Report on the Radio Testing

For

SigFox SA

on

SBS T 902 V2.2

Report no. TRA-028228-47-01A

6th October 2016

Report Number: TRA-028228-47-01A
Issue: A

REPORT ON THE RADIO TESTING OF A
SigFox SA
SBS T 902 V2.2
WITH RESPECT TO SPECIFICATION
FCC 47CFR 15.247 & IC RSS-247

TEST DATE: 22nd August- 19th September 2016

Written by: S Hodgkinson

S Hodgkinson

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Department Manger – Radio

Date: 6th October 2016

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Company Reg No. 02536659

1 Revision Record

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

2 Summary

TEST REPORT NUMBER:	TRA-028228-47-01A
WORKS ORDER NUMBER	TRA-028228-01
PURPOSE OF TEST:	USA: Testing of radio frequency equipment per the relevant authorization procedure of chapter 47 of CFR (code of federal regulations) Part 2, subpart J. Canada: Testing of radio apparatus for TAC (technical acceptance certificate) per subsections 4(2) of the Radio communication Act and 21(1) of the Radio communication Regulations.
TEST SPECIFICATION(S):	47CFR15.247 & RSS-247
EQUIPMENT UNDER TEST (EUT):	SBS T 902 V2.2
FCC IDENTIFIER: INDUSTRY CANADA:	2ACK7SBST902v22 12204A-SBST902v22
EUT SERIAL NUMBER:	S00005
MANUFACTURER/AGENT:	SigFox SA
ADDRESS:	425 Rue Jean Rostand Labège 31670
CLIENT CONTACT:	Susana Barreiro ☎ +33 5 34 31 03 16 ✉ susana.barreiro@sigfox.com
TEST DATE:	22nd August- 19th September 2016
TESTED BY:	S Hodgkinson 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*
Carrier frequency separation	247, 5.1 (2)	15.247(a)(1)	☒	*Pass*
Number of hopping channels	247, 5.1 (3), (4) and (5)	15.247(a)(1) (i), (ii) and (iii)	☒	*Pass*
Average time of occupancy	247, 5.1 (3), (4) and (5)	15.247(a)(1) (i), (ii) and (iii)	☒	*Pass*
Maximum peak conducted output power	247, 5.4 (1), (2) and (3)	15.247 (a)(1), (b)(1) and (b)(2)	☒	*Pass*
20dB emission bandwidth	247, 5.1 (1)	15.247(a)(1) (i) and (ii)	☒	*Pass*
Out-of-band emissions	247, 5.5	15.247(d)	☒	*Pass*

Notes:

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

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

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

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4 Introduction

This report TRA-028228-47-01A presents the results of the Radio testing on a SigFox SA, SBS T 902 V2.2 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 SigFox SA 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-4

The test site requirements of ANSI C63.4-2014 are met up to 1GHz.

The test site SVSWR requirements of CISPR 16-1-4:2010 are met over the frequency range 1 GHz to 18 GHz.

5 Test Specifications

5.1 Normative References

- FCC 47 CFR Ch. I – Part 15 – Radio Frequency Devices.
- ANSI C63.10-2013 – American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices.
- ANSI C63.4-2014 – American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz.
- Industry Canada RSS-247, Issue 1, May 2015 – Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and Licence-Exempt Local Area Network (LE-LAN) Devices
- Industry Canada RSS-Gen, Issue 4, November 2014 – General Requirements for Compliance of Radio Apparatus.

5.2 Deviations from Test Standards

There were no deviations from the test standard.

6 Glossary of Terms

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

7 Equipment Under Test

7.1 EUT Identification

- Name: SBS T 902 V2.2
- Serial Number: S00005
- Model Number: SBS T 902 V2.2
- Software Revision: V4.1
- Build Level / Revision Number: V 2.2

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.

support/monitoring equipment used.

Dell Vostro PC
Cat 6 Patch Cable

7.3 EUT Mode of Operation

7.3.1 Transmission

EUT Transmitting a modulated carrier at top, middle or bottom frequency
or hopping as required

7.4 EUT Radio Parameters

7.4.1 General

Frequency of operation:	902MHz – 928MHz
Modulation type(s):	600 bps D-BPSK
Occupied channel bandwidth(s):	175kHz
Channel spacing:	300kHz
ITU emission designator(s):	180KB7D
Declared output power(s):	Max 36 dBm eirp
Nominal Supply Voltage:	110Vac
Duty cycle:	Maximum of 2%

7.4.2 Antennas

Type:	Procom CXL900-6LW/h
Frequency range:	890-960MHz
Gain:	8dBi
Connector type:	N Type

7.5 EUT Description

The SBS T 902v2.2 is a FHSS device operating in the 902 -928 MHz Band

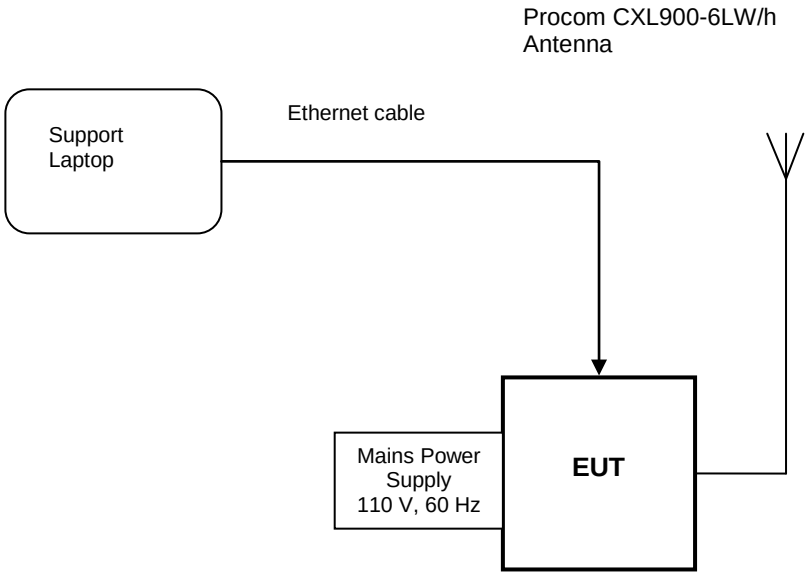
8 Modifications

No modifications were performed during this assessment.

9 EUT Test Setup

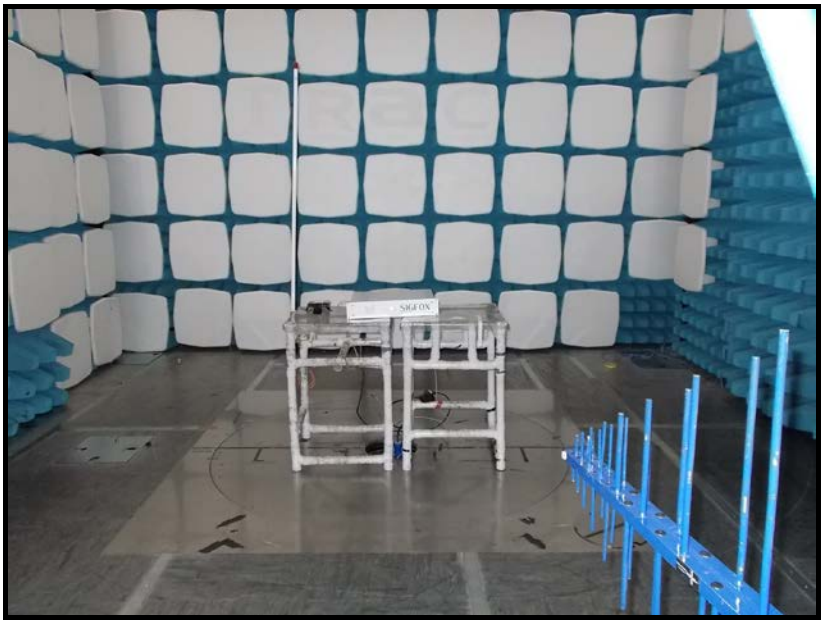
9.1 Block Diagram

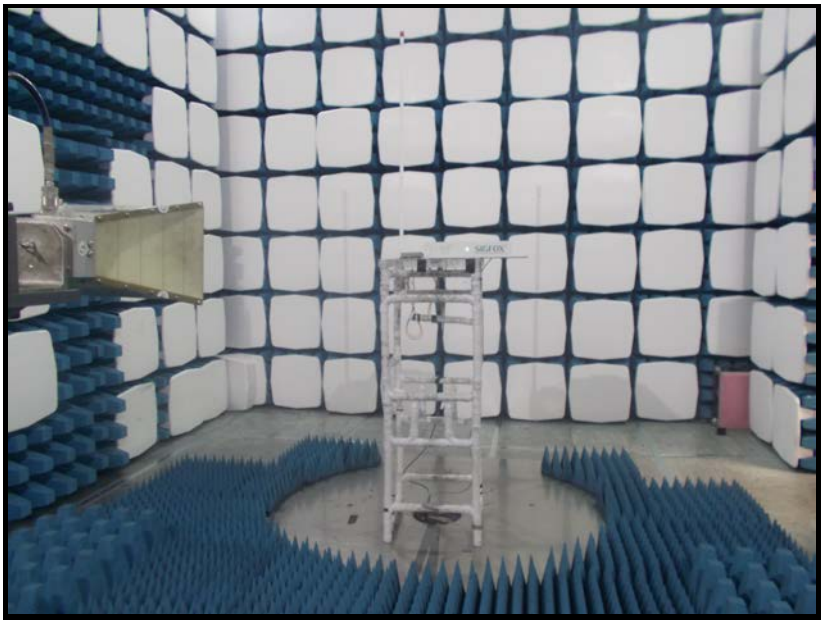
The following diagram shows basic EUT interconnections with cable type and cable lengths identified:



9.2 General Set-up Photograph

The following photograph shows basic EUT set-up:





General Technical Parameters

9.3 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. 110 V ac, 60 Hz, from the mains.

9.4 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

10 Radiated emissions

10.1 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.

10.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Chamber 3
Test Standard and Clause:	ANSI C63.10-2013, Clause 6.5 and 6.6
EUT Channels / Frequencies Measured:	Low / Mid / High
EUT Channel Bandwidths:	180kHz
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: average and 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: 110V ac	110 V ac ±10 % (as declared)

10.3 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

10.4 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:

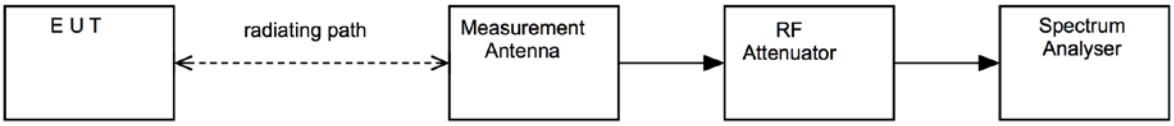
$$FS = PR + CL + AF – PA + DC – CF$$

Where,

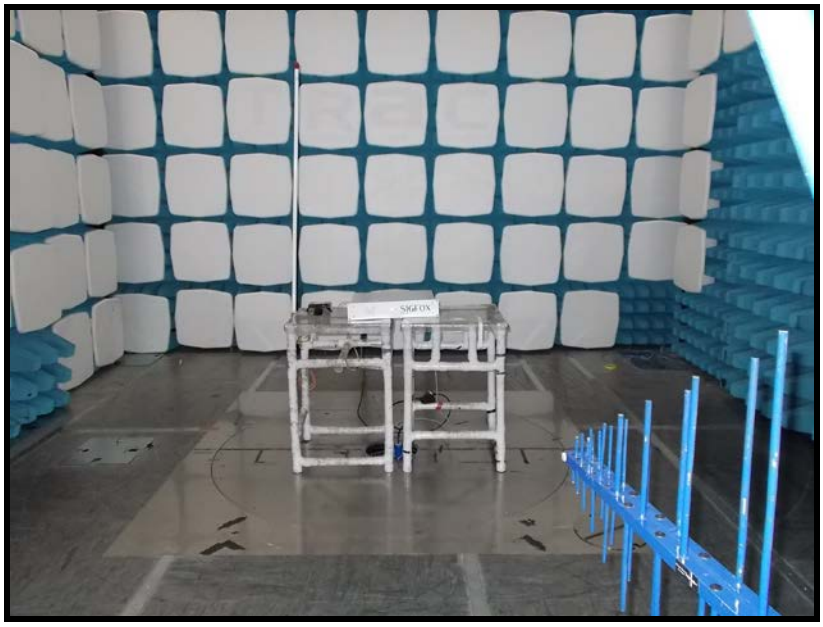
PR is the power recorded on the receiver / spectrum analyzer in dBµV;
CL is the cable loss in dB;
AF is the test antenna factor in dB/m;
PA is the pre-amplifier gain in dB (where used);
DC is the duty correction factor in dB (where used, e.g. harmonics of pulsed fundamental);
CF is the distance factor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

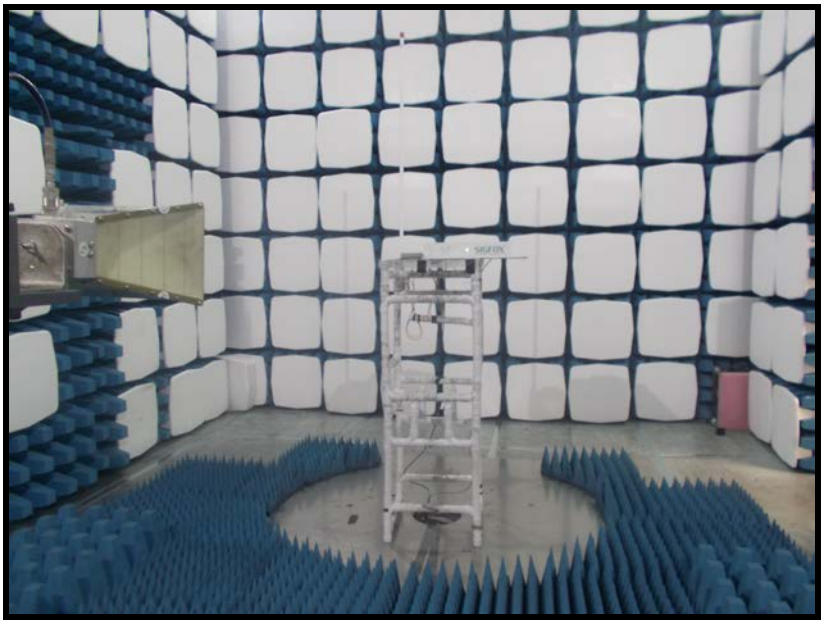
This field strength value is then compared with the regulatory limit.

Figure i Test Setup



10.5 Test Set-up Photograph





10.6 Test Equipment

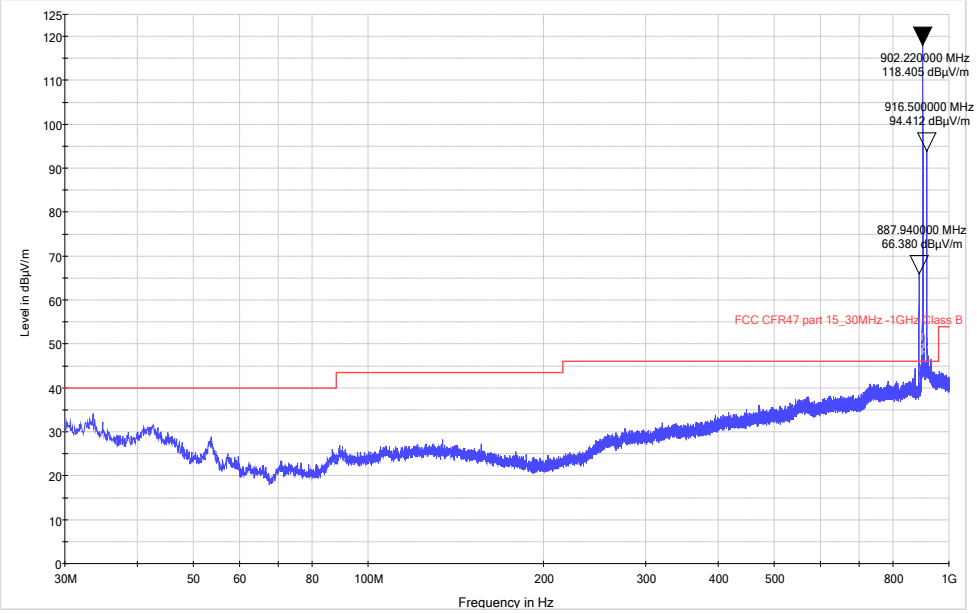
Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
ESVS10	R&S	Receiver	L352	14/07/2017
CBL611/A	Chase	Bilog	U191	26/02/2017
3115	EMCO	1-18GHz Horn	L139	25/09/2017
FSU46	R&S	Spectrum Analyser	U281	07/06/2017
SH4141	BSC	High Pass Filter	REF977	25/02/2017
8449B	Agilent	Pre Amp	L572	16/02/2017

10.7 Test Results

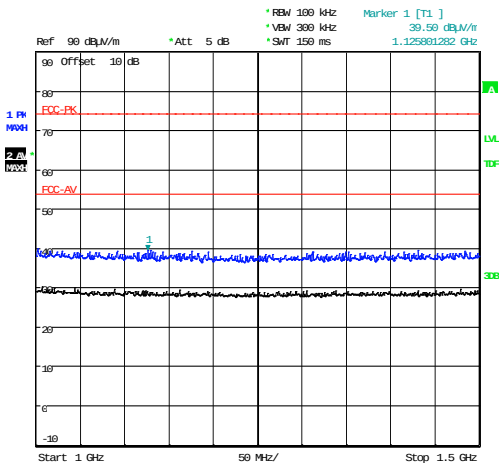
Ref No.	FREQ. (MHz)	MEAS Rx (dBµV)	CABLE LOSS (dB)	ANT FACT. (dB/m)	PRE AMP (dB)	Filter loss (dB)	FIELD ST'GH (dBµV/m)	Margin (dBm)	LIMIT (20dBc)
1.	916.5	70.1	3.8	23	N/A	N/A	96.9	-5.1	102.0 dBµV/m

Ref No.	FREQ. (MHz)	MEAS Rx (dBµV)	CABLE LOSS (dB)	ANT FACT. (dB/m)	PRE AMP (dB)	Filter loss (dB)	FIELD ST'GH (dBµV/m)	Margin (dBm)	FIELD ST'GH (µV/m)	LIMIT (µV/m)
2.	4511.0	52.3	4.2	32.1	35.7	1.1	53.97pk	-20.03	499.5	5011.9
3.	4511.0	33.36	4.2	32.1	35.7	1.1	35.03av	-19.00	56.4	500.00

Tx bottom Channel 902.2MHz



1GHz – 1.5GHz



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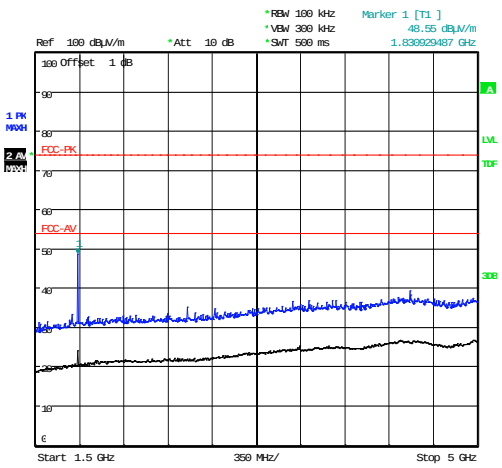
1.5GHz – 5GHz



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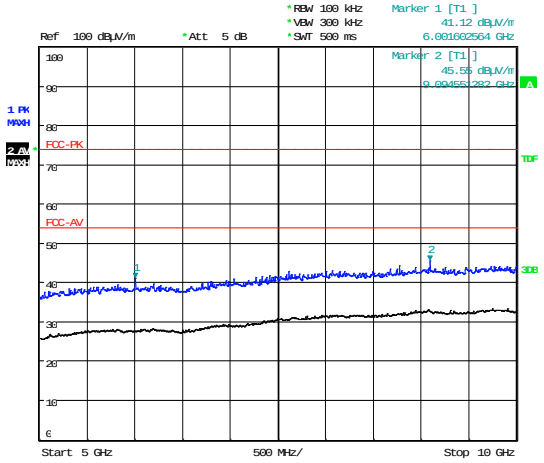
5-10GHz



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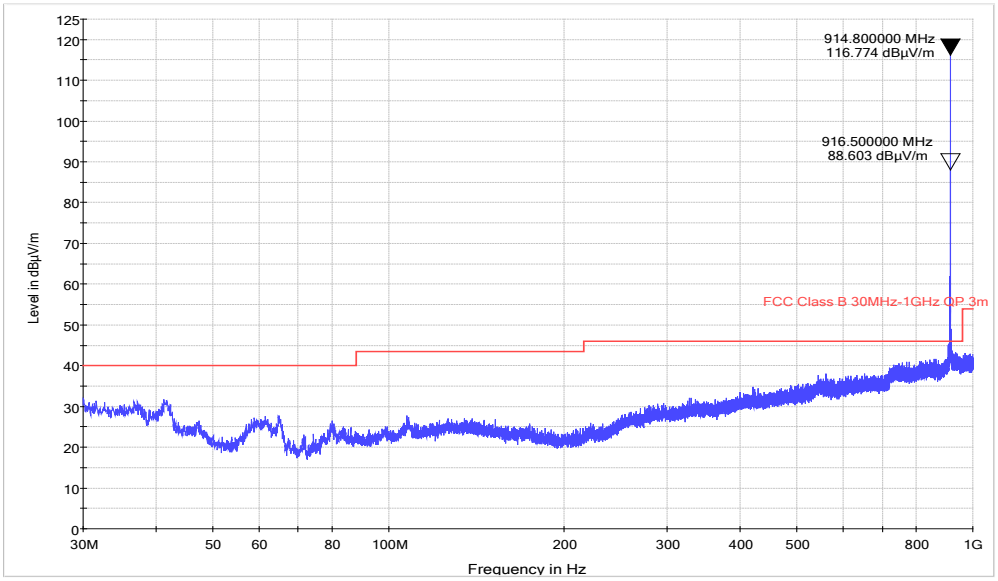
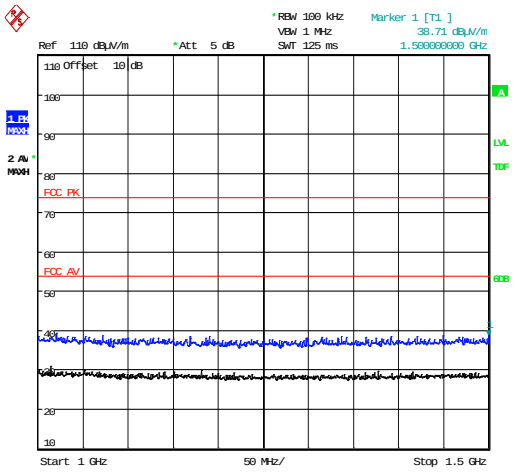
Ref No.	FREQ. (MHz)	MEAS Rx (dBµV)	CABLE LOSS (dB)	ANT FACT. (dB/m)	PRE AMP (dB)	Filter loss (dB)	FIELD ST'GH (dBµV/m)	Margin (dBm)	LIMIT (20dBc)
1.	916.5	70.1	3.8	23	N/A	N/A	96.9	-6.3	103.2 dBµV/m

Ref No.	FREQ. (MHz)	MEAS Rx (dBµV)	CABLE LOSS (dB)	ANT FACT. (dB/m)	PRE AMP (dB)	Filter loss (dB)	FIELD ST'GH (dBµV/m)	Margin (dBm)	FIELD ST'GH (µV/m)	LIMIT (µV/m)
2.	2744.32	54.06	3.5	29.20	36.1	0.4	51.10pk	-22.9	358.9	5011.9
3.	2744.32	37.50	3.5	29.20	36.1	0.4	34.54av	-19.5	53.3	500.00
4.	4573.95	54.63	4.3	32.20	35.8	1.2	56.58pk	-17.4	674.5	5011.9
5.	4573.95	36.47	4.3	32.20	35.8	1.2	38.42	-15.6	83.4	500.00

Tx mid channel 914.8MHz



1GHz-1.5GHz



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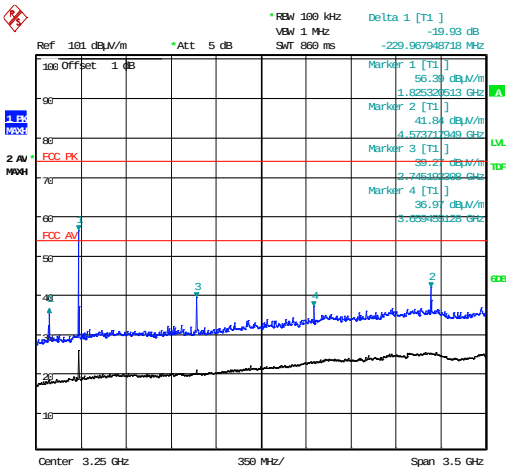
1.5GHz – 5GHz



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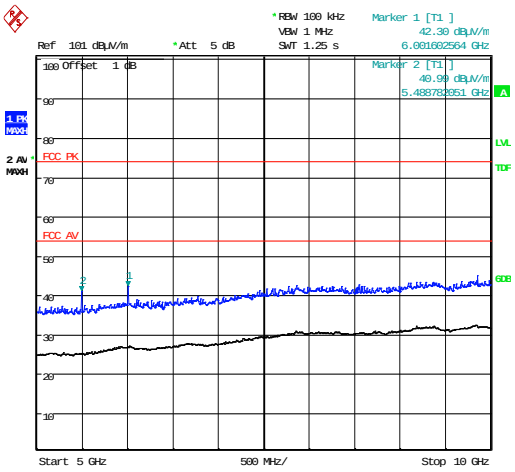
5GHz -10GHz



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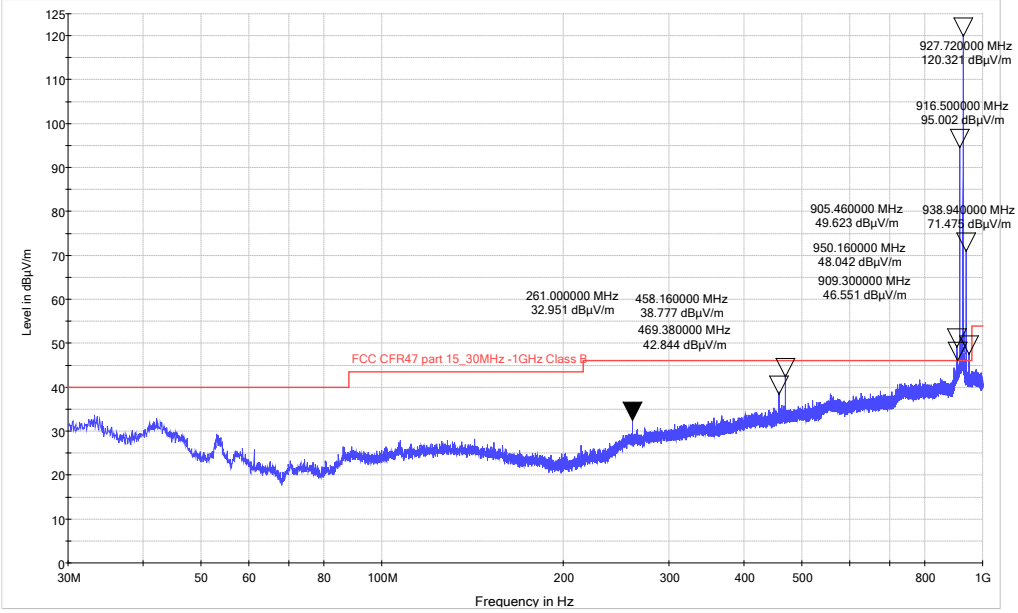
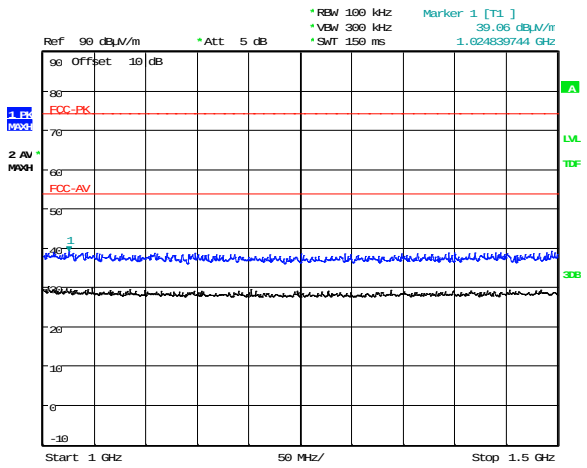
Ref No.	FREQ. (MHz)	MEAS Rx (dBµV)	CABLE LOSS (dB)	ANT FACT. (dB/m)	PRE AMP (dB)	Filter loss (dB)	FIELD ST'GH (dBµV/m)	Margin (dBm)	LIMIT (20dBc)
1.	916.5	70.1	3.8	23	N/A	N/A	97	-8.4	Pass

Ref No.	FREQ. (MHz)	MEAS Rx (dBµV)	CABLE LOSS (dB)	ANT FACT. (dB/m)	PRE AMP (dB)	Filter loss (dB)	FIELD ST'GH (dBµV/m)	Margin (dBm)	FIELD ST'GH (µV/m)	LIMIT (µV/m)
2.	4638.5	59.37	4.5	32.4	35.8	1.3	61.79pk	-12.2	1228.9	5011.9
3.	4638.5	32.48	4.5	32.4	35.8	1.3	34.90av	-19.1	55.6	500.00

Tx top channel 927.7MHz



1GHz- 1.5GHz



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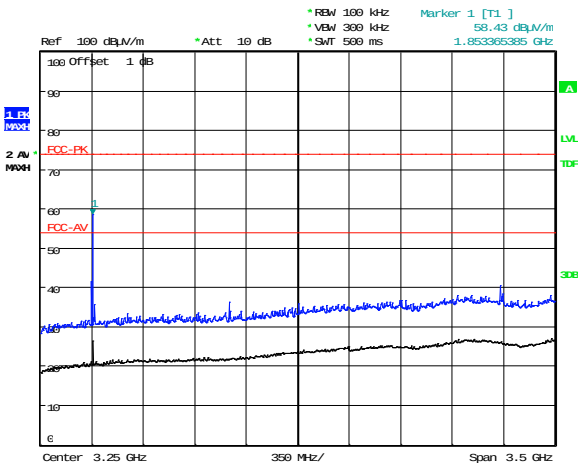
1.5GHz-5GHz



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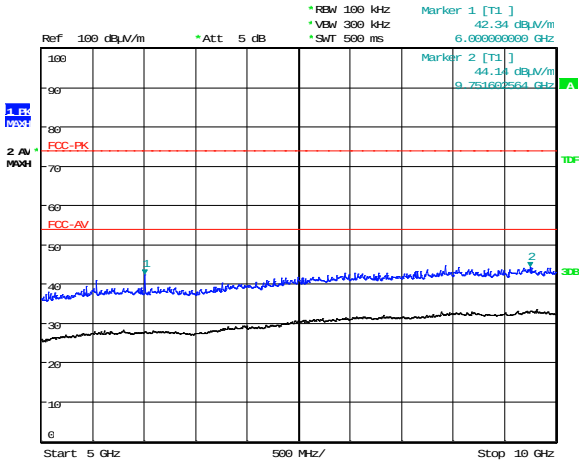
5GHz-10GHz



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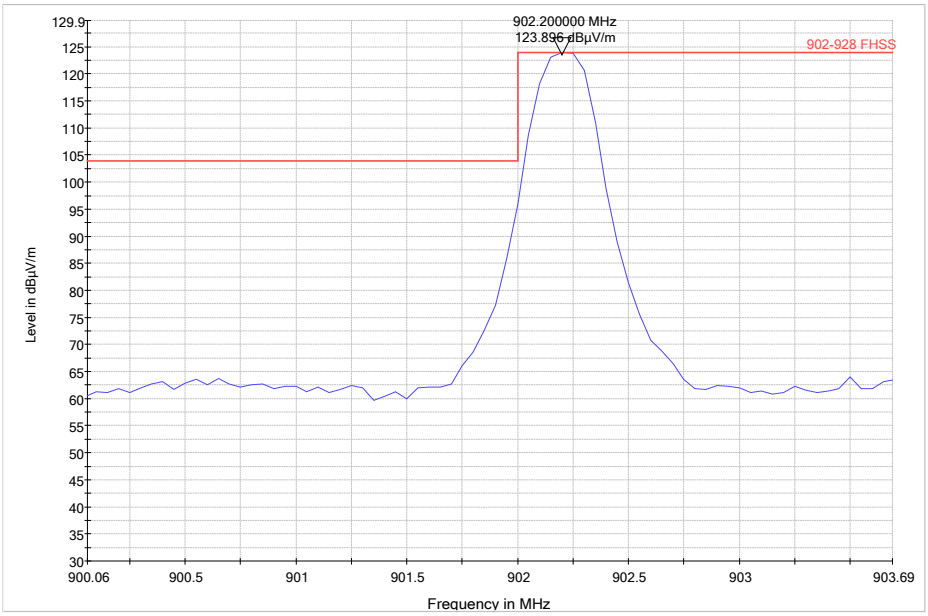
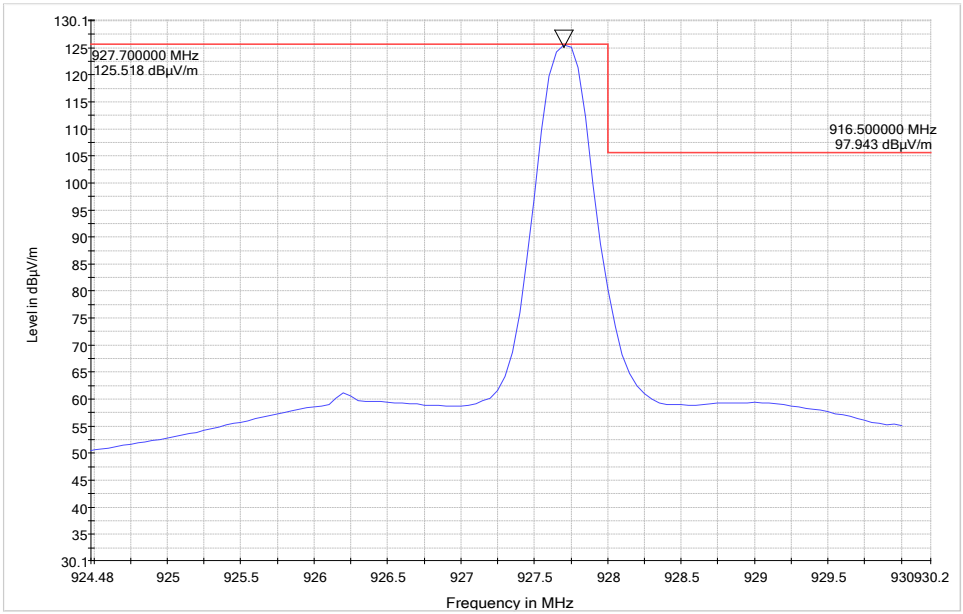
Lower radiated bandedge



Upper radiated bandedge



11 AC power-line conducted emissions

11.1 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.

11.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Transient Lab 2
Test Standard and Clause:	ANSI C63.10-2013, Clause 6.2
EUT Channels / Frequencies Measured:	Mid
EUT Channel Bandwidths:	180kHz
EUT Modulation:	600 bps D-BPSK
Deviations From Standard:	None
Measurement BW:	10kHz
Measurement Detectors:	Quasi-Peak and Average,

Environmental Conditions (Normal Environment)

Temperature: 24 °C	+15 ºC to +35 ºC (as declared)
Humidity: 53 % RH	20 % RH to 75 % RH (as declared)
Supply: 110 V ac	110 V ac ±10 % (as declared)

Test Limit

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

Table 3 – AC Power Line Conducted Emission Limits

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

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

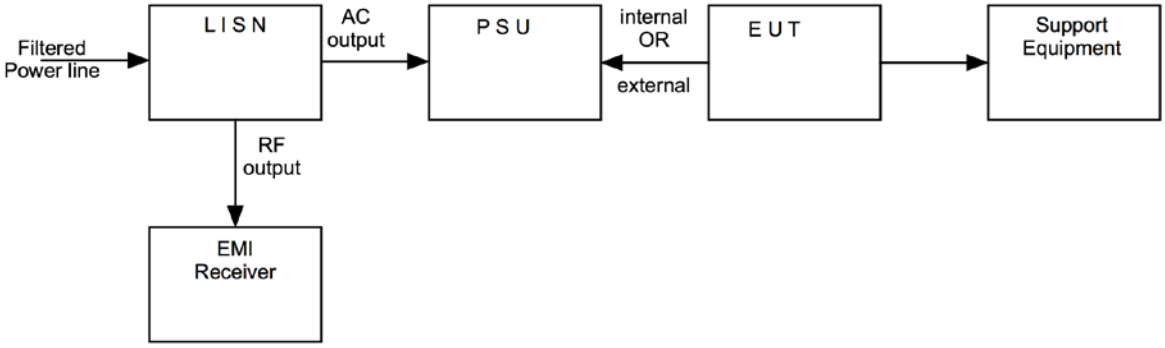
11.3 Test Method

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



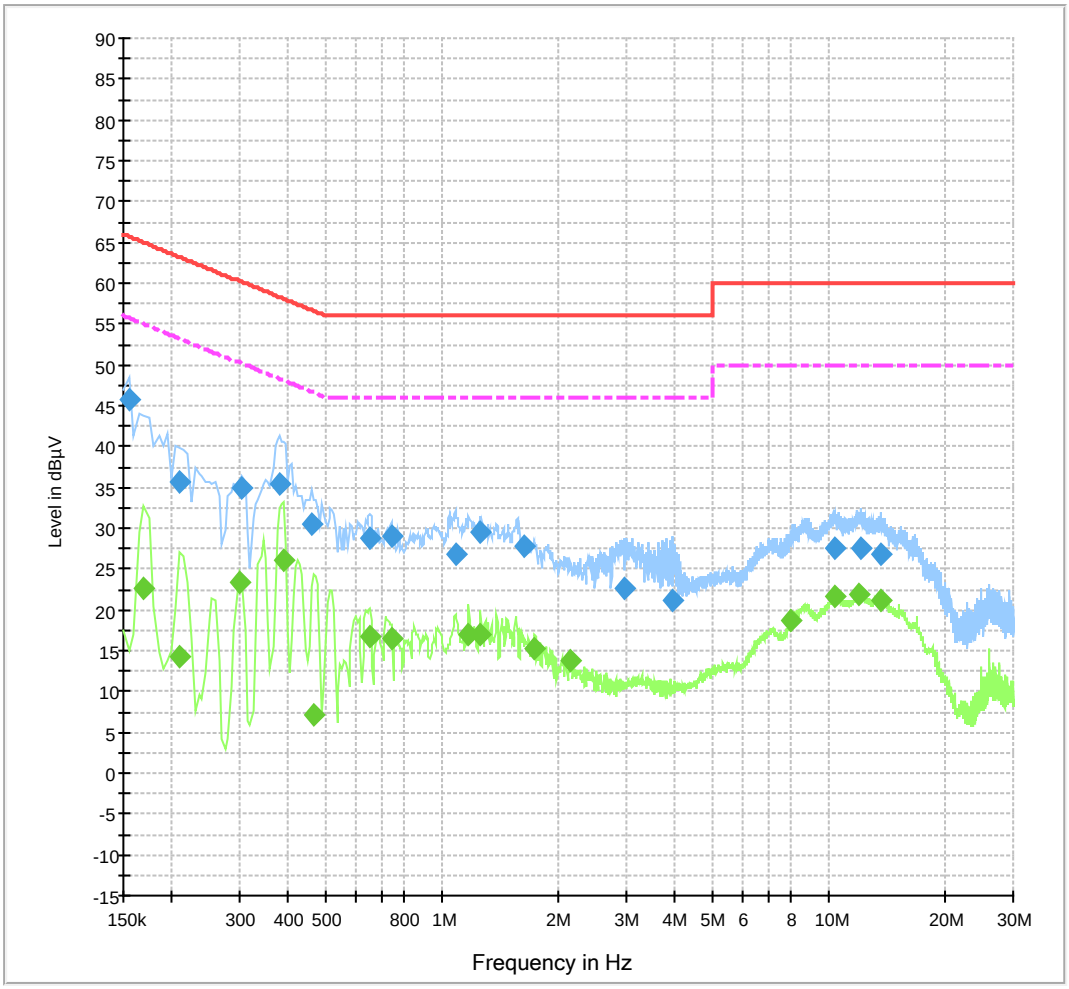
11.4 Test Set-up Photograph

11.5 Test Equipment

Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
ENV216	R&S	Lisn	U396	29/06/2017
ESHS10	R&S	Receiver	U003	25/06/2017

11.6 Test Results

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



Frequency (MHz)	QuasiPeak (dBµV)	Meas. Time (ms)	Bandwidth (kHz)	Line	Corr. (dB)	Margin (dB)	Limit (dBµV)	Comment
0.155000	45.8	2000.0	10.000	N	9.6	19.9	65.7	Pass
0.210000	35.8	2000.0	10.000	L1	9.6	27.4	63.2	Pass
0.305000	34.8	2000.0	10.000	L1	9.6	25.3	60.1	Pass
0.380000	35.5	2000.0	10.000	N	9.6	22.8	58.3	Pass
0.460000	30.5	2000.0	10.000	L1	9.6	26.2	56.7	Pass
0.650000	28.9	2000.0	10.000	L1	9.6	27.1	56.0	Pass
0.740000	29.1	2000.0	10.000	N	9.6	26.9	56.0	Pass
1.085000	26.9	2000.0	10.000	N	9.6	29.1	56.0	Pass
1.260000	29.5	2000.0	10.000	N	9.6	26.5	56.0	Pass
1.635000	27.7	2000.0	10.000	N	9.7	28.3	56.0	Pass
2.980000	22.5	2000.0	10.000	L1	9.7	33.5	56.0	Pass
3.930000	21.1	2000.0	10.000	L1	9.7	34.9	56.0	Pass
10.350000	27.6	2000.0	10.000	N	9.6	32.4	60.0	Pass
12.070000	27.5	2000.0	10.000	N	9.6	32.5	60.0	Pass
13.695000	26.7	2000.0	10.000	N	9.7	33.3	60.0	Pass

Frequency (MHz)	Average (dBµV)	Meas. Time (ms)	Bandwidth (kHz)	Line	Corr. (dB)	Margin (dB)	Limit (dBµV)	Comment
0.170000	22.6	2000.0	10.000	L1	9.6	32.3	55.0	Pass
0.210000	14.2	2000.0	10.000	N	9.6	39.0	53.2	Pass
0.300000	23.4	2000.0	10.000	L1	9.6	26.9	50.2	Pass
0.390000	26.0	2000.0	10.000	L1	9.6	22.1	48.1	Pass
0.465000	7.2	2000.0	10.000	N	9.6	39.4	46.6	Pass
0.650000	16.8	2000.0	10.000	L1	9.6	29.2	46.0	Pass
0.740000	16.6	2000.0	10.000	L1	9.6	29.4	46.0	Pass
1.175000	16.9	2000.0	10.000	N	9.6	29.1	46.0	Pass
1.255000	17.0	2000.0	10.000	N	9.6	29.0	46.0	Pass
1.740000	15.3	2000.0	10.000	L1	9.7	30.7	46.0	Pass
2.145000	13.7	2000.0	10.000	L1	9.7	32.3	46.0	Pass
7.965000	18.6	2000.0	10.000	N	9.7	31.4	50.0	Pass
10.350000	21.6	2000.0	10.000	N	9.6	28.4	50.0	Pass
12.035000	21.8	2000.0	10.000	N	9.6	28.2	50.0	Pass
13.720000	21.1	2000.0	10.000	N	9.7	28.9	50.0	Pass

12 Carrier frequency separation

12.1 Definition

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

12.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Radio lab
Test Standard and Clause:	ANSI C63.10-2013, Clause 7.8.2
EUT Channels / Frequencies Measured:	All; 2405 to 2480 MHz
EUT 20dB Bandwidth:	175kHz
EUT Test Modulations:	Internal pattern generation – hopping enabled
Deviations From Standard:	None
Measurement BW:	100kHz
Measurement Detector:	Peak

Environmental Conditions (Normal Environment)

Temperature: 25 °C	+15 ºC to +35 ºC (as declared)
Humidity: 45 % RH	20 % RH to 75 % RH (as declared)
Supply: 110 V ac	230 V ac ±10 % (as declared)

12.3 Test Limit

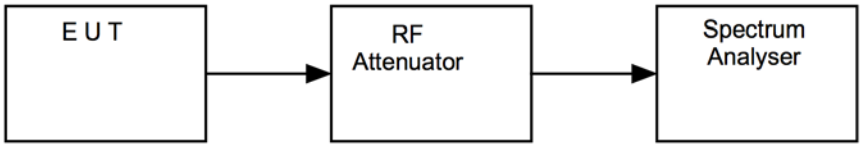
Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the -20 dB bandwidth of the hopping channel, whichever is greater. Alternatively, frequency hopping systems operating in the band 2400 to 2483.5 MHz may have hopping channel carrier frequencies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

12.4 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

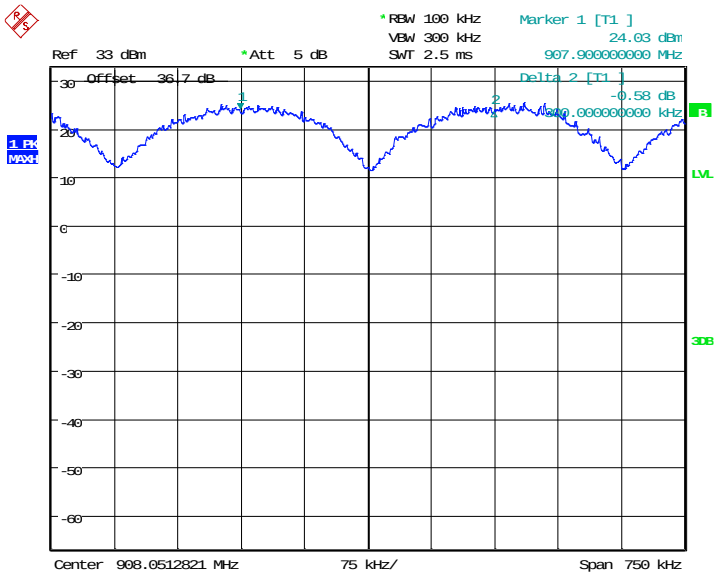


12.5 Test Equipment

Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
FSU50	R&S	Spectrum Analyser	U544	16/03/2017

12.6 Test Results

low hop set, high hop set.				
Data Rate	***$F1_c$ (MHz)***	***$F2_c$ (MHz)***	***Channel Separation, $F2_c - F1_c$ (kHz)***	***Result***
600 bps D-BPSK	907.9MHz	908.2MHz	300	PASS
600 bps D-BPSK	919.6MHz	919.9MHz	300	PASS



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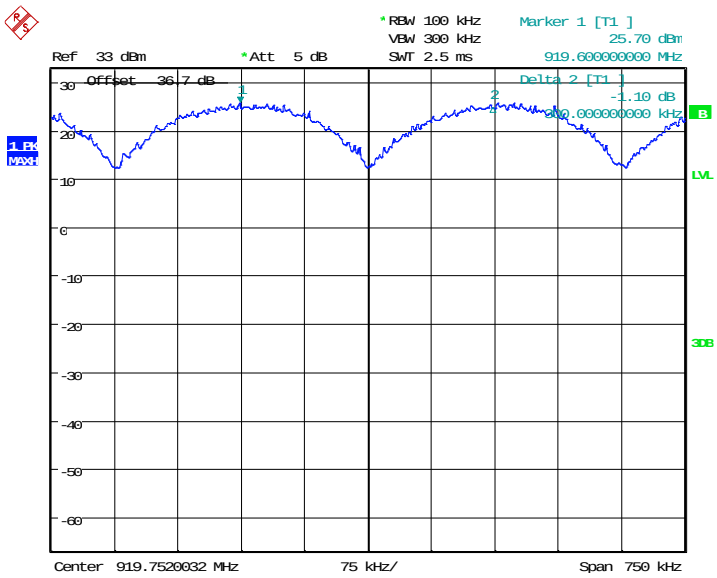


Date: 12.SEP.2016 17:11:26

13 Number of hopping frequencies

13.1 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.

13.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Radio lab
Test Standard and Clause:	ANSI C63.10-2013, Clause 7.8.3
EUT Channels / Frequencies Measured:	All; 2405 – 2480 MHz
EUT 20dB Bandwidth:	180kHz
EUT Test Modulations:	Internal pattern generation – hopping enabled
Deviations From Standard:	None
Measurement BW:	50kHz
Measurement Detector:	Peak

Environmental Conditions (Normal Environment)

Temperature: 23 °C	+15 ºC to +35 ºC (as declared)
Humidity:45 % RH	20 % RH to 75 % RH (as declared)
Supply: 110 V ac	110 V ac ±10 % (as declared)

13.3 Test Limit

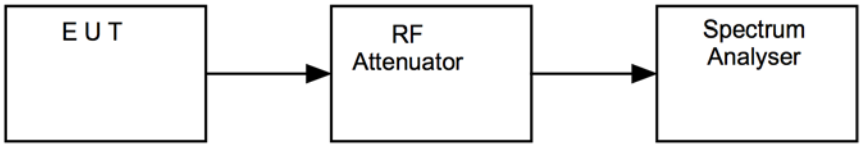
- For frequency hopping systems in the band 902 to 928 MHz: if the -20 dB bandwidth of the hopping channel is less than 250 kHz, the system shall use at least 50 hopping channels;
  If the -20 dB bandwidth of the hopping channel is 250 kHz or greater, the system shall use at least 25 hopping channels;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

13.4 Test Method

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

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

Figure iv Test Setup



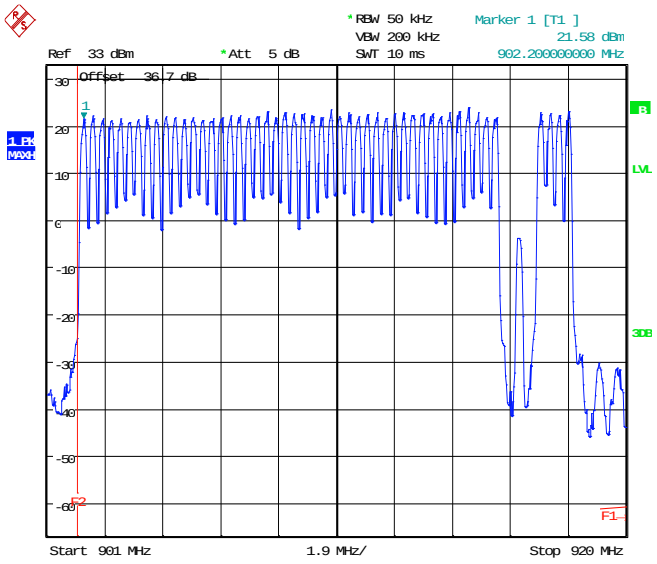
13.5 Test Equipment

Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
FSU50	R&S	Spectrum Analyser	U544	16/03/2017

13.6 Test Results

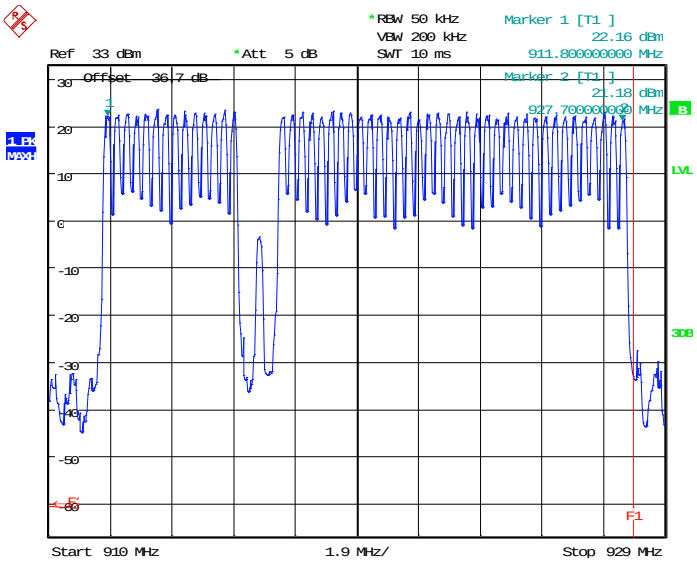
Power setting: High				
Data Rate	***Lowest channel, F_{CL} (MHz)***	***Highest channel, F_{CH} (MHz)***	***Number of channels observed***	***Result***
600 bps D-BPSK	902.2	918.1	50	PASS
600 bps D-BPSK	911.8	927.7	50	PASS

Hop set 1



Date: 12.SEP.2016 17:54:34

Hop set 2



Date: 12.SEP.2016 17:34:13

14 Average channel occupancy

14.1 Definition

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

14.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Radio lab
Test Standard and Clause:	ANSI C63.10-2013, Clause 7.8.4
EUT Channels / Frequencies Measured:	Mid
EUT 20dB bandwidth:	175kHz
EUT Number of hopping channels:	50
EUT Test Modulations:	Internal pattern generation – hopping enabled
Deviations From Standard:	None
Measurement BW:	300kHz
Measurement Detector:	Peak

Environmental Conditions (Normal Environment)

Temperature: 24 °C	+15 ºC to +35 ºC (as declared)
Humidity: 45x % RH	20 % RH to 75 % RH (as declared)
Supply: 110x V ac	110 V ac ±10 % (as declared)

14.3 Test Limit

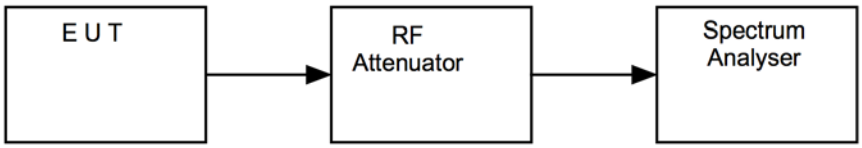
- For frequency hopping systems in the band 902 to 928 MHz: if the -20 dB bandwidth of the hopping channel is less than 250 kHz, the average time of occupancy on any channel shall not be greater than 0.4 seconds within a 20 second period;
  If the -20 dB bandwidth of the hopping channel is 250 kHz or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

14.4 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



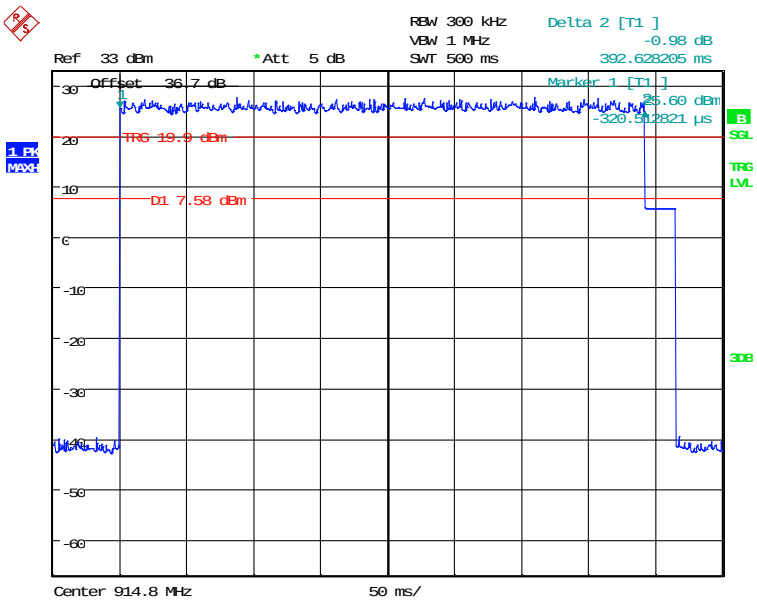
14.5 Test Equipment

Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
FSU50	R&S	Spectrum Analyser	U544	16/03/2017

14.6 Test Results

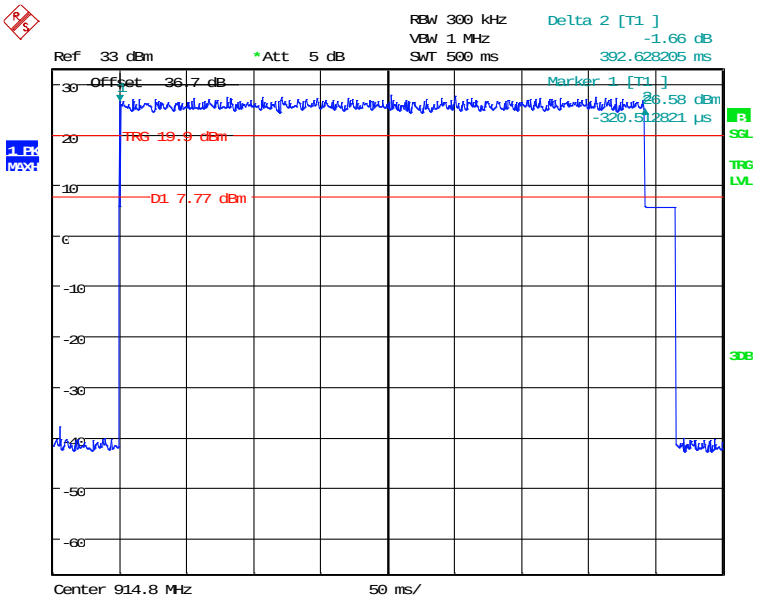
***Modulation:* 600 bps D-BPSK Low hopset/high hop set**					
Data Rate	***Individual occupancy time (ms)***	***Observation period (s)***	***Number of hops observed***	***Average time of occupancy (s)***	***Result***
600 bps D-BPSK low hopset	392.628	25	1	392.628	PASS
600 bps D-BPSK Hi hopset	392.628	25	1	392.628	PASS

Transmitter on time Low hopset



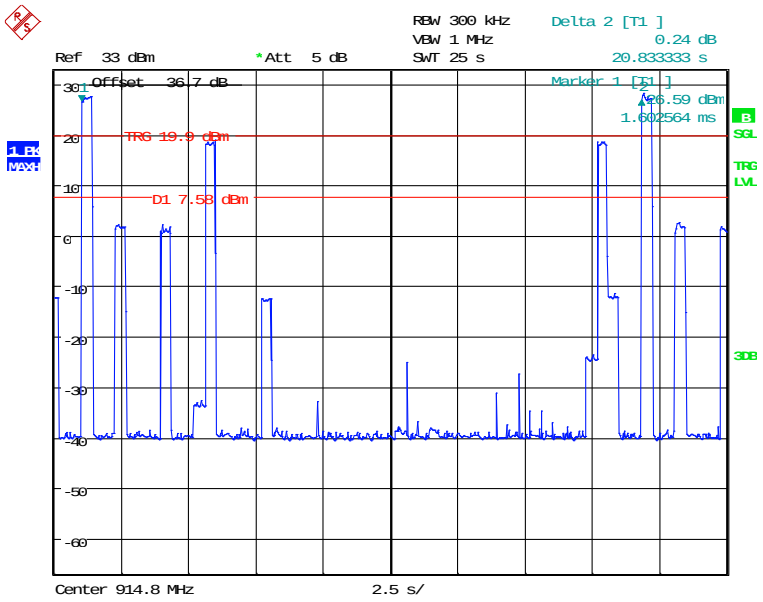
Date: 13.SEP.2016 11:21:42

Transmitter on time Hi hopset

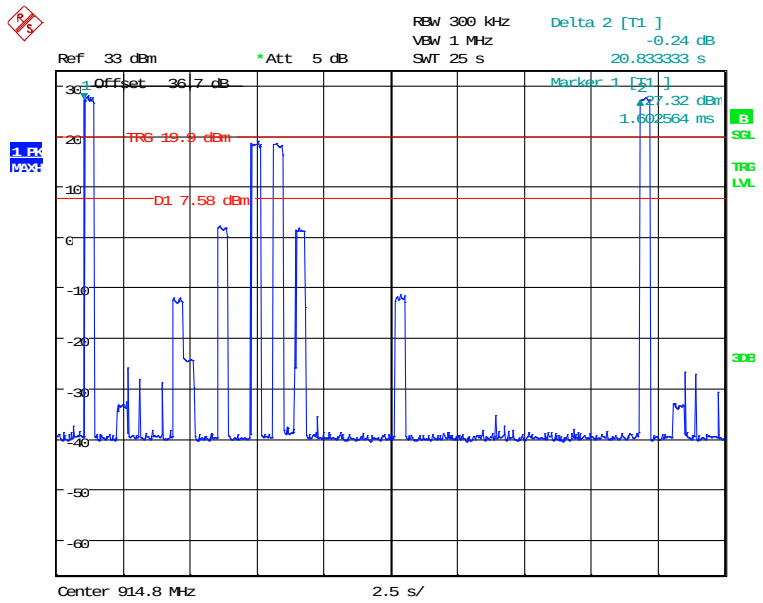


Date: 13.SEP.2016 11:19:40

Transmitter on time Low hopset



Date: 13.SEP.2016 11:27:42



Date: 13.SEP.2016 11:29:44

15 Maximum peak conducted output power

15.1 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.

15.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Radio Lab
Test Standard and Clause:	ANSI C63.10-2013, Clause 7.8.5
EUT Channels / Frequencies Measured:	Low / Mid / High – hopping disabled.
EUT Channel Bandwidths:	175kHz
Deviations From Standard:	None
Measurement BW:	1MHz
Spectrum Analyzer Video BW:	3MHz
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: 23 °C	+15 ºC to +35 ºC (as declared)
Humidity:45 % RH	20 % RH to 75 % RH (as declared)

15.3 Test Limit

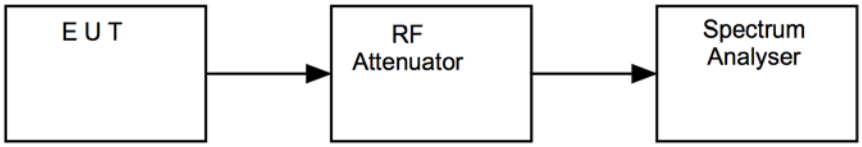
- For frequency hopping systems operating in the band 902 to 928 MHz, the maximum peak conducted output power shall not exceed 1 W, and the e.i.r.p. shall not exceed 4 W, if the hopset uses 50 or more hopping channels;
  the maximum peak conducted output power shall not exceed 0.25 W, and the e.i.r.p.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

15.4 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



15.5 Test Equipment

Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
FSU50	R&S	Spectrum Analyser	U544	16/03/2017

15.6 Test Results

600 bps D-BPSK						
Channel Frequency (MHz)	***Analyzer Level (dBm)***	***Cable loss Antenna loss Ref offset used (dB)***	***Maximum peak conducted output power (W)***	***Antenna gain (dBi)***	***E.I.R.P. (W)***	***Result***
902.2	27.19	36.7	0.523	8.0	3.303	PASS
914.8	27.56	36.7	0.571	8.0	3.597	PASS
927.7	27.62	36.7	0.578	8.0	3.647	PASS

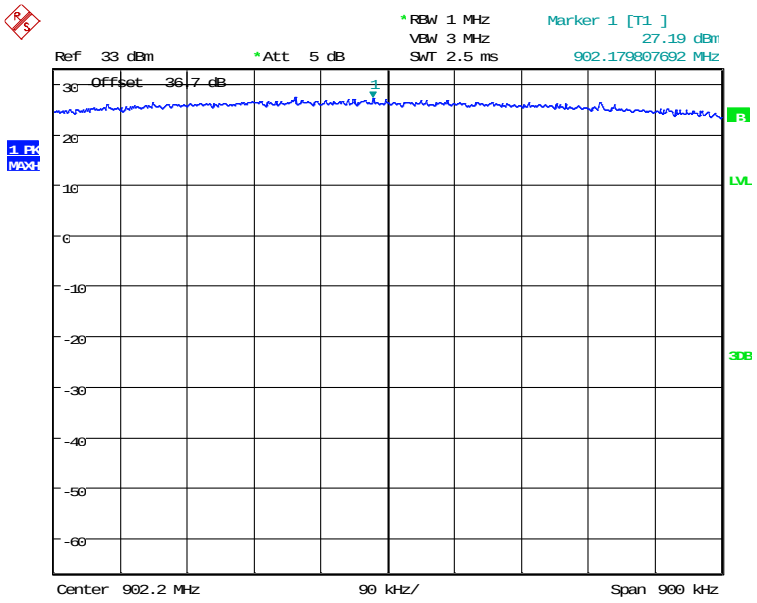
Software values used for the transmitter output power (with noise selected).

902.2MHz = 20
914.8MHz = 21
927.7MHz = 20

As per 15.247(b)(4)and RSS 247 (5.4)(2) the gain of the antenna is greater than 6dBi the conducted output power limit is reduced as appropriate, by the amount in dB that the directional gain of the antenna exceeds 6 dBi

Antenna gain exceeds 6 dBi by 2 dB therefore conducted output power limit of 1W (30 dBm) is reduced to 0.631W (28 dBm)

Transmitter output power 902.2MHz



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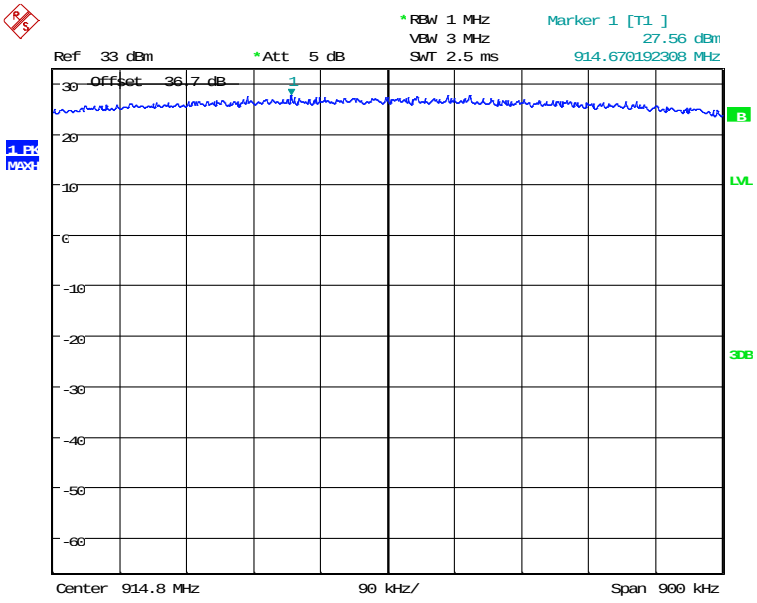
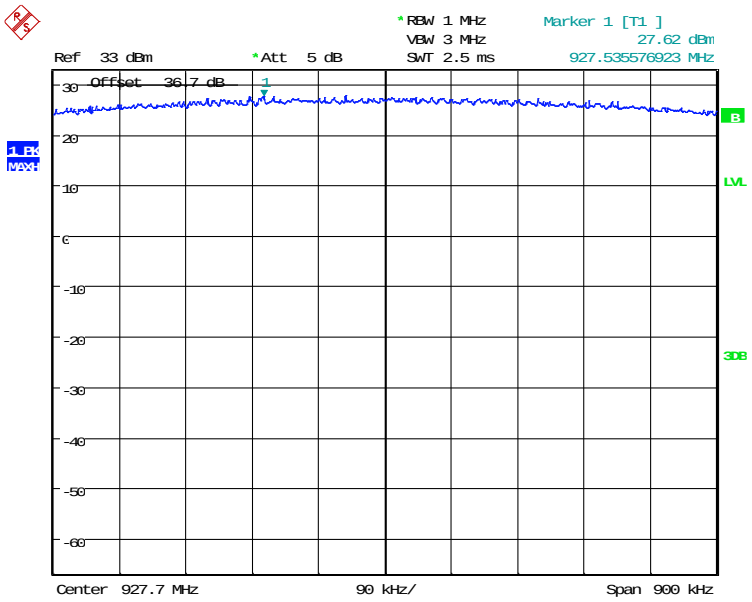
Transmitter output power 914.8MHz



Date: 12.SEP.2016 16:32:55

Transmitter output power 927.7MHz



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16 Occupied Bandwidth

16.1 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.

16.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Radio Lab
Test Standard and Clause:	ANSI C63.10-2013, Clause 6.9
EUT Channels / Frequencies Measured:	Low / Mid / High – hopping stopped.
EUT Channel Bandwidths:	175.48kHz
EUT Test Modulations:	600 bps D-BPSK
Deviations From Standard:	None
Measurement BW: (requirement: 1 % to 5 % OBW)	2kHz
Spectrum Analyzer Video BW: (requirement at least 3x RBW)	10kHz
Measurement Span: (requirement 2 to 5 times OBW)	500kHz
Measurement Detector:	Peak

Environmental Conditions (Normal Environment)

Temperature: 23 °C	+15 ºC to +35 ºC (as declared)
Humidity: 45 % RH	20 % RH to 75 % RH (as declared)
Supply: 110 V ac	110 V ac ±10 % (as declared)

16.3 Test Limit

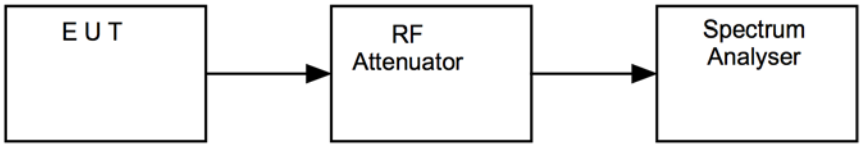
- For frequency hopping systems in the band 902 to 928 MHz: The maximum allowed -20 dB bandwidth of the hopping channel is 500 kHz.
- Frequency hopping systems operating in the band 5725 to 5850 MHz: The maximum -20 dB bandwidth of the hopping channel shall be 1 MHz

16.4 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



16.5 Test Equipment

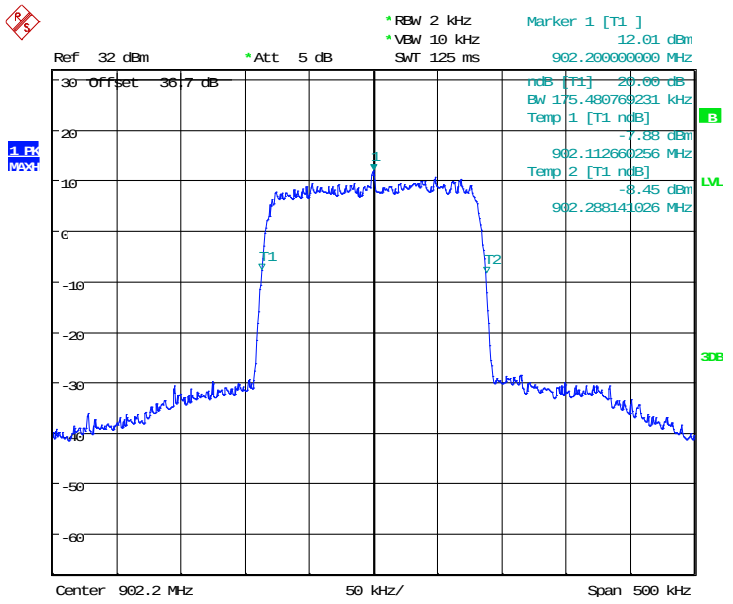
Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
FSU50	R&S	Spectrum Analyser	U544	16/03/2017

16.6 Test Results

600 bps D-BPSK 20dB Bandwidth				
Channel Frequency (MHz)	***F_L (MHz)***	***F_H (MHz)***	***20dB Bandwidth (kHz)***	***Result***
902.20	902.112660	902.288141	175.48	PASS
914.80	914.712660	914.888141	175.48	PASS
927.70	927.612660	927.788141	175.48	PASS

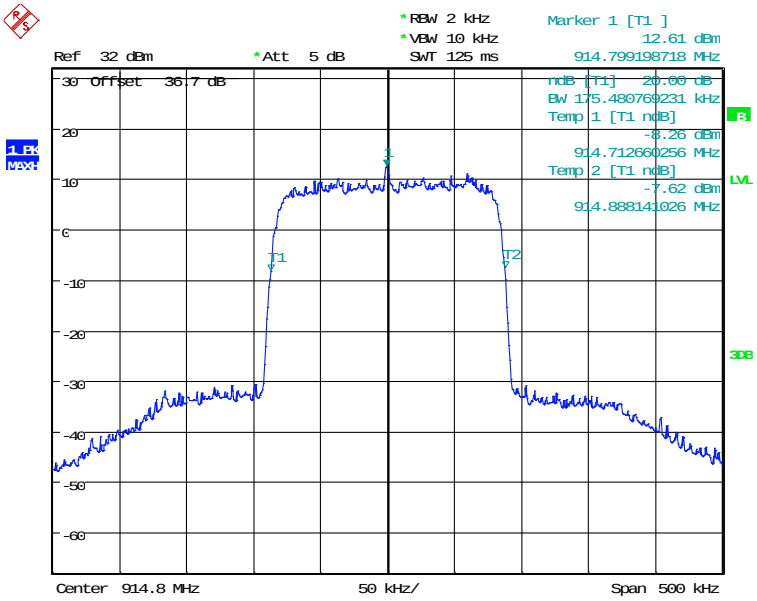
600 bps D-BPSK 99% Bandwidth				
Channel Frequency (MHz)	***F_L (MHz)***	***F_H (MHz)***	***995 Bandwidth (kHz)***	***Result***
902.20	902.118269	902.282532	164.26	PASS
914.80	914.718269	914.882532	164.26	PASS
927.70	927.618266	927.782532	164.26	PASS

20dB Bandwidth



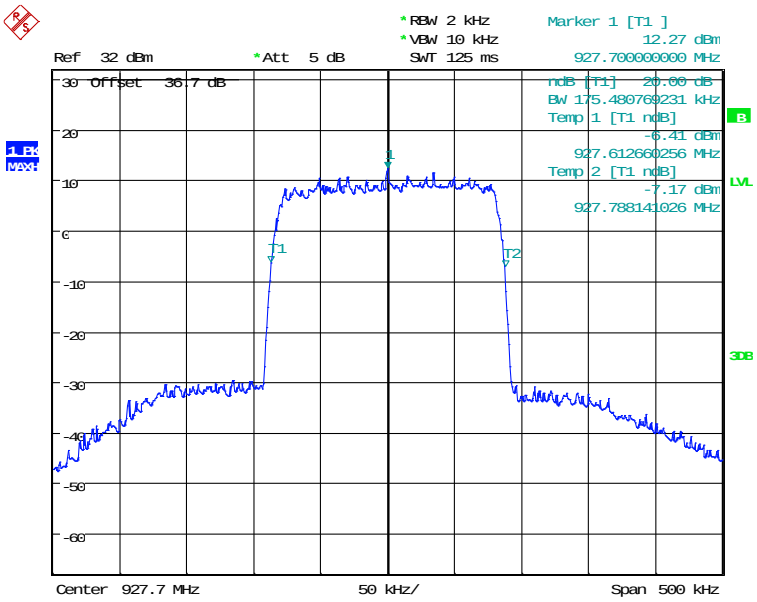
Date: 12.SEP.2016 16:03:45

20dB Bandwidth



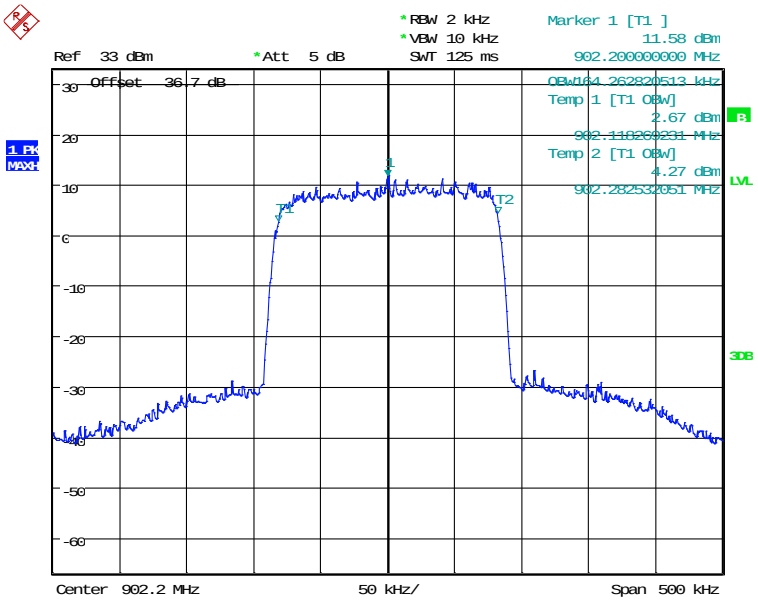
Date: 12.SEP.2016 16:07:49

20dB Bandwidth



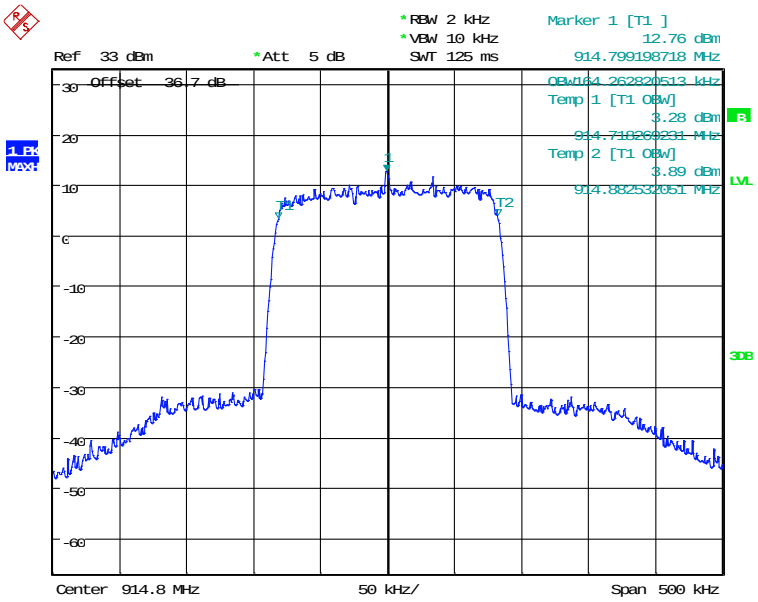
Date: 12.SEP.2016 16:05:52

99% Bandwidth



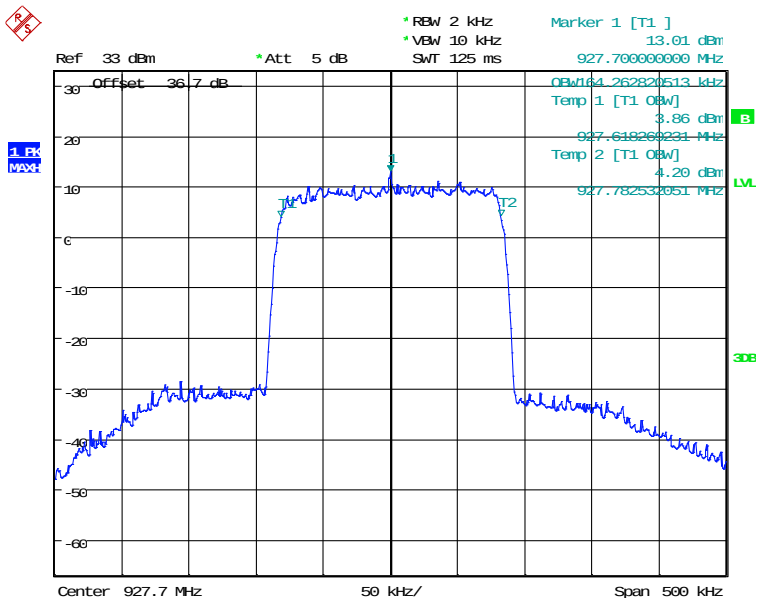
Date: 12.SEP.2016 16:21:54

99% Bandwidth



Date: 12.SEP.2016 16:19:51

99% Bandwidth



Date: 12.SEP.2016 16:24:15

17 Out-of-band and conducted spurious emissions

17.1 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.

17.2 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:	180kHz
Deviations From Standard:	None
Measurement BW:	100 kHz
Spectrum Analyzer Video BW: (requirement at least 3x RBW)	300kHz
Measurement Detector:	Peak
Measurement Range:	30 MHz to 10GHz

Environmental Conditions (Normal Environment)

Temperature: 24 °C	+15 ºC to +35 ºC (as declared)
Humidity: 41 % RH	20 % RH to 75 % RH (as declared)
Supply: 110 V ac	110V ac ±10 % (as declared)

17.3 Test Limits

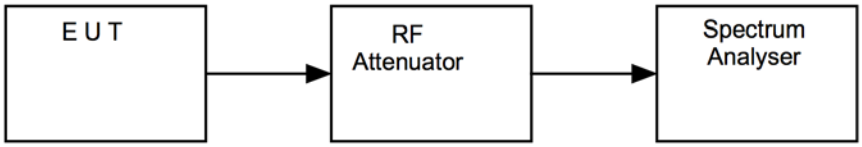
In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated device is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either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

17.4 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



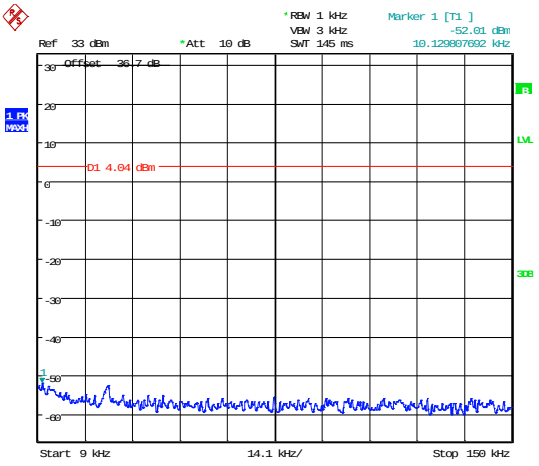
17.5 Test Equipment

Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
FSU46	R&S	Spectrum Analyser	U281	07/06/2017

17.6 Test Results

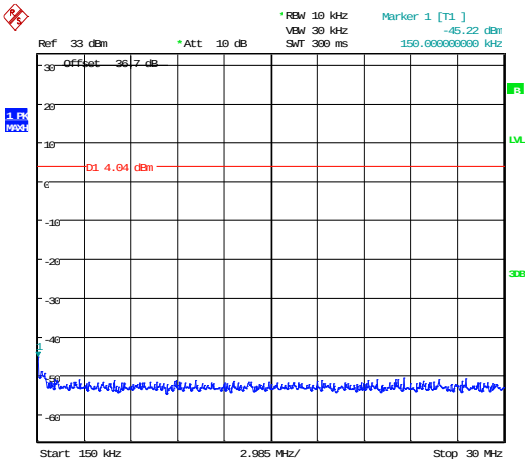
902.2MHz					
Channel Frequency (MHz)	***Emission Frequency (MHz)***	***Emission Level (dBm)***	***Limit (dBm)***	***Margin (dB)***	***Result***
Low	916.5	-2.41	4.04dBm	6.45	PASS

902.2MHz 9-150kHz



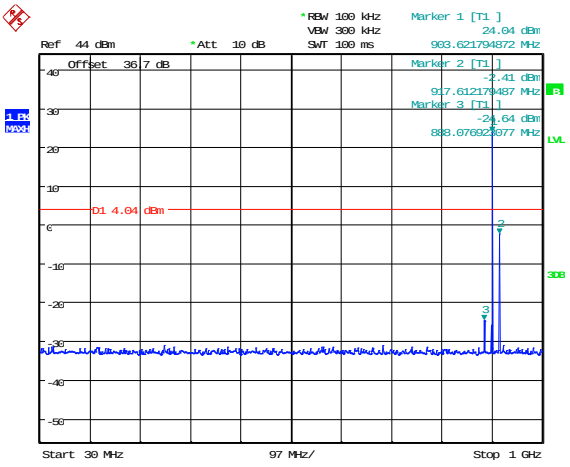
Date: 13.SEP.2016 12:19:41

902.2MHz 150-30MHz



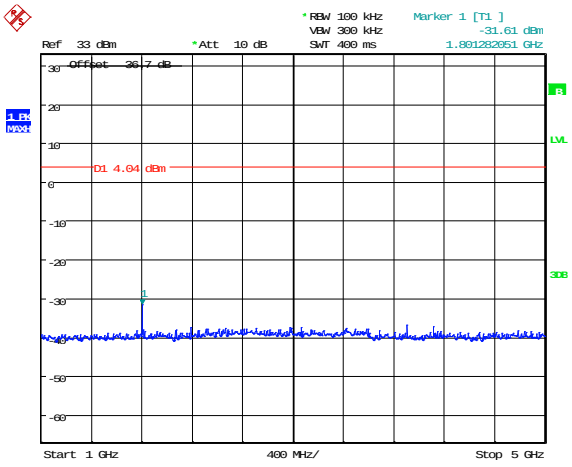
Date: 13.SEP.2016 12:20:34

902.2MHz 30MHz -1GHz



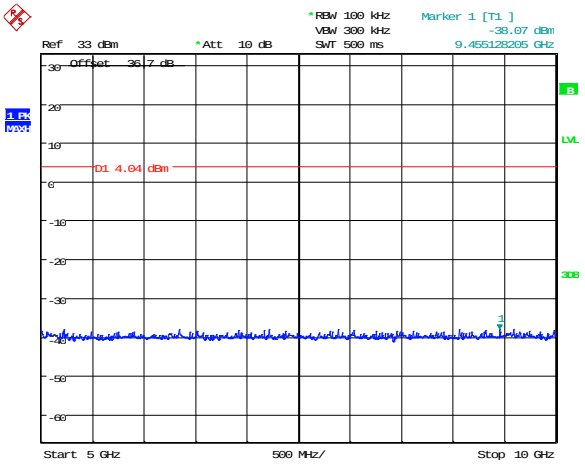
Date: 13.SEP.2016 12:18:32

902.2MHz 1-5GHz



Date: 13.SEP.2016 12:21:24

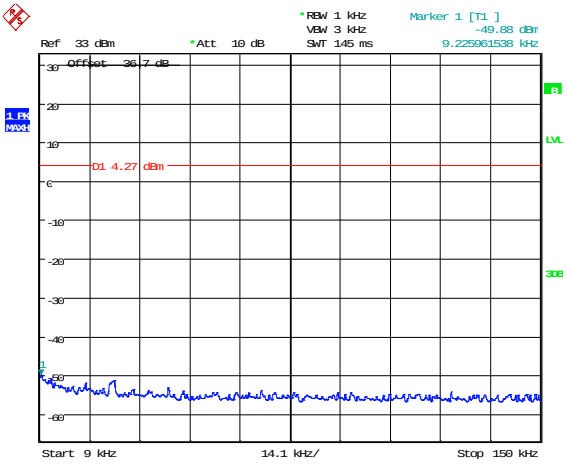
902.2MHz 5-10GHz



Date: 13.SEP.2016 12:22:44

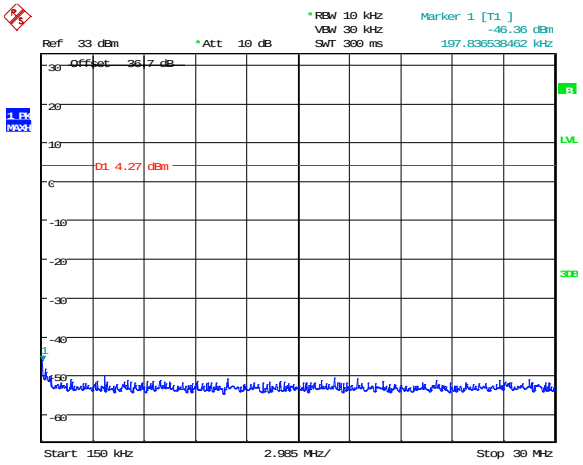
914.8MHz					
Channel Frequency (MHz)	**Emission Frequency (MHz)**	**Emission Level (dBm)**	**Limit (dBm)**	**Margin (dB)**	**Result**
Mid	916.5	-2.03	4.27	6.3	PASS

914.8MHz 9-150kHz



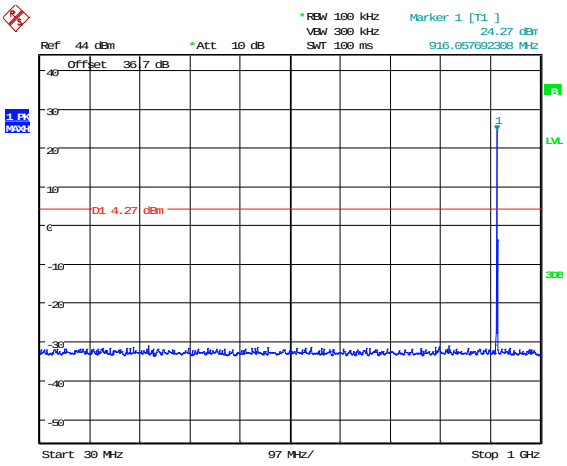
Date: 13.SEP.2016 12:46:18

914.8MHz 150-30MHz



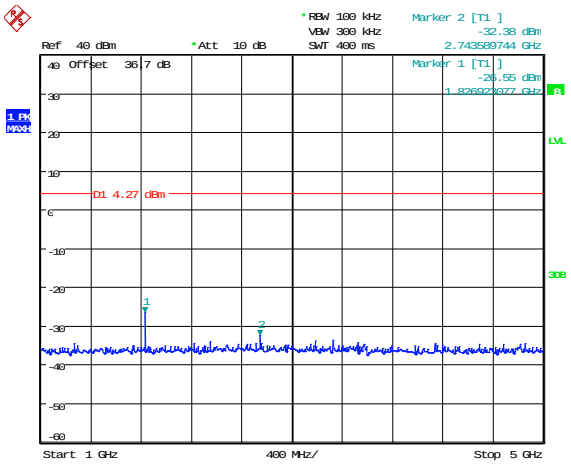
Date: 13.SEP.2016 12:46:51

914.8MHz 30MHz -1GHz



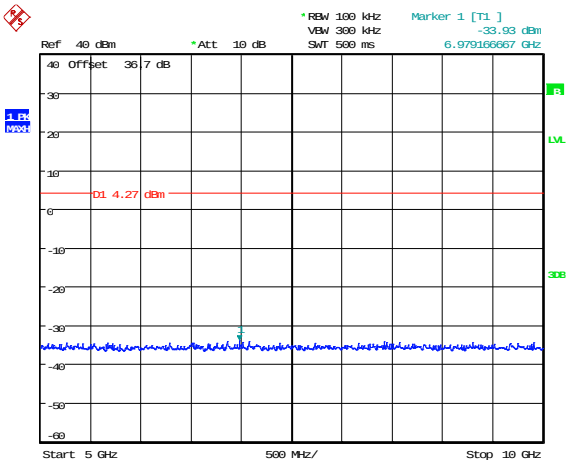
Date: 13.SEP.2016 12:33:38

914.8MHz 1GHz-5GHz



Date: 13.SEP.2016 12:49:26

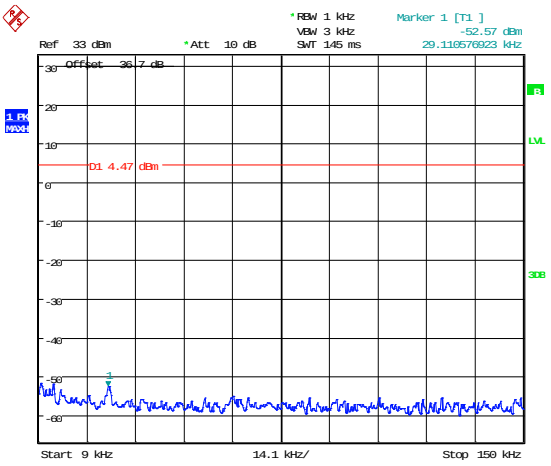
914.8MHz 5GHz-10GHz



Date: 13.SEP.2016 12:54:15

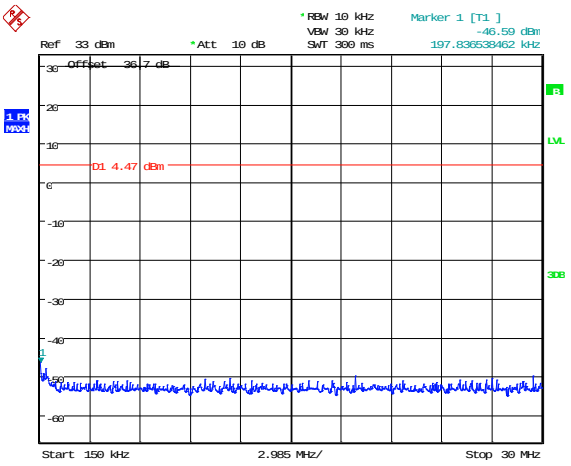
927.7MHz					
Channel Frequency (MHz)	**Emission Frequency (MHz)**	**Emission Level (dBm)**	**Limit (dBm)**	**Margin (dB)**	**Result**
High	916.5	-3.8	4.47	-8.27	PASS
High	1855.4	-12.5	4.47	-16.97	PASS

927.7MHz 9-150kHz



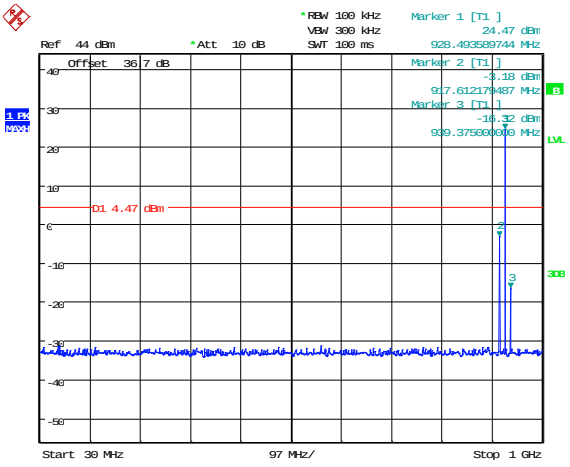
Date: 13.SEP.2016 13:01:21

927.7MHz 150-30MHz



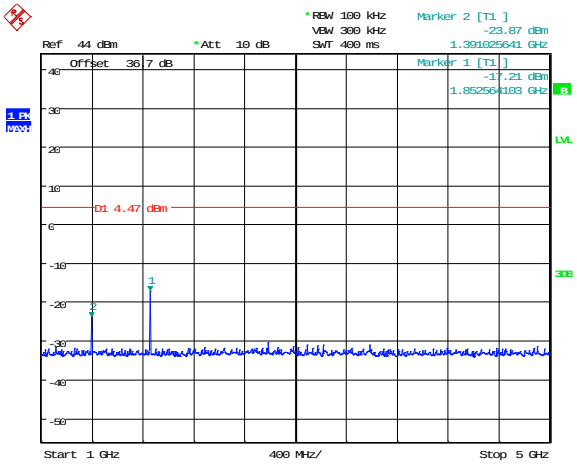
Date: 13.SEP.2016 13:01:58

927.7MHz 30MHz



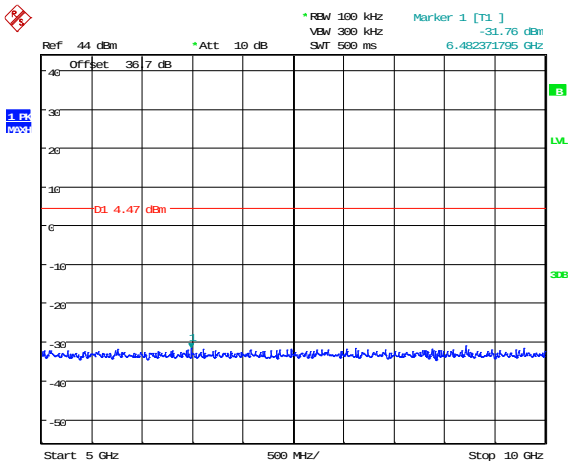
Date: 13.SEP.2016 13:00:44

927.7MHz 30MHz-1GHz



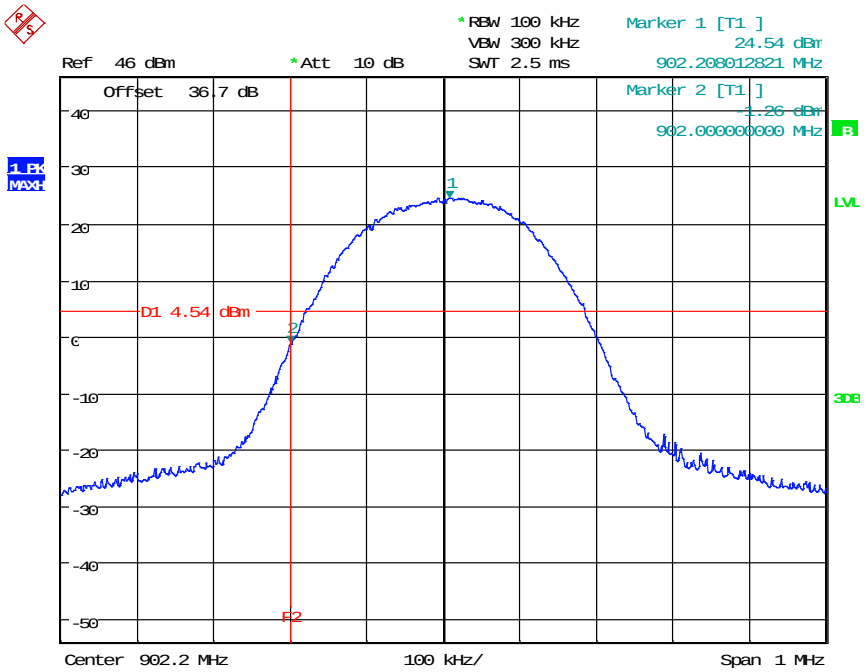
Date: 13.SEP.2016 13:06:52

927.7MHz 5GHz-10GHz



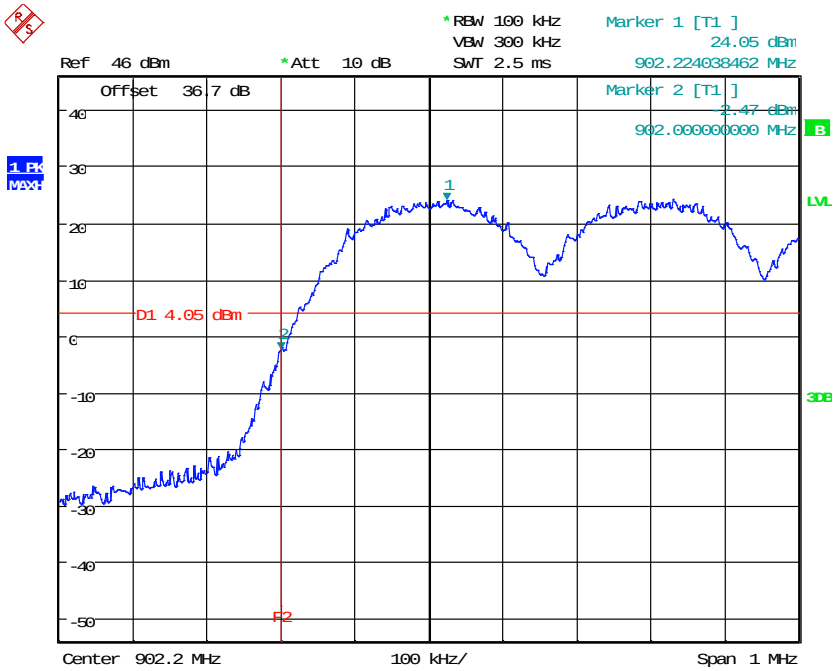
Date: 13.SEP.2016 13:07:39

Lower frequency hopset bandedge not hopping



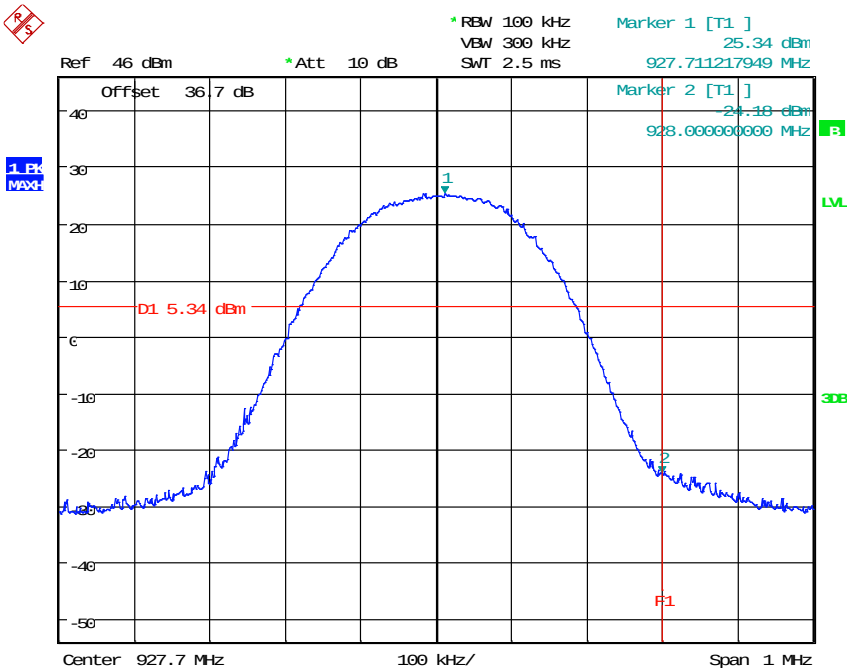
Date: 13.SEP.2016 11:41:04

Lower frequency hopset bandedge hopping



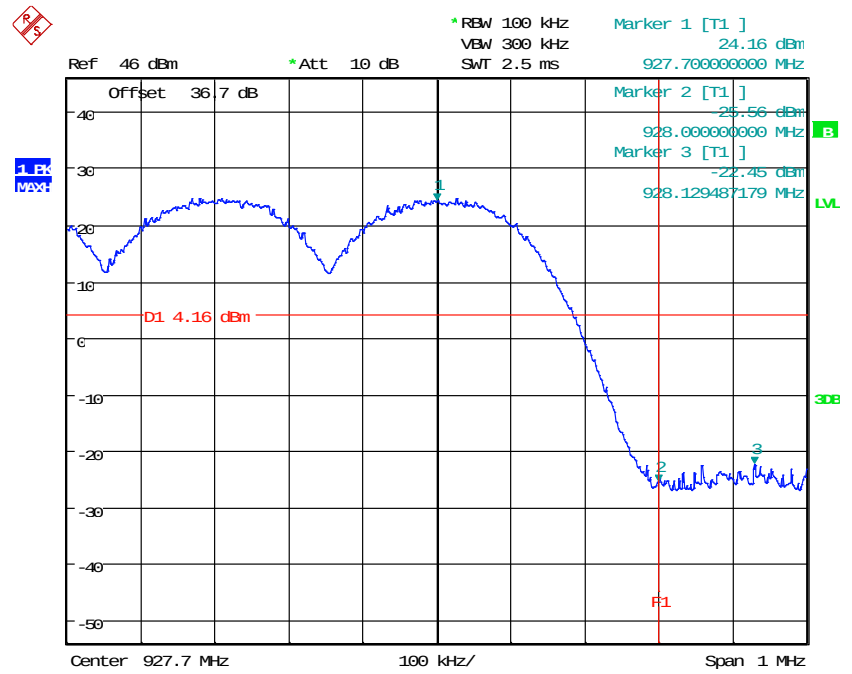
Date: 13.SEP.2016 11:47:41

High frequency hopset bandedge not hopping



Date: 13.SEP.2016 12:02:55

High frequency hopset bandedge hopping



Date: 13.SEP.2016 11:59:04

18 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 %**

19 RF Exposure

RF Exposure **MPE Calculation**

KDB 447498

Prediction of MPE limit at a given distance

Equation from IEEE C95.1

$$S = \frac{EIRP}{4\pi R^2} \quad \text{re-arranged } R = \sqrt{\frac{EIRP}{S4\pi}}$$

where:

S = power density
R = distance to the centre of radiation of the antenna
EIRP = EUT Maximum power

Note:

The EIRP was calculated by addition of the maximum conducted carrier power plus the antenna gain.

OR

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

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

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

Result

Prediction Frequency (MHz)	Maximum Conducted Power (dBm)	Antenna Gain (dBi)	Maximum EIRP (mW)	Minimum Distance (cm)	Power density at distance (mW/cm^2)	Power density limit (S) (mW/cm^2)
902.2	27.19	8	3303.695	21.0	0.596	0.601
914.8	27.56	8	3597.493	21.8	0.602	0.609
927.7	27.62	8	3647.539	21.7	0.616	0.618

RADIO FREQUENCY RADIATION EXPOSURE

RSS-102 issue 5

Exemption Limits for Routine Evaluation

All transmitters are exempt from routine SAR and RF exposure evaluations provided that they comply with the requirements of sections RSS-102 Issue 5 sections 2.5.1 or 2.5.2

If the EUT does not meet the appropriate exemption limit, a complete SAR or RF exposure evaluation shall be performed. However, the power exemption limits in RSS-102 Issue 5 Table 1 can be applied to reduce the number of test configurations (e.g. testing of a tablet edge).

RF exposure evaluation is required if the separation distance between the user and/or bystander and the device's radiating element is greater than 20 cm, except when the device operates as follows:

- below 20 MHz and the source-based, time-averaged maximum e.i.r.p. of the device is equal to or less than 1 W (adjusted for tune-up tolerance);
- at or above 20 MHz and below 48 MHz and the source-based, time-averaged maximum e.i.r.p. of the device is equal to or less than 4.49/f0.5W (adjusted for tune-up tolerance), where f is in MHz;
- at or above 48 MHz and below 300 MHz and the source-based, time-averaged maximum e.i.r.p. of the device is equal to or less than 0.6 W (adjusted for tune-up tolerance);
- at or above 300 MHz and below 6 GHz and the source-based, time-averaged maximum e.i.r.p. of the device is equal to or less than 1.31 x 10-2 f0.6834 W (adjusted for tune-up tolerance), where f is in MHz;
- at or above 6 GHz and the source-based, time-averaged maximum e.i.r.p. of the device is equal to or less than 5 W (adjusted for tune-up tolerance).

Exemption Limits for Routine Evaluation – RF Exposure Evaluation

$$S = \frac{EIRP}{4\pi R^2} \quad \text{re-arranged } R = \sqrt{\frac{EIRP}{S4\pi}}$$

where:

S = power density
R = distance to the centre of radiation of the antenna
ERP = EUT Maximum power

RSS-102 i5		
Evaluation Frequency	927.7	MHz
Section 2.5 Exemption limits	1.4	Watts
Conduced Power	27.62	dBm
Antenna Gain	8	dBi
EIRP	3.647	W
Evaluation Required		
R =	0.33	Meters
MPE Level =	2.67	W/m^2
IC Limit =	2.79	W/m^2

OR

RSS-102 i5		
Evaluation Frequency		MHz
Section 2.5 Exemption limits		Watts
Radiated Carrier Power		dBµV/m
Measurement Distance		meters
EIRP		W
Evaluation Required / Exempt		
R =		Meters
MPE Level =		W/m^2
IC Limit =		W/m^2

EIRP Calculated From Field Strength As Per ANSI C63.10