Report on the Radio Testing

For

Centrical Connected Home Limited

on

Hive Hub 360

Report no. TRA-034282-02-47-00D

15th January 2018

RF915 4.0

Report Number: TRA-034282-02-47-00D
Issue: B

REPORT ON THE RADIO TESTING OF A
Centrical Connected Home Limited
Hive Hub 360
(ZigBee operation)
WITH RESPECT TO SPECIFICATION
FCC 47CFR 15.247 & IC RSS-247

TEST DATE: 25th September-27th September 2017

Written by: Daniel Moncayola
Radio Test Engineer

Digitally signed by Daniel Moncayola
DN: cn=Daniel Moncayola, o=Element Materials Technology, ou, email=Daniel.Moncayola@Element.com, c=GB
Reason: I am the author of this document
Date: 2018.01.19 11:50:20 Z

Approved by: John Charters
Manager Department-Radio

Digitally signed by John Charters
DN: cn=John Charters, o, ou=Element Materials Technology Ltd., email=john.charters@element.com, c=GB
Reason: I am approving this document
Date: 2018.01.19 11:31:28 Z

Date: 15th January 2018

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

1 Revision Record

Issue Number	*Issue Date*	*Revision History*
A	23rd November 2017	Original
B	18th January 2018	TCB update

2 Summary

TEST REPORT NUMBER:	TRA-034282-02-47-00D
WORKS ORDER NUMBER	TRA-034282-02
PURPOSE OF TEST:	USA: Testing of radio frequency equipment per the relevant authorization procedure of chapter 47 of CFR (code of federal regulations) Part 2, subpart J. Canada: Testing of radio apparatus for TAC (technical acceptance certificate) per subsections 4(2) of the Radiocommunication Act and 21(1) of the Radiocommunication Regulations.
TEST SPECIFICATION(S):	47CFR15.247 & RSS-247
EQUIPMENT UNDER TEST (EUT):	Hive Hub 360
FCC IDENTIFIER:	WJHHUB450
ISED IDENTIFIER:	21719-HUB450
EUT SERIAL NUMBER:	UFD-637
MANUFACTURER/AGENT:	Centrical Connected Home Limited
ADDRESS:	Millstream Madenhead Road Windsor, Berkshire SL4 SCO United Kingdom
CLIENT CONTACT:	Darrell Harris ☎ 01223 222150 ✉ darrell.harris@hivehome.com
ORDER NUMBER:	6500467481
TEST DATE:	25th September-27th September 2017
TESTED BY:	Daniel Moncayola S Hodgkinson S Garwell Jack Whitehead Element

2.1 Test Summary

Test Method and Description		*Requirement Clause*		*Applicable to this equipment*	*Result / Note*
		RSS	*47CFR15*		
Radiated spurious emissions (restricted bands of operation and cabinet radiation)		Gen, 8.10	15.205	☒	*Pass*
AC power line conducted emissions		Gen, 8.8	15.207	☒	*Pass*
Occupied bandwidth		247, 5.2 (1)	15.247(a)(2)	☒	*Pass*
Conducted carrier power	Peak	247, 5.4 (4)	15.247(b)(3)	☒	*Pass*
	Max.			☐	
Conducted / radiated RF power out-of-band		247, 5.5	15.247(d)	☒	*Pass*
Power spectral density, conducted		247, 5.2 (2)	15.247(e)	☒	*Pass*
Calculation of duty correction		-	15.35(c)	☐	*N/A*

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

1 Revision Record 3
2 Summary 4
2.1 Test Summary 5
3 Contents 6
4 Introduction 8
5 Test Specifications 9
5.1 Normative References 9
5.2 Deviations from Test Standards 9
6 Glossary of Terms 10
7 Equipment Under Test 11
7.1 EUT Identification 11
7.2 System Equipment 11
7.3 EUT Mode of Operation 11
7.3.1 Transmission 11
7.3.2 Reception 11
7.4 EUT Radio Parameters 12
7.4.1 General 12
7.4.2 Antennas 12
7.5 EUT Description 12
8 Modifications 13
9 EUT Test Setup 14
9.1 Block Diagram 14
9.2 General Setup Photograph 15
10 General Technical Parameters 16
10.1 Normal Conditions 16
10.2 Varying Test Conditions 16
11 Radiated emissions 17
11.1 Definitions 17
11.2 Test Parameters 17
11.3 Test Limit 17
11.4 Test Method 18
11.5 Test Set-up Photograph 19
11.6 Test Equipment 19
11.7 Test Results 20
12 AC power-line conducted emissions 26
12.1 Definition 26
12.2 Test Parameters 26
12.3 Test Limit 26
12.4 Test Method 27
12.5 Test Set-up Photograph 27
12.6 Test Equipment 28
12.7 Test Results 29
13 Occupied Bandwidth 31
13.1 Definition 31
13.2 Test Parameters 31
13.3 Test Limit 31
13.4 Test Method 32
13.5 Test Equipment 32
13.6 Test Results 33
14 Maximum peak conducted output power 35
14.1 Definition 35
14.2 Test Parameters 35
14.3 Test Limit 35
14.4 Test Method 36
14.5 Test Equipment 36
14.6 Test Results 37
15 Out-of-band and conducted spurious emissions 38
15.1 Definition 38
15.2 Test Parameters 38
15.3 Test Limit 38
15.4 Test Method 39
15.5 Test Equipment 39
15.6 Test Results 40

16 Power spectral density 46
16.1 Definition 46
16.2 Test Parameters 46
16.3 Test Limit 46
16.4 Test Method 47
16.5 Test Equipment 47
16.6 Test Results 48
17 Measurement Uncertainty 49

4 Introduction

This report TRA-034282-02-47-00D presents the results of the Radio testing on a Centrical Connected Home Limited, Hive Hub 360 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 Centrical Connected Home Limited by Element, at the address 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 2, February 2017 – 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: Hive Hub 360
- Serial Number: UFD-637
- Model Number: Hub 450
- Software Revision: Not Stated
- 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.

Test laptop (Dell Latitude E6440)
USB Programming cable

7.3 EUT Mode of Operation

7.3.1 Transmission

The mode of operation for transmit tests was as follows:

The selection of channels and output powers and modulation was selected using client software. The equipment under test was tested on the bottom, middle, and top channels.

7.3.2 Reception

Not applicable

Note: This test report only covers part 15 C for intentional radiators.

7.4 EUT Radio Parameters

7.4.1 General

Frequency of operation:	2405MHz-2470MHz
Modulation type(s):	DSSS
Occupied channel bandwidth(s):	5MHz
Channel spacing:	5MHz
Declared output power(s):	20dBm
Nominal Supply Voltage:	110 Vac
Duty cycle:	27% (Max transmit time 27ms per 100ms)

7.4.2 Antennas

Type:	6dBi printed antenna on flexi

7.5 EUT Description

The EUT is a smart home device with Wi-Fi, Zigbee, Bluetooth, and Z wave connection capabilities. The unit also has a function to detect specific sounds in the environment.

Note: This test report only covers part 15 C (intentional radiators) of the ZigBee operation.

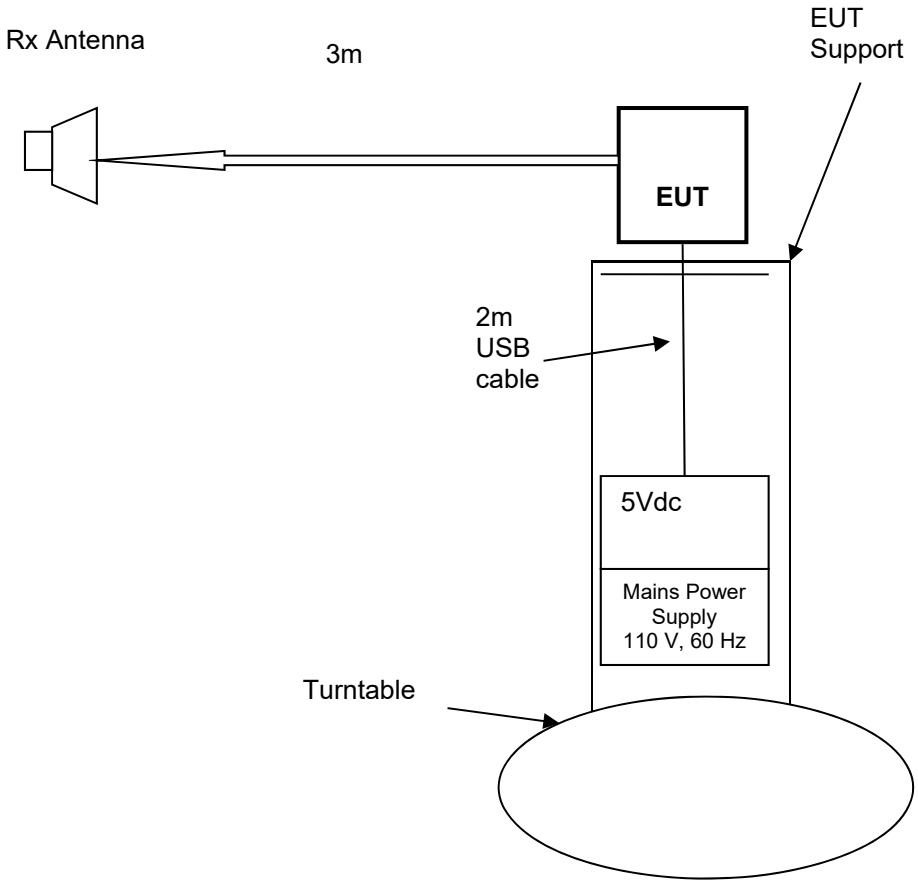
8 Modifications

No modifications were performed during this assessment.

9 EUT Test Setup

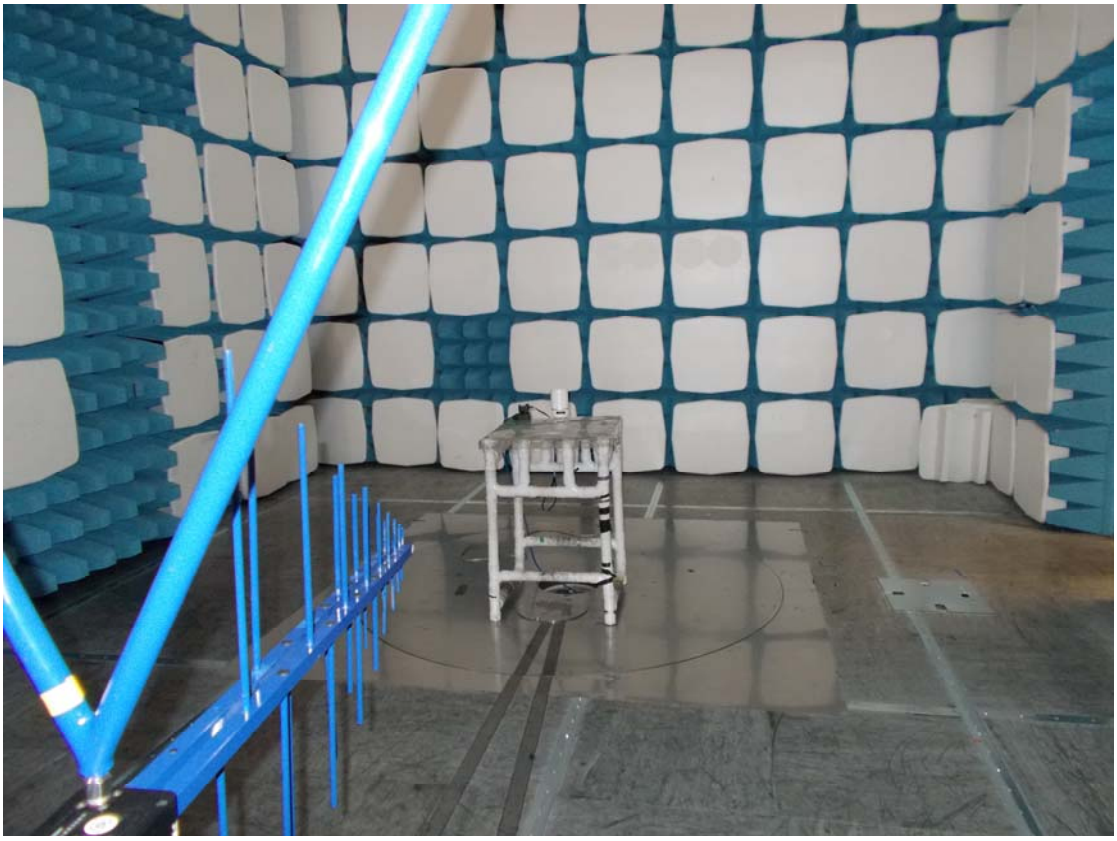
9.1 Block Diagram

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



9.2 General Setup Photograph

The following photograph shows basic EUT setup:



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 110 V ac 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	New battery	N/A

11 Radiated emissions

11.1 Definitions

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

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

11.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Radio Chamber
Test Standard and Clause:	ANSI C63.10-2013, Clause 6.5 and 6.6
EUT Channels / Frequencies Measured:	Low / Mid / High
EUT Channel Bandwidths:	5 MHz
Deviations From Standard:	None
Measurement BW:	30 MHz to 1 GHz: 120 kHz Above 1 GHz: 1 MHz
Measurement Detector:	Up to 1 GHz: quasi-peak Above 1 GHz: RMS average and Peak

Environmental Conditions (Normal Environment)

Temperature: 24 °C	+15 ºC to +35 ºC (as declared)
Humidity: 40 % RH	20 % RH to 75 % RH (as declared)
Supply: 110 V ac	110 V ac ±10 % (as declared)

11.3 Test Limit

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

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

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

11.4 Test Method

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

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

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

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

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

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

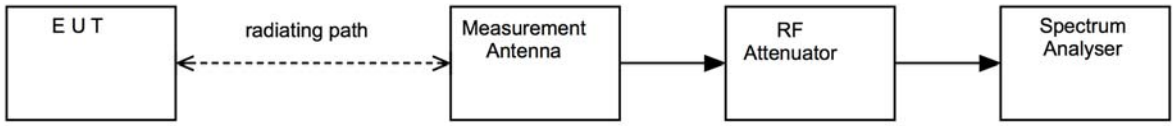
$$FS = PR + CL + AF – PA + DC – CF$$

Where,

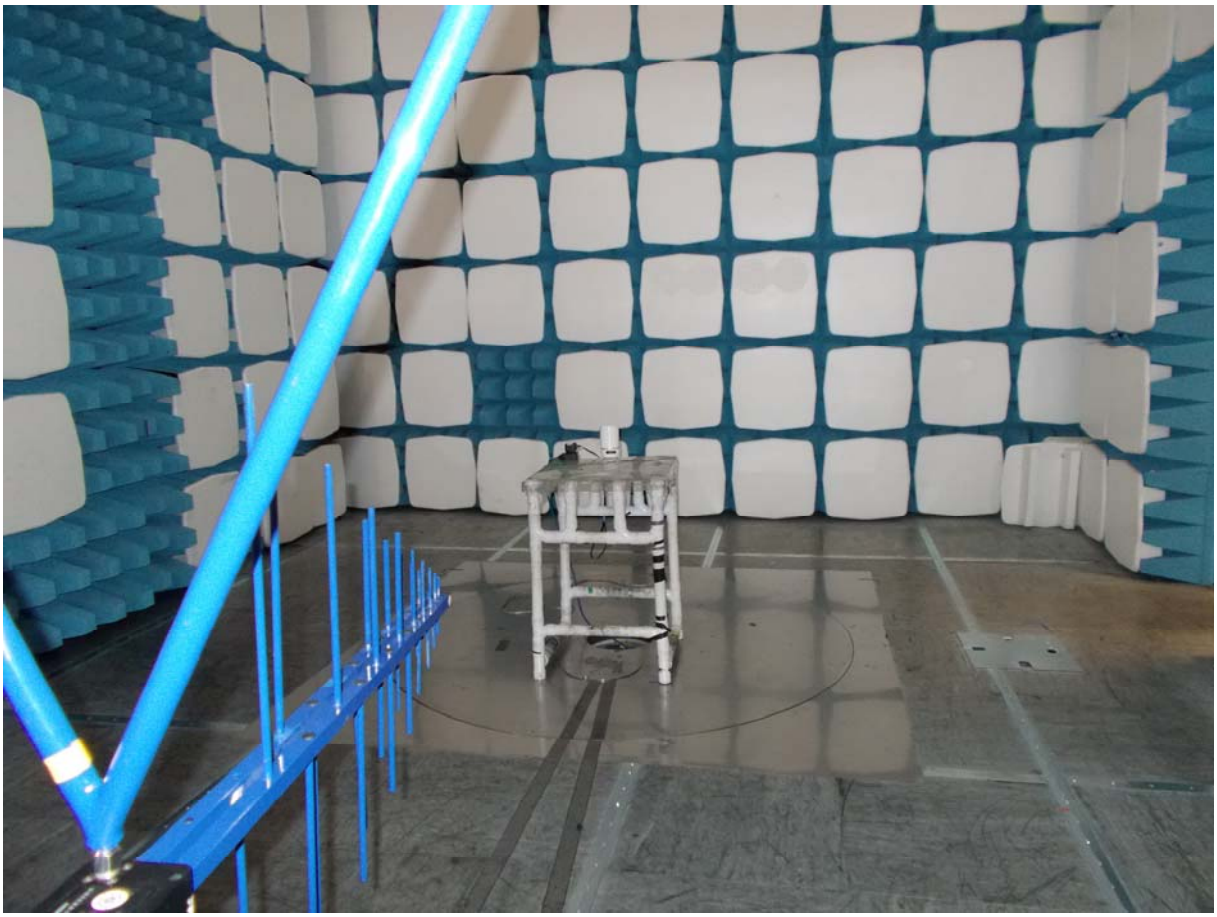
PR is the power recorded on the receiver / spectrum analyzer in dBµV;
CL is the cable loss in dB;
AF is the test antenna factor in dB/m;
PA is the pre-amplifier gain in dB (where used);
DC is the duty correction factor in dB (where used, e.g. harmonics of pulsed fundamental);
CF is the distance factor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

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

Figure i Test Setup



11.5 Test Set-up Photograph

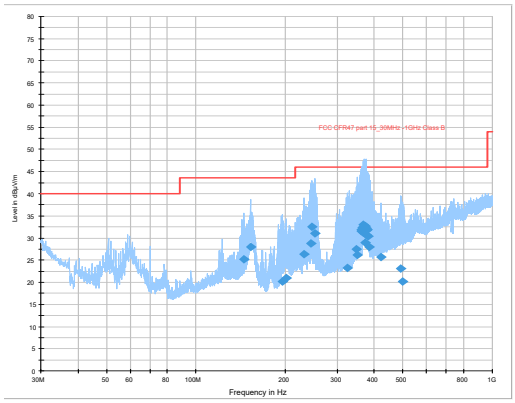


11.6 Test Equipment

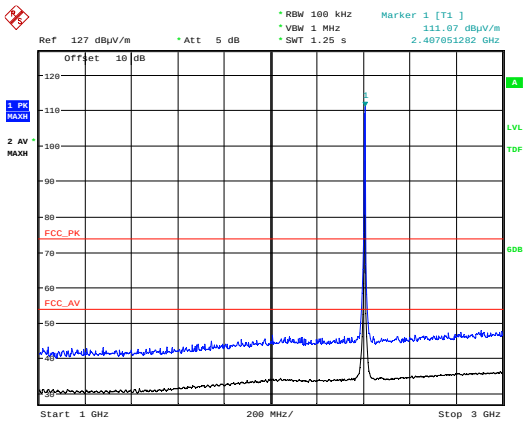
Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
ESVS10	R&S	Receiver	L317	22/03/2018
FSU46	R&S	Spectrum Analyser	U281	19/06/2018
CBL611/A	Chase	Bilog	U191	23/02/2019
3115	EMCO	1-18GHz Horn	L138	13/04/2018
8449B	Agilent	Pre Amp	L572	07/02/2018
20240-20	Flann	Horn 18-26GHz (&U330)	L300	07/04/2018

11.7 Test Results

Bottom channel 2405 MHz

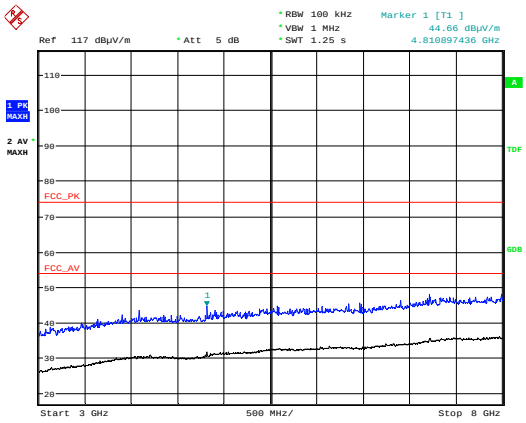


30 MHz to 1 GHz



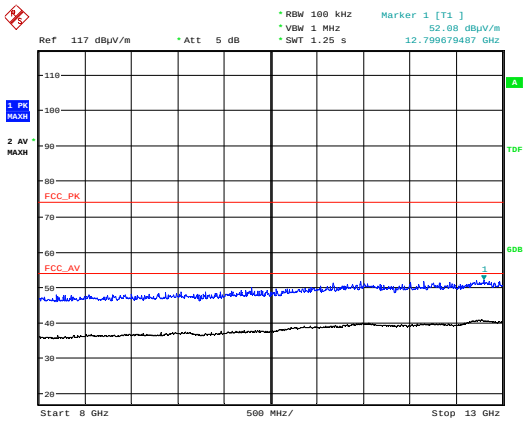
Date: 13.SEP.2017 15:27:45

1 GHz to 3 GHz



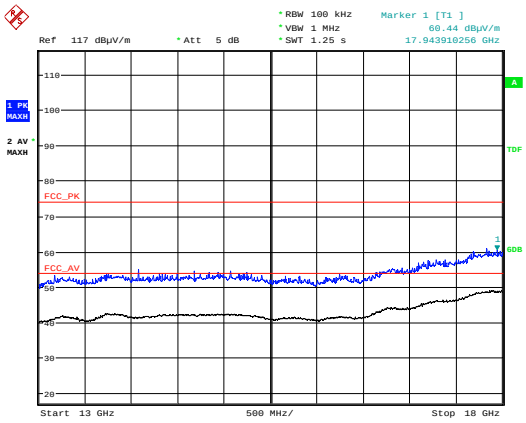
Date: 13.SEP.2017 15:54:51

3 GHz to 8 GHz



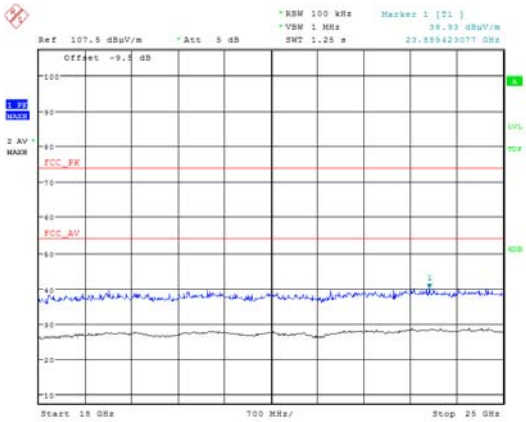
Date: 13.SEP.2017 17:23:06

8 GHz to 13 GHz



Date: 13.SEP.2017 17:45:04

13 to 18 GHz

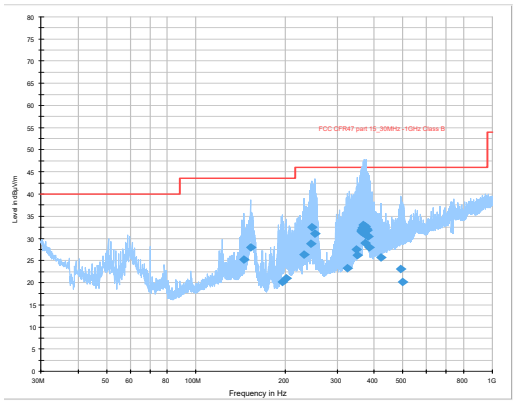


Date: 13.SEP.2017 18:59:31

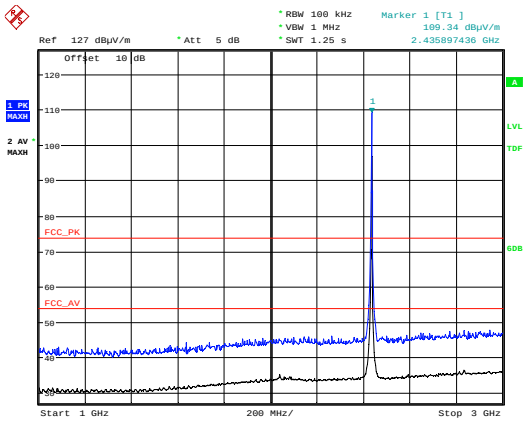
18 GHz to 25 GHz

High Power: -2 dBm ; Channel: 2405 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	4810.00	56.30	4.70	33.10	35.88	0.00	0.00	58.22	814.70	5000
Av	4810.00	48.34	4.70	33.10	35.88	0.00	0.00	50.26	325.84	500

Middle channel 2435 MHz

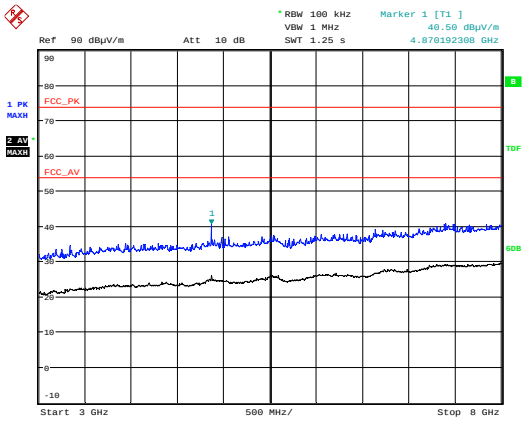


30 MHz to 1 GHz

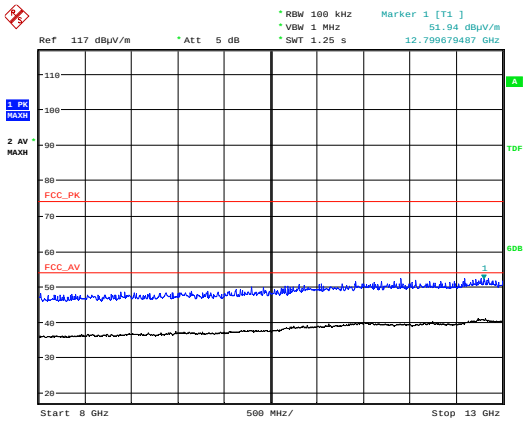


Date: 13.SEP.2017 15:38:31

1 GHz to 3 GHz

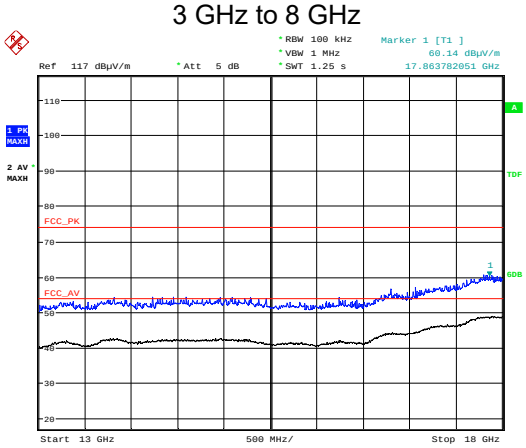


Date: 19.JAN.2018 08:25:08

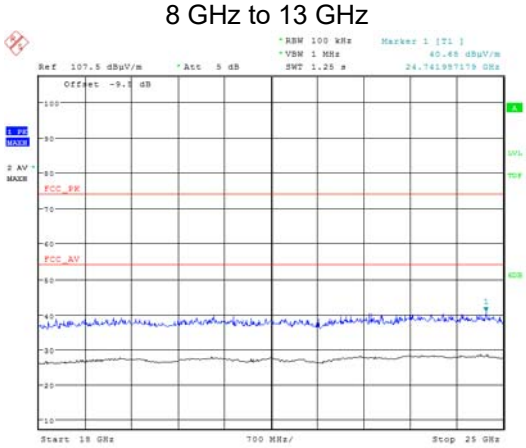


Date: 13.SEP.2017 17:28:02

3 GHz to 8 GHz



Date: 13.SEP.2017 17:42:22



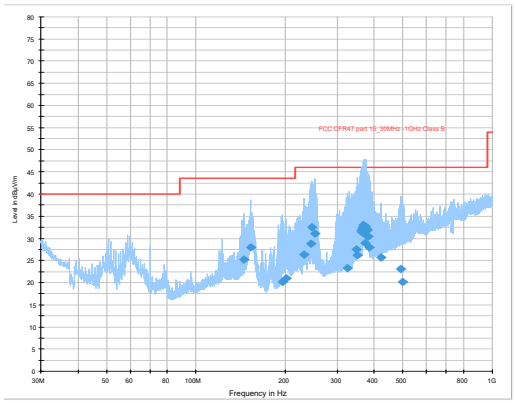
Date: 13.SEP.2017 19:01:59

13 to 18 GHz

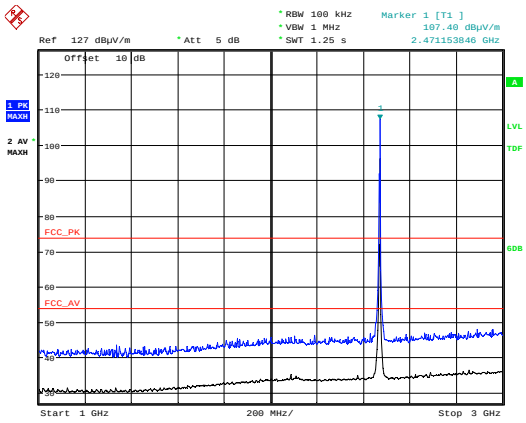
18 GHz to 25 GHz

High Power: -2 dBm ; Channel: 2435 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	4870.00	57.32	4.60	33.30	35.90	0.00	0.00	59.32	924.70	5000
Av	4870.00	48.95	4.60	33.30	35.90	0.00	0.00	50.95	352.78	500
Pk	7305.00	25.13	6.70	36.40	36.22	0.00	0.00	32.01	39.86	5000
Av	7305.00	22.72	6.70	36.40	36.22	0.00	0.00	29.60	30.20	500

Top channel 2470 MHz

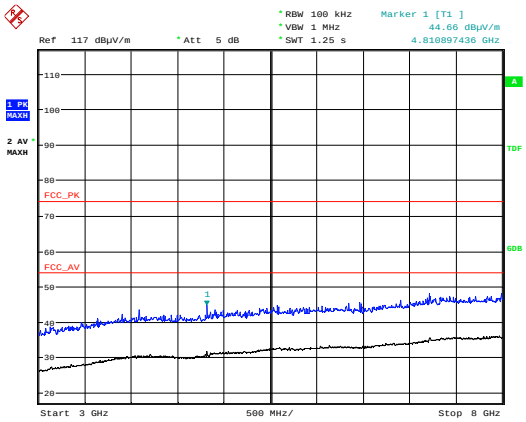


30 MHz to 1 GHz

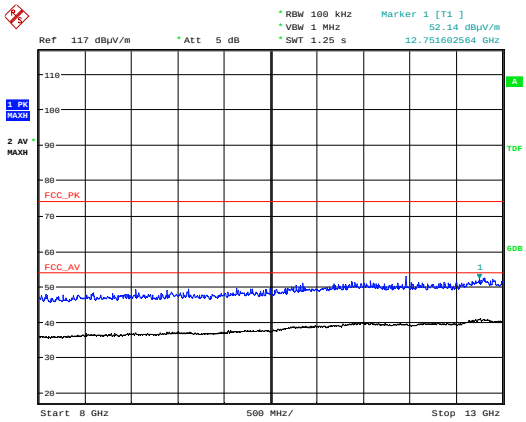


Date: 13.SEP.2017 15:45:07

1 GHz to 3 GHz

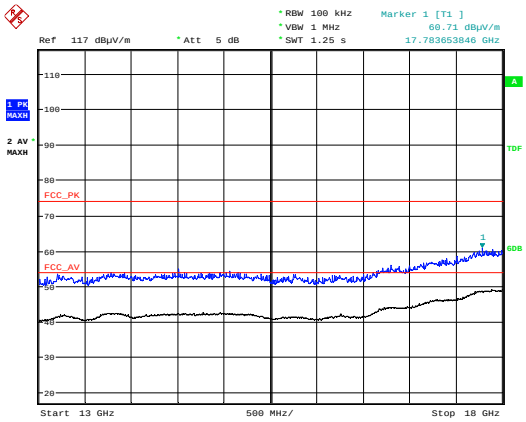


Date: 13.SEP.2017 15:54:51

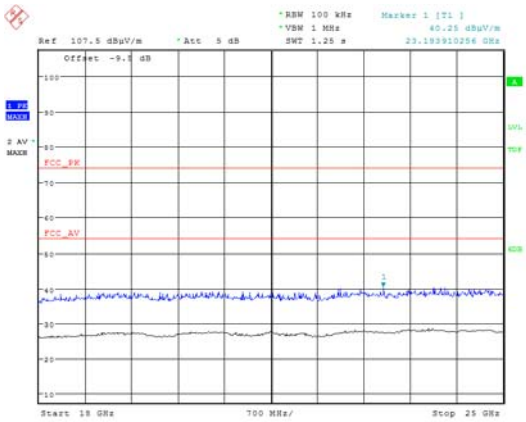


Date: 13.SEP.2017 17:33:30

3 GHz to 8 GHz



Date: 13.SEP.2017 17:36:34

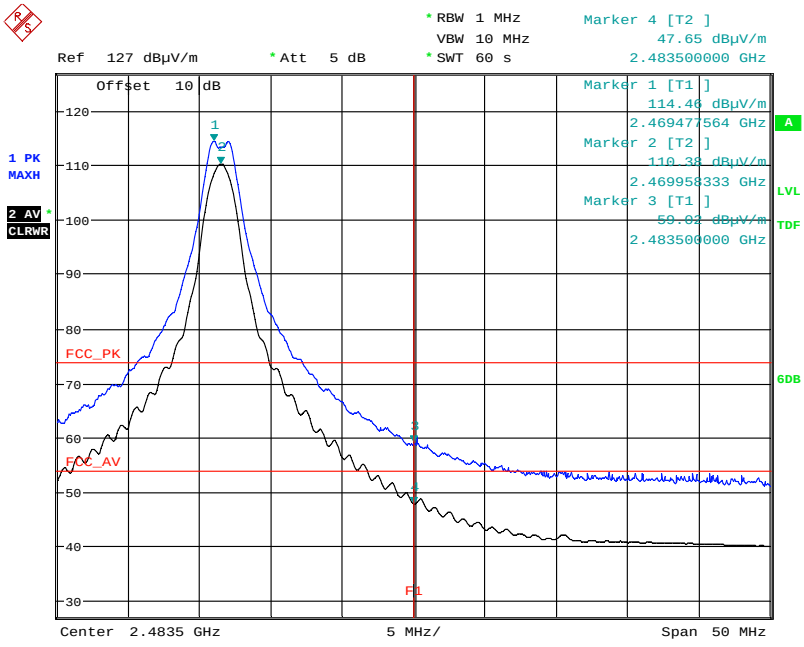


Date: 13.SEP.2017 19:09:09

13 to 18 GHz

18 GHz to 25 GHz

High Power: -2 dBm ; Channel: 2470 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	4940.00	56.46	4.60	33.40	35.93	0.00	0.00	58.53	844.31	5000
Av	4940.00	48.67	4.60	33.40	35.93	0.00	0.00	50.74	344.35	500
Pk	7410.00	56.09	6.30	36.60	36.24	0.00	0.00	62.75	1372.46	5000
Av	7410.00	47.30	6.30	36.60	36.24	0.00	0.00	53.96	498.88	500



Date: 13.SEP.2017 15:05:16

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:	Transient 1
Test Standard and Clause:	ANSI C63.10-2013, Clause 6.2
EUT Channels / Frequencies Measured:	Wifi 2412MHz Zigbee 2470MHz Zwave 908.4MHz
Deviations From Standard:	None
Measurement BW:	
Measurement Detectors:	Quasi-Peak and Average, RMS

Note: Worst case was performed (all radios on)

Environmental Conditions (Normal Environment)

Temperature: 23 °C	+15 ºC to +35 ºC (as declared)
Humidity: 44 % RH	20 % RH to 75 % RH (as declared)
Supply: 110 V ac	110 V ac ±10 % (as declared)

12.3 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.

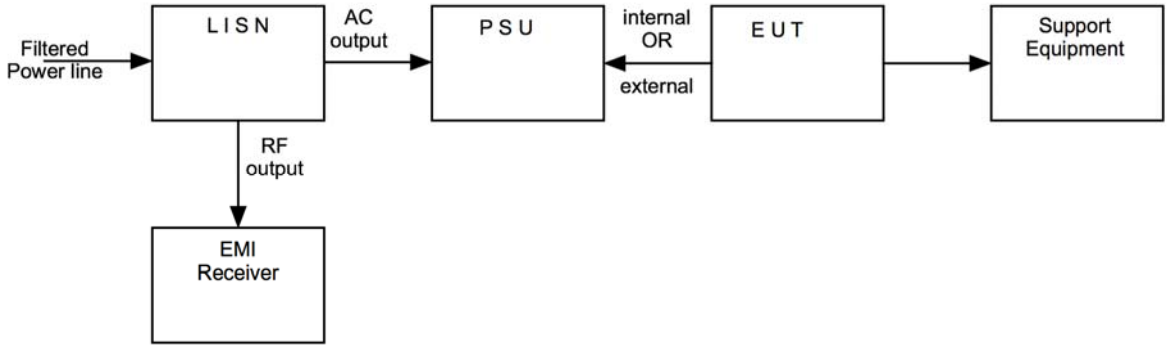
12.4 Test Method

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



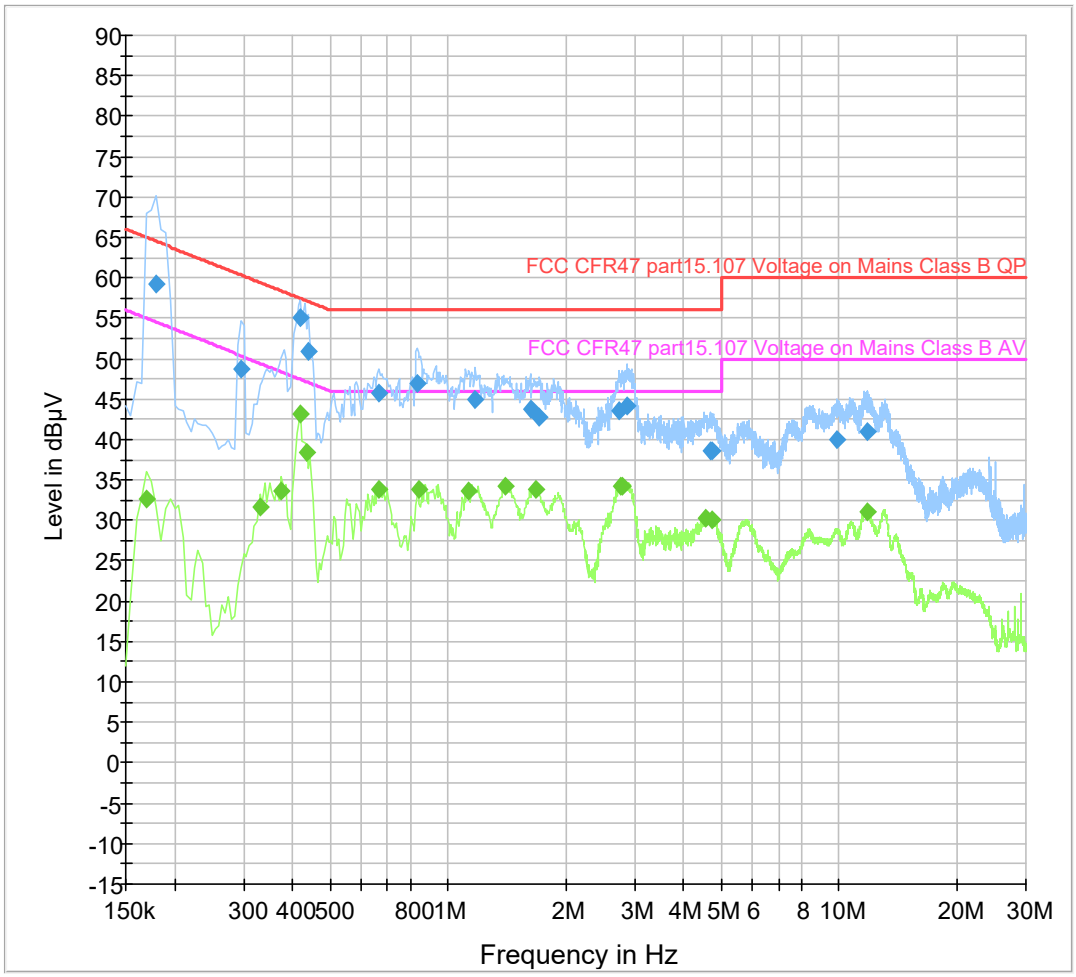
12.5 Test Set-up Photograph

12.6 Test Equipment

Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
ESHS10	R&S	Receiver	U003	24/08/2018
ENV216	R&S	LISN	U396	05/07/2018

12.7 Test Results

Conducted emissions on Mains 9kHz-30MHz ESHS10+UH396+UH443PL



Quasi Peak

Frequency (MHz)	QuasiPeak (dBµV)	Meas. Time (ms)	Bandwidth (kHz)	Line	Corr. (dB)	Margin (dB)	Limit (dBµV)	Comment
0.180000	59.3	2000.0	10.000	L1	19.6	5.2	64.5	Pass
0.295000	48.8	2000.0	10.000	L1	19.6	11.6	60.4	Pass
0.420000	55.2	2000.0	10.000	L1	19.6	2.3	57.4	Pass
0.440000	50.9	2000.0	10.000	L1	19.6	6.2	57.1	Pass
0.665000	45.8	2000.0	10.000	L1	19.7	10.2	56.0	Pass
0.835000	46.9	2000.0	10.000	L1	19.7	9.1	56.0	Pass
1.175000	45.0	2000.0	10.000	L1	19.7	11.0	56.0	Pass
1.625000	43.7	2000.0	10.000	L1	19.7	12.3	56.0	Pass
1.715000	42.7	2000.0	10.000	L1	19.7	13.3	56.0	Pass
2.735000	43.6	2000.0	10.000	L1	19.7	12.4	56.0	Pass
2.865000	44.1	2000.0	10.000	L1	19.7	11.9	56.0	Pass
4.690000	38.6	2000.0	10.000	L1	19.8	17.4	56.0	Pass
4.720000	38.6	2000.0	10.000	L1	19.8	17.4	56.0	Pass
9.840000	40.0	2000.0	10.000	L1	19.9	20.0	60.0	Pass
11.780000	41.0	2000.0	10.000	L1	19.9	19.0	60.0	Pass

Average

Frequency (MHz)	Average (dBµV)	Meas. Time (ms)	Bandwidth (kHz)	Line	Corr. (dB)	Margin (dB)	Limit (dBµV)	Comment
0.170000	32.6	2000.0	10.000	L1	19.6	22.3	55.0	Pass
0.330000	31.6	2000.0	10.000	L1	19.6	17.9	49.5	Pass
0.375000	33.7	2000.0	10.000	L1	19.6	14.7	48.4	Pass
0.420000	43.3	2000.0	10.000	L1	19.6	4.2	47.4	Pass
0.435000	38.4	2000.0	10.000	L1	19.6	8.7	47.2	Pass
0.665000	33.7	2000.0	10.000	L1	19.7	12.3	46.0	Pass
0.840000	33.8	2000.0	10.000	L1	19.7	12.2	46.0	Pass
1.130000	33.6	2000.0	10.000	L1	19.7	12.4	46.0	Pass
1.405000	34.2	2000.0	10.000	L1	19.7	11.8	46.0	Pass
1.670000	33.9	2000.0	10.000	L1	19.7	12.1	46.0	Pass
2.760000	34.3	2000.0	10.000	L1	19.7	11.7	46.0	Pass
2.800000	34.3	2000.0	10.000	L1	19.7	11.7	46.0	Pass
4.565000	30.3	2000.0	10.000	L1	19.8	15.7	46.0	Pass
4.745000	30.0	2000.0	10.000	L1	19.8	16.0	46.0	Pass
11.780000	31.0	2000.0	10.000	N	19.9	19.0	50.0	Pass

13 Occupied Bandwidth

13.1 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.

13.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Radio Laboratory
Test Standard and Clause:	IC: ANSI C63.10-2013, Clause 6.9 FCC: ANSI C63.10-2013, Clause 11.8
EUT Channels / Frequencies Measured:	Low / Mid / High
EUT Channel Bandwidths:	5 MHz
EUT Test Modulations:	DSSS
Deviations From Standard:	None
Measurement BW: (IC requirement: 1% to 5% OBW; FCC requirement: 100 kHz)	50 kHz and 100 KHz
Spectrum Analyzer Video BW: (requirement at least 3x RBW)	200 kHz and 300 kHz
Measurement Span: (requirement 2 to 5 times OBW)	6 MHz and 7 MHz
Measurement Detector:	Peak

Environmental Conditions (Normal Environment)

Temperature: 24 °C	+15 ºC to +35 ºC (as declared)
Humidity: 40 % RH	20 % RH to 75 % RH (as declared)
Supply: 110 V ac	110 V ac ±10 % (as declared)

13.3 Test Limit

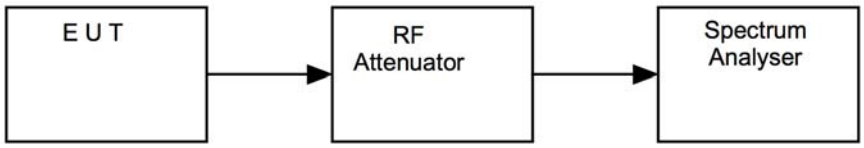
The minimum -6 dB bandwidth shall be at least 500 kHz.

13.4 Test Method

With the EUT setup as per section 9 of this report and connected as per Figure iii, 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 iii Test Setup

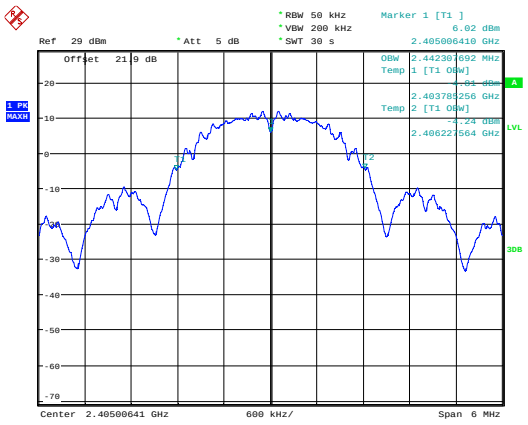


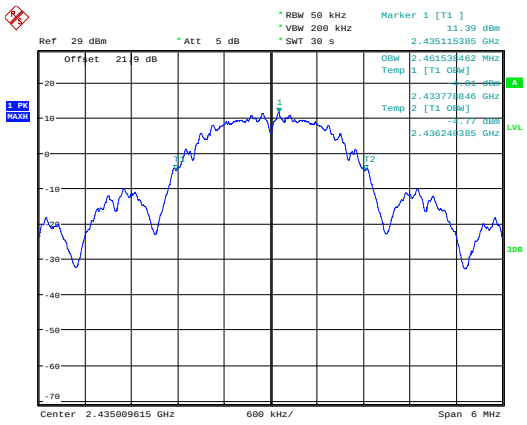
13.5 Test Equipment

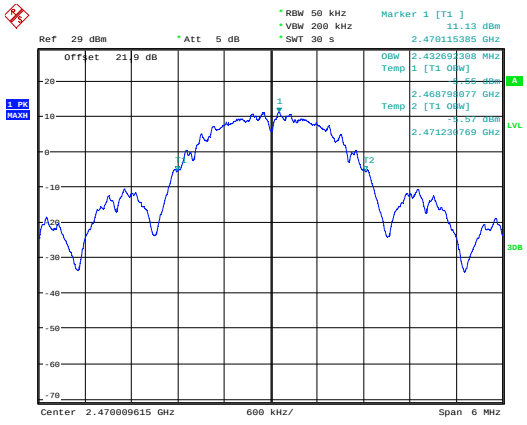
Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
FSU46	R&S	Spectrum Analyser	U281	19/06/2018

13.6 Test Results

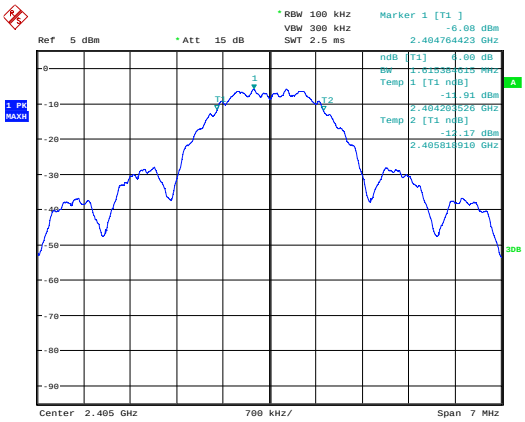
RSS-210.; Power setting: -2 dBm				
Channel Frequency (MHz)	**F_L (MHz)**	**F_H (MHz)**	**99% Bandwidth (kHz)**	**Result**
2405	2403.785256	2406.227564	2442.307692	PASS
2435	2433.778846	2436.240385	2461.538462	PASS
2470	2468.798077	2471.230769	2432.692308	PASS



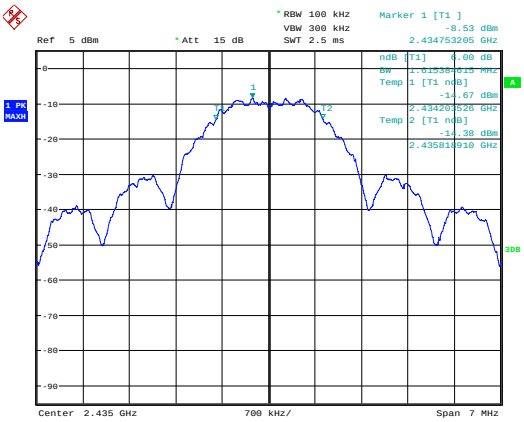




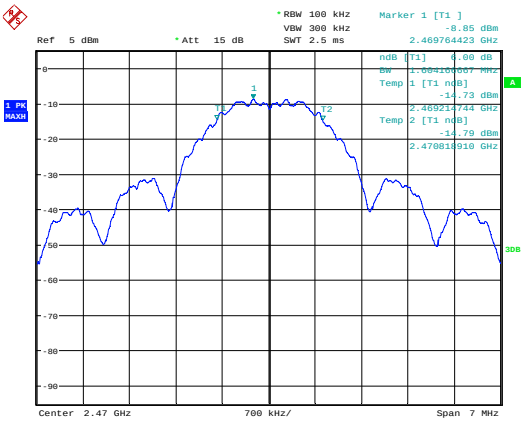
FCC 15.247.; Power setting: -2 dBm				
Channel Frequency (MHz)	**F_L (MHz)**	**F_H (MHz)**	**6dB Bandwidth (kHz)**	**Result**
2405	2404.203526	2405.81891	1615.384	PASS
2435	2434.203526	2435.81891	1615.384	PASS
2470	2469.214744	2470.81891	1604.166	PASS



Date: 25.SEP.2017 12:25:29



Date: 25.SEP.2017 12:30:50



Date: 25.SEP.2017 12:37:17

14 Maximum peak conducted output power

14.1 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.

The maximum conducted output power is defined as the total transmit power delivered to all antennas and antenna elements averaged across all symbols in the signaling alphabet when the transmitter is operating at its maximum power control level.

14.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Radio Chamber
Test Standard and Clause:	ANSI C63.10-2013, Clause 11.9.1
EUT Channels / Frequencies Measured:	Low / Mid / High
EUT Channel Bandwidths:	5 MHz
Deviations From Standard:	None
Measurement Detector:	Peak
Voltage Extreme Environment Test Range:	Mains Power = 85 % and 115 % of Nominal (FCC only requirement)

Environmental Conditions (Normal Environment)

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

14.3 Test Limit

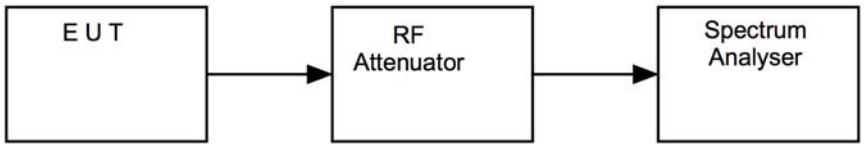
For systems employing digital modulation techniques operating in the bands 902 to 928 MHz, 2400 to 2483.5 MHz and 5725 to 5850 MHz, the maximum peak conducted output power shall not exceed 1 W.

14.4 Test Method

With the EUT setup as per section 9 of this report and connected as per Figure iv, 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 iv Test Setup



14.5 Test Equipment

Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
RPR3006W	Dare	Power Meter	REF2111	03/03/2018

14.6 Test Results

Modulation: DSSS; Power setting: -2 dBm				
Channel Frequency (MHz)	***Analyzer Level (dBm)***	***Cable loss (dB)***	***Power (dBm)***	***Result***
2405	-3.10	21.90	18.80	PASS
2435	-1.10	21.90	20.80	PASS
2470	-4.10	21.90	17.80	PASS

15 Out-of-band and conducted spurious emissions

15.1 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.

15.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Radio Laboratory
Test Standard and Clause:	ANSI C63.10-2013, Clause 11.11
EUT Channels / Frequencies Measured:	Low / Mid / High
EUT Channel Bandwidths:	5 MHz
Deviations From Standard:	None
Measurement BW:	1 kHz/ 10 kHz/ 100 kHz
Spectrum Analyzer Video BW: (requirement at least 3x RBW)	3 kHz/ 30 kHz/ 300 kHz
Measurement Detector:	Peak
Measurement Range:	9 kHz to 26.5 GHz

Environmental Conditions (Normal Environment)

Temperature: 25 °C	+15 ºC to +35 ºC (as declared)
Humidity: 42 % RH	20 % RH to 75 % RH (as declared)
Supply: 110 V ac	110 V ac ±10 % (as declared)

15.3 Test Limit

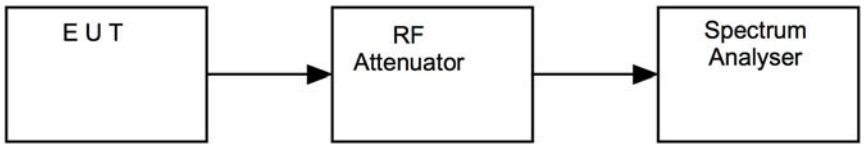
In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated device is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either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

15.4 Test Method

With the EUT setup as per section 9 of this report and connected as per Figure v, 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 v Test Setup

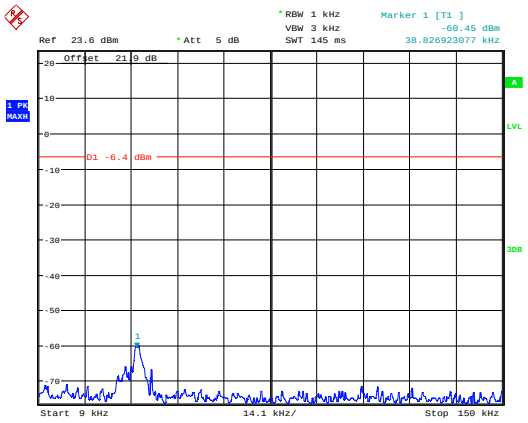


15.5 Test Equipment

Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
FSU46	R&S	Spectrum Analyser	U281	19/06/2018

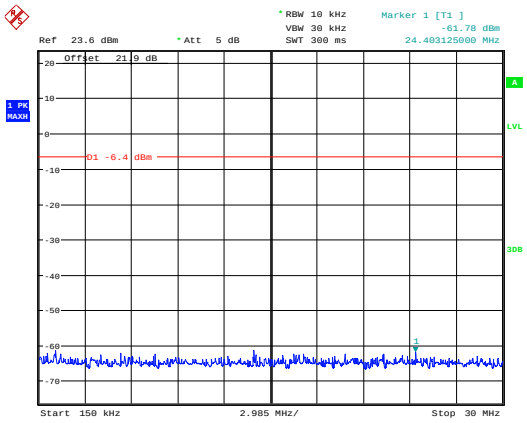
15.6 Test Results

Bottom Channel 2405 MHz



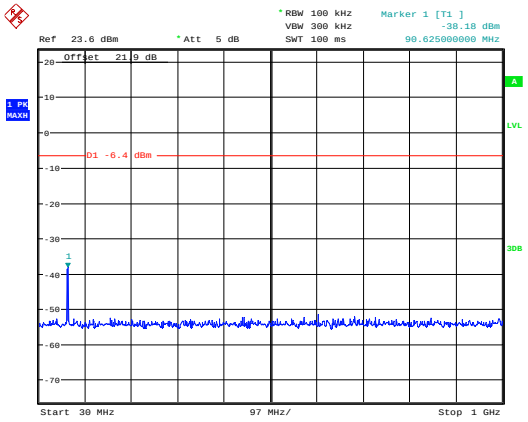
Date: 25.SEP.2017 17:05:35

9 kHz to 150 kHz



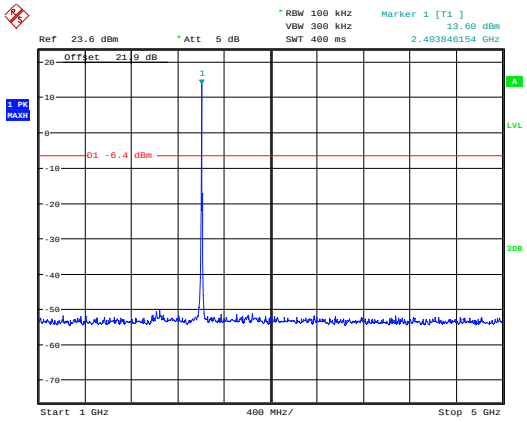
Date: 25.SEP.2017 17:06:17

150kHz to 30 MHz



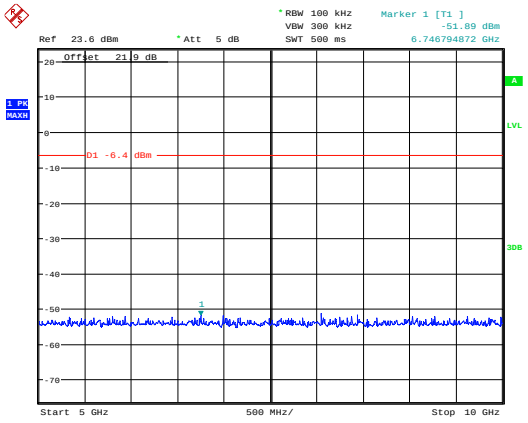
Date: 25.SEP.2017 17:06:46

30 MHz to 1 GHz



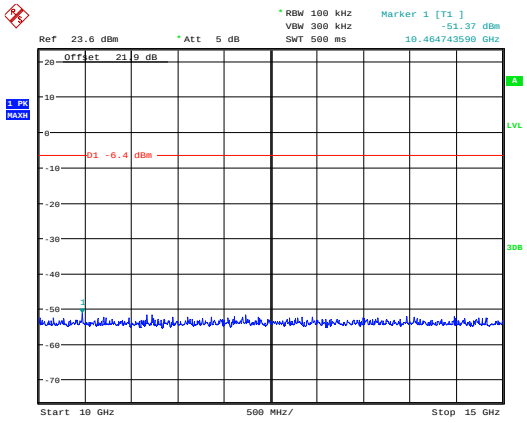
Date: 25.SEP.2017 17:04:49

1 GHz to 5 GHz



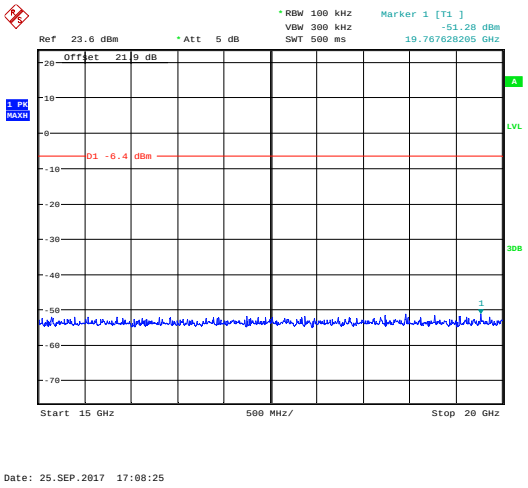
Date: 25.SEP.2017 17:07:18

5 GHz to 10 GHz

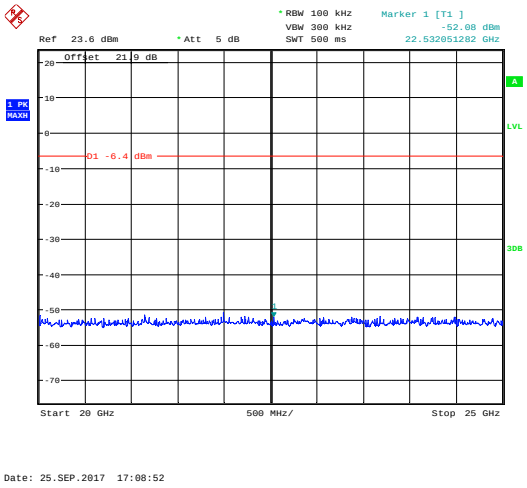


Date: 25.SEP.2017 17:07:45

10 GHz to 15 GHz



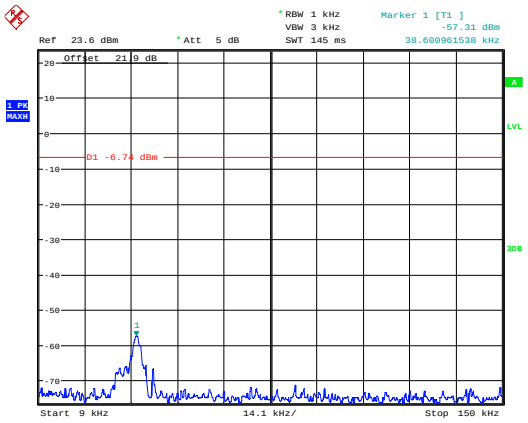
15 GHz to 20 GHz



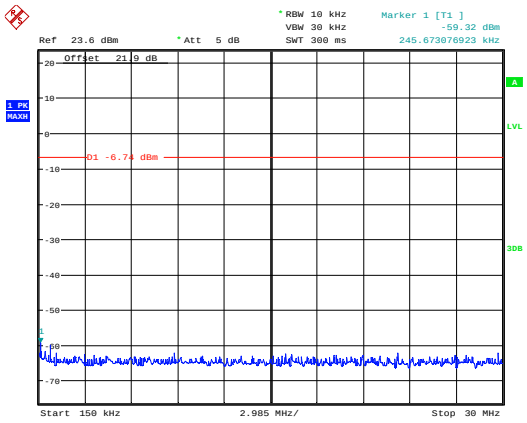
20 GHz to 25 GHz

Frequency: 2405 MHz; Modulation: DSSS; Power setting: -2						
Channel Frequency (MHz)	***Emission Frequency (MHz)***	***Analyzer Level (dBm)***	***Emission Level (dBm)***	***Limit (dBm)***	***Margin (dB)***	***Result***
No emissions within 20 dB to the limit						PASS

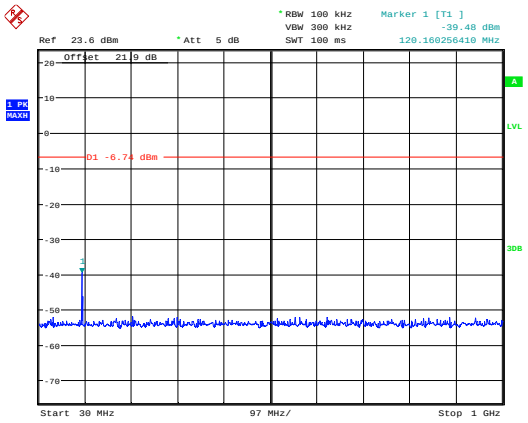
Middle Channel 2435 MHz



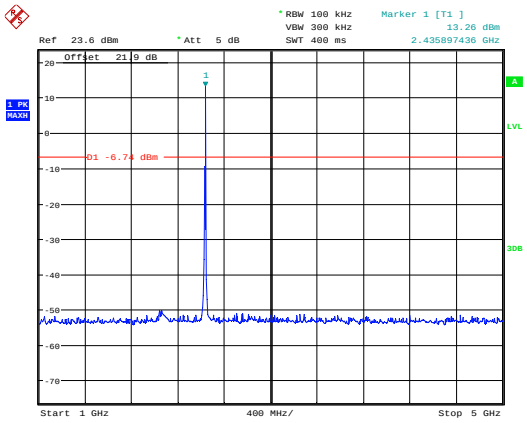
9 kHz to 150 kHz



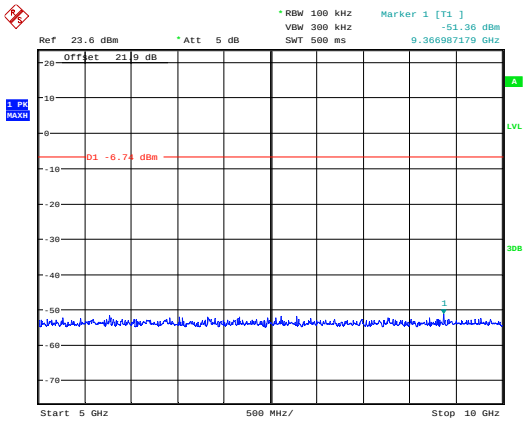
150kHz to 30 MHz



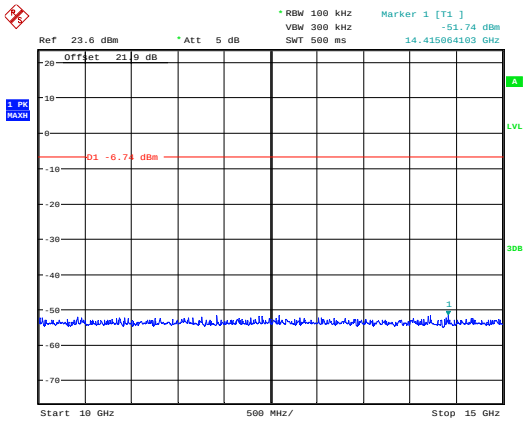
30 MHz to 1 GHz



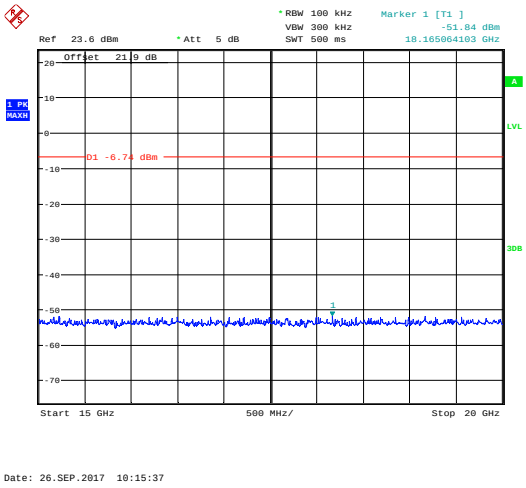
1 GHz to 5 GHz



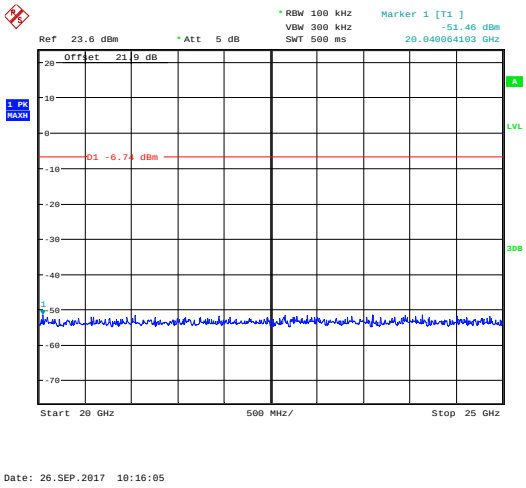
5 GHz to 10 GHz



10 GHz to 15 GHz



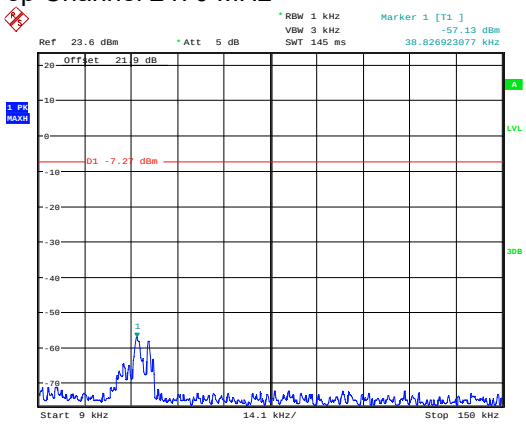
15 GHz to 20 GHz



20 GHz to 25 GHz

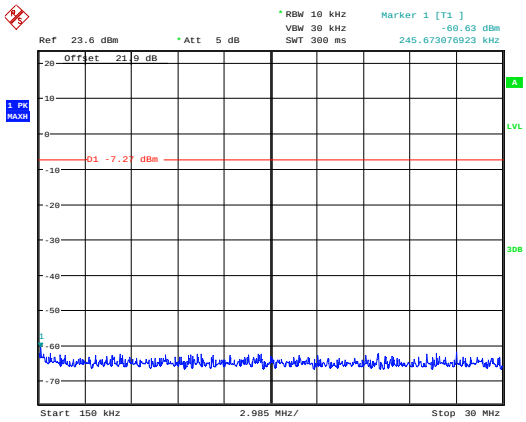
Frequency: 2435 MHz; Modulation: DSSS; Power setting: -2						
Channel Frequency (MHz)	***Emission Frequency (MHz)***	***Analyzer Level (dBm)***	***Emission Level (dBm)***	***Limit (dBm)***	***Margin (dB)***	***Result***
No Emissions within 20 dB to the limit						PASS

Top Channel 2470 MHz



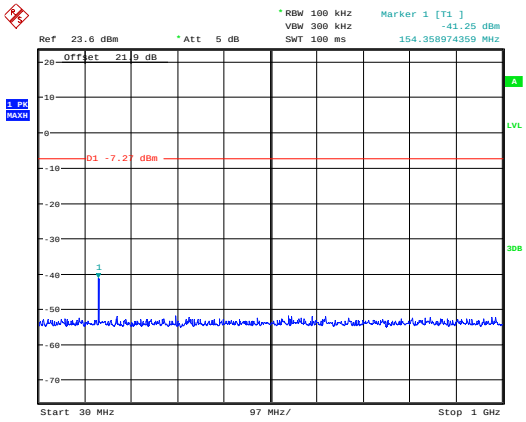
Date: 26.SEP.2017 10:28:42

9 kHz to 150 kHz



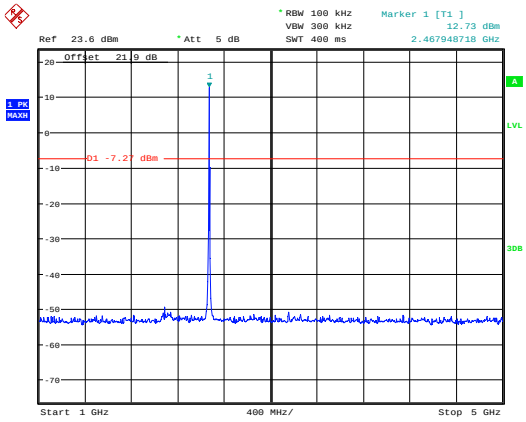
Date: 26.SEP.2017 10:29:14

150kHz to 30 MHz



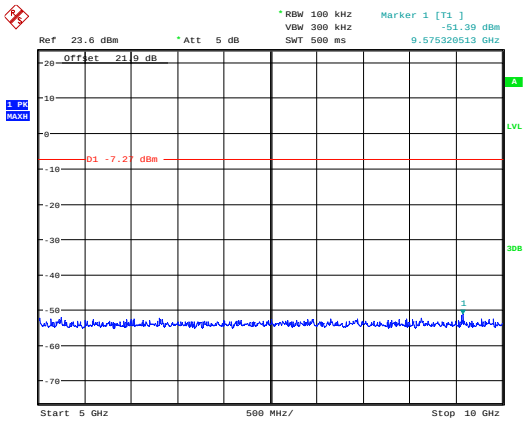
Date: 26.SEP.2017 10:29:48

30 MHz to 1 GHz



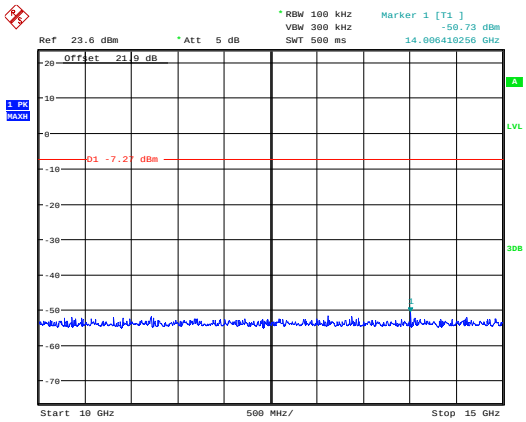
Date: 26.SEP.2017 10:26:12

1 GHz to 5 GHz



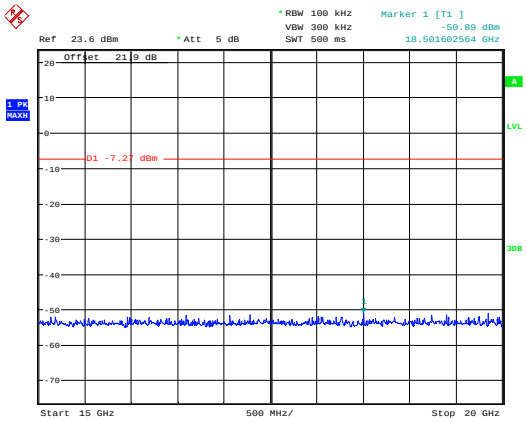
Date: 26.SEP.2017 10:26:37

5 GHz to 10 GHz

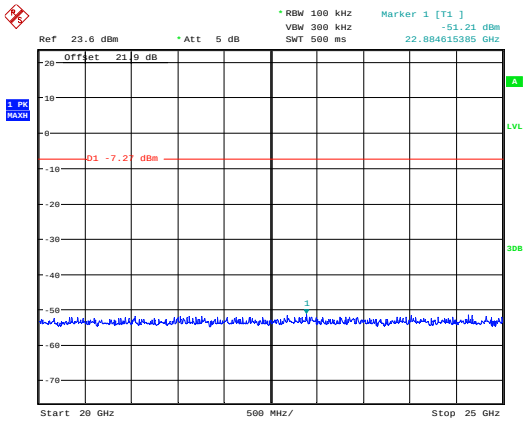


Date: 26.SEP.2017 10:27:05

10 GHz to 15 GHz

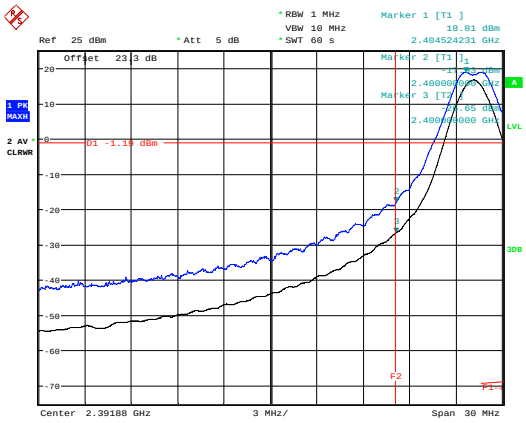


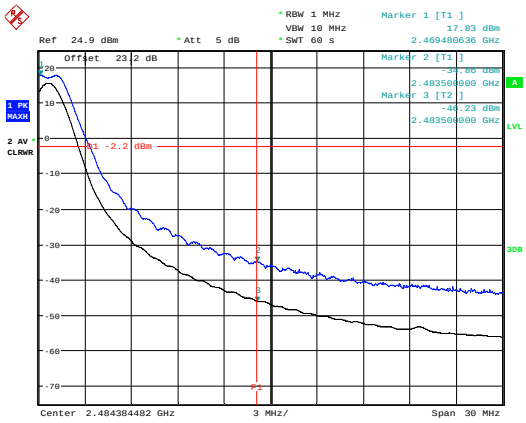
15 GHz to 20 GHz



20 GHz to 25 GHz

Frequency: 2470 MHz; Modulation: DSSS; Power setting: -2						
Channel Frequency (MHz)	***Emission Frequency (MHz)***	***Analyzer Level (dBm)***	***Emission Level (dBm)***	***Limit (dBm)***	***Margin (dB)***	***Result***
No Emissions within 20 dB to the limit						PASS





16 Power spectral density

16.1 Definition

The power per unit bandwidth.

16.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Radio Chamber
Test Standard and Clause:	ANSI C63.10-2013, Clause 11.10
EUT Channels / Frequencies Measured:	Low / Mid / High
EUT Channel Bandwidths:	5 MHz
Deviations From Standard:	None
Measurement BW:	3 kHz
Spectrum Analyzer Video BW:	10 kHz
Measurement Span:	5 MHz
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: 110 V ac	110 V ac ±10% (as declared)

16.3 Test Limit

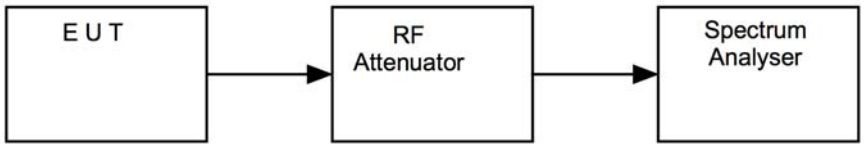
The transmitter power spectral density conducted from the transmitter to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.

16.4 Test Method

With the EUT setup as per section 9 of this report and connected as per Figure vi, the peak emission of the EUT was measured on a spectrum analyser, with path losses taken into account.

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

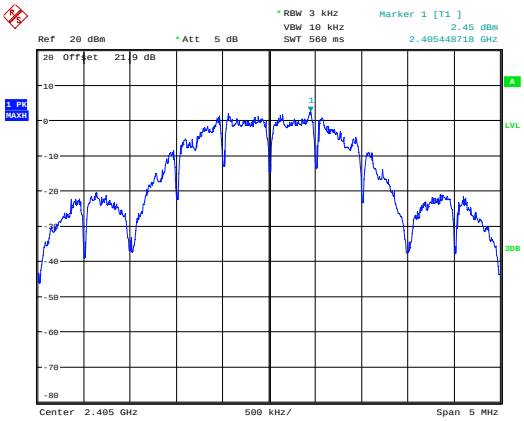


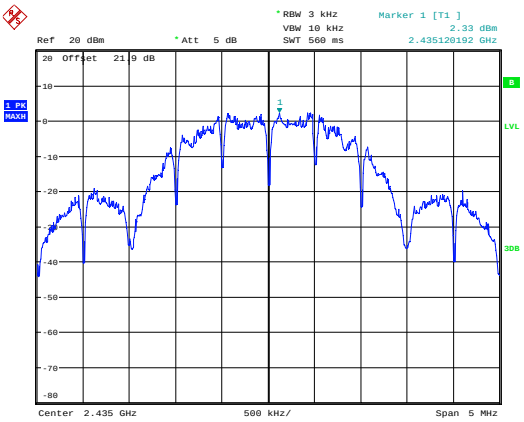
16.5 Test Equipment

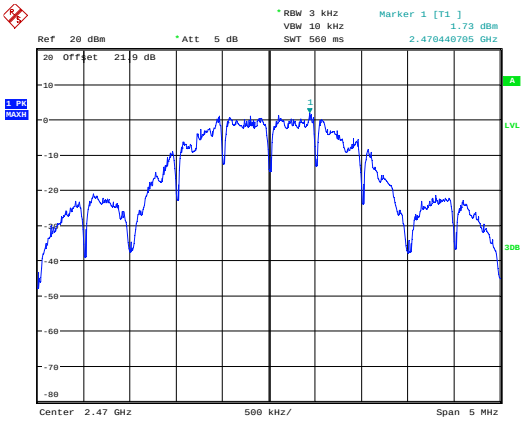
Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
FSU46	R&S	Spectrum Analyser	U281	19/06/2018

16.6 Test Results

Modulation: DSSS; Power setting: -2dBm				
Channel Frequency (MHz)	***Analyzer Level (dBm)***	***Cable loss (dB)***	***Power (dBm)***	***Result***
2405	2.45	0.00	2.45	PASS
2435	2.33	0.00	2.33	PASS
2470	1.73	0.00	1.73	PASS







17 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] Power spectral density

Uncertainty in test result (Spectrum Analyser) = **2.48 dB**