Report on the Radio Testing

For

EkkoSense Ltd

on

EkkoAir

Report no. TRA-046269-47-00A

4 September 2019

0026

Report Number: TRA-046269-47-00A
Issue: A

REPORT ON THE RADIO TESTING OF A
EkkoSense Ltd
EkkoAir
WITH RESPECT TO SPECIFICATION
FCC 47CFR 15.247 & IC RSS-247

TEST DATE: 23rd July 2019 - 1st August 2019

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Date:	4 September 2019	

Disclaimers:

[1] THIS DOCUMENT MAY BE REPRODUCED ONLY IN ITS ENTIRETY AND WITHOUT CHANGE
[2] THE RESULTS CONTAINED IN THIS DOCUMENT RELATE ONLY TO THE ITEM(S) TESTED

1 Revision Record

Issue Number	*Issue Date*	*Revision History*
A	4 September 2019	Original

2 Summary

TEST REPORT NUMBER:	TRA-046269-47-00A
WORKS ORDER NUMBER:	TRA-046269-02
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.
TEST SPECIFICATION(S):	47CFR15.247
EQUIPMENT UNDER TEST (EUT):	EkkoAir
FCC IDENTIFIER:	2AP4G-FS-EA-10
EUT SERIAL NUMBER:	E535:ZB
MANUFACTURER/AGENT:	EkkoSense Ltd
ADDRESS:	Sir Colin Campbell Building University of Nottingham Innovation Park Triumph Road Nottingham NG7 2TU United Kingdom
CLIENT CONTACT:	David Corder ☎ 01158 232 664 ✉ david.corder@ekkosense.co.uk
TEST DATE:	23rd July 2019 - 1st August 2019
TESTED BY:	D Winstanley Element

2.1 Test Summary

Test Method and Description		*Requirement Clause*		*Applicable to this equipment*	*Result / Note*
		RSS	*47CFR15*		
Radiated spurious emissions (restricted bands of operation and cabinet radiation)		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

4 Introduction

This report TRA-046269-47-00A presents the results of the Radio testing on a EkkoSense Ltd, EkkoAir to specification 47CFR15 Radio Frequency Devices

The testing was carried out for EkkoSense Ltd 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.

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: EkkoAir
- Serial Number: E535:ZB
- Model Number: FS-EA-10
- Software Revision: Production 1.1
- Build Level / Revision Number: Production D0

7.2 System Equipment

Equipment listed below forms part of the overall test setup and is required for equipment functionality and/or monitoring during testing. The compliance levels achieved in this report relate only to the EUT and not items given in the following list.

Not Applicable – No support/monitoring equipment required.

7.3 EUT Mode of Operation

7.3.1 Transmission

The mode of operation for transmitter tests was as follows:-
The EkkoAir was programmed to transmit a permanently modulated carrier when powered up.

7.4 EUT Radio Parameters

7.4.1 General

Frequency of operation:	923 MHz
Modulation type(s):	GFSK
Occupied channel bandwidth(s):	600 kHz
Channel spacing:	Wideband
ITU emission designator(s):	F1D
Declared output power(s):	<10 dBm
Nominal Supply Voltage:	Battery 2.2Vdc to 3.7Vdc External input 12Vdc to 24Vdc

7.4.2 Antennas

Type:	Option 1: DELTA2A/X/SMAM/S/RA/11
Frequency range:	850MHz, 868MHz, 900MHz, 915MHz, 1.8GHz, 1.9GHz, 2.1GHz
Impedance:	50 Ohms
VSWR:	2
Gain:	2.4dBi at 915MHz.
Polarisation:	Omni
Connector type:	SMA
Cable Length:	Not Applicable
Mounting:	Connector Mount

Type:	Option 2: ALPHA14/2.5M/SMAM/S/S/26
Frequency range:	850MHz, 868MHz, 900MHz, 915MHz, 1.8GHz, 1.9GHz, 2.1GHz
Impedance:	50 Ohms
VSWR:	2
Gain:	-1.1dBi at 915MHz.
Polarisation:	Omni
Connector type:	SMA
Cable Length:	2.5 Meter
Mounting:	Adhesive

7.4.3 Product specific declarations

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

7.5 EUT Description

The EUT is a monitoring device fitted with temperature and current sensors intended for monitoring the performance of cooling systems. It contains an 923 MHz transmitter to send this data to an EkkoHub wireless data receiver.

8 Modifications

No modifications were performed during this assessment.

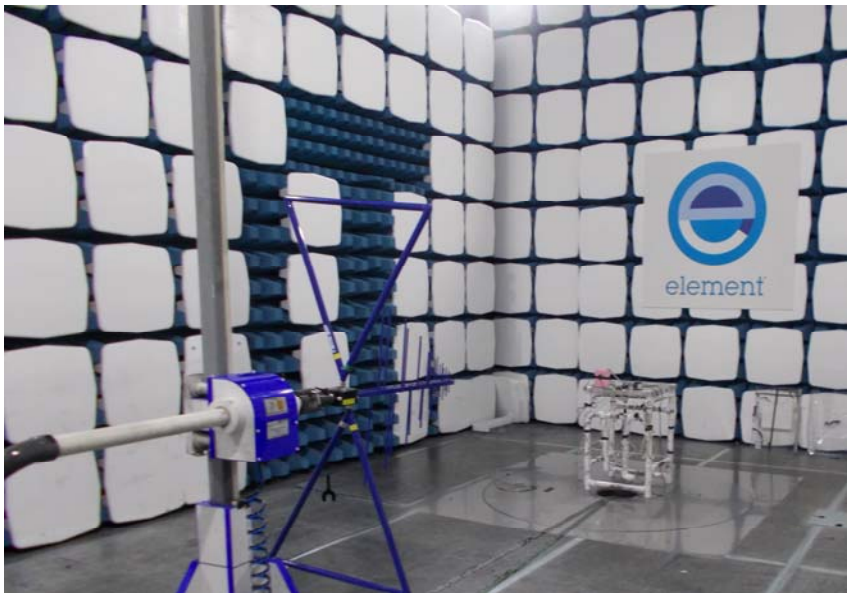
9 EUT Test Setup

9.1 Block Diagram

The following diagram shows basic EUT interconnections:

9.2 General Set-up Photograph

The following photograph shows basic EUT set-up:



9.3 Measurement software

Where applicable, the following software was used to perform measurements contained within this report.

Rohde and Schwarz EMC32 V8.53
Rohde and Schwarz EMC32 V9.21
Element Emissions R5 (See Note)
Element Transmitter Bench Test (See Note)
ETS Lindgren EMPower V1.0.4.2

Note:

The version of the Element software used is recorded in the results sheets contained within this report.

10 General Technical Parameters

10.1 Normal Conditions

The E U T was tested under the normal environmental conditions of the test laboratory, except where otherwise stated. The normal power source applied was approx. 12 Vdc from the adaptor / 2.2V dc from batteries

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
☒	Other	12 Vdc – 24 Vdc	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 Laboratory
Test Standard and Clause:	ANSI C63.10-2013, Clause 6.5 and 6.6
EUT Frequency Measured:	923 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: 57 % RH	20 % RH to 75 % RH (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:

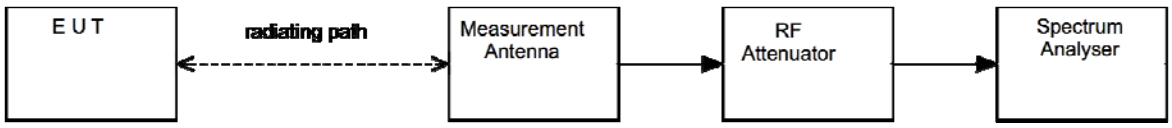
$$FS = PR + CL + AF – PA + DC – CF$$

Where,

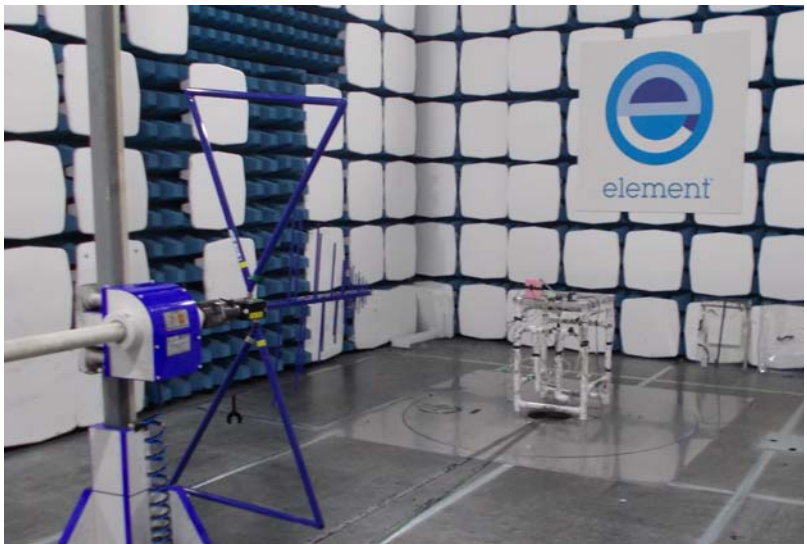
PR is the power recorded on the receiver / spectrum analyzer in dBµV;
CL is the cable loss in dB;
AF is the test antenna factor in dB/m;
PA is the pre-amplifier gain in dB (where used);
DC is the duty correction factor in dB (where used, e.g. harmonics of pulsed fundamental);
CF is the distance factor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

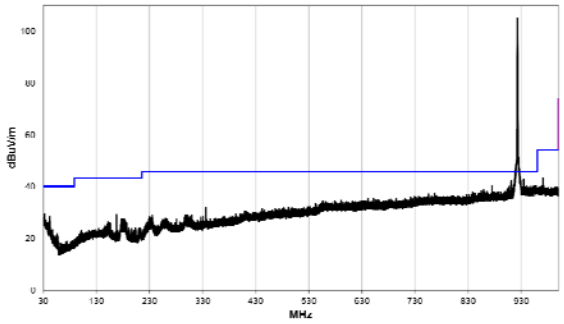


11.6 Test Equipment

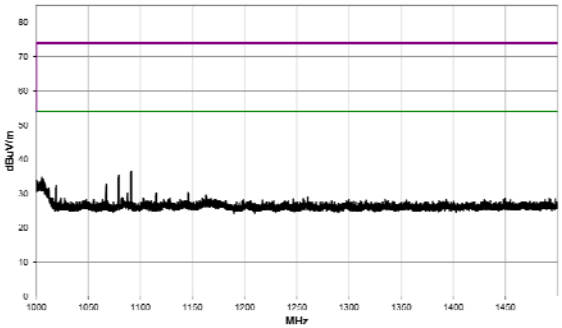
Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
3115	EMCO	1-18GHz Horn	U223	2019-10-25
8449B	Agilent	Pre Amp	L572	2019-10-12
CBL611/A	Chase	Bilog	U573	2019-08-02
6201-69	Watkins Johnson	PreAmp	U372	2020-02-25
FSU26	R&S	Spectrum Analyser	U405	2019-09-21

11.7 Test Results

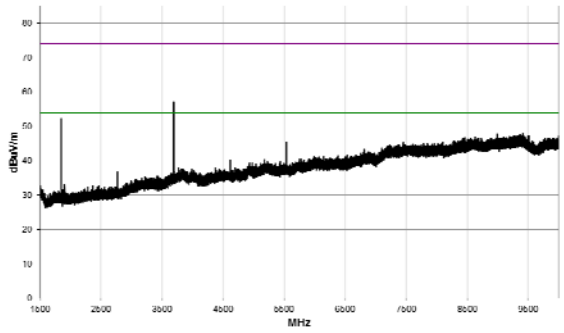
Antenna Option 1: DELTA2A/X/SMAM/S/RA/11								
Detector	***Freq. (MHz)***	***Meas'd Emission (dBµV)***	***Factor (dB)***	***Duty Cycle Corr'n (dB)***	***Distance Extrap'n Factor (dB)***	***Field Strength (dBµV/m)***	***Limit (dBµV/m)***	***Margin (dB)***
QP	970.820	34.3	6.6	-	-	40.9	54.0	-13.1
PK	1845.542	60.2	-5.5	-	-	54.7	74.0	-19.3
AV	1846.042	55.0	-5.5	-	-	49.5	54.0	-4.5
PK	3691.125	58.5	0.5	-	-	59.0	74.0	-15.0
AV	3691.292	50.6	0.5	-	-	51.1	54.0	-2.9
AV	5536.833	35.0	4.5	-	-	39.5	54.0	-14.5



30 MHz – 1 GHz

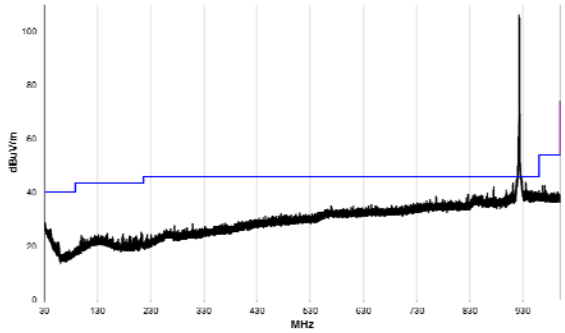


1 GHz – 1.5 GHz

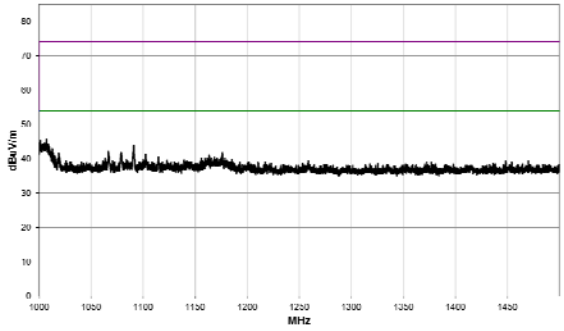


1.5 GHz – 10 GHz

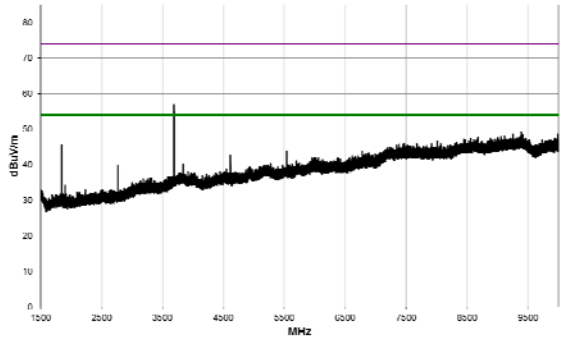
Antenna Option 2: ALPHA14/2.5M/SMAM/S/S/26									
Detector	***Freq. (MHz)***	***Meas'd Emission (dBµV)***	***Factor (dB)***	***Pre-amp Gain (dB)***	***Duty Cycle Corr'n (dB)***	***Distance Extrap'n Factor (dB)***	***Field Strength (dBµV/m)***	***Limit (dBµV/m)***	***Margin (dB)***
QP	970.820	33.9	6.6	-	-	-	40.5	54.0	-13.5
AV	1846.083	46.4	-5.5	-	-	-	40.9	54.0	-13.1
AV	3691.292	50.3	0.5	-	-	-	50.8	54.0	-3.2
PK	3691.042	58.3	0.5	-	-	-	58.8	74.0	-15.2
AV	5536.833	33.9	4.5	-	-	-	38.4	54.0	-15.6



30 MHz – 1 GHz



1 GHz – 1.5 GHz



1.5 GHz – 10 GHz

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:	U404
Test Standard and Clause:	ANSI C63.10-2013, Clause 6.2
EUT Frequencies Measured:	923 MHz
EUT Modulation:	FSK
Deviations From Standard:	None
Measurement BW:	10 kHz
Measurement Detectors:	Quasi-Peak and, Average, RMS

Environmental Conditions (Normal Environment)

Temperature: 25 °C	+15 ºC to +35 ºC (as declared)
Humidity: 54 % RH	20 % RH to 75 % RH (as declared)
Supply: 110 V ac	

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.

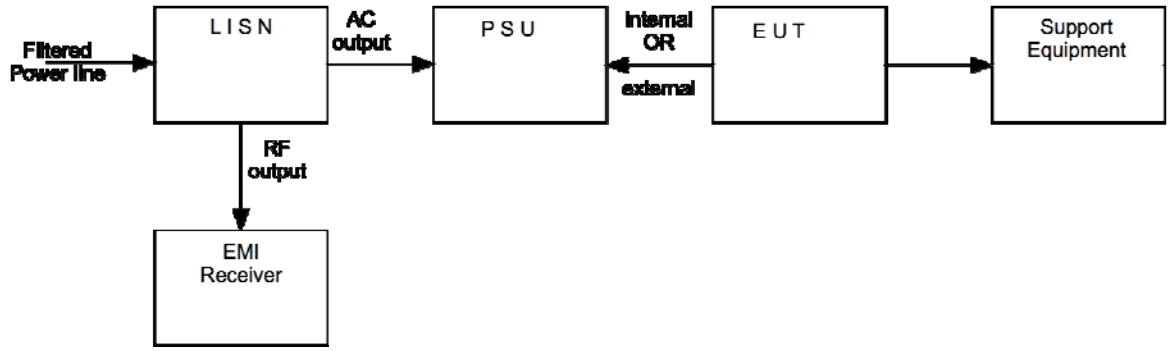
12.4 Test Method

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



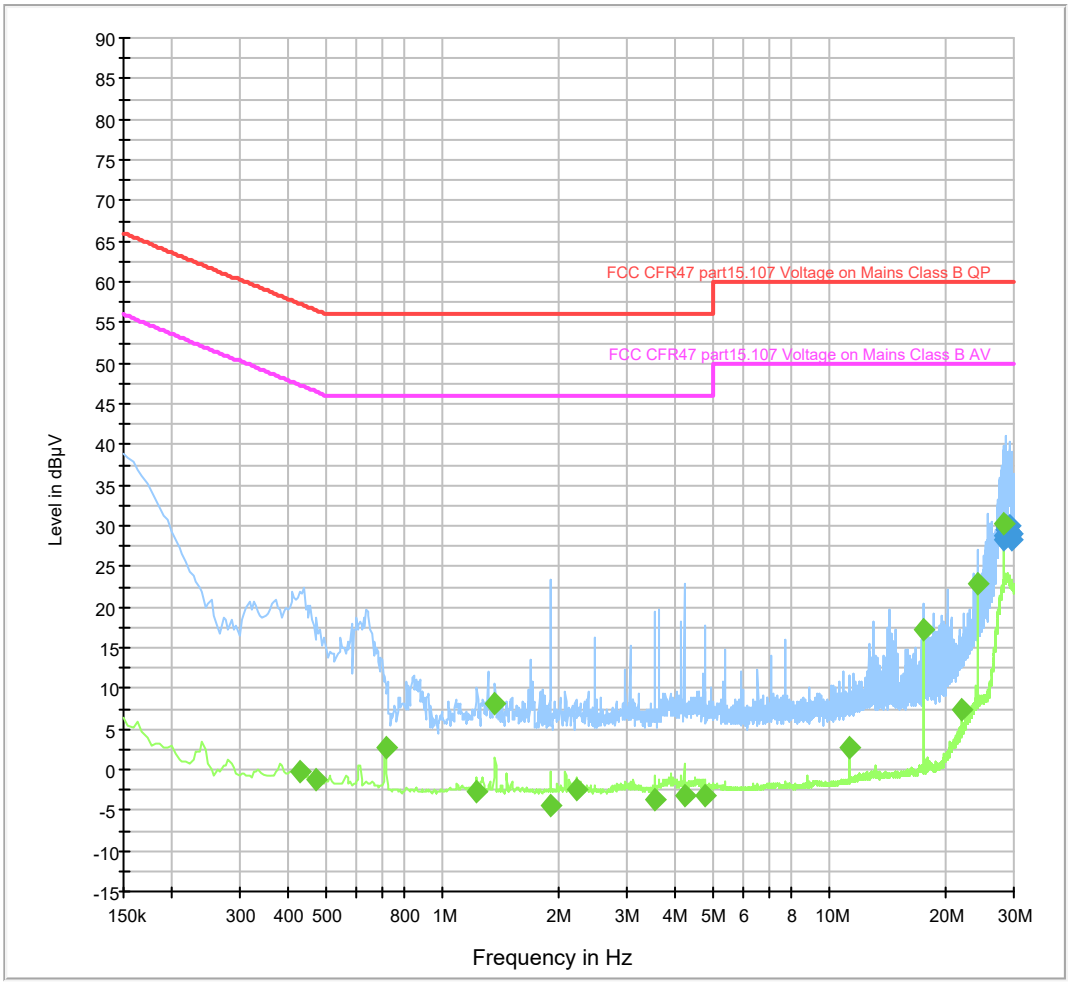
12.5 Test Set-up Photograph

12.6 Test Equipment

Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
ESH3-Z5.831.5	R&S	Lisn	U195	2019-09-12
ESHS10	R&S	Receiver	U003	2019-09-21
ESH3-Z2	R&S	Pulse Limiter	U443	2019-10-03

12.7 Test Results

Conducted emissions on Mains 9kHz-30MHz ESHS10 + UH195+UH443PL



Quasi Peak Detector								
Frequency (MHz)	QuasiPeak (dBµV)	Meas. Time (ms)	Bandwidth (kHz)	PE	Line	Corr. (dB)	Margin (dB)	Limit (dBµV)
28.279500	28.2	2000.0	10.000	GND	N	11.2	31.8	60.0
28.311000	28.8	2000.0	10.000	GND	L1	11.4	31.2	60.0
28.477500	29.4	2000.0	10.000	GND	N	11.2	30.6	60.0
28.536000	29.5	2000.0	10.000	GND	N	11.2	30.5	60.0
28.626000	29.9	2000.0	10.000	GND	L1	11.4	30.1	60.0
28.675500	29.7	2000.0	10.000	GND	N	11.2	30.3	60.0
28.756500	29.6	2000.0	10.000	GND	N	11.2	30.4	60.0
28.878000	29.4	2000.0	10.000	GND	N	11.2	30.6	60.0
29.044500	29.7	2000.0	10.000	GND	L1	11.4	30.3	60.0
29.166000	29.9	2000.0	10.000	GND	L1	11.4	30.1	60.0
29.328000	28.7	2000.0	10.000	GND	N	11.2	31.3	60.0
29.413500	28.9	2000.0	10.000	GND	L1	11.4	31.1	60.0
29.463000	29.2	2000.0	10.000	GND	L1	11.4	30.8	60.0
29.670000	29.1	2000.0	10.000	GND	N	11.3	30.9	60.0
29.796000	28.4	2000.0	10.000	GND	L1	11.5	31.6	60.0

Average Detector Measurements								
Frequency (MHz)	Average (dBµV)	Meas. Time (ms)	Bandwidth (kHz)	PE	Line	Corr. (dB)	Margin (dB)	Limit (dBµV)
0.429000	-0.3	2000.0	10.000	GND	N	10.1	47.5	47.3
0.469500	-1.2	2000.0	10.000	GND	N	10.1	47.7	46.5
0.712500	2.6	2000.0	10.000	GND	N	10.1	43.4	46.0
1.225500	-2.6	2000.0	10.000	GND	L1	10.1	48.6	46.0
1.369500	8.0	2000.0	10.000	GND	N	10.1	38.0	46.0
1.900500	-4.3	2000.0	10.000	GND	L1	10.1	50.3	46.0
2.229000	-2.5	2000.0	10.000	GND	N	10.1	48.5	46.0
3.547500	-3.7	2000.0	10.000	GND	N	10.2	49.7	46.0
4.213500	-3.2	2000.0	10.000	GND	L1	10.3	49.2	46.0
4.789500	-3.1	2000.0	10.000	GND	L1	10.3	49.1	46.0
11.319000	2.7	2000.0	10.000	GND	L1	10.6	47.3	50.0
17.574000	17.3	2000.0	10.000	GND	L1	11.0	32.7	50.0
21.970500	7.5	2000.0	10.000	GND	L1	11.2	42.5	50.0
24.072000	22.9	2000.0	10.000	GND	N	11.2	27.1	50.0
28.162500	30.1	2000.0	10.000	GND	L1	11.4	19.9	50.0

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:	ANSI C63.10-2013, Clause 11.8
EUT Frequency Measured:	923 MHz
EUT Test Modulations:	GFSK
Deviations From Standard:	None
Measurement BW:	100 kHz
Spectrum Analyzer Video BW:	300 kHz
Measurement Detector:	Peak

Environmental Conditions (Normal Environment)

Temperature: 25 °C	+15 ºC to +35 ºC (as declared)
Humidity: 51 % RH	20 % RH to 75 % RH (as declared)

13.3 Test Limit

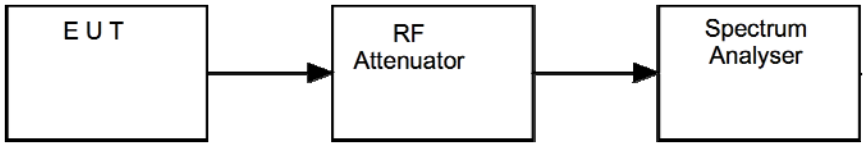
The minimum -6 dB bandwidth shall be at least 500 kHz.

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

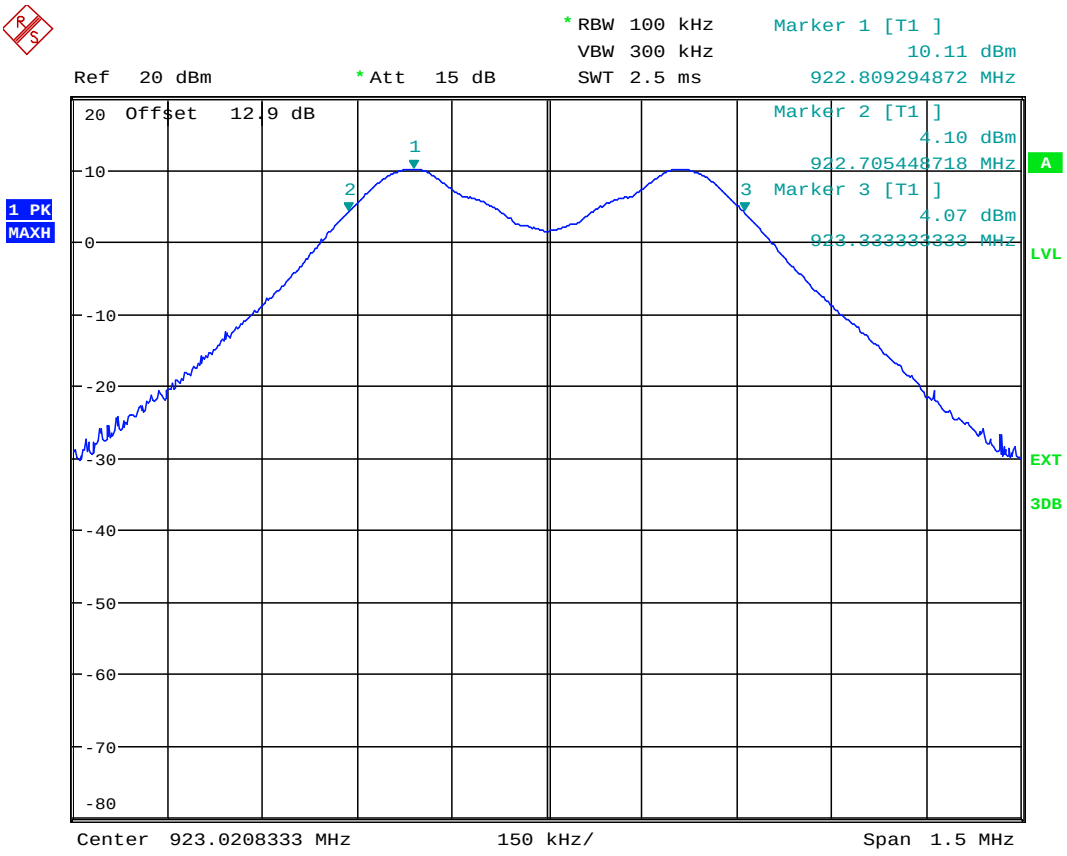


13.5 Test Equipment

Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
FSU46	R&S	Spectrum Analyser	REF910	2019-08-31

13.6 Test Results

Channel Frequency (MHz)	F_L (MHz)	F_H (MHz)	6dB Bandwidth (kHz)	Result
923	922.7054487	923.3333333	627.884615	PASS



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 Laboratory
Test Standard and Clause:	ANSI C63.10-2013, Clause 11.9.1
EUT Frequency Measured:	923 MHz
Deviations From Standard:	None
Measurement BW:	1 MHz
Spectrum Analyzer Video BW:	3 MHz
Measurement Detector:	Peak

Environmental Conditions (Normal Environment)

Temperature: 25 °C	+15 ºC to +35 ºC (as declared)
Humidity: 51 % RH	20 % RH to 75 % RH (as declared)

14.3 Test Limit

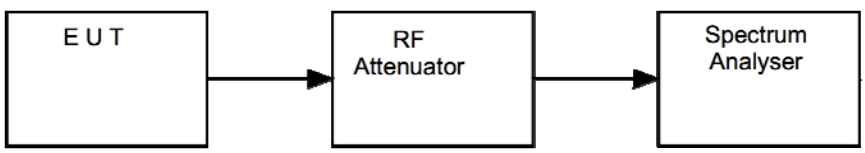
For systems employing digital modulation techniques operating in the bands 902 to 928 MHz, 2400 to 2483.5 MHz and 5725 to 5850 MHz, the maximum peak conducted output power shall not exceed 1 W.

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

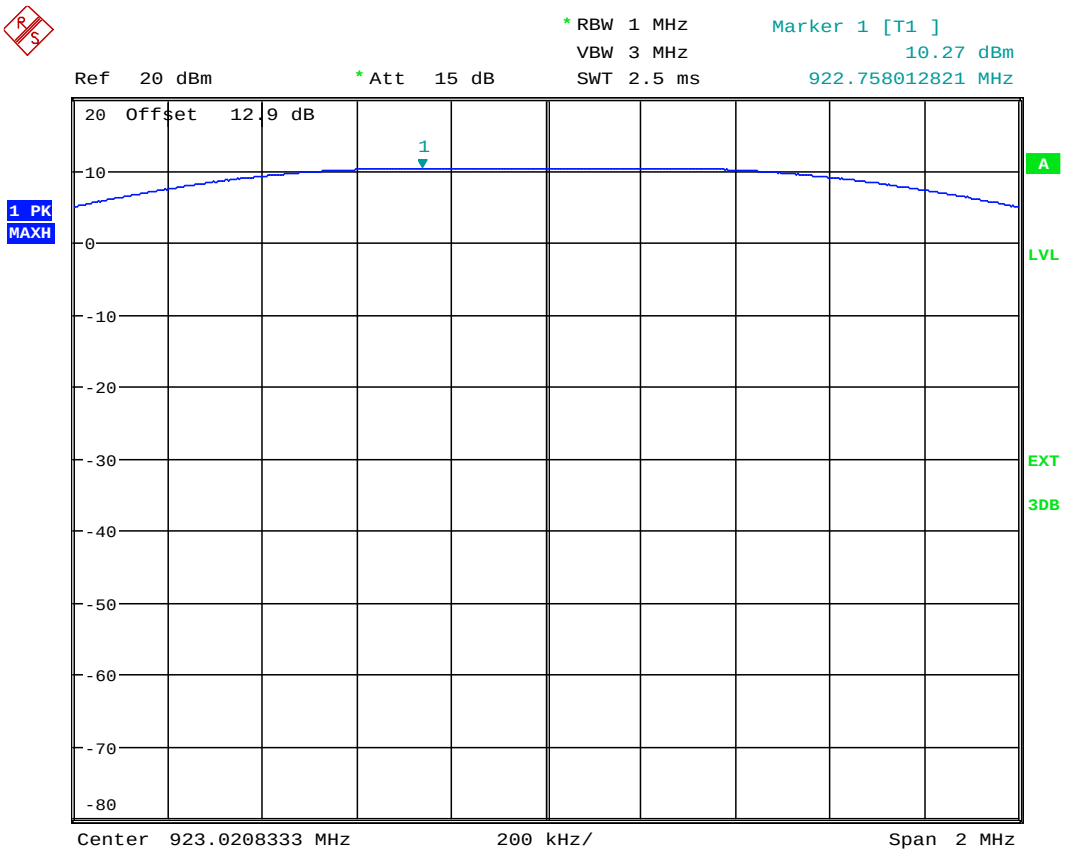


14.5 Test Equipment

Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
FSU46	R&S	Spectrum Analyser	REF910	2019-08-31

14.6 Test Results

Channel Frequency (MHz)	*Analyzer Level (dBm)*	*Cable loss (dB)*	*Power (dBm)*	*Result*
923	-2.63	12.90	10.27	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 Frequency Measured:	923 MHz
Deviations From Standard:	None
Measurement BW:	100 kHz
Spectrum Analyzer Video BW:	300 kHz
Measurement Detector:	Peak
Measurement Range:	9 kHz to 10 GHz

Environmental Conditions (Normal Environment)

Temperature: 25 °C	+15 ºC to +35 ºC (as declared)
Humidity: 51 % RH	20 % RH to 75 % RH (as declared)

15.3 Test Limit

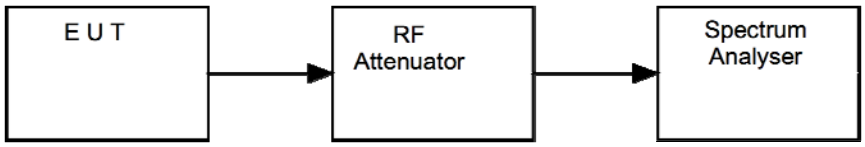
In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated device is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either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

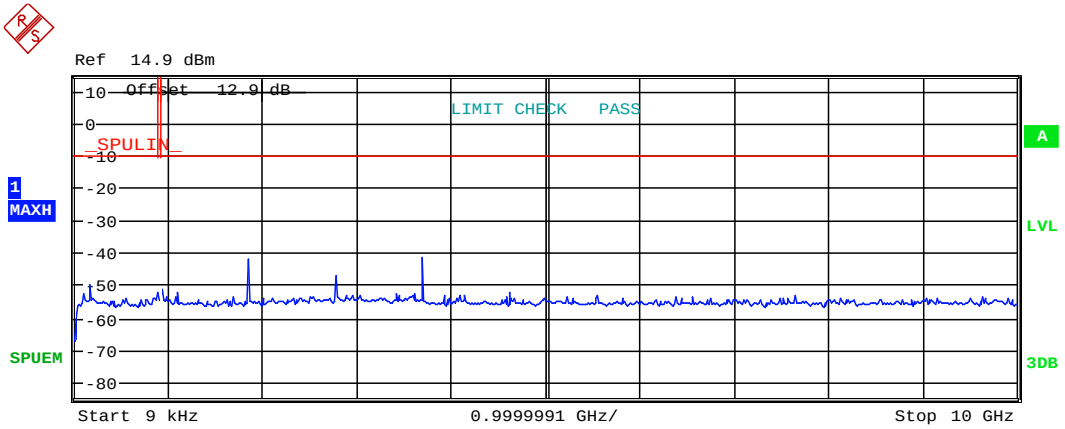


15.5 Test Equipment

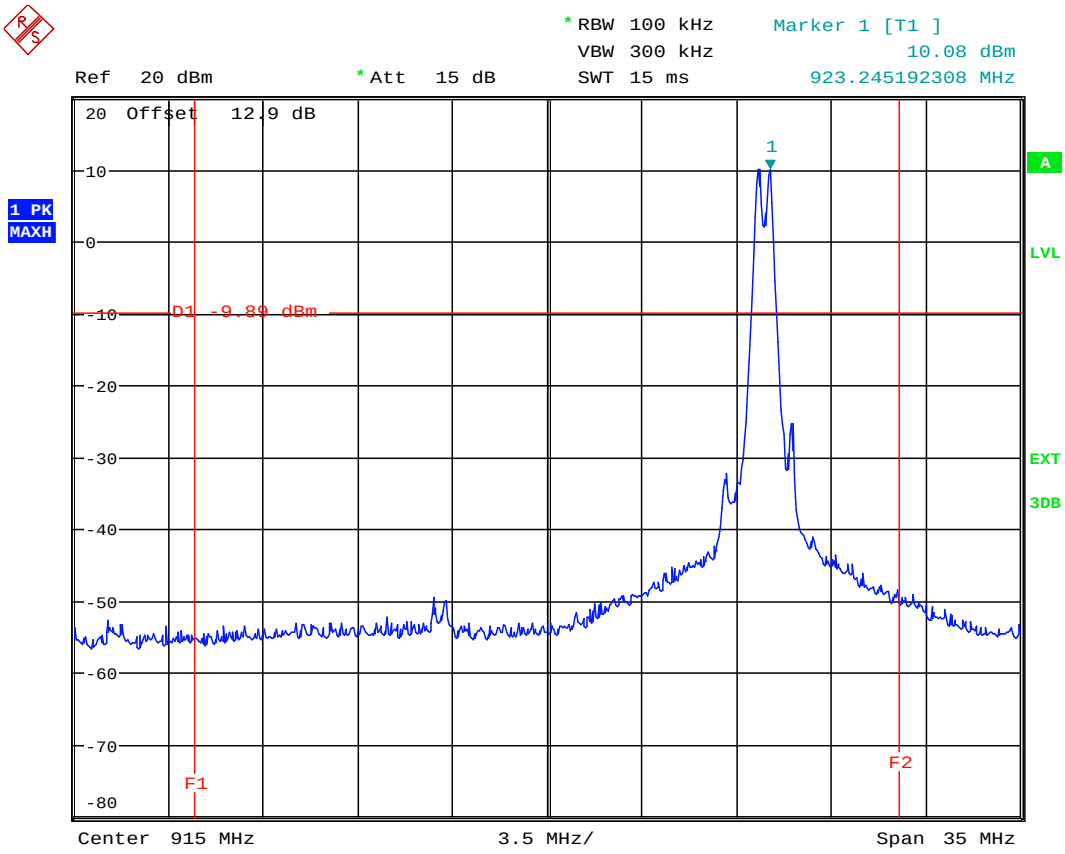
Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
FSU46	R&S	Spectrum Analyser	REF910	2019-08-31

15.6 Test Results

Channel Frequency (MHz)	***Emission Frequency (MHz)***	***Analyzer Level (dBm)***	***Emission Level (dBm)***	***Limit (dBm)***	***Margin (dB)***	***Result***
923	2405	10.11	10.11	N/A	N/A	PASS
No Significant Emissions Within 20 dB of the Limit						PASS



Start [Hz]	Stop [Hz]	RBW [Hz]	Freq [Hz]	PwrAbs [dBm]	Δ Limit [dB]
9.000 k	150.000 k	1.00 k	9.000000 k	-67.30	-57.41
150.000 k	30.000 M	10.00 k	167.910000 k	-60.67	-50.78
30.000 M	902.000 M	100.00 k	167.950400 M	-50.28	-40.39
928.000 M	3.000 G	100.00 k	1.845689 G	-42.29	-32.40
3.000 G	6.000 G	100.00 k	3.693000 G	-41.48	-31.59
6.000 G	10.000 G	100.00 k	7.642400 G	-53.48	-43.59



16 Power spectral density

16.1 Definition

The power per unit bandwidth.

16.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Radio Laboratory
Test Standard and Clause:	ANSI C63.10-2013, Clause 11.10
EUT Frequency Measured:	923 MHz
Deviations From Standard:	None
Measurement BW:	3 kHz
Spectrum Analyzer Video BW:	
Measurement Detector:	Peak

Environmental Conditions (Normal Environment)

Temperature: 25 °C	+15 ºC to +35 ºC (as declared)
Humidity: 51 % RH	20 % RH to 75 % RH (as declared)

16.3 Test Limit

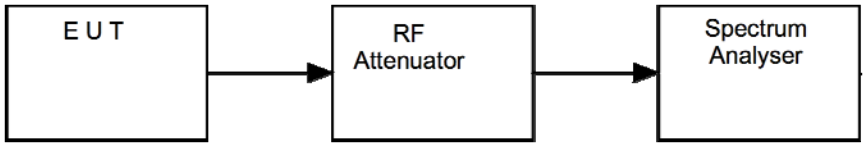
The transmitter power spectral density conducted from the transmitter to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.

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

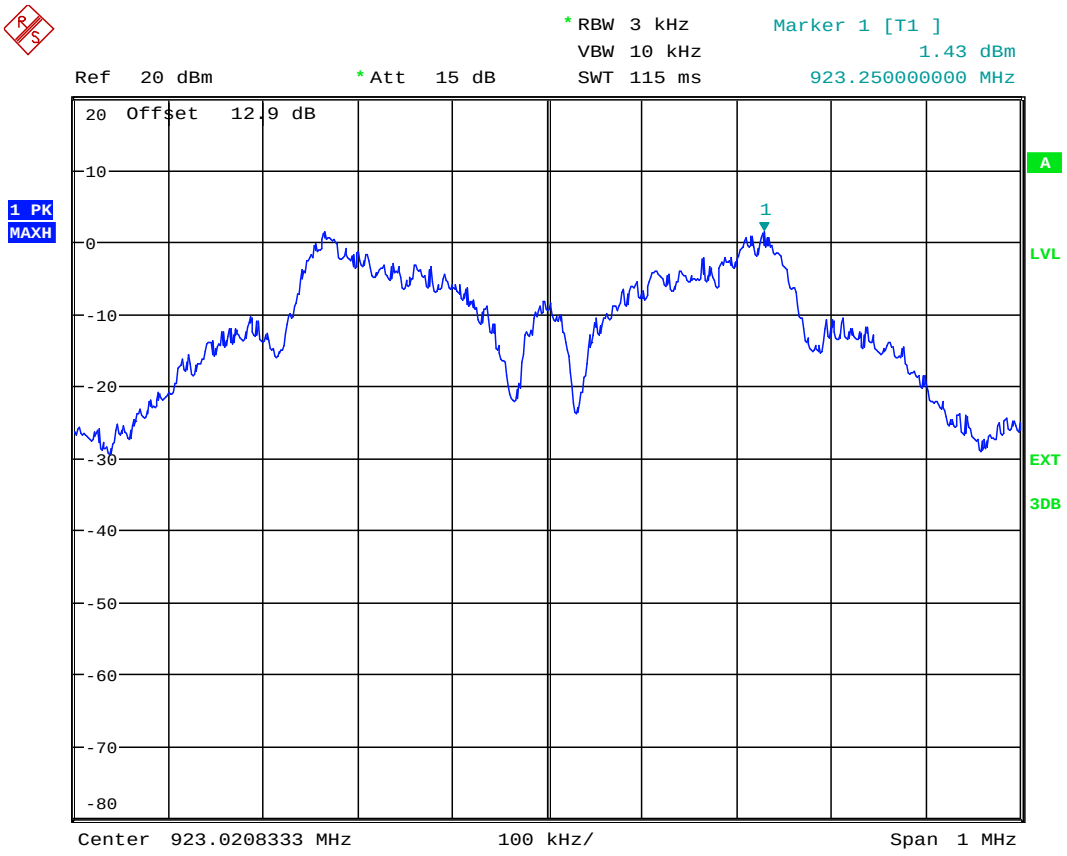


16.5 Test Equipment

Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
FSU46	R&S	Spectrum Analyser	REF910	2019-08-31

16.6 Test Results

Channel Frequency (MHz)	Analyzer Level (dBm)	Cable loss (dB)	Power (dBm)	Result
923	-11.47	12.90	1.43	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) = **4.75 dB**
Uncertainty in test result (1 GHz to 18 GHz) = **4.46 dB**

[2] AC power line conducted emissions

Uncertainty in test result = **3.2 dB**

[3] Occupied bandwidth

Uncertainty in test result = **15.58 %**

[4] Conducted carrier power

Uncertainty in test result (Power Meter) = **0.93 dB**

[5] Conducted 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**

[6] Radiated RF power out-of-band

Uncertainty in test result (30 MHz to 1 GHz) = **4.75 dB**
Uncertainty in test result (1 GHz to 18 GHz) = **4.46 dB**

[7] Power spectral density

Uncertainty in test result (Spectrum Analyser) = **3.11 dB**

[8] ERP / EIRP

Uncertainty in test result (Laboratory) = **4.71 dB**
Uncertainty in test result (Pershore OATS) = **4.26 dB**

18 RF Exposure

KDB 447498 Section 4.3 General SAR test reduction and exclusion guidance

For Standalone SAR exclusion consideration, when SAR exclusion Threshold requirement in KDB 447498 is satisfied, standalone SAR evaluation for general population exposure conditions by measurement or numerical simulation is not required.

In the frequency range below 100 MHz to 6 GHz and test separation distance of 6mm, the SAR Test Exclusion Threshold for operation at 923 MHz will be determined as follows

SAR Exclusion Threshold (SARET)

$$NT = [(MP/TSD^{A}) * \sqrt{f_{GHz}}]$$

NT	=	Numeric Threshold (3.0 for 1-g SAR and 7.5 for 10-g SAR)
MP	=	Max Power of channel (mW) (inc tune up)
TSD^{A}	=	Min Test separation Distance or 50mm (whichever is lower) = 6mm

We can transpose this formula to allow us to find the maximum power of a channel allowed and compare this to the measured maximum power.

$$= [(NT \times TSD^{A}) / \sqrt{f_{GHz}}]$$

Operating Frequency 923 MHz

MP= [(3.0 x 6) / √0.923]
MP= [18 / 0.9607]
MP= 18.74mW

The calculated output power 18.49mw (Peak) is less than the SAR Exclusion Threshold of 18.74mW at a separation distance of 6mm.

Prediction of MPE limit at a given distance

Equation from IEEE C95.1

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

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)
923	10.27	2.4	18.49	1.6	0.57	0.62