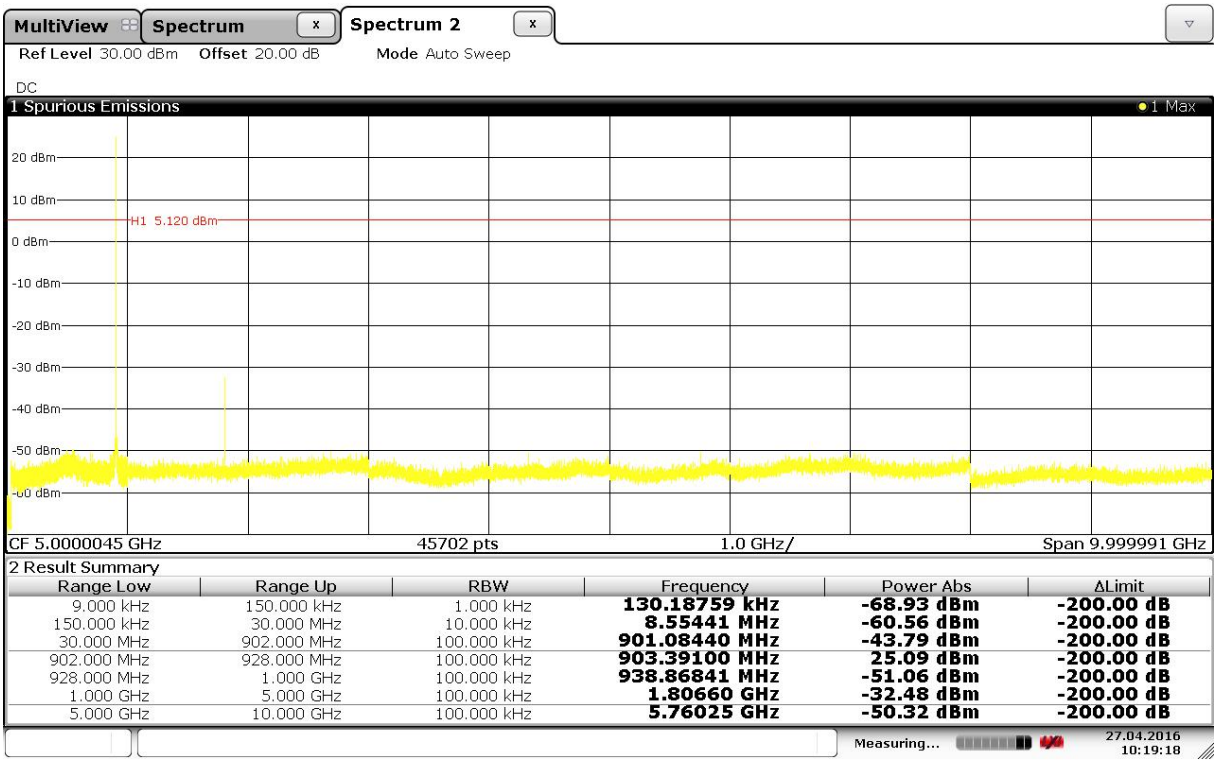
18.5 Test Equipment

Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration	Calibration Period
FSU46	R&S	Spectrum Analyser	REF910	28/05/2016	12

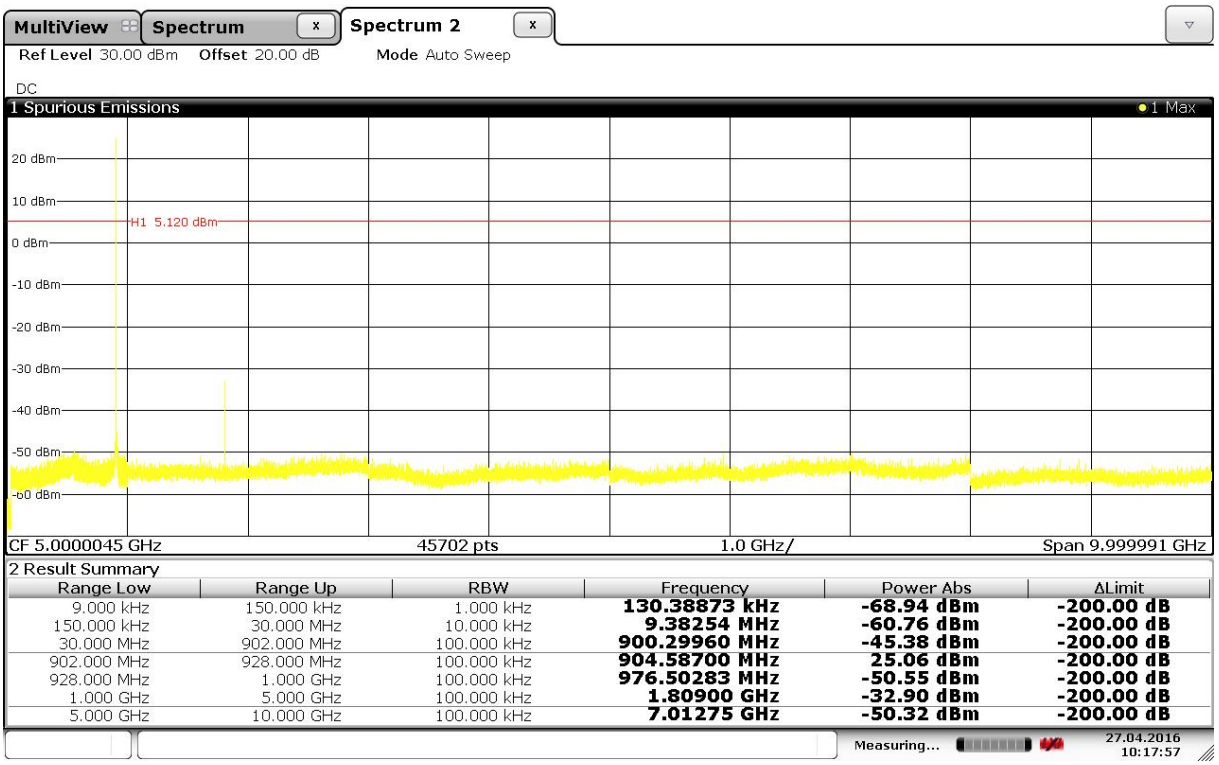
18.6 Test Results



Date: 27.APR.2016 10:15:59



Date: 27.APR.2016 10:19:17



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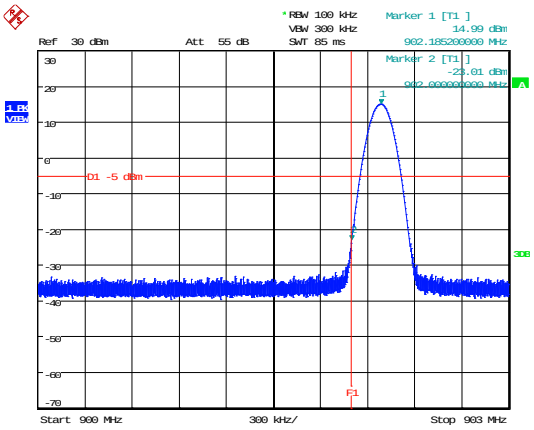

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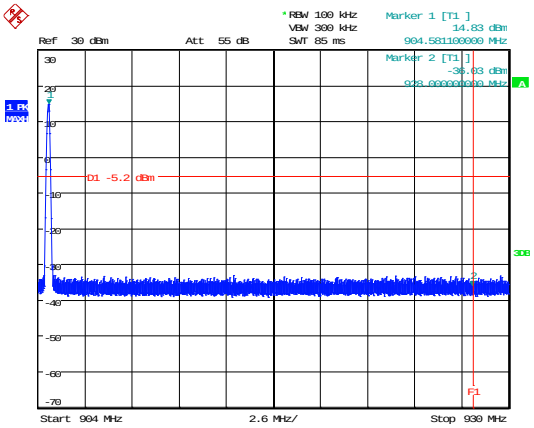

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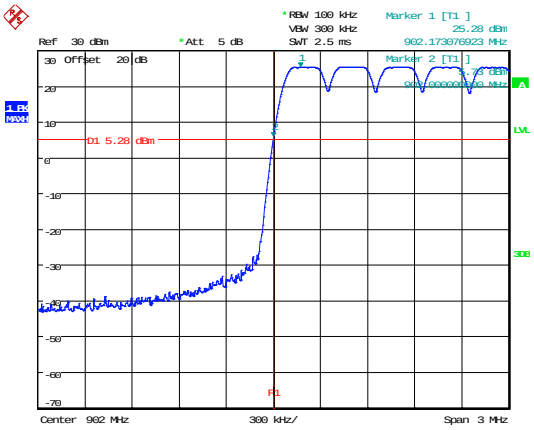
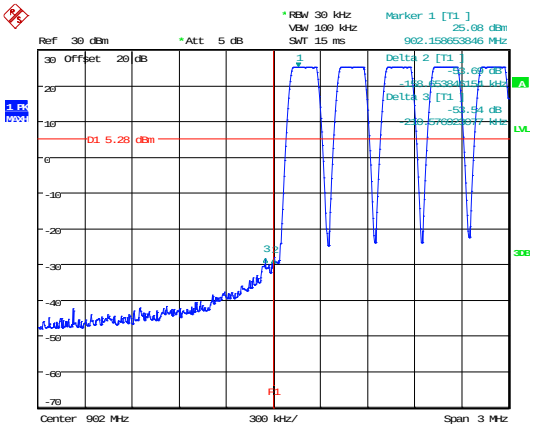
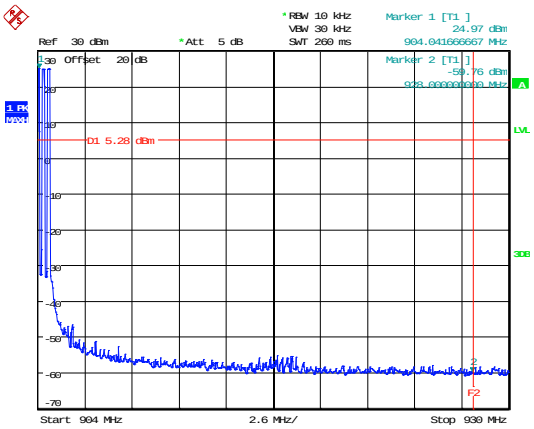


Date: 13.MAY.2016 10:13:28



Date: 13.MAY.2016 10:18:24



Date: 13.MAY.2016 10:22:08

19 Radiated emissions – unintentional radiation / receiver emissions

19.1 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.

19.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Chamber 1
Test Standard and Clause:	ANSI C63.10-2013, Clause 6.5 and 6.6
EUT Channels / Frequencies Measured:	902.2 MHz / 904.6 MHz
EUT Channel Bandwidths:	25 kHz
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: 22 °C	+15 ºC to +35 ºC (as declared)
Humidity: 48 % RH	20 % RH to 75 % RH (as declared)
Supply: 3.3 V dc	3.3 V dc

19.3 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

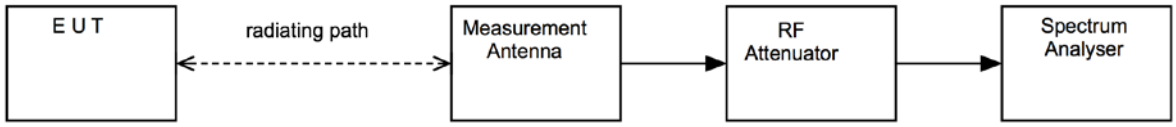
Frequency (MHz)	***Field Strength (µV/m at 3 m)***
30 to 88	100
88 to 216	150
216 to 960	200
Above 960	500

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 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

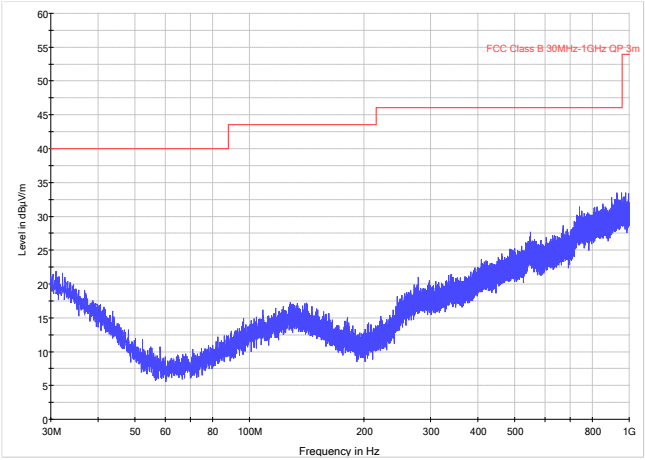


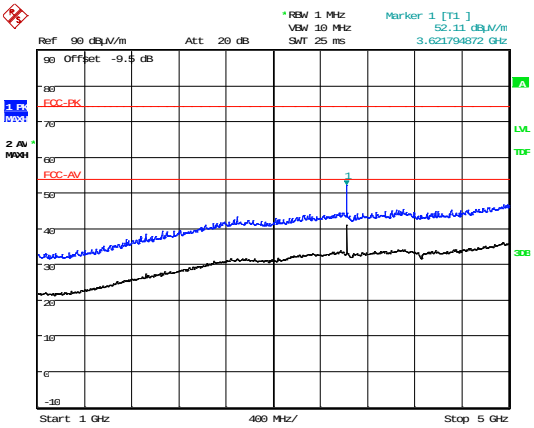
19.5 Test Set-up Photograph

19.6 Test Equipment

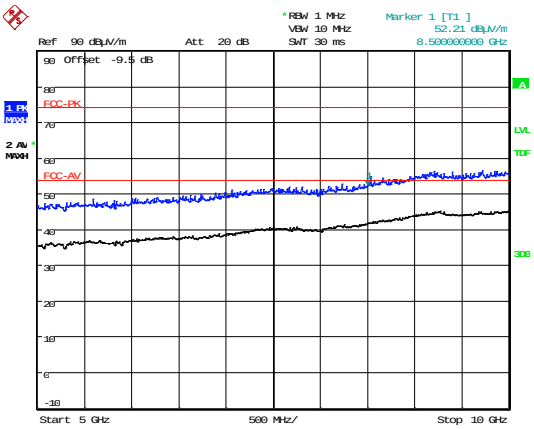
Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration	Calibration Period
FSU26	R&S	Spectrum Analyser	REF909	26/04/2017	12
3115	EMCO	1-18GHz Horn	L138	13/04/2018	24
8449B	Agilent	Pre Amp	U457	18/08/2016	12
ESVS10	R&S	Receiver	L352	07/08/2016	12
CBL6112B	Chase	Bilog	U093	17/06/2017	24

19.7 Test Results



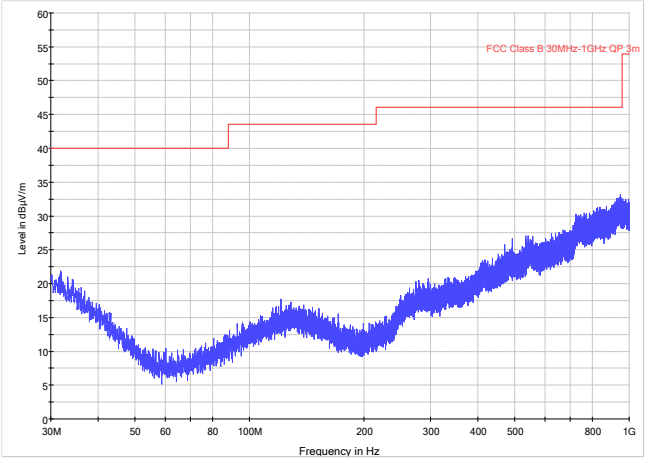


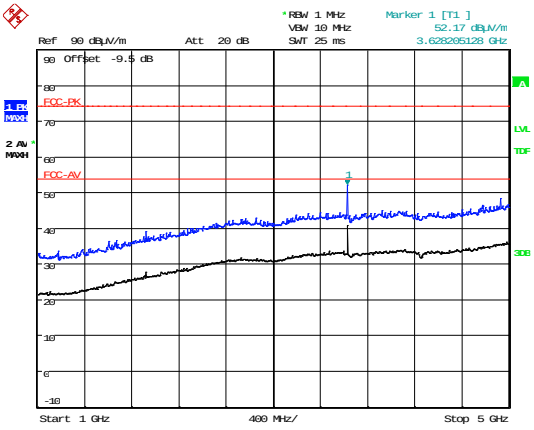
Date: 15.APR.2016 13:39:29



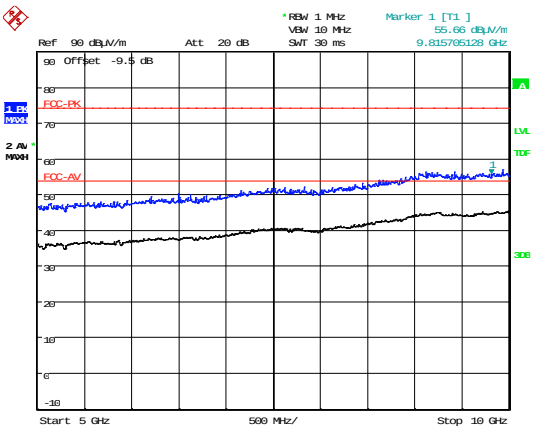
Date: 15.APR.2016 13:37:07

High Power; Channel: 902.2 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	3618.86	52.22	4.90	31.20	35.50	0.00	-9.54	43.28	145.84
Av	3618.86	51.05	4.90	31.20	35.50	0.00	-9.54	42.11	127.46





Date: 15.APR.2016 13:51:29



Date: 15.APR.2016 13:49:41

High Power; Channel: high 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	3682.45	54.58	4.90	31.40	35.49	0.00	-9.54	45.85	196.06
Av	3682.45	50.50	4.90	31.40	35.49	0.00	-9.54	41.77	122.57

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 %**