Report on the Radio Testing

For

Inductosense Limited

on

WAND ULTRASONIC PROBE

Report no. TRA-042826-47-00C

27 June 2019

Report Number: TRA-042826-47-00C
Issue: C

REPORT ON THE RADIO TESTING OF A
Inductosense Limited
WAND ULTRASONIC PROBE
WITH RESPECT TO SPECIFICATION
FCC 47CFR 15.247

TEST DATE: 7th - 24th May 2019

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Date:	27 June 2019	

1 Revision Record

Issue Number	*Issue Date*	*Revision History*
A	10th June 2019	Original
B	13th June 2019	Amendments
C	27th June 2019	Amendments

2 Summary

TEST REPORT NUMBER:	TRA-042826-47-00C
WORKS ORDER NUMBER:	TRA-042826-01
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.
TEST SPECIFICATION(S):	47CFR15.247
EQUIPMENT UNDER TEST (EUT):	WAND ULTRASONIC PROBE
FCC IDENTIFIER:	2ARVM0001
EUT SERIAL NUMBER:	48
MANUFACTURER/AGENT:	Inductosense Limited
ADDRESS:	Unit DX St Philips Central Albert Road Bristol, BS2 0XJ United Kingdom
CLIENT CONTACT:	Ashwin Rao ☎ 07714991098 ✉ ashwin@inductosense.com
TEST DATE:	7th - 24th May 2019
TESTED BY:	S Garwell, D Winstanley Element

2.1 Test Summary

Test Method and Description	*Requirement Clause47CFR15*	*Applicable to this equipment*	*Result / Note*
Radiated spurious emissions (restricted bands of operation and cabinet radiation)	15.205	☒	*Pass*
AC power line conducted emissions	15.207	☒	*Pass*
Carrier frequency separation	15.247(a)(1)	☒	*Pass*
Number of hopping channels	15.247(a)(1) (i), (ii) and (iii)	☒	*Pass*
Average time of occupancy	15.247(a)(1) (i), (ii) and (iii)	☒	*Pass*
Maximum peak conducted output power	15.247 (a)(1), (b)(1) and (b)(2)	☒	*Pass*
20dB emission bandwidth	15.247(a)(1) (i) and (ii)	☒	*Pass*
Out-of-band emissions	15.247(d)	☒	*Pass*

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-042826-47-00C presents the results of the Radio testing on an Inductosense Limited, WAND ULTRASONIC PROBE to specification 47CFR15 Radio Frequency Devices.

The testing was carried out for Inductosense Limited by Element, at the address detailed below.

☐ Element Hull
Unit E
South Orbital Trading Park
Hedon Road
Hull
HU9 1NJ
UK

☒ Element Skelmersdale
Unit 1
Pendle Place
Skemersdale
West Lancashire
WN8 9PN
UK

This report details the configuration of the equipment, the test methods used and any relevant modifications where appropriate.

All test and measurement equipment under the control of the laboratory and requiring calibration is subject to an established programme and procedures to control and maintain measurement standards. The quality management system meets the principles of ISO 9001, and has quality control procedures for monitoring the validity of tests undertaken. Records and sufficient detail are retained to establish an audit trail of calibration records relating to its test results for a defined period. Under control of the established calibration programme, key quantities or values of the test & measurement instrumentation are within specification and comply with the relevant traceable internationally recognised and appropriate standard specifications, which are UKAS calibrated as such where these properties have a significant effect on results. Participation in inter-laboratory comparisons and proficiency testing ensures satisfactory correlation of results conform to Elements own procedures, as well as statistical techniques for analysis of test data providing the appropriate confidence in measurements.

Throughout this report EUT denotes equipment under test.

FCC Site Listing:
Element is accredited for the above sites under the US-EU MRA, Designation number UK0009.

IC Registration Number(s):

Element Hull	3483A
Element North West	3930B

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

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

5 Test Specifications

5.1 Normative References

- FCC 47 CFR Ch. I – Part 15 – Radio Frequency Devices.
- ANSI C63.10-2013 – American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices.
- ANSI C63.4-2014 – American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz.

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: WAND ULTRASONIC PROBE
- Serial Number: 48
- Software Revision: v1.23 & CE test
- Build Level / Revision Number: v1.0

7.2 System Equipment

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

Not Applicable – No support/monitoring equipment required.

7.3 EUT Mode of Operation

7.3.1 Transmission

The mode of operation for Tx tests was as follows:-
The EUT was set to transmit a modulated signal on bottom or top operating frequency as required
The EUT was set to transmit a modulated signal hopping over all channels as required.

Python script 'SetEngRfidPower.py' version 1.0 is use to enable the EUT
Universal reader assistant v4.2 was used to set the EUT to a specific channel
Think Magic Autonomous configuration tool (v1.2.1.4) was used to set the dwell time per hop to 23ms and start the EUT hopping over all channels.
The EUT was set to transmit power setting 18.

All software was running on the manufacturer supplied laptop.

7.4 EUT Radio Parameters

7.4.1 General

Frequency of operation:	917.5 MHz – 922.5 MHz
Modulation type(s):	FHSS
Occupied channel bandwidth(s):	56.5 kHz
Channel spacing:	100 kHz
Warning against use of alternative antennas in user manual (yes/no):	Integral antenna
Location of notice for license exempt use:	Label / user manual / both.

7.4.2 Product specific declarations

Multiple antenna configuration(s), e.g. MIMO:	Single
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 Wireless And Non Destructive (WAND) system can be used for monitoring of internal corrosion or erosion on pipework or vessels. The sensors are compact, wireless, battery-free and RFID tagged and become activated when the WAND Data Collector is brought near by.

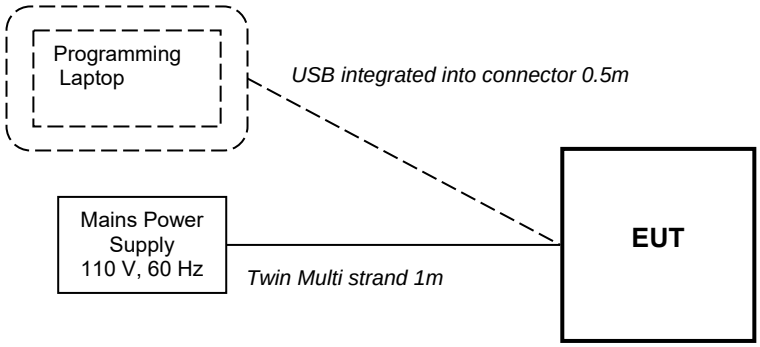
8 Modifications

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:



During test the EUT was programmed and a Power supply without integrated USB lead was used.

General Technical Parameters

9.2 Normal Conditions

The EUT was tested under the normal environmental conditions of the test laboratory, except where otherwise stated. The normal power source applied was 110 V ac, 60 Hz, from the mains.

9.3 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	Fully Charged 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:	Radio Laboratory
Test Standard and Clause:	ANSI C63.10-2013, Clause 6.5 and 6.6
EUT Channels Measured:	Low / High
EUT Channel Bandwidths:	56.5 kHz
Deviations From Standard:	None
Measurement BW:	30 MHz to 1 GHz: 120 kHz; Above 1 GHz: 1 MHz
Measurement Detector:	Up to 1 GHz: quasi-peak; Above 1 GHz: RMS average and Peak

Environmental Conditions (Normal Environment)

Temperature: 21 °C	+15 ºC to +35 ºC (as declared)
Humidity: 36 % RH	20 % RH to 75 % RH (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:

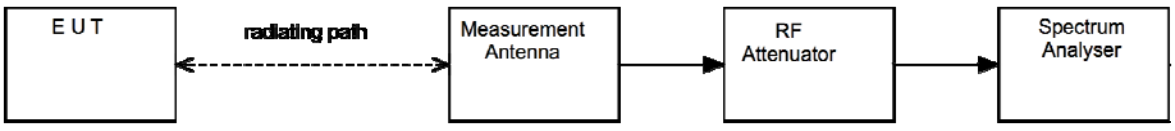
$$FS = PR + CL + AF – PA + DC – CF$$

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.

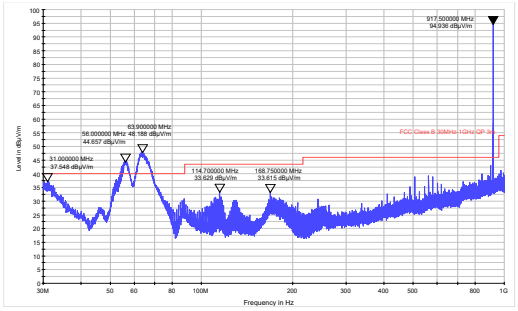
Figure i Test Setup



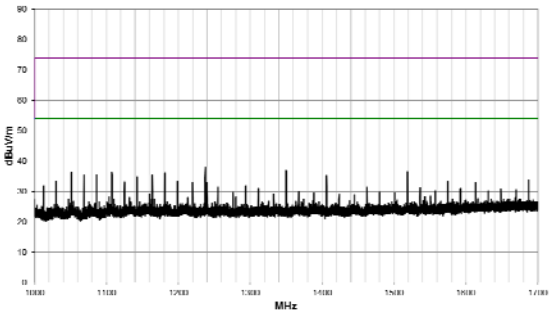
10.5 Test Equipment

Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
FSU26	R&S	Spectrum Analyser	U405	2019-09-21
CBL611/A	Chase	Bilog	U573	2019-08-02
ESVS10	R&S	Receiver	L317	2020-04-24
8449B	Agilent	Pre Amp	L572	2019-10-12
3115	EMCO	1-18GHz Horn	L139	2019-09-25

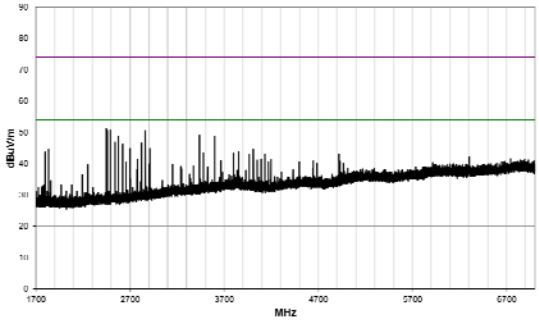
10.6 Test Results



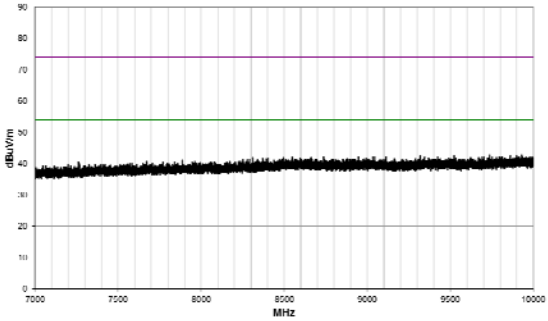
30 MHz – 1GHz



1 GHz – 1.7 GHz



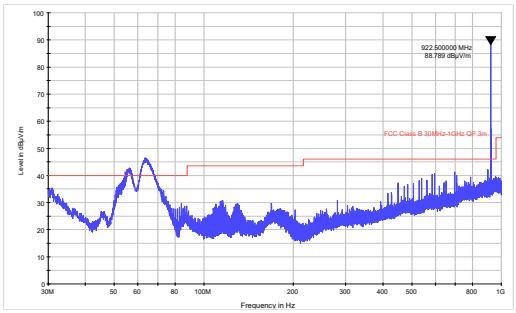
1.7 GHz – 7 GHz



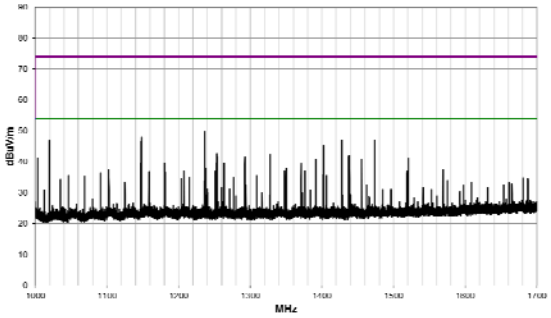
7 GHz – 10 GHz

917.5 MHz							
Freq (MHz)	**Amplitude (dBuV)**	**Factor (dB)**	**Detector**	**Distance Adjustment (dB)**	**Adjusted Measurement (dBuV/m)**	**Limit (dBuV/m)**	**Margin (dB)**
1051.322	47.2	-11.5	AV	0.0	35.7	54.0	-18.3
1051.447	53.1	-11.5	PK	0.0	41.6	74.0	-32.4
1107.560	46.8	-10.9	AV	0.0	35.9	54.0	-18.1
1107.343	53.0	-10.9	PK	0.0	42.1	74.0	-31.9
1237.553	47.0	-10.3	AV	0.0	36.7	54.0	-17.3
1237.470	52.1	-10.3	PK	0.0	41.8	74.0	-32.2
1350.045	44.5	-10.0	AV	0.0	34.5	54.0	-19.5
1349.870	51.7	-10.0	PK	0.0	41.7	74.0	-32.3
1518.818	45.0	-9.2	AV	0.0	35.8	54.0	-18.2
1518.810	50.6	-9.2	PK	0.0	41.4	74.0	-32.6
2700.092	51.0	-3.5	AV	0.0	47.5	54.0	-6.5
2699.942	54.1	-3.6	PK	0.0	50.5	74.0	-23.5
3600.125	39.9	0.2	AV	0.0	40.1	54.0	-13.9
3599.967	47.6	0.2	PK	0.0	47.8	74.0	-26.2

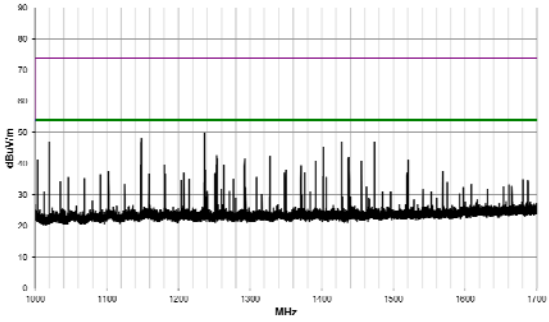
The above table covers emissions in restricted bands only, for emissions in non-restricted bands see section 18. Per §15.247(d), attenuation below the general limits specified in §15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in §15.205(a), must also comply with the radiated emission limits specified in §15.209(a) (see §15.205(c)). A pre-scan plot showing two emissions above the general limits in §15.209(a) are in non-restricted bands and therefore acceptable with no further assessment – not listed in the table.



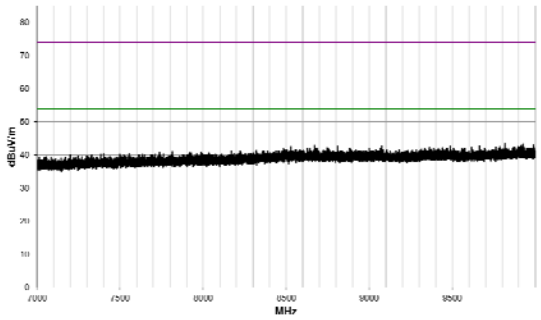
30 MHz – 1GHz



1 GHz – 1.7 GHz



1.7 GHz – 7 GHz



7 GHz – 10 GHz

922.5 MHz							
Freq (MHz)	**Amplitude (dBuV)**	**Factor (dB)**	**Detector**	**Distance Adjustment (dB)**	**Adjusted Measurement (dBuV/m)**	**Limit (dBuV/m)**	**Margin (dB)**
1102.575	48.4	-10.9	AV	0.0	37.5	54.0	-16.5
1102.600	54.3	-10.9	PK	0.0	43.4	74.0	-30.6
1147.500	46.1	-10.6	AV	0.0	35.5	54.0	-18.5
1147.375	52.3	-10.6	PK	0.0	41.7	74.0	-32.3
1181.275	46.4	-10.3	AV	0.0	36.1	54.0	-17.9
1181.233	51.8	-10.3	PK	0.0	41.5	74.0	-32.5
1237.542	48.6	-10.3	AV	0.0	38.3	54.0	-15.7
1237.617	53.2	-10.3	PK	0.0	42.9	74.0	-31.1
1350.067	47.9	-10.0	AV	0.0	37.9	54.0	-16.1
1350.092	53.0	-10.0	PK	0.0	43.0	74.0	-31.0
1518.808	45.7	-9.2	AV	0.0	36.5	54.0	-17.5
1518.817	51.2	-9.2	PK	0.0	42.0	74.0	-32.0
2700.100	51.0	-3.5	AV	0.0	47.5	54.0	-6.5
2700.158	54.1	-3.5	PK	0.0	50.6	74.0	-23.4
3600.158	36.8	0.2	AV	0.0	37.0	54.0	-17.0
3599.900	47.1	0.2	PK	0.0	47.3	74.0	-26.7

The above table covers emissions in restricted bands only, for emissions in non-restricted bands see section 18. Per §15.247(d), attenuation below the general limits specified in §15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in §15.205(a), must also comply with the radiated emission limits specified in §15.209(a) (see §15.205(c)). A pre-scan plot showing two emissions above the general limits in §15.209(a) are in non-restricted bands and therefore acceptable with no further assessment – not listed in the table.

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
Test Standard and Clause:	ANSI C63.10-2013, Clause 6.2
EUT Channels / Frequencies Measured:	All Hopping
Deviations From Standard:	None
Measurement BW:	10 kHz
Measurement Detectors:	Quasi-Peak and Average, RMS

Environmental Conditions (Normal Environment)

Temperature: 19 °C	+15 ºC to +35 ºC (as declared)
Humidity: 37 % RH	20 % RH to 75 % RH (as declared)
Supply: 110 V ac	

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.

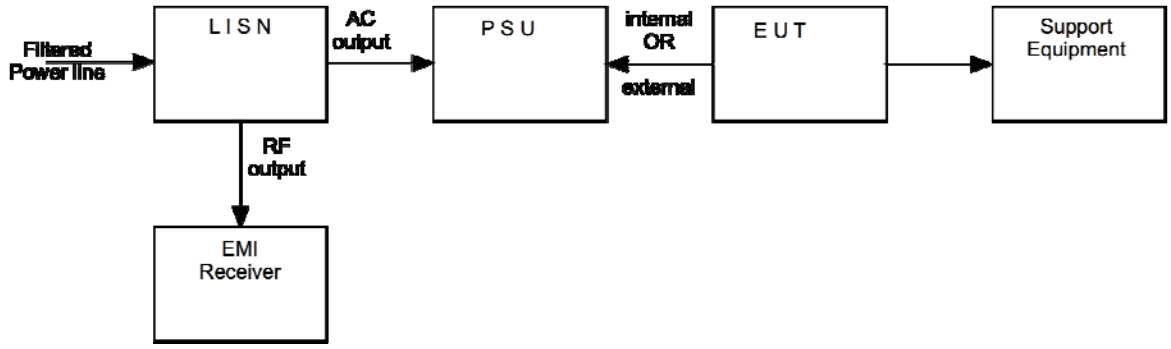
11.3 Test Method

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

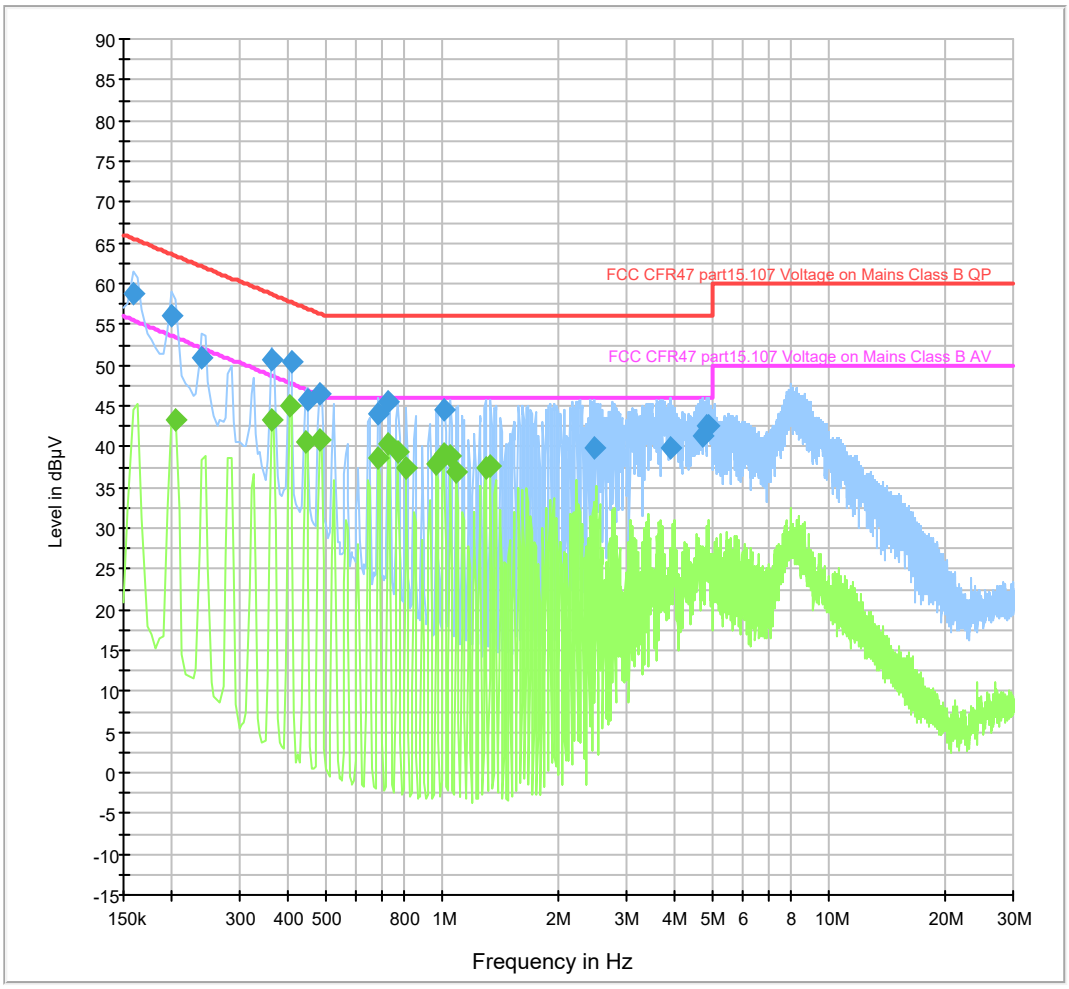


11.4 Test Equipment

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	U187	2019-11-29

11.5 Test Results

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



Final Result 1

Quasi peak detector, EUT Hopping over all channels								
Frequency (MHz)	Quasi Peak (dBµV)	Meas. Time (ms)	Bandwidth (kHz)	PE	Line	Corr. (dB)	Margin (dB)	Limit (dBµV)
0.159000	58.9	2000.0	10.000	GND	L1	10.0	6.6	65.5
0.199500	56.0	2000.0	10.000	GND	N	10.0	7.6	63.6
0.240000	50.8	2000.0	10.000	GND	N	10.0	11.3	62.1
0.361500	50.6	2000.0	10.000	GND	N	10.1	8.1	58.7
0.406500	50.4	2000.0	10.000	GND	N	10.1	7.3	57.7
0.447000	45.8	2000.0	10.000	GND	N	10.1	11.1	56.9
0.483000	46.4	2000.0	10.000	GND	N	10.1	9.9	56.3
0.685500	44.0	2000.0	10.000	GND	N	10.1	12.0	56.0
0.726000	45.5	2000.0	10.000	GND	N	10.1	10.5	56.0
1.014000	44.4	2000.0	10.000	GND	N	10.1	11.6	56.0
2.476500	39.8	2000.0	10.000	GND	N	10.2	16.2	56.0
3.894000	39.9	2000.0	10.000	GND	N	10.2	16.1	56.0
4.722000	41.3	2000.0	10.000	GND	N	10.3	14.7	56.0
4.830000	42.5	2000.0	10.000	GND	N	10.3	13.5	56.0
4.911000	42.5	2000.0	10.000	GND	N	10.3	13.5	56.0

Final Result 2

Average detector, EUT Hopping over all channels								
Frequency (MHz)	Average (dBµV)	Meas. Time (ms)	Bandwidth (kHz)	PE	Line	Corr. (dB)	Margin (dB)	Limit (dBµV)
0.204000	43.3	2000.0	10.000	GND	L1	10.1	10.1	53.4
0.361500	43.2	2000.0	10.000	GND	N	10.1	5.5	48.7
0.402000	44.9	2000.0	10.000	GND	N	10.1	2.9	47.8
0.442500	40.5	2000.0	10.000	GND	N	10.1	6.5	47.0
0.483000	40.8	2000.0	10.000	GND	N	10.1	5.5	46.3
0.685500	38.7	2000.0	10.000	GND	N	10.1	7.3	46.0
0.726000	40.2	2000.0	10.000	GND	N	10.1	5.8	46.0
0.766500	39.4	2000.0	10.000	GND	N	10.1	6.6	46.0
0.807000	37.3	2000.0	10.000	GND	N	10.1	8.7	46.0
0.969000	38.0	2000.0	10.000	GND	N	10.1	8.0	46.0
1.009500	39.2	2000.0	10.000	GND	N	10.1	6.8	46.0
1.050000	38.9	2000.0	10.000	GND	N	10.1	7.1	46.0
1.090500	37.0	2000.0	10.000	GND	N	10.1	9.0	46.0
1.293000	37.5	2000.0	10.000	GND	N	10.1	8.5	46.0
1.333500	37.5	2000.0	10.000	GND	N	10.1	8.5	46.0

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 Laboratory
Test Standard and Clause:	ANSI C63.10-2013, Clause 7.8.2
EUT Channels Measured:	All; Hopping
EUT 20dB Bandwidth:	56.5 kHz
EUT Test Modulations:	Internal pattern generation – hopping enabled
Deviations From Standard:	None
Measurement BW:	30 kHz
Measurement Detector:	Peak

Environmental Conditions (Normal Environment)

Temperature: 23 °C	+15 ºC to +35 ºC (as declared)
Humidity: 37 % RH	20 % RH to 75 % RH (as declared)

12.3 Test Limit

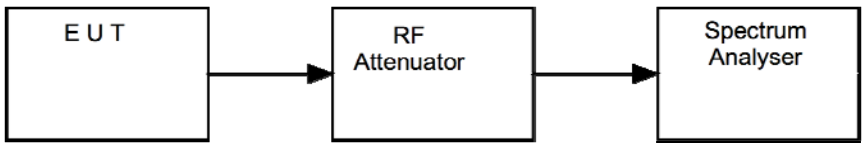
Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the -20 dB bandwidth of the hopping channel, whichever is greater. Alternatively, frequency hopping systems operating in the band 2400 to 2483.5 MHz may have hopping channel carrier frequencies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

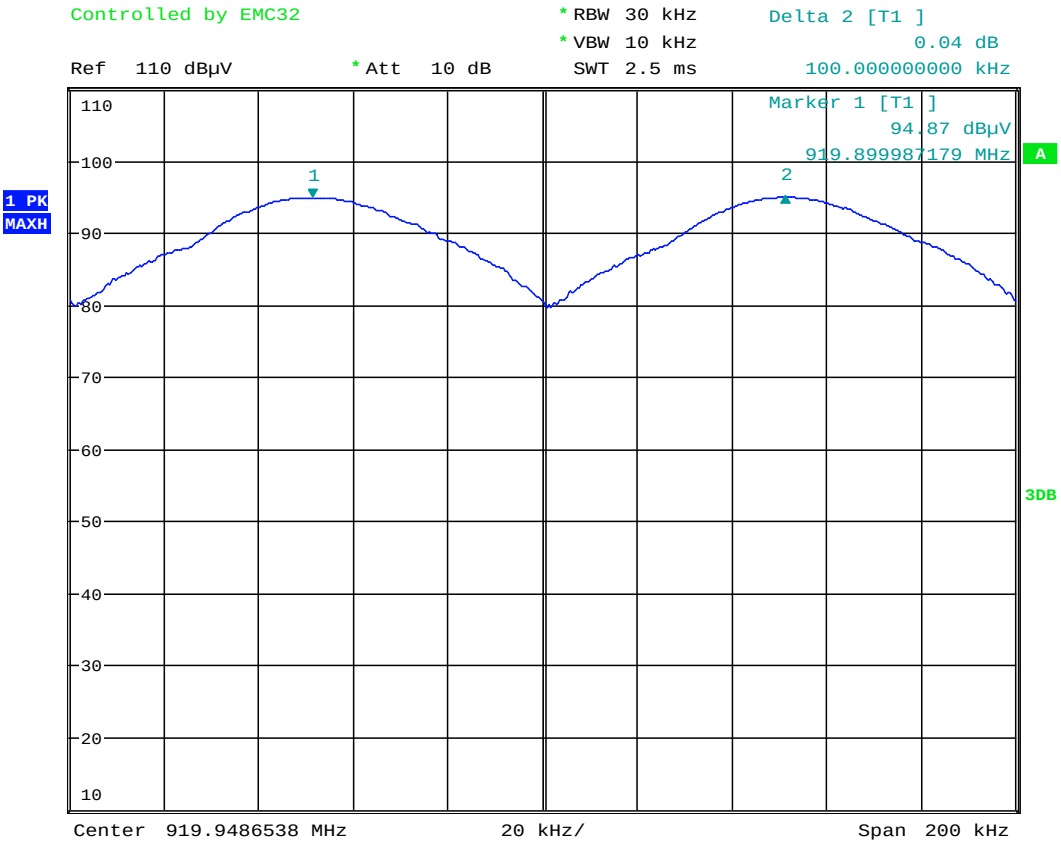


12.5 Test Equipment

Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
FSU26	R&S	Spectrum Analyser	U405	2019-09-21

12.6 Test Results

$F1_c$ (MHz)	$F2_c$ (MHz)	Channel Separation, $F2_c - F1_c$ (kHz)	Result
919.899	919.999	100 kHz	PASS



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 Laboratory
Test Standard and Clause:	ANSI C63.10-2013, Clause 7.8.3
EUT Channels Measured:	All; Hopping
EUT 20dB Bandwidth:	56.5 kHz
EUT Test Modulations:	Internal pattern generation – hopping enabled
Deviations From Standard:	None
Measurement BW:	20 kHz
Measurement Detector:	Peak

Environmental Conditions (Normal Environment)

Temperature: 23 °C	+15 ºC to +35 ºC (as declared)
Humidity: 37 % RH	20 % RH to 75 % RH (as declared)

13.3 Test Limit

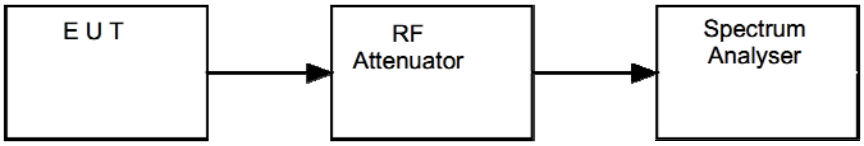
- For frequency hopping systems in the band 902 to 928 MHz: if the -20 dB bandwidth of the hopping channel is less than 250 kHz, the system shall use at least 50 hopping channels; If the -20 dB bandwidth of the hopping channel is 250 kHz or greater, the system shall use at least 25 hopping channels;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

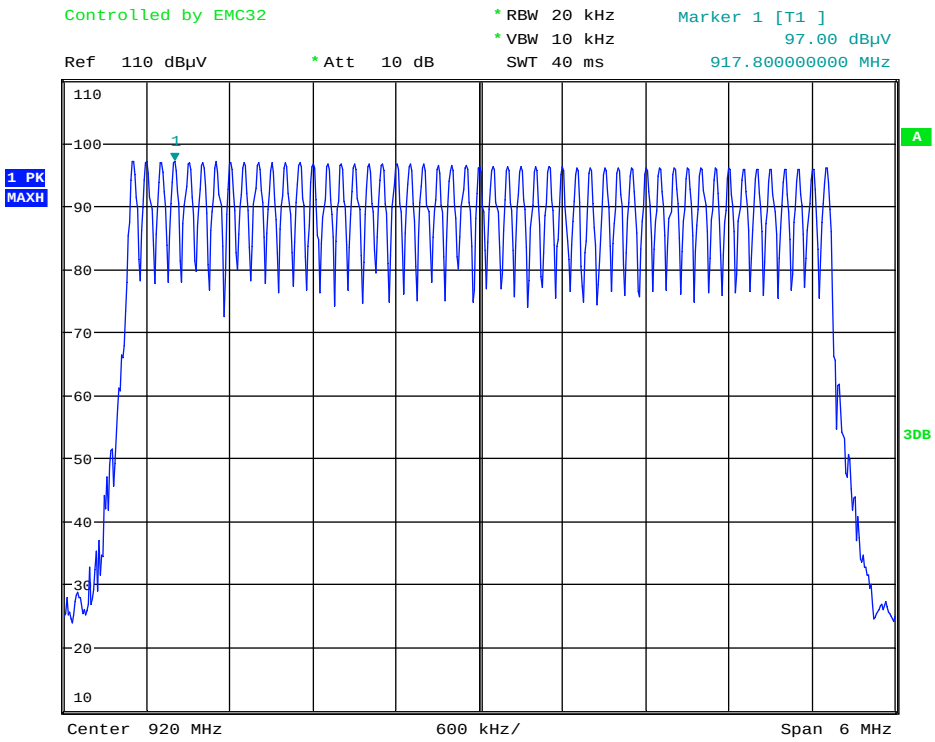


13.5 Test Equipment

Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
FSU26	R&S	Spectrum Analyser	U405	2019-09-21

13.6 Test Results

Lowest channel, F_{CL} (MHz)	***Highest channel, F_{CH} (MHz)***	***Number of channels observed***	***Result***
917.5	922.5	51	PASS



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 Laboratory
Test Standard and Clause:	ANSI C63.10-2013, Clause 7.8.4
EUT Frequency Measured:	919.2 MHz
EUT 20dB bandwidth:	56.5 kHz
EUT Number of hopping channels:	51
EUT Test Modulations:	Internal pattern generation – hopping enabled
Deviations From Standard:	None
Measurement BW:	50 kHz
Measurement Detector:	Peak

Environmental Conditions (Normal Environment)

Temperature: 23 °C	+15 ºC to +35 ºC (as declared)
Humidity: 37 % RH	20 % RH to 75 % RH (as declared)

14.3 Test Limit

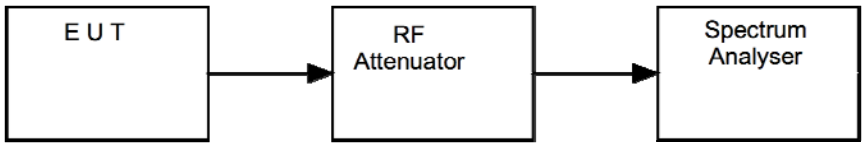
- For frequency hopping systems in the band 902 to 928 MHz: if the -20 dB bandwidth of the hopping channel is less than 250 kHz, the average time of occupancy on any channel shall not be greater than 0.4 seconds within a 20 second period;
  If the -20 dB bandwidth of the hopping channel is 250 kHz or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

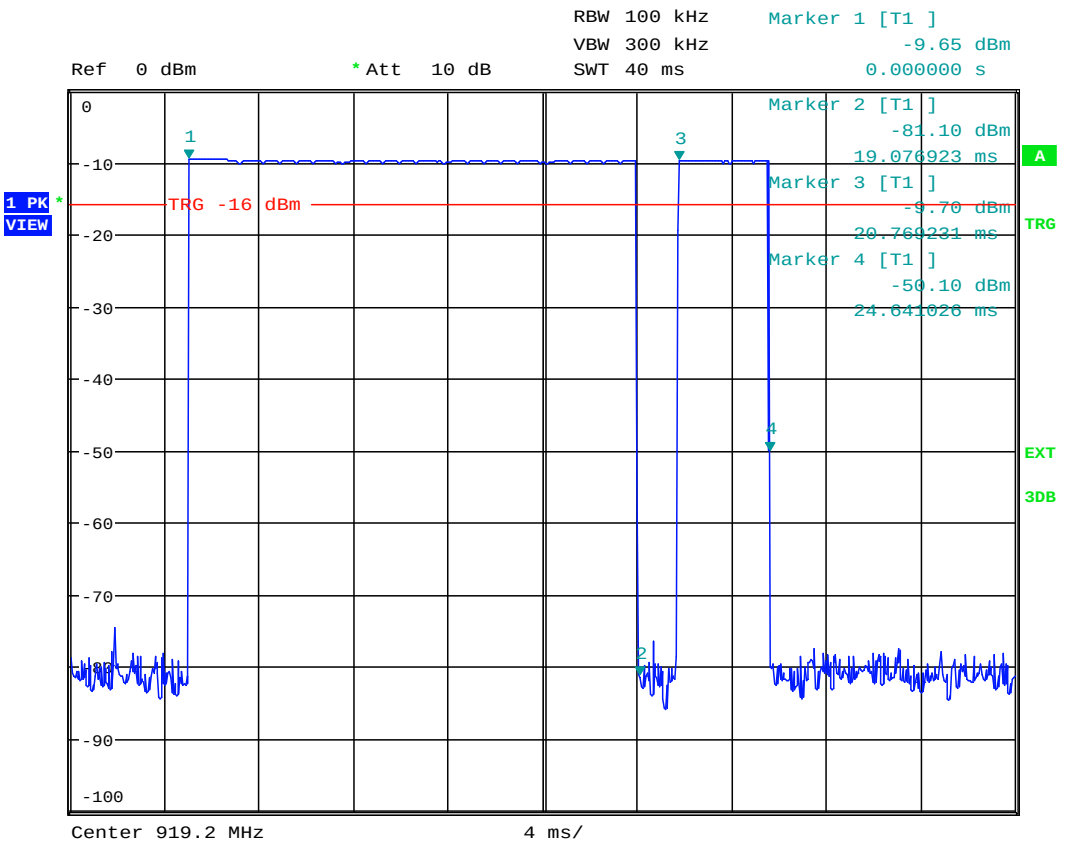


14.5 Test Equipment

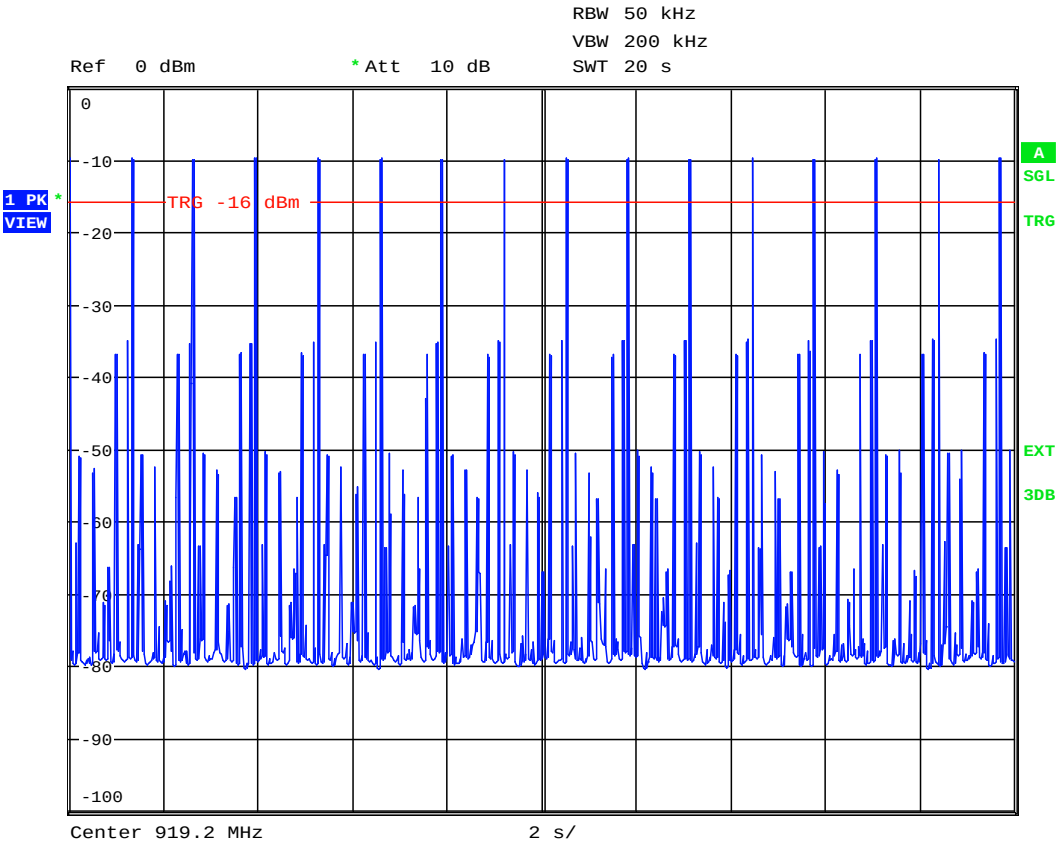
Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
FSU26	R&S	Spectrum Analyser	U405	2019-09-21

14.6 Test Results

Individual occupancy time T1 (ms)	***Individual occupancy Time T2 (ms)***	***Total Individual occupancy Time (ms)***	***Observation period (s)***	***Number of hops observed***	***Average time of occupancy (s)***	***Result***
19.07	3.87	22.94	20	16	0.36704	PASS



T1 Individual Occupancy Time T2



Number Of Hops In Occupancy Period

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 Chamber
Test Standard and Clause:	ANSI C63.10-2013, Clause 7.8.5
EUT Channels Measured:	Low / High – hopping disabled.
EUT Channel Bandwidths:	56.5 kHz
Deviations From Standard:	None
Measurement BW:	100 kHz
Spectrum Analyzer Video BW:	30 kHz
Measurement Detector:	Peak
Voltage Extreme Environment Test Range:	Battery Power = Fully Charged

Environmental Conditions (Normal Environment)

Temperature: 22 °C	+15 ºC to +35 ºC (as declared)
Humidity: 38 % RH	20 % RH to 75 % RH (as declared)

15.3 Test Limit

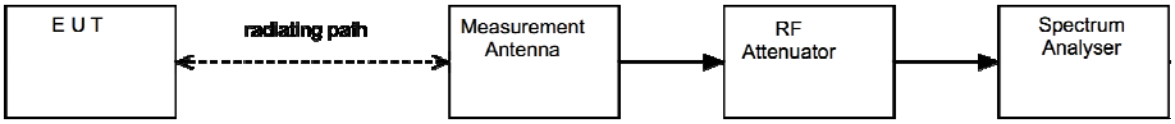
- For frequency hopping systems operating in the band 902 to 928 MHz, the maximum peak conducted output power shall not exceed 1 W, and the e.i.r.p. shall not exceed 4 W, if the hopset uses 50 or more hopping channels;
  the maximum peak conducted output power shall not exceed 0.25 W, and the e.i.r.p. 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
FSU26	R&S	Spectrum Analyser	U405	2019-09-21
CBL611/A	Chase	Bilog	U573	2019-08-02

15.6 Test Results

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

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

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

Channel Frequency (MHz)	*Peak Field Strength (dBµV/m)*	*Peak Field Strength (V/m)*	*Distance (m)*	*Antenna Gain*	*E.I.R.P. (W)*	*Maximum EIRP (W)*	*Result*
917.5	105.3	0.18	3	1	0.010	4	PASS
922.5	106.4	0.21	3	1	0.013	4	PASS

Maximum EIRP determined from maximum conducted output power (30 dBm) and maximum allowable antenna gain (6 dBi)

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 Labotory
Test Standard and Clause:	ANSI C63.10-2013, Clause 6.9
EUT Channels / Frequencies Measured:	Low / High – hopping stopped.
Deviations From Standard:	None
Measurement Detector:	Peak

Environmental Conditions (Normal Environment)

Temperature: 23 °C	+15 ºC to +35 ºC (as declared)
Humidity: 37 % RH	20 % RH to 75 % RH (as declared)

16.3 Test Limit

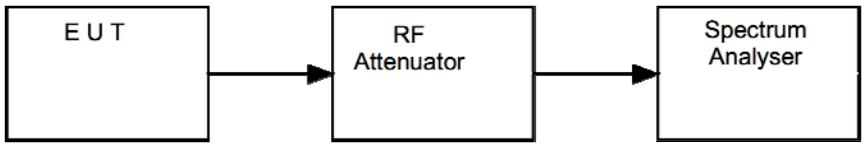
- For frequency hopping systems in the band 902 to 928 MHz: The maximum allowed -20 dB bandwidth of the hopping channel is 500 kHz.
- Frequency hopping systems operating in the band 5725 to 5850 MHz: The maximum -20 dB bandwidth of the hopping channel shall be 1 MHz

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

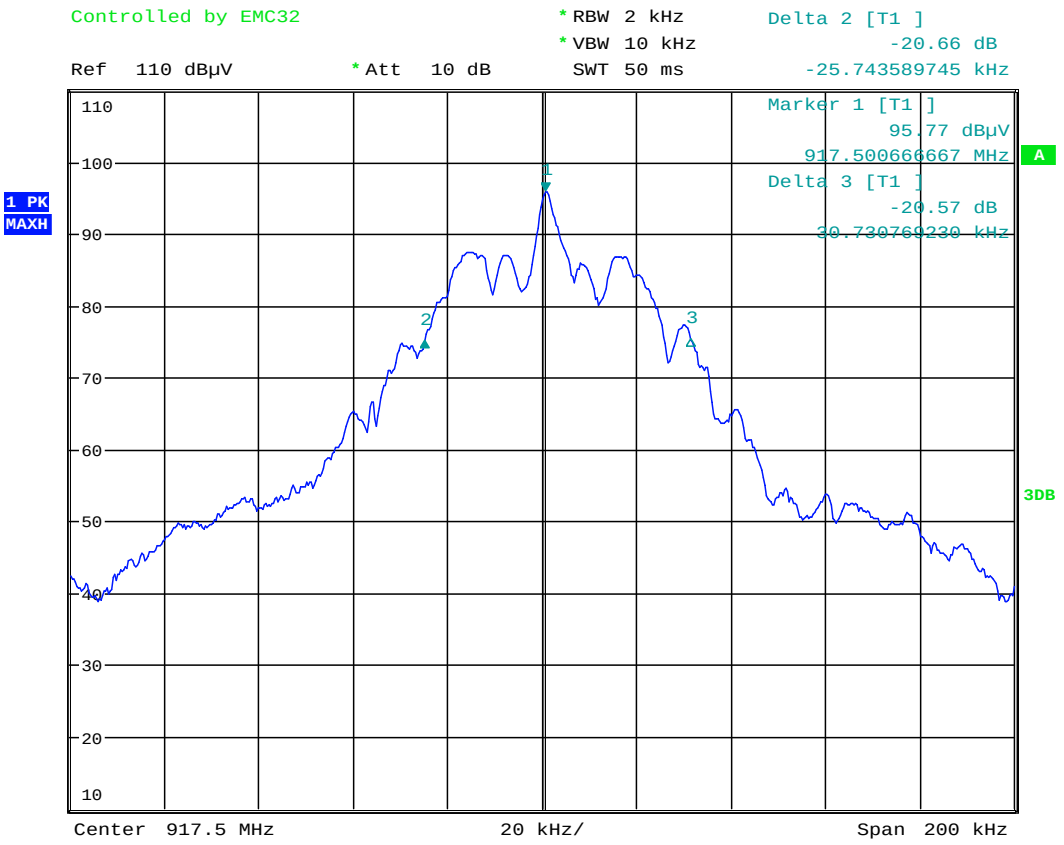


16.5 Test Equipment

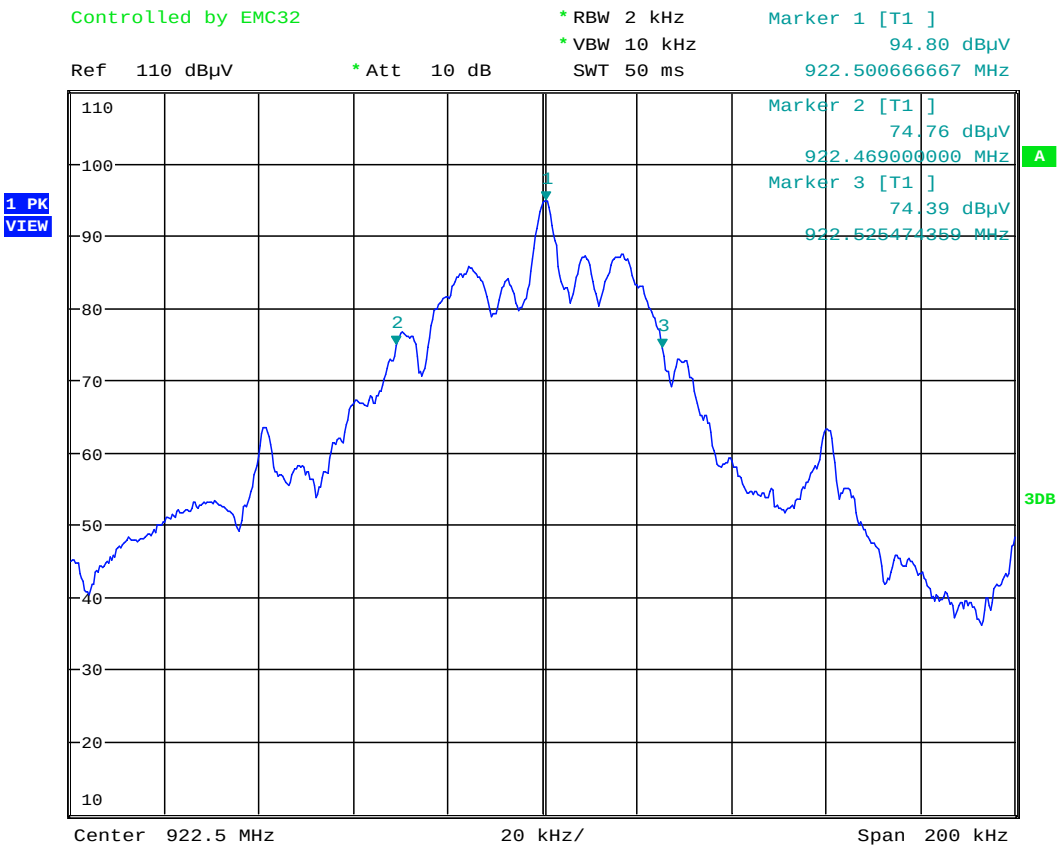
Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
FSU26	R&S	Spectrum Analyser	U405	2019-09-21

16.6 Test Results

Channel Frequency (MHz)	***F_L (MHz)***	***F_H (MHz)***	***20dB Bandwidth (kHz)***	***Result***
917.5	917.4749231	917.5313974	56.47	PASS
922.5	922.4690000	922.5254744	56.47	PASS



917.5 MHz – 20 dB Bandwidth



922.5 MHz – 20 dB Bandwidth

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 Chamber
Test Standard and Clause:	ANSI C63.10-2013, Clause 7.8.8
EUT Channels Measured:	Low / High / Hopping
EUT Channel Bandwidths:	56.5 kHz
Deviations From Standard:	None
Measurement BW:	100 kHz
Spectrum Analyzer Video BW: (requirement at least 3x RBW)	200 kHz
Measurement Detector:	Peak
Measurement Range:	30 MHz to 10 GHz

Environmental Conditions (Normal Environment)

Temperature: 21 °C	+15 ºC to +35 ºC (as declared)
Humidity: 36 % RH	20 % RH to 75 % RH (as declared)

17.3 Test Limits

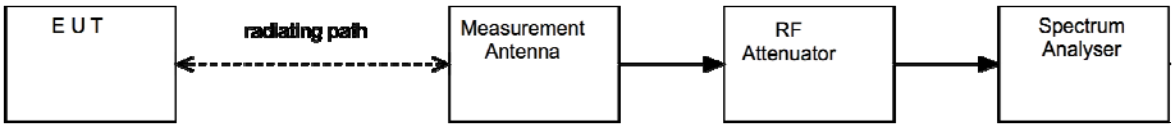
In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated device is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either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

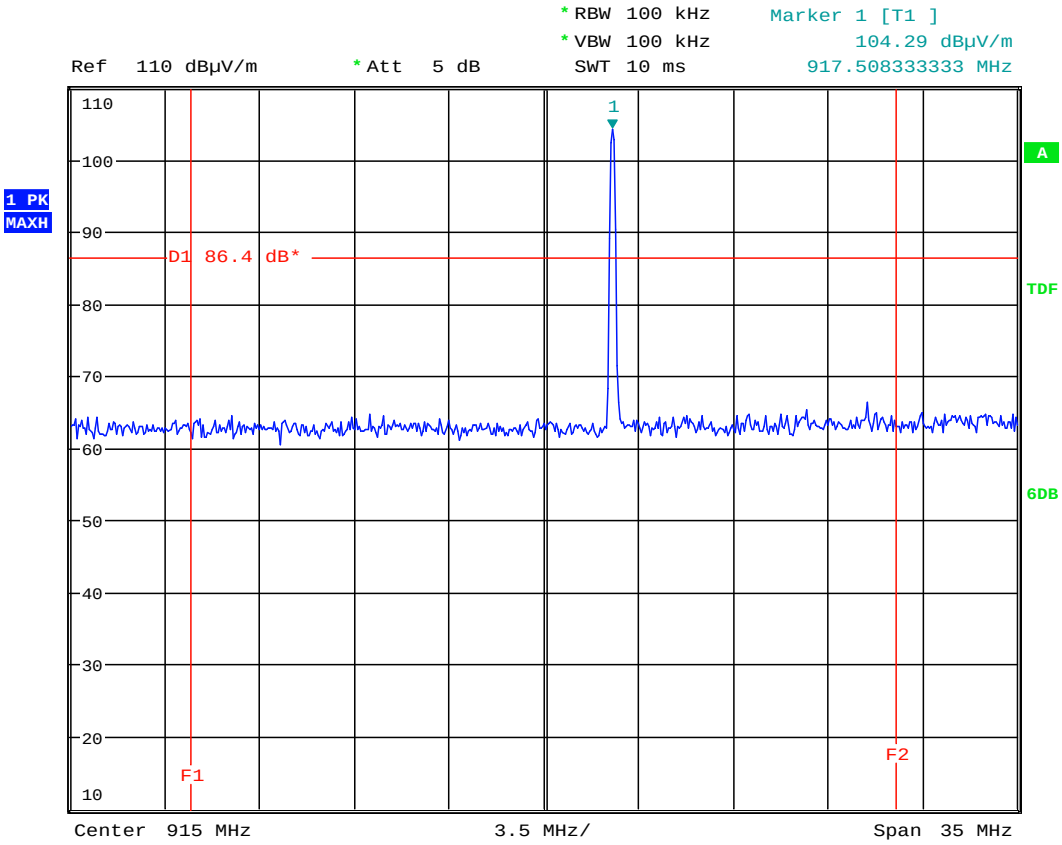


17.5 Test Equipment

Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
CBL611/A	Chase	Bilog	U573	2019-08-02
6201-69	Watkins Johnson	PreAmp	U372	2020-02-25
8449B	Agilent	Pre Amp	L572	2019-10-12
3115	EMCO	1-18GHz Horn	L139	2019-09-25
FSU46	R&S	Spectrum Analyser	REF910	2019-08-31

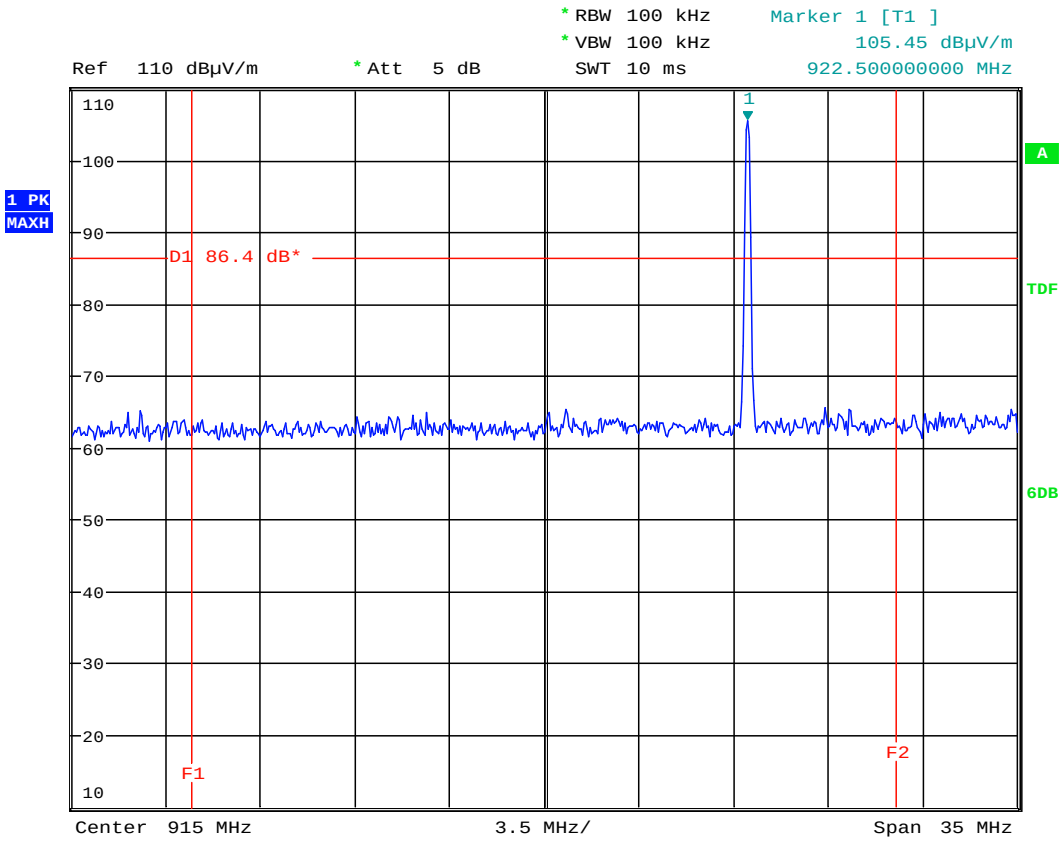
17.6 Test Results

Operating Frequency 917.5 MHz						
Emission Frequency (MHz)	***Peak Field Strength (dBµV/m)***	***Distance (m)***	***Power (dBm)***	***Limit (dBm)***	***Margin (dB)***	***Result***
No Significant Emissions Within 20 dB of Limit						PASS

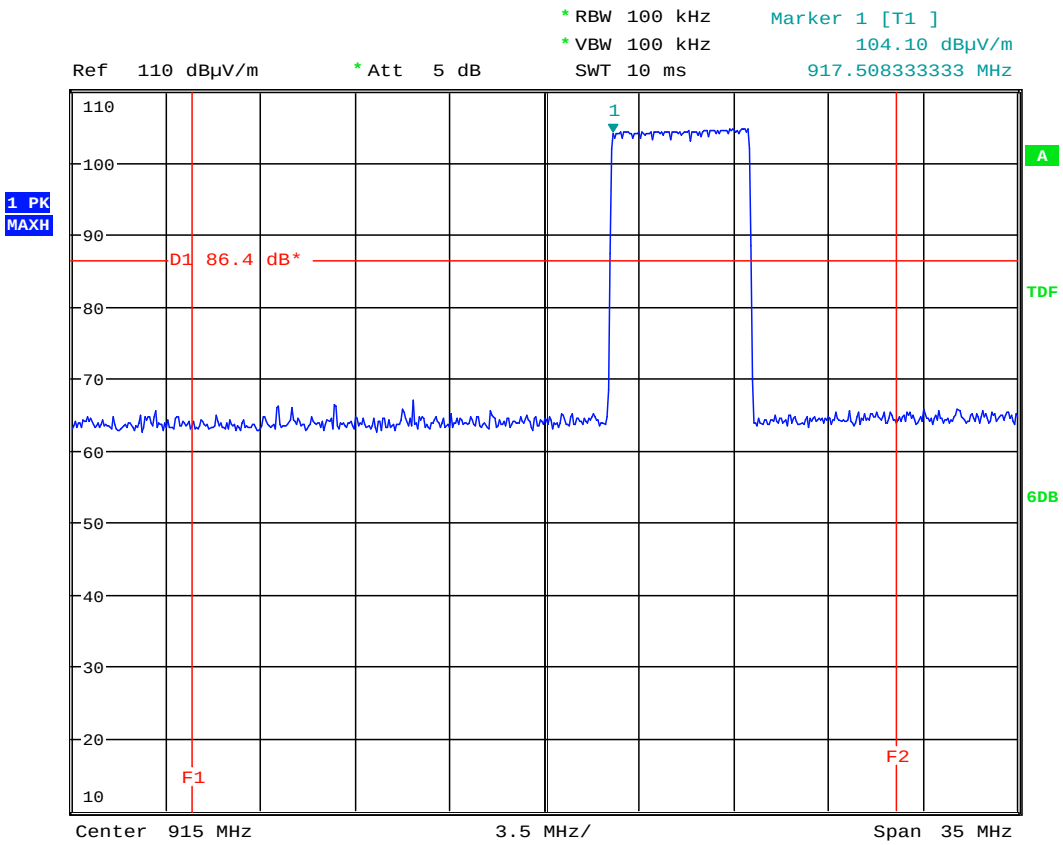


Bandedge Compliance 917.5 MHz

Operating Frequency 922.5 MHz						
Emission Frequency (MHz)	***Peak Field Strength (dBµV/m)***	***Distance (m)***	***Power (dBm)***	***Limit (dBm)***	***Margin (dB)***	***Result***
No Significant Emissions Within 20 dB of Limit						PASS



Bandedge Compliance 922.5 MHz



Date: 8.MAY.2019 15:07:06

Bandedge Compliance Hopping All Channels

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 General SAR test reduction and exclusion

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 5mm, the SAR Test Exclusion Threshold for operation at 917.5 and 922.5 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) = 5

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.

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

Operating Frequency 917.5 MHz

MP= [(3.0 x 5) / √0.9175]
MP= [15 / 0.9578]
MP= 15.6 mW
The calculated output power 10 mw is less than the SAR Exclusion Threshold of 15.6mW.

Operating Frequency 922.5 MHz

MP= [(3.0 x 5) / √0.9225]
MP= [15 / 0.9604]
MP= 15.6 mW
The calculated output power 13 mw is less than the SAR Exclusion Threshold of 15.6 mW.

Therefore standalone SAR evaluation for general population exposure conditions by measurement or numerical simulation is not required. Section 4.3 General SAR test reduction and exclusion guidance