Report on the Radio Testing

For

Rentokil Initial 1927 plc

on

Control Panel / Autogate / Radar R

Report no. TRA-033559-45-00B

7th February 2018

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

Report Number: TRA-033559-45-00B
Issue: A

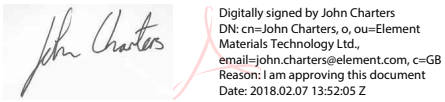
REPORT ON THE RADIO TESTING OF A
Rentokil Initial 1927 plc
Control Panel / Autogate / Radar R
WITH RESPECT TO SPECIFICATION
FCC 47CFR 15.247 & IC RSS-247

TEST DATE: 13/01/2017 to 28/04/2017

Written by: A Longley

A Longley
Radio Test Engineer

Approved by:



J Charters
Department Manager - Radio

Date: 7th February 2018

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1 Revision Record

Issue Number	*Issue Date*	*Revision History*
A	3rd August 2017	Original
B	7th February 2018	Typos corrected, SAR assessment replaced with MPE calculation

2 Summary

TEST REPORT NUMBER:	TRA-033559-45-00B
WORKS ORDER NUMBER	TRA-033559-05
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):	Control Panel / Autogate / Radar R
FCC IDENTIFIER:	2AK3PGSD-500349
ISED ID	22407-GSD500349
EUT SERIAL NUMBER:	Prototype
MANUFACTURER/AGENT:	Rentokil Initial 1927 plc
ADDRESS:	Marketing and Innovation Riverbank Meadows Business Park Camberley GU17 9AB United Kingdom
CLIENT CONTACT:	Ning Pan ☎ 01276536676 ✉ ning.pan@rentokil-initial.com
TEST DATE:	13/01/2017 to 28/04/2017
TESTED BY:	A Longley 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) and (f)	☒	*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*
Power Spectral Density	247, 5.2 (2)	15.247(e)	☒	*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-033559-45-00B presents the results of the Radio testing on a Rentokil Initial 1927 plc, Control Panel / Autogate / Radar R 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 Rentokil Initial 1927 plc by Element, at the address(es) detailed below.

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

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

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

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

Throughout this report EUT denotes equipment under test.

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

IC Registration Number(s):

Element Hull	3483A
Element North West	3930B

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

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

5 Test Specifications

5.1 Normative References

- FCC 47 CFR Ch. I – Part 15 – Radio Frequency Devices.
- ANSI C63.10-2013 – American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices.
- ANSI C63.4-2014 – American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz.
- 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: Control Panel / Autogate / Radar R
- Serial Number: Prototype
- Model Number: Radar R (304778); AutoGate Connect (304765); Control Panel (304768)
- Software Revision: Not Applicable
- Build Level / Revision Number: Not Applicable

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.

Laptop PC.

7.3 EUT Mode of Operation

7.3.1 Transmission

The mode of operation for Tx tests was as follows:-
The EUT was placed into continuous Tx modes using the “hardware_test_r428.bin” firmware, when hopping operation was required the standard firmware version “module_r422.bin” was used.

7.3.2 Reception

The mode of operation for Rx tests was as follows:-
The EUT was placed into continuous Rx modes using the “hareware_test_r428.bin” firmware.

7.4 EUT Radio Parameters

7.4.1 General

Frequency of operation:	915.25 to 927.5 MHz
Modulation type(s):	Phase
Occupied channel bandwidth(s):	125 kHz
Channel spacing:	250 kHz
ITU emission designator(s):	125G1DEX
Declared output power(s):	14 dBm
Warning against use of alternative antennas in user manual (yes/no):	yes
Nominal Supply Voltage:	6 Vdc
Location of notice for license exempt use:	Label / user manual / both.
Method of prevention of use on non-US / non-Canadian frequencies:	Set by server, which takes its information from the connected cell tower.
Duty cycle:	Control Panel <10% / others <1%

7.4.2 Antennas

Type:	Fixed antenna
Frequency range:	915.25 to 927.5 MHz
Impedance:	50Ω
SWR:	Unknown
Gain:	Unknown but < 6dBi
Polarisation:	Linear
Beam width:	Unknown
Connector type:	Soldered to PCB
Length:	12 cm
Weight:	Unknown
Environmental limits:	-20 C to 50 C
Mounting:	Soldered to PCB

7.4.3 Product specific declarations

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

7.5 EUT Description

The EUT is a LoRa module installed in a Control Panel and pest traps to monitor trap operation.

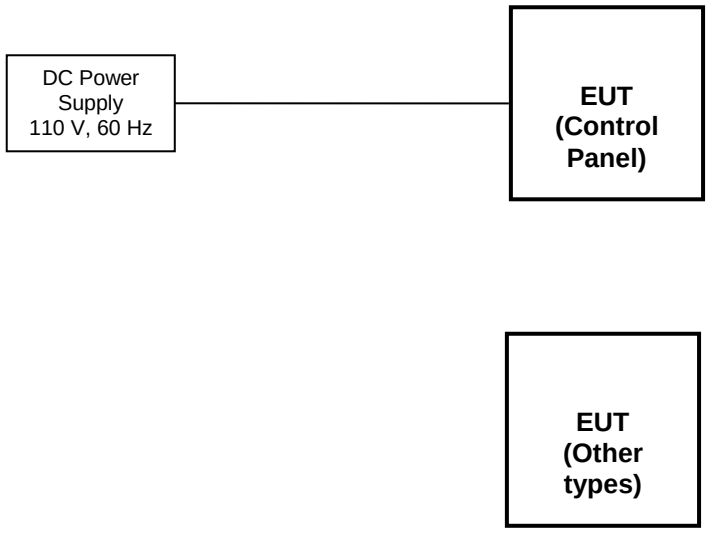
8 Modifications

No modifications were performed during this assessment.

9 EUT Test Setup

9.1 Block Diagram

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



9.2 General Set-up Photograph

The following photograph shows basic EUT set-up (all 3 EUTs are shown during EMC testing, radio testing was performed on individual units):

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. 6 V dc from the adaptor (Control Panel) or 6 V dc from the battery for other types.

10.2 Varying Test Conditions

There are no specific frequency stability requirements for the type of device. The results contained in this report demonstrate that the occupied bandwidth is contained within the authorised band and the manufacturer has declared sufficient frequency stability (refer to section 7.4).

Variation of supply voltage is required to ensure stability of the declared output power. During carrier power testing the following variations were made:

	Category	***Nominal***	***Variation***
☒	Mains	110 V ac +/-2 %	85 % and 115 %
☒	Battery	New battery	N/A

11 Radiated emissions

11.1 Definitions

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

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

11.2 Test Parameters

Test Location:	Element Hull
Test Chamber:	Lab 16
Test Standard and Clause:	ANSI C63.10-2013, Clause 6.5 and 6.6
EUT Channels / Frequencies Measured:	Low / Mid / High
EUT Channel Bandwidths:	200 kHz
Deviations From Standard:	None
Measurement BW:	30 MHz to 1 GHz: 120 kHz Above 1 GHz: 1 MHz
Measurement Detector:	Up to 1 GHz: quasi-peak Above 1 GHz: RMS average and Peak

Environmental Conditions (Normal Environment)

Temperature: 22 °C	+15 ºC to +35 ºC (as declared)
Humidity: 33 % RH	20 % RH to 75 % RH (as declared)
Supply: 6 V dc (Control Panel 110Vac)	

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:

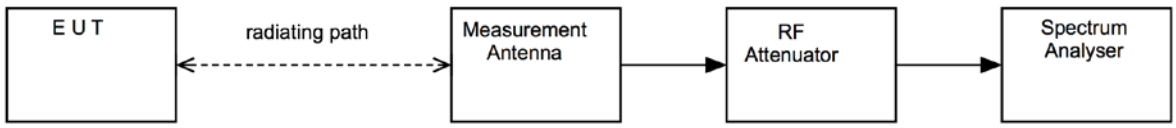
$$FS = PR + CL + AF – PA + DC – CF$$

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

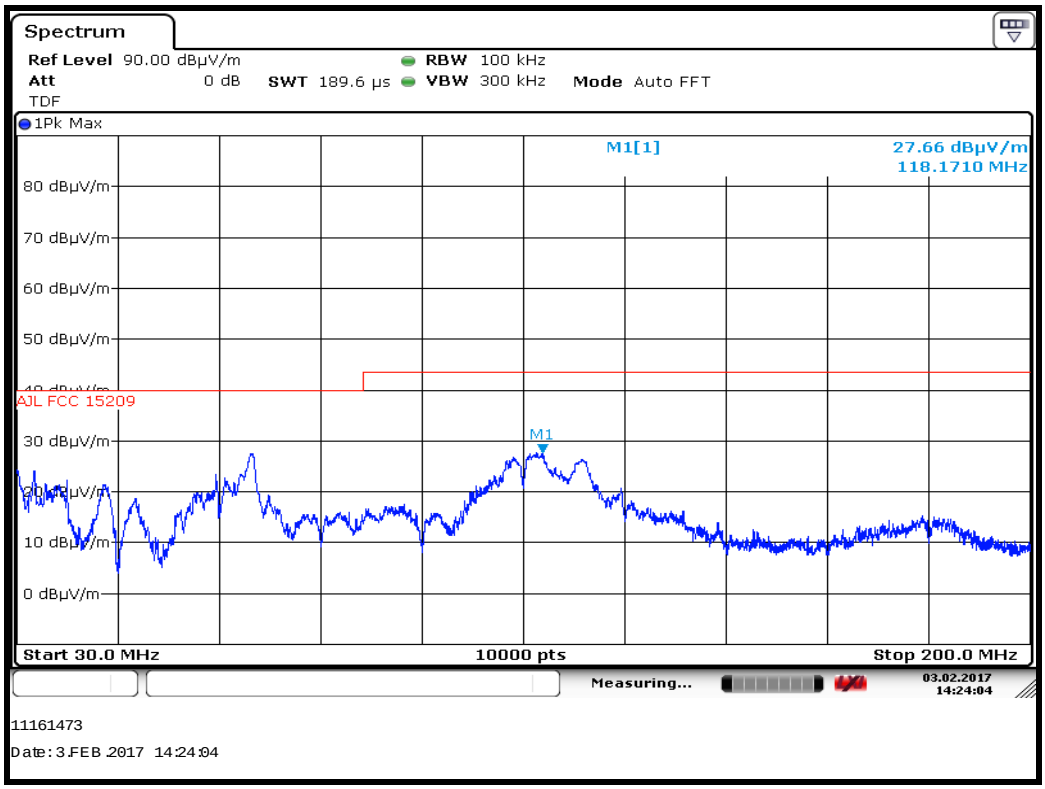


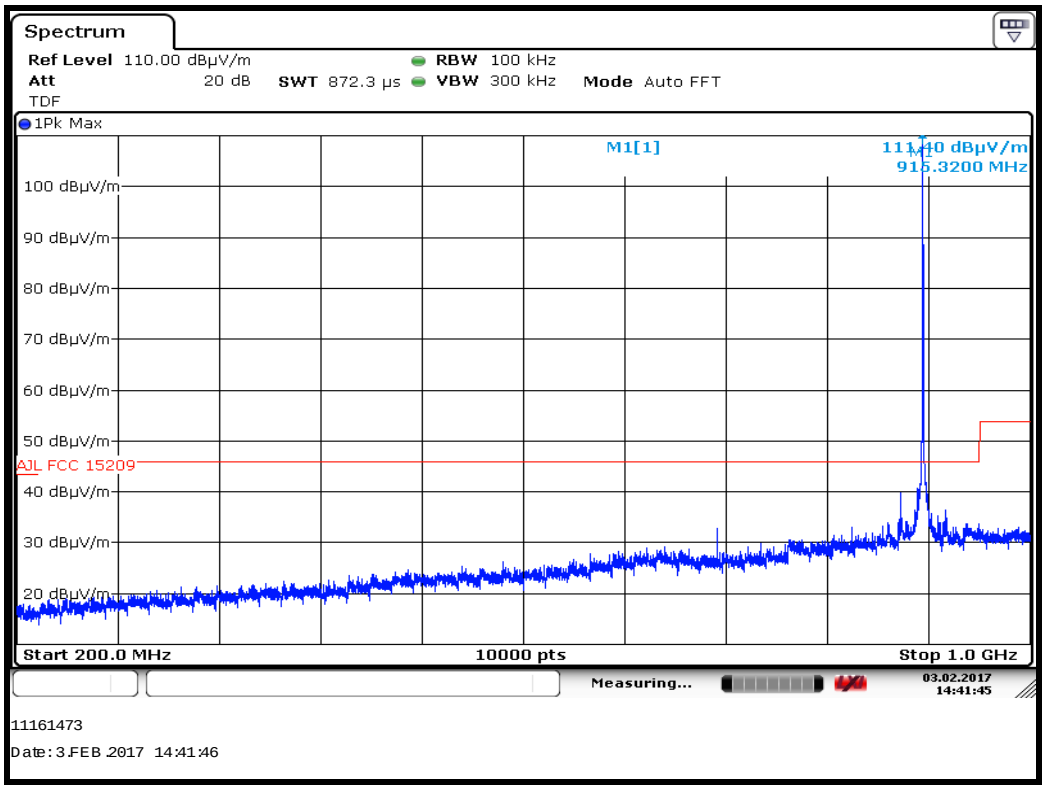
11.5 Test Equipment

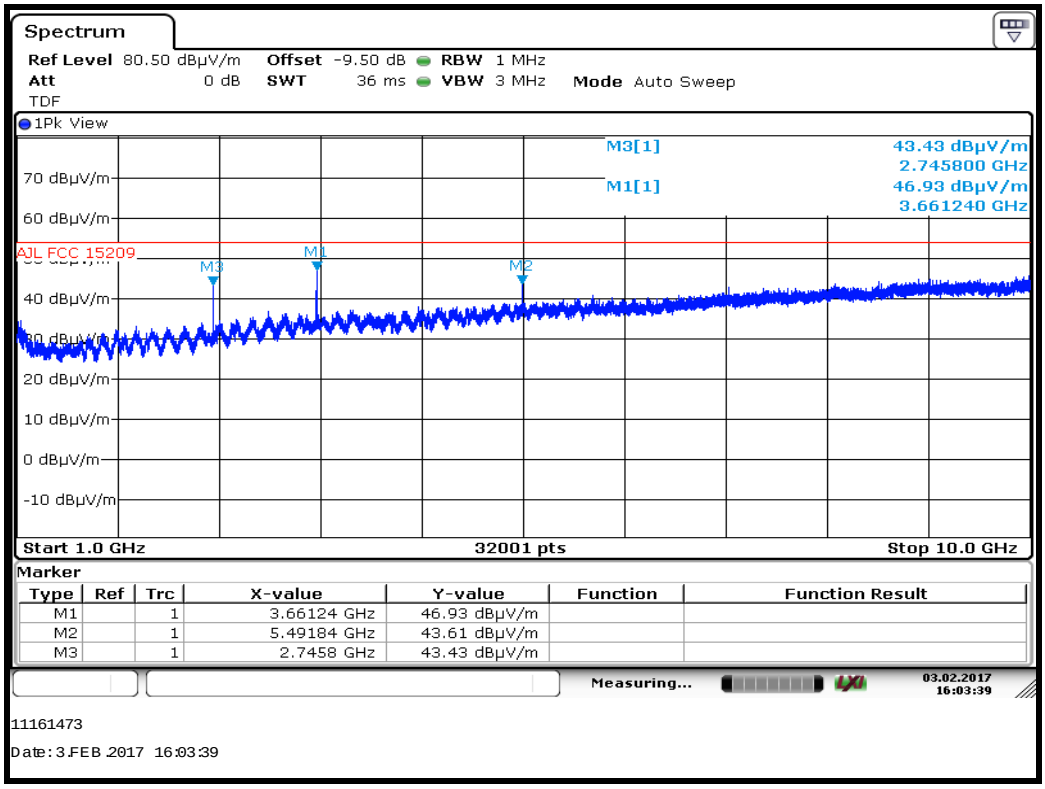
Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
FSV	Rohde & Schwarz	Spectrum Analyser	N/A	07/06/2017
FSU46	R&S	Spectrum Analyser	REF910	05/07/2017
3109	EMCO	Biconical Antenna	RFG095	17/05/2019
3146	EMCO	Log Periodic Antenna	RFG191	17/05/2019
3115	EMCO	Horn Antenna	RFG129	09/02/2018
310	Sonoma	Pre-Amp (9kHz – 1GHz)	REF927	30/06/2018
8449B	Agilent	Pre-Amp (1 – 26.5GHz)	REF913	02/02/2018

11.6 Test Results – Control Panel

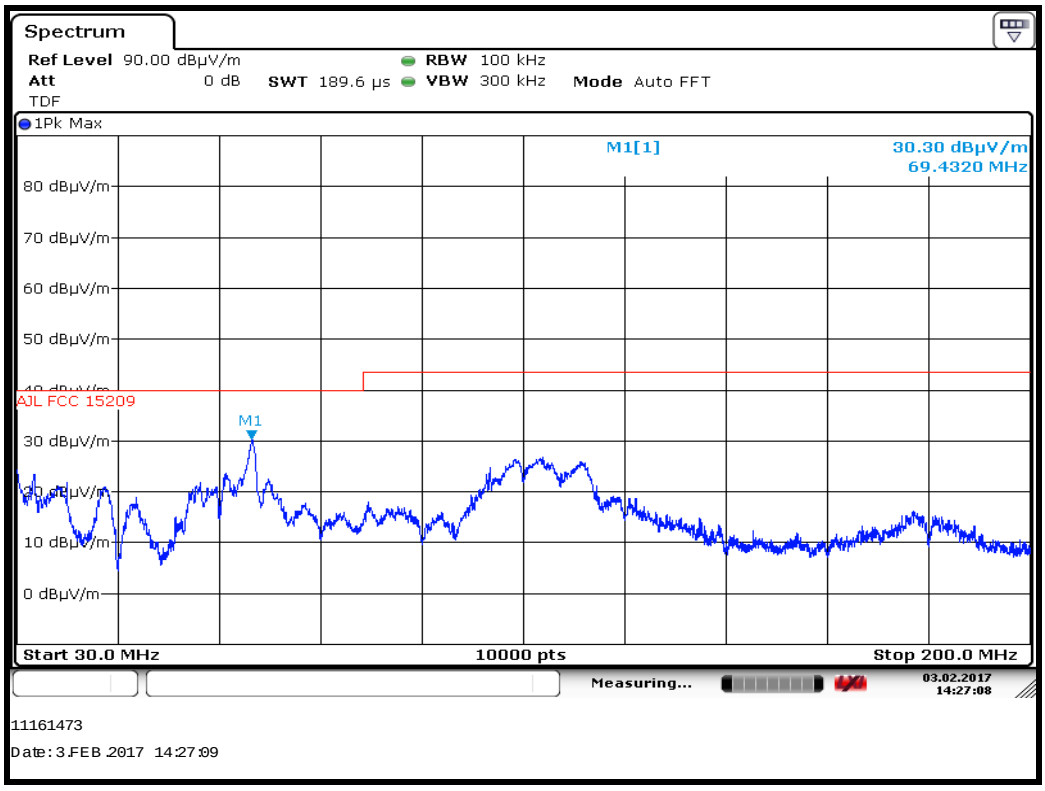
Channel 6 : 915.25 MHz

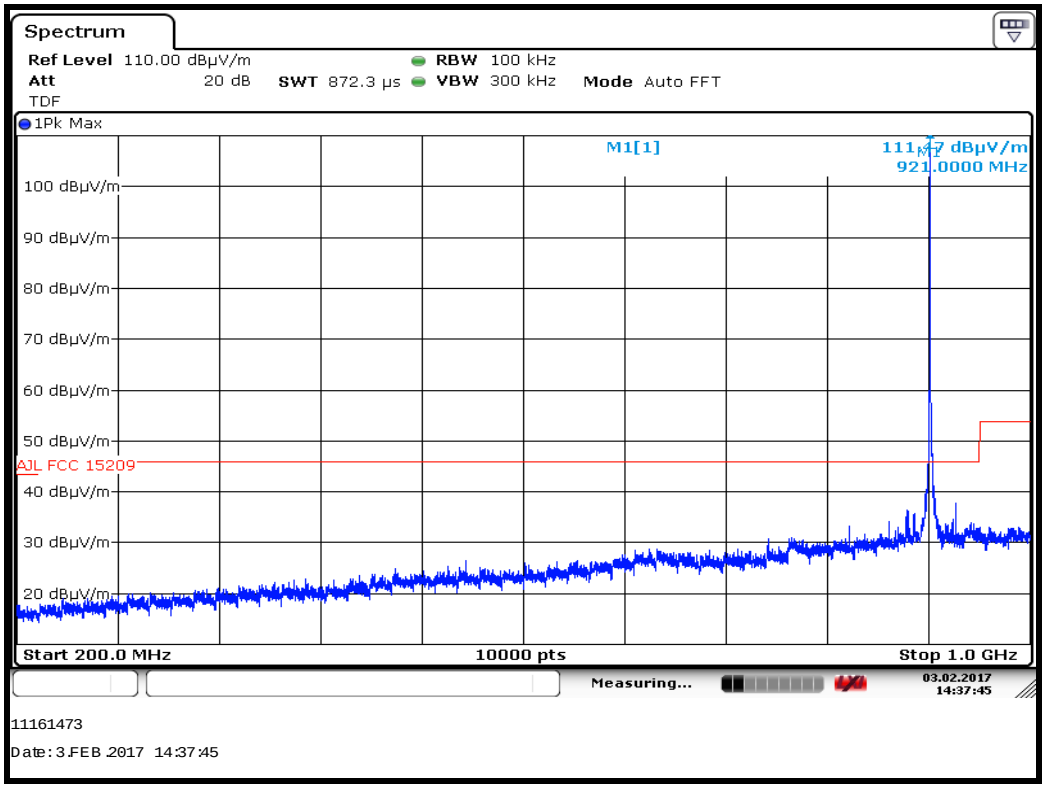


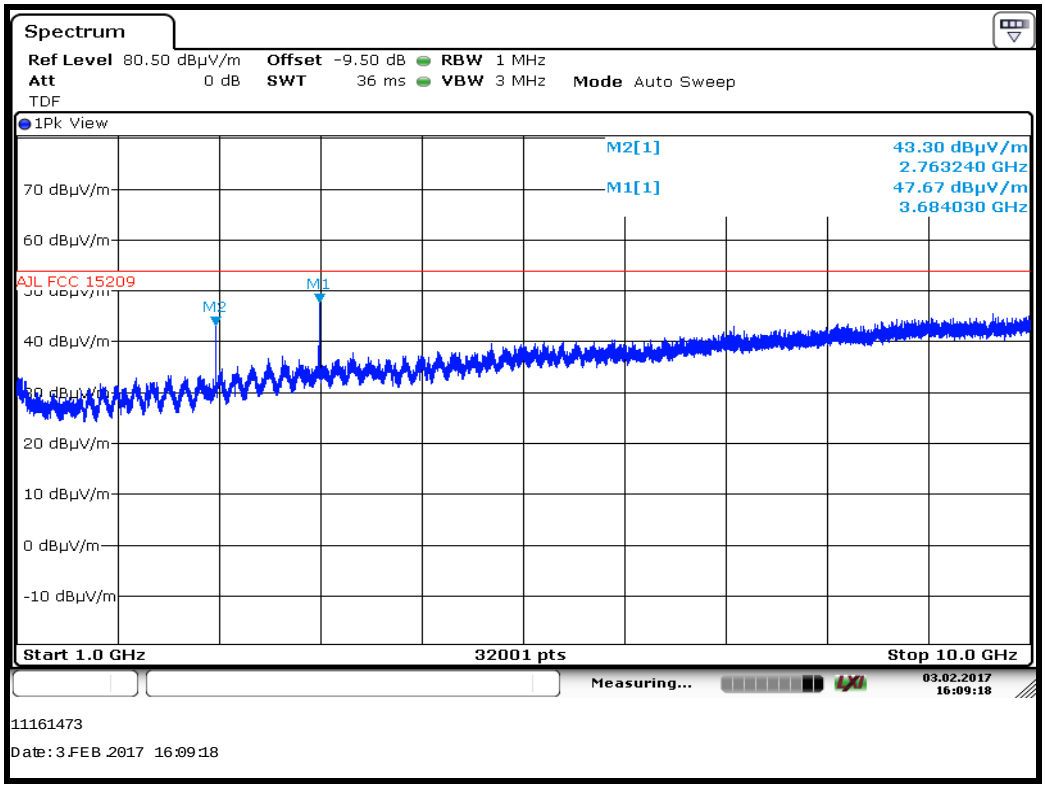



Spectrum
Ref Level 80.50 dBµV/m
Offset -9.50 dB
RBW 1 MHz
Att 0 dB
SWT 36 ms
VBW 3 MHz
Mode Auto Sweep
TDF
1Pk View
M3[1]
43.43 dBµV/m
2.745800 GHz
M1[1]
46.93 dBµV/m
3.661240 GHz
70 dBµV/m
60 dBµV/m
AJL FCC 15209
40 dBµV/m
20 dBµV/m
10 dBµV/m
0 dBµV/m
-10 dBµV/m
M3
M1
M2
Start 1.0 GHz
32001 pts
Stop 10.0 GHz
Marker
Type Ref Trc X-value Y-value Function Function Result
M1 1 3.66124 GHz 46.93 dBµV/m
M2 1 5.49184 GHz 43.61 dBµV/m
M3 1 2.7458 GHz 43.43 dBµV/m
Measuring...
03.02.2017
16:03:39
11161473
Date: 3.FEB.2017 16:03:39

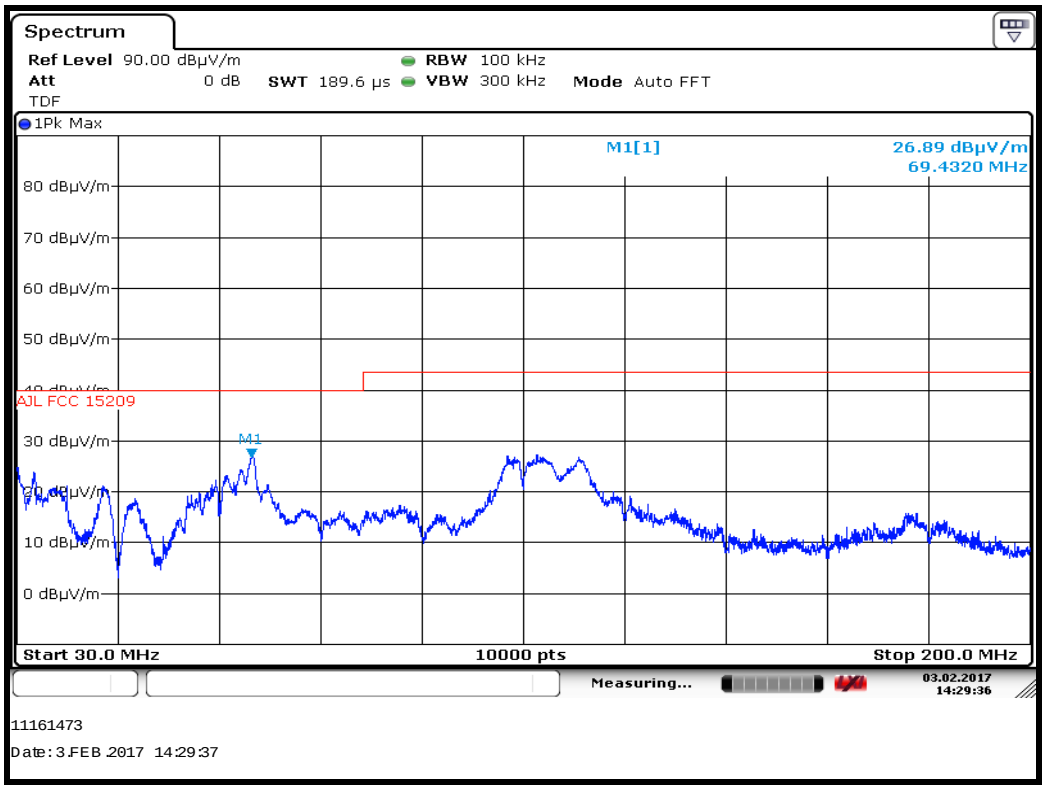
Channel 29 : 921 MHz

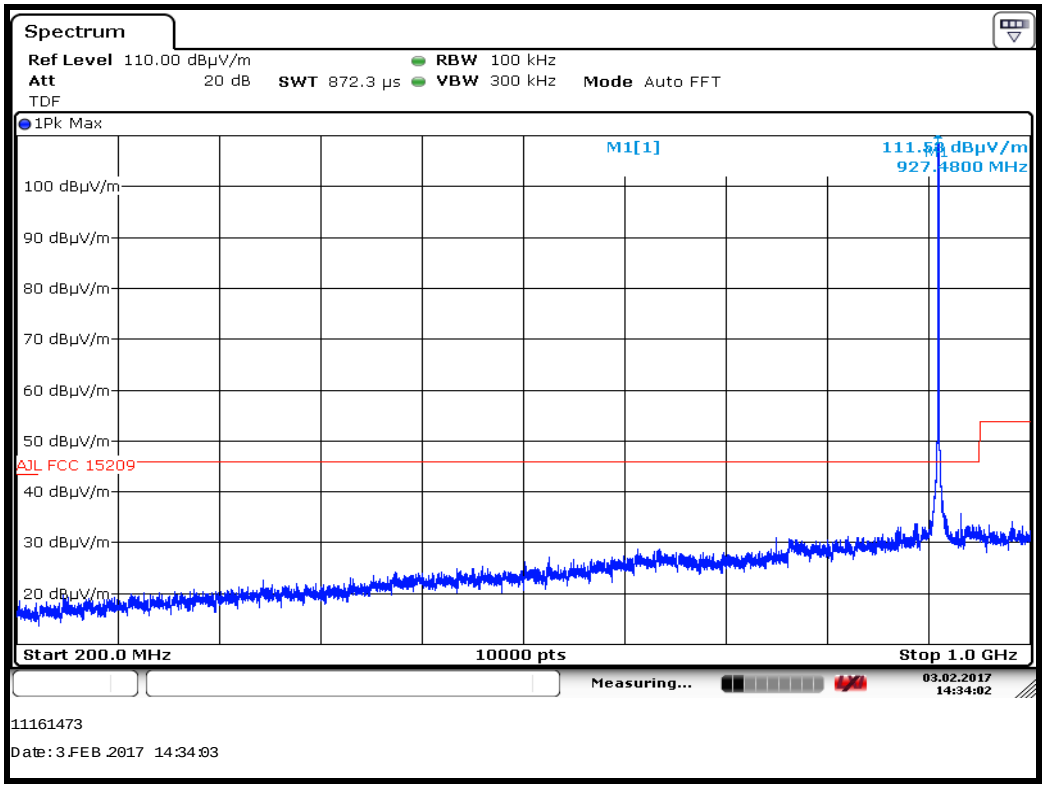


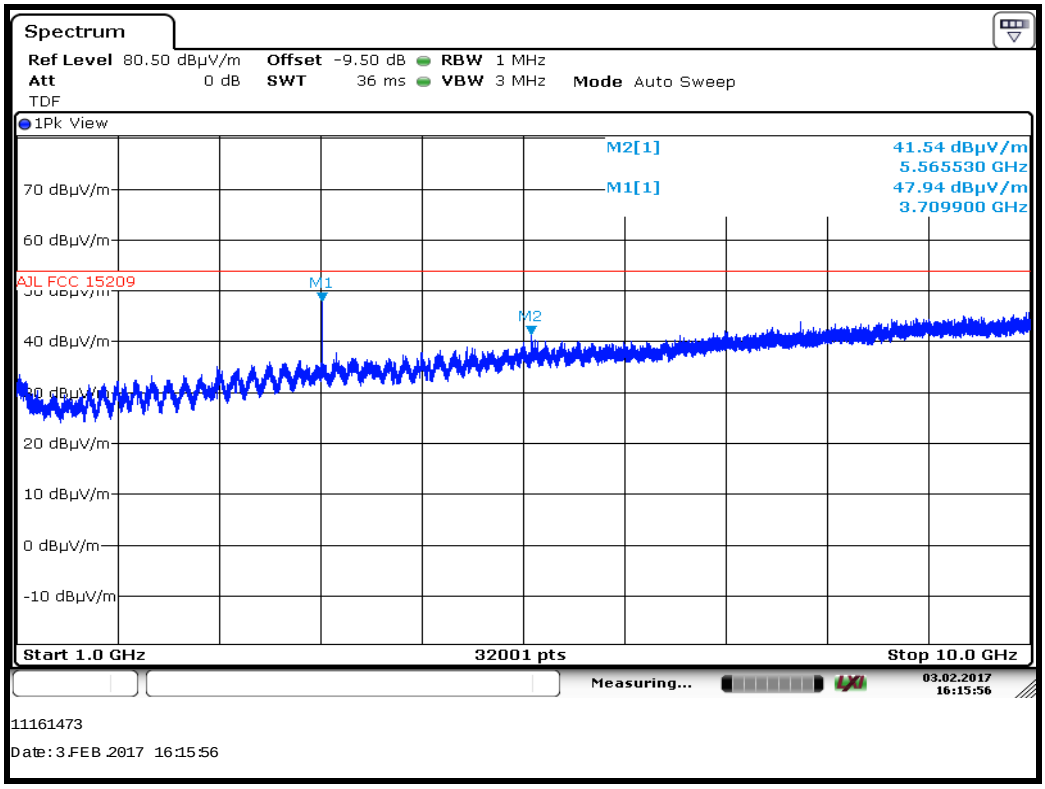



Spectrum
Ref Level 80.50 dBµV/m
Offset -9.50 dB
RBW 1 MHz
Att 0 dB
SWT 36 ms
VBW 3 MHz
Mode Auto Sweep
TDF
1Pk View
M2[1]
43.30 dBµV/m
2.763240 GHz
M1[1]
47.67 dBµV/m
3.684030 GHz
70 dBµV/m
60 dBµV/m
AJL FCC 15209
M1
M2
40 dBµV/m
20 dBµV/m
10 dBµV/m
0 dBµV/m
-10 dBµV/m
Start 1.0 GHz
32001 pts
Stop 10.0 GHz
Measuring...
03.02.2017
16:09:18
11161473
Date: 3.FEB.2017 16:09:18

Channel 55 : 927.50






Spectrum
Ref Level 80.50 dBµV/m
Offset -9.50 dB
RBW 1 MHz
Att 0 dB
SWT 36 ms
VBW 3 MHz
Mode Auto Sweep
TDF
1Pk View
M2[1]
41.54 dBµV/m
5.565530 GHz
M1[1]
47.94 dBµV/m
3.709900 GHz
70 dBµV/m
60 dBµV/m
AJL FCC 15209
M1
M2
40 dBµV/m
20 dBµV/m
10 dBµV/m
0 dBµV/m
-10 dBµV/m
Start 1.0 GHz
32001 pts
Stop 10.0 GHz
Measuring...
03.02.2017
16:15:56
11161473
Date: 3.FEB.2017 16:15:56

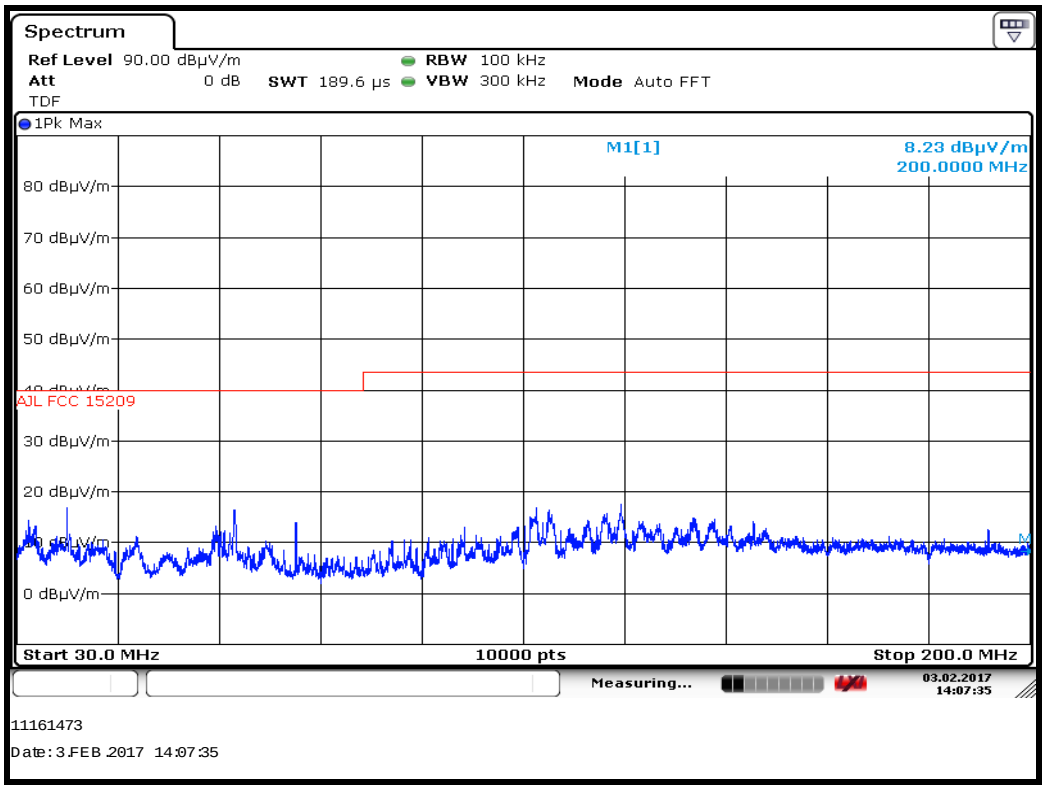
High Power; Channel: 915.25 MHz										
Detector	**Freq. (MHz)**	**Meas'd Emission (dBµV)**	**Cable Loss (dB)**	**Antenna Factor (dB/m)**	**Pre-amp Gain (dB)**	**Duty Cycle Corr'n (dB)**	**Distance Extrap'n Factor (dB)**	**Field Strength (dBµV/m)**	**Field Strength (µV/m)**	**Limit (µV/m)**
QP	120.02	48.70	1.2	11.9	32.5	0	0	29.3	29.17	150
QP	132.01	36.70	1.2	12.5	32.5	0	0	18.0	7.94	150
QP	960.10	35.50	3.3	21.9	31.3	0	0	29.4	29.51	500
Pk	2745.65	57.92	3.8	29.3	35.3	0	-9.5	46.16	203.24	5000
Av	2745.65	55.78	3.8	29.3	35.3	0	-9.5	44.02	158.85	500
Pk	3661.04	56.69	4.6	31.6	35.4	0	-9.5	47.99	250.90	5000
Av	3661.04	53.75	4.6	31.6	35.4	0	-9.5	45.05	178.85	500

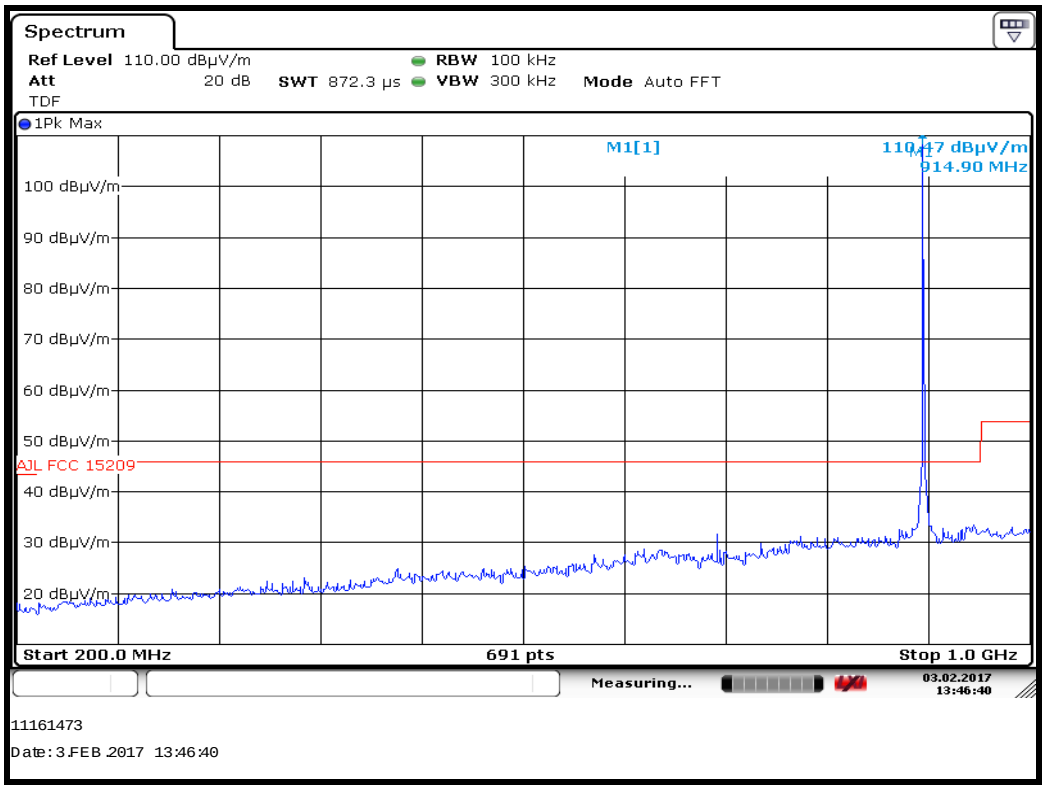
High Power; Channel: 921.00 MHz										
Detector	**Freq. (MHz)**	**Meas'd Emission (dBµV)**	**Cable Loss (dB)**	**Antenna Factor (dB/m)**	**Pre-amp Gain (dB)**	**Duty Cycle Corr'n (dB)**	**Distance Extrap'n Factor (dB)**	**Field Strength (dBµV/m)**	**Field Strength (µV/m)**	**Limit (µV/m)**
QP	120.02	48.70	1.2	11.9	32.5	0	0	29.3	29.17	150
QP	132.01	36.70	1.2	12.5	32.5	0	0	18.0	7.94	150
QP	960.10	35.50	3.3	21.9	31.3	0	0	29.4	29.51	500
Pk	2763.09	57.43	4.2	29.4	35.3	0.0	-9.5	46.16	203.24	5000
Av	2763.09	54.89	4.2	29.4	35.3	0.0	-9.5	43.62	151.71	500
Pk	3684.03	58.29	4.6	31.6	35.4	0.0	-9.5	49.59	301.65	5000
Av	3684.03	56.05	4.6	31.6	35.4	0.0	-9.5	47.35	233.08	500

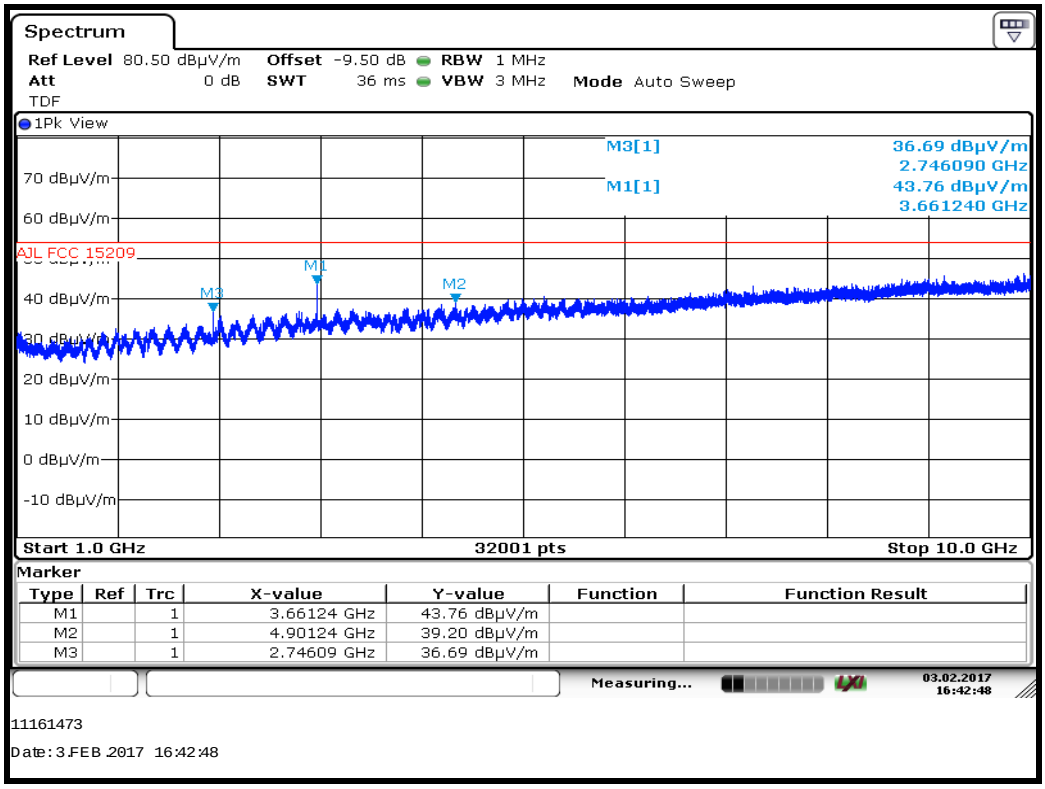
High Power; Channel: 927.50 MHz										
Detector	**Freq. (MHz)**	**Meas'd Emission (dBµV)**	**Cable Loss (dB)**	**Antenna Factor (dB/m)**	**Pre-amp Gain (dB)**	**Duty Cycle Corr'n (dB)**	**Distance Extrap'n Factor (dB)**	**Field Strength (dBµV/m)**	**Field Strength (µV/m)**	**Limit (µV/m)**
QP	120.02	48.70	1.2	11.9	32.5	0	0	29.3	29.17	150
QP	132.01	36.70	1.2	12.5	32.5	0	0	18.0	7.94	150
QP	960.10	35.50	3.3	21.9	31.3	0	0	29.4	29.51	500
Pk	3709.90	57.80	4.6	31.7	35.4	0	-9.5	49.20	288.40	5000
Av	3709.90	55.15	4.6	31.7	35.4	0	-9.5	46.55	212.57	500

11.7 Test Results – Auto Gate

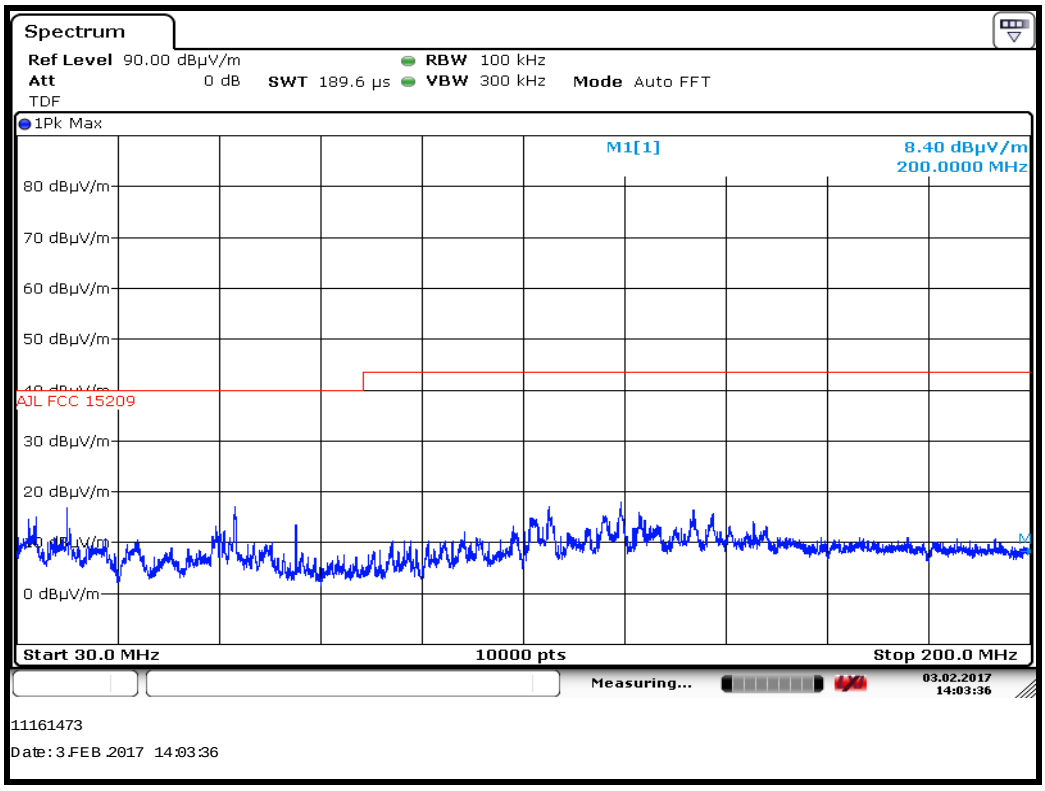
Channel 6 : 915.25

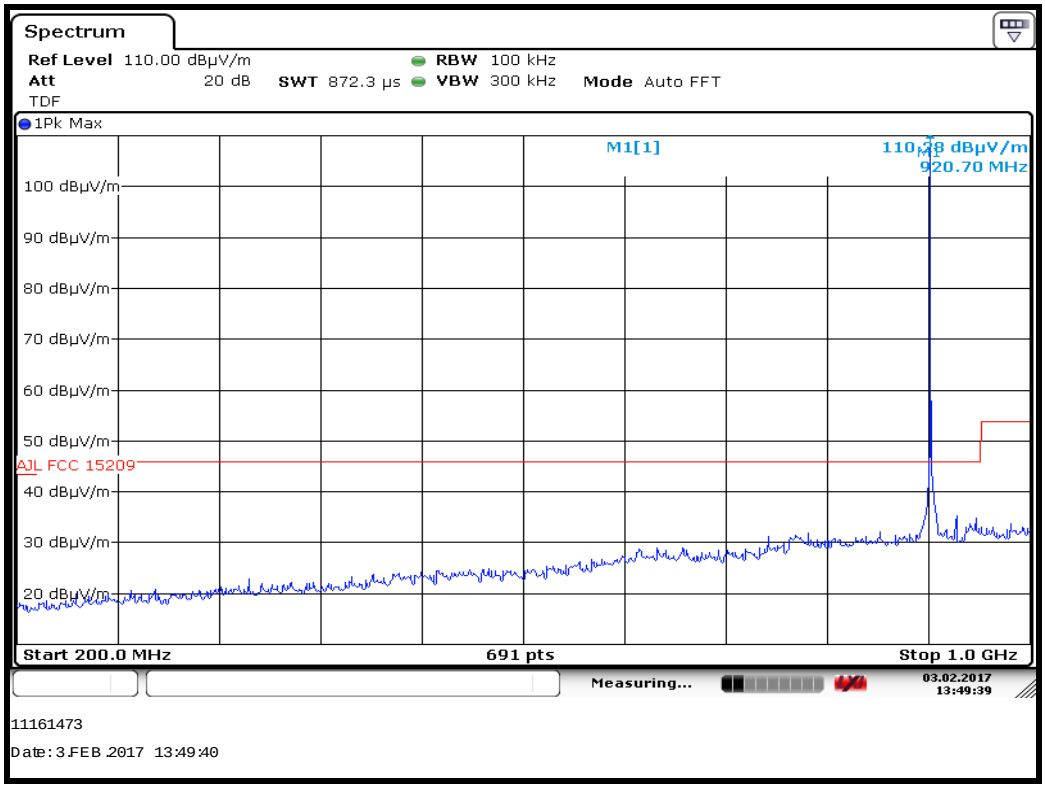


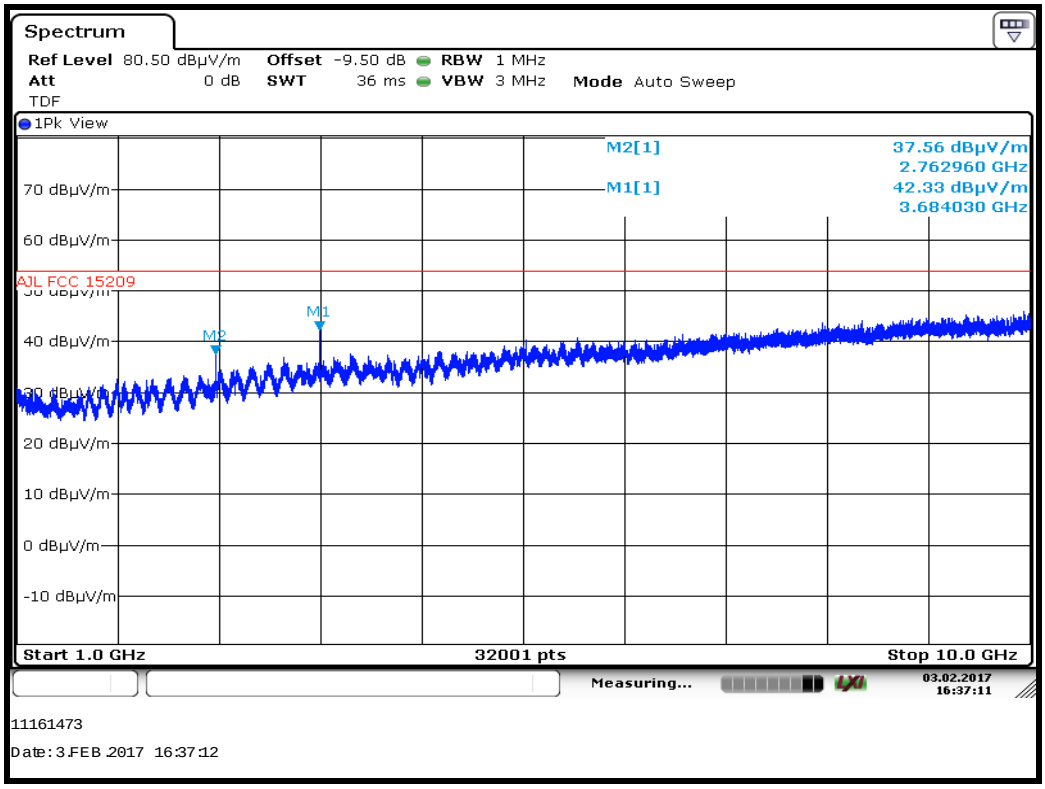



Spectrum
Ref Level 80.50 dBµV/m
Offset -9.50 dB
RBW 1 MHz
Att 0 dB
SWT 36 ms
VBW 3 MHz
Mode Auto Sweep
TDF
1Pk View
M3[1] 36.69 dBµV/m 2.746090 GHz
M1[1] 43.76 dBµV/m 3.661240 GHz
70 dBµV/m
60 dBµV/m
AJL FCC 15209
40 dBµV/m
20 dBµV/m
10 dBµV/m
0 dBµV/m
-10 dBµV/m
M1
M2
M3
Start 1.0 GHz
32001 pts
Stop 10.0 GHz
Marker
Type Ref Trc X-value Y-value Function Function Result
M1 1 3.66124 GHz 43.76 dBµV/m
M2 1 4.90124 GHz 39.20 dBµV/m
M3 1 2.74609 GHz 36.69 dBµV/m
Measuring...
03.02.2017 16:42:48
11161473
Date: 3.FEB.2017 16:42:48

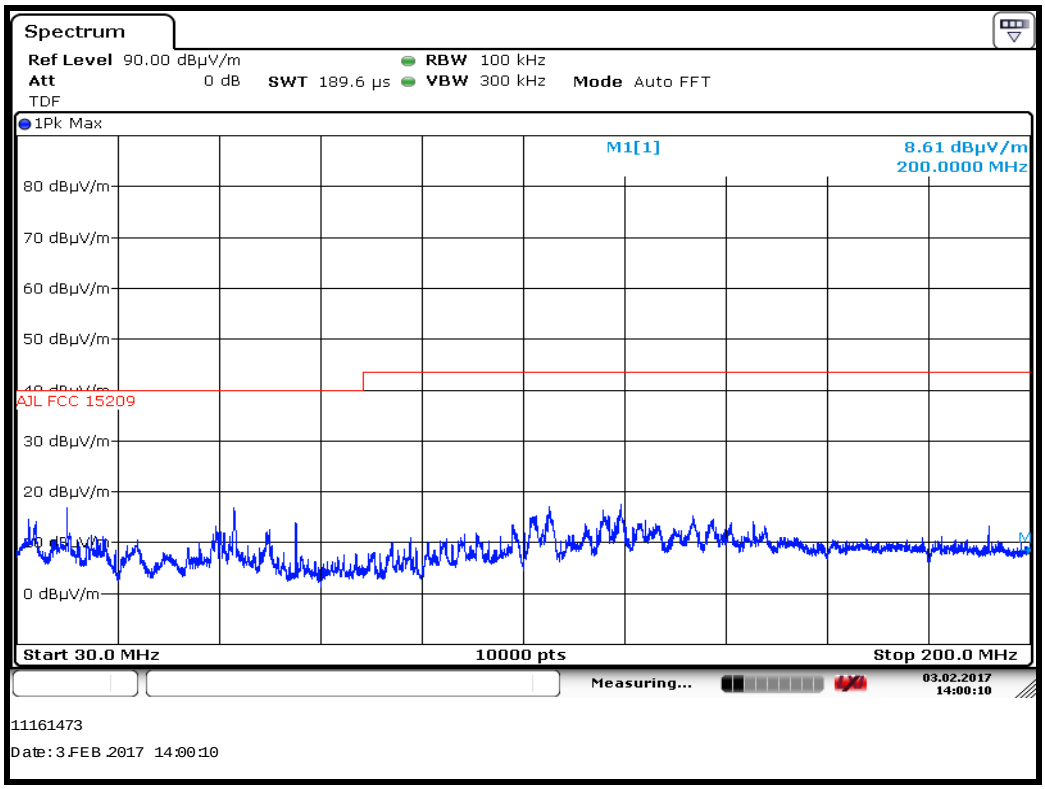
Channel 29 : 921.00

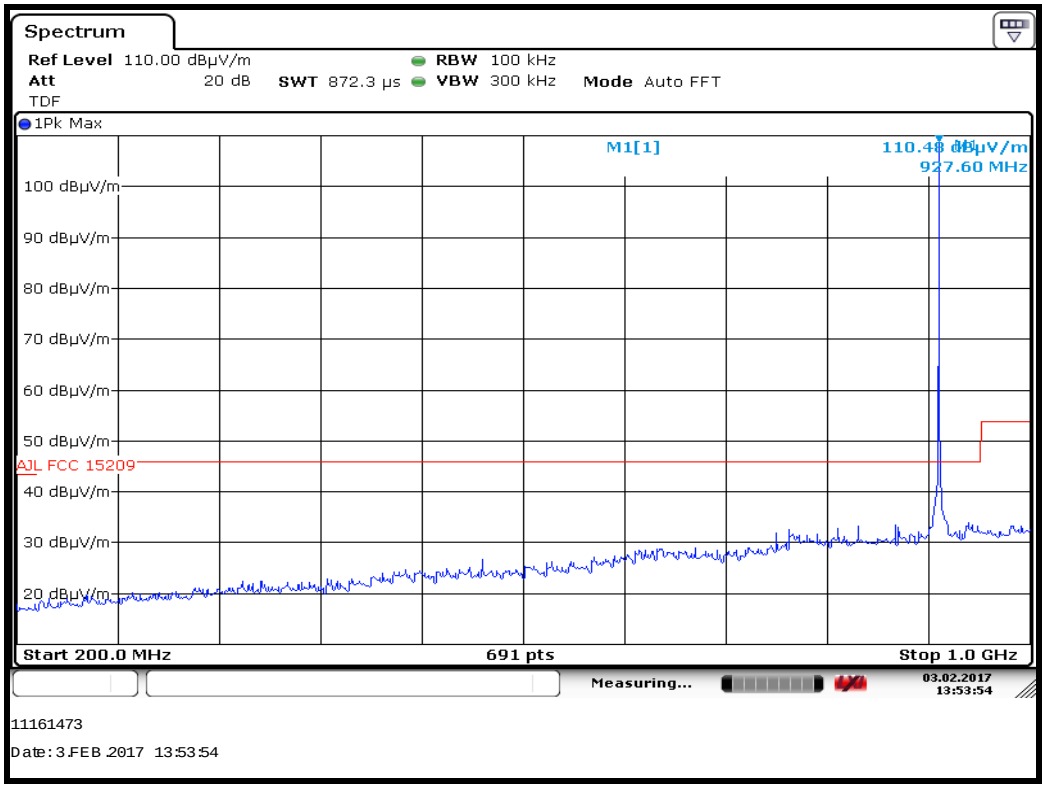


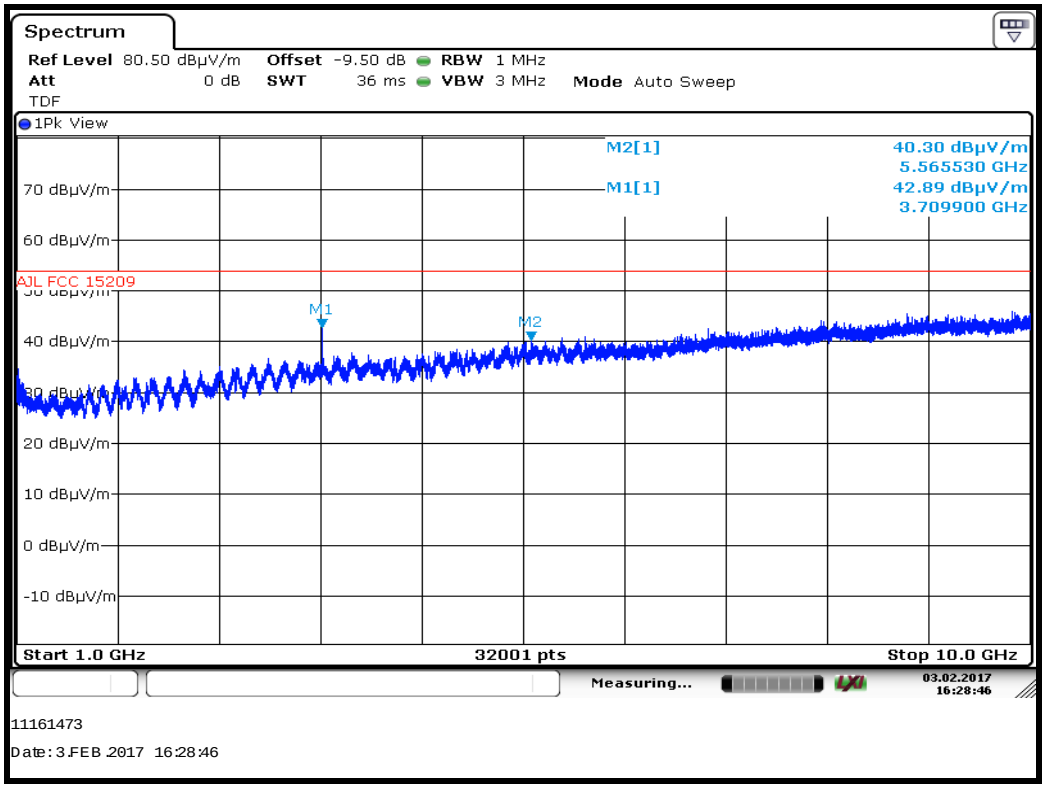



Spectrum
Ref Level 80.50 dBµV/m
Offset -9.50 dB
RBW 1 MHz
Att 0 dB
SWT 36 ms
VBW 3 MHz
Mode Auto Sweep
TDF
1Pk View
M2[1] 37.56 dBµV/m
2.762960 GHz
M1[1] 42.33 dBµV/m
3.684030 GHz
70 dBµV/m
60 dBµV/m
AJL FCC 15209
40 dBµV/m
20 dBµV/m
10 dBµV/m
0 dBµV/m
-10 dBµV/m
M1
M2
Start 1.0 GHz
32001 pts
Stop 10.0 GHz
Measuring...
03.02.2017
16:37:11
11161473
Date: 3.FEB.2017 16:37:12

Channel 55 : 927.50






Spectrum
Ref Level 80.50 dBµV/m
Offset -9.50 dB
RBW 1 MHz
Att 0 dB
SWT 36 ms
VBW 3 MHz
Mode Auto Sweep
TDF
1Pk View
M2[1]
40.30 dBµV/m
5.565530 GHz
M1[1]
42.89 dBµV/m
3.709900 GHz
70 dBµV/m
60 dBµV/m
AJL FCC 15209
40 dBµV/m
20 dBµV/m
10 dBµV/m
0 dBµV/m
-10 dBµV/m
M1
M2
Start 1.0 GHz
32001 pts
Stop 10.0 GHz
Measuring...
03.02.2017
16:28:46
11161473
Date: 3.FEB.2017 16:28:46

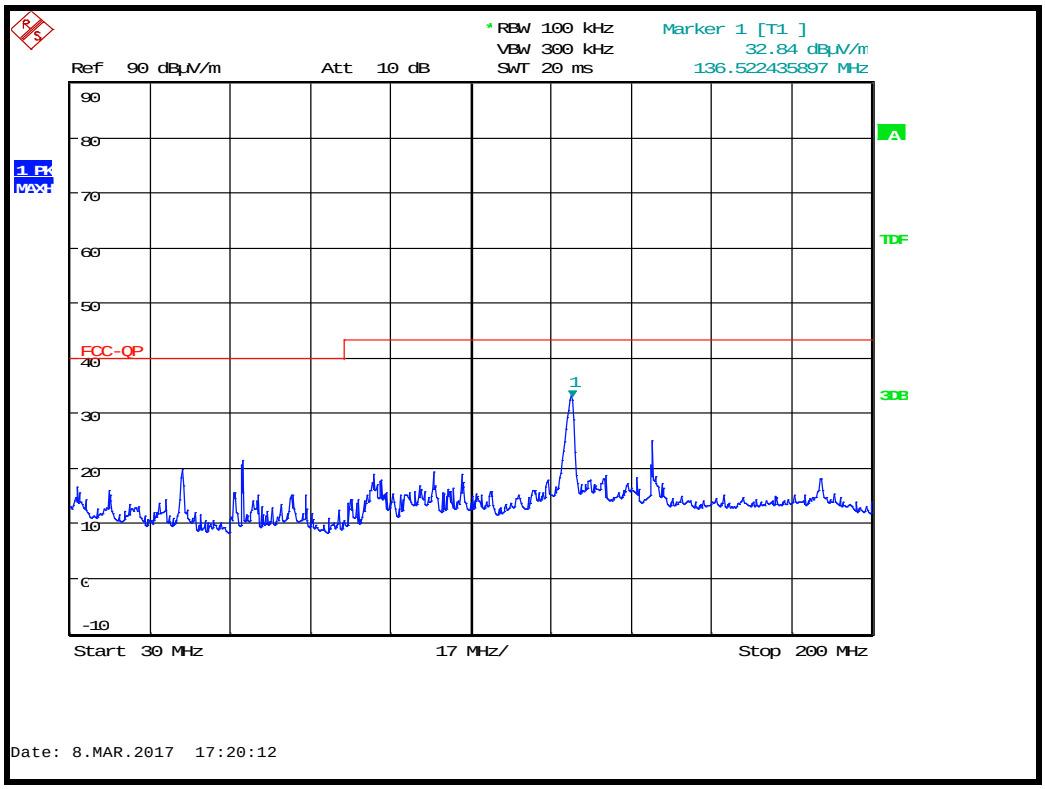
High Power; Channel: 915.25 MHz										
Detector	***Freq. (MHz)***	***Meas'd Emission (dBµV)***	***Cable Loss (dB)***	***Antenna Factor (dB/m)***	***Pre-amp Gain (dB)***	***Duty Cycle Corr'n (dB)***	***Distance Extrap'n Factor (dB)***	***Field Strength (dBµV/m)***	***Field Strength (µV/m)***	***Limit (µV/m)***
QP	120.02	47.00	1.2	11.9	32.5	0	0	27.6	23.99	150
QP	336.06	38.10	2.0	13.7	32.4	0	0	21.4	11.75	200
QP	960.11	32.80	3.3	21.9	31.3	0	0	26.7	21.63	500
Pk	2745.66	53.13	3.8	29.3	35.3	0.0	-9.5	41.37	117.08	5000
Av	2745.66	47.61	3.8	29.3	35.3	0.0	-9.5	35.85	62.02	500
Pk	3660.98	54.38	4.6	31.6	35.4	0.0	-9.5	45.68	192.31	5000
Av	3660.98	50.13	4.6	31.6	35.4	0.0	-9.5	41.43	117.90	500

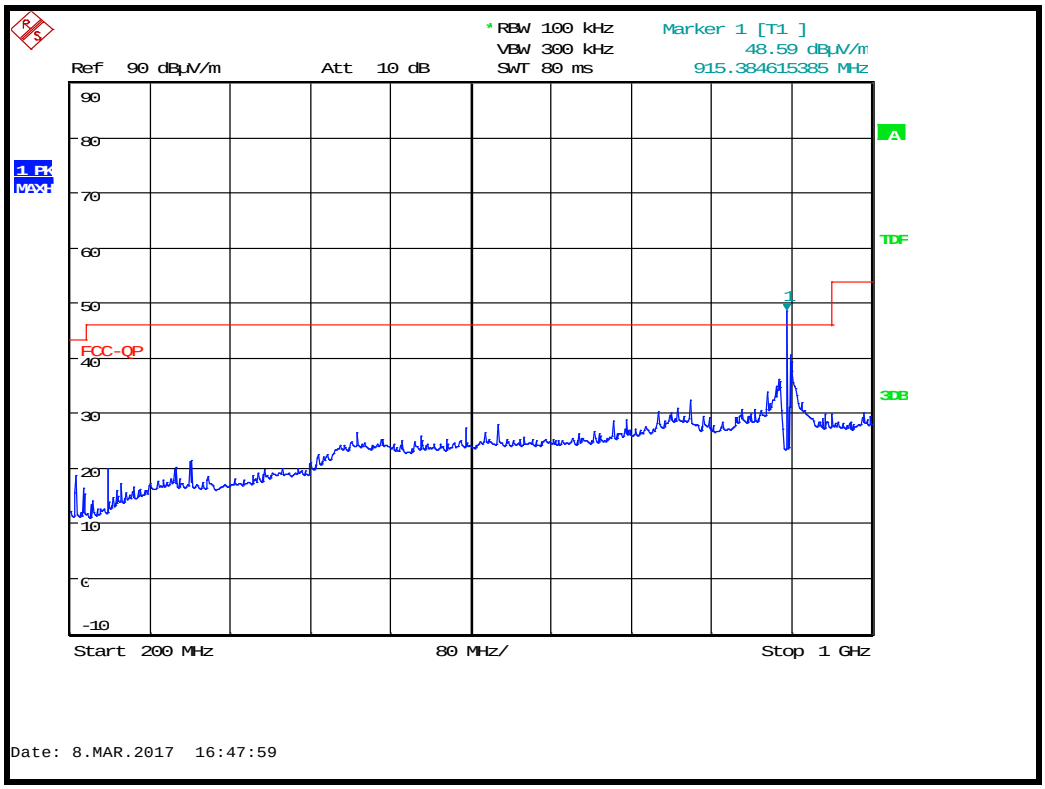
High Power; Channel: 921.00 MHz										
Detector	***Freq. (MHz)***	***Meas'd Emission (dBµV)***	***Cable Loss (dB)***	***Antenna Factor (dB/m)***	***Pre-amp Gain (dB)***	***Duty Cycle Corr'n (dB)***	***Distance Extrap'n Factor (dB)***	***Field Strength (dBµV/m)***	***Field Strength (µV/m)***	***Limit (µV/m)***
QP	120.02	47.00	1.2	11.9	32.5	0	0	27.6	23.99	150
QP	336.06	38.10	2.0	13.7	32.4	0	0	21.4	11.75	200
QP	960.11	32.80	3.3	21.9	31.3	0	0	26.7	21.63	500
Pk	2762.96	53.58	4.2	29.4	35.3	0.0	-9.5	42.31	130.47	5000
Av	2762.96	48.47	4.2	29.4	35.3	0.0	-9.5	37.20	72.44	500
Pk	3684.03	54.91	4.6	31.6	35.4	0.0	-9.5	46.21	204.41	5000
Av	3684.03	51.19	4.6	31.6	35.4	0.0	-9.5	42.49	133.20	500

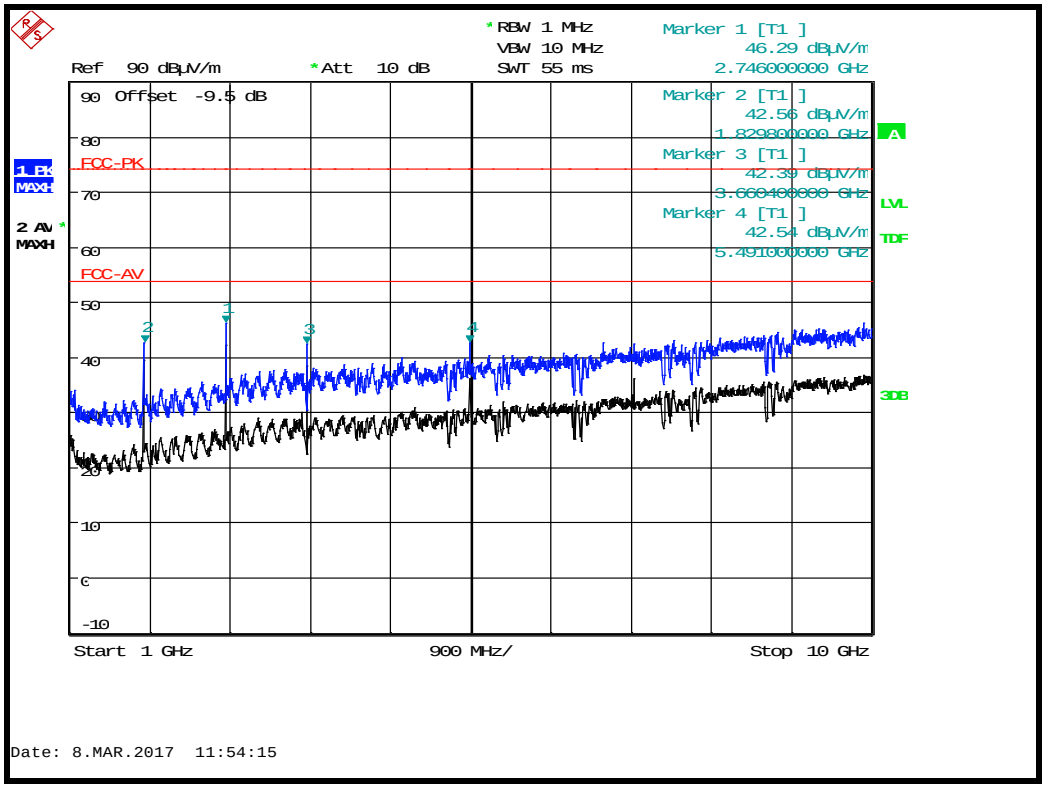
High Power; Channel: 927.50 MHz										
Detector	***Freq. (MHz)***	***Meas'd Emission (dBµV)***	***Cable Loss (dB)***	***Antenna Factor (dB/m)***	***Pre-amp Gain (dB)***	***Duty Cycle Corr'n (dB)***	***Distance Extrap'n Factor (dB)***	***Field Strength (dBµV/m)***	***Field Strength (µV/m)***	***Limit (µV/m)***
QP	120.02	47.00	1.2	11.9	32.5	0	0	27.6	23.99	150
QP	336.06	38.10	2.0	13.7	32.4	0	0	21.4	11.75	200
QP	960.11	32.80	3.3	21.9	31.3	0	0	26.7	21.63	500
Pk	3709.90	54.32	4.6	31.7	35.4	0	-9.5	45.72	193.20	5000
Av	3709.90	50.56	4.6	31.7	35.4	0	-9.5	41.96	125.31	500

11.8 Test Results – Mouse Radar

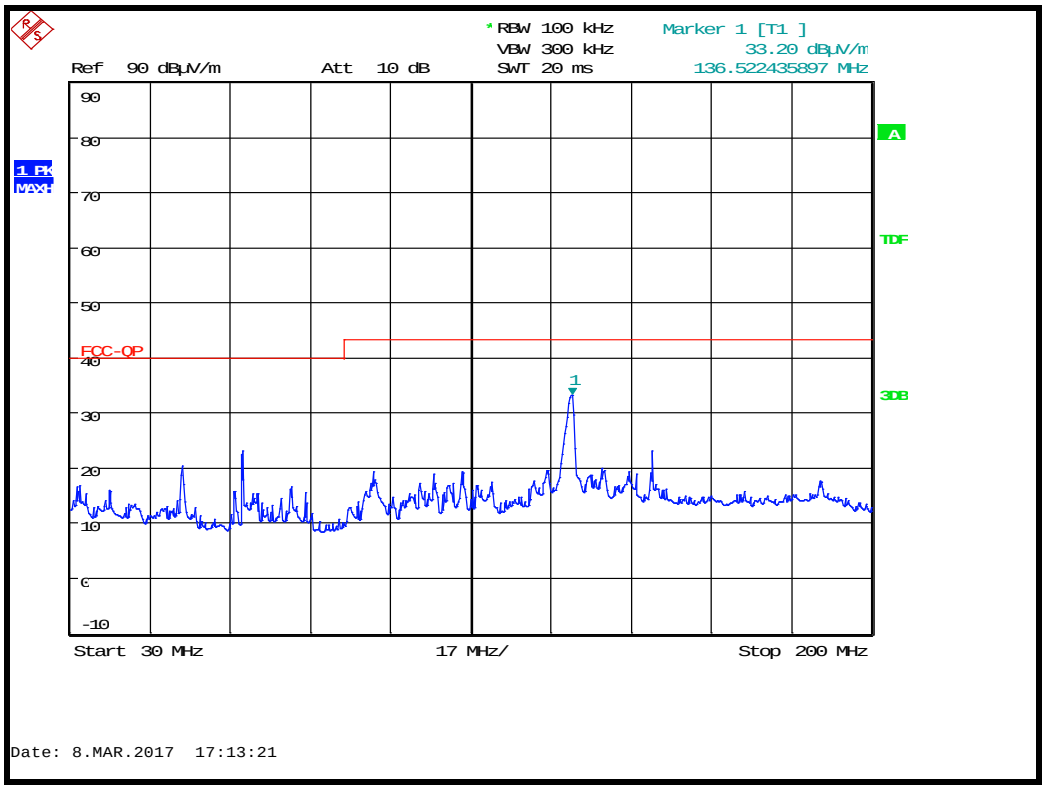
Channel 6 : 915.25

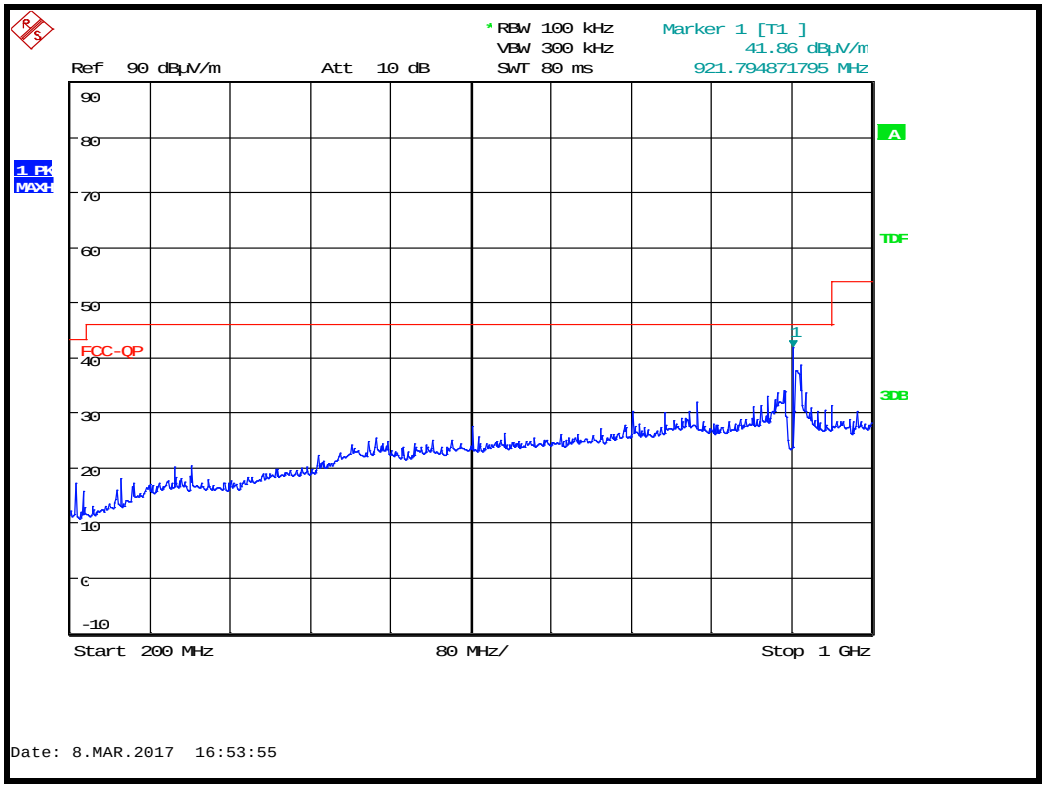


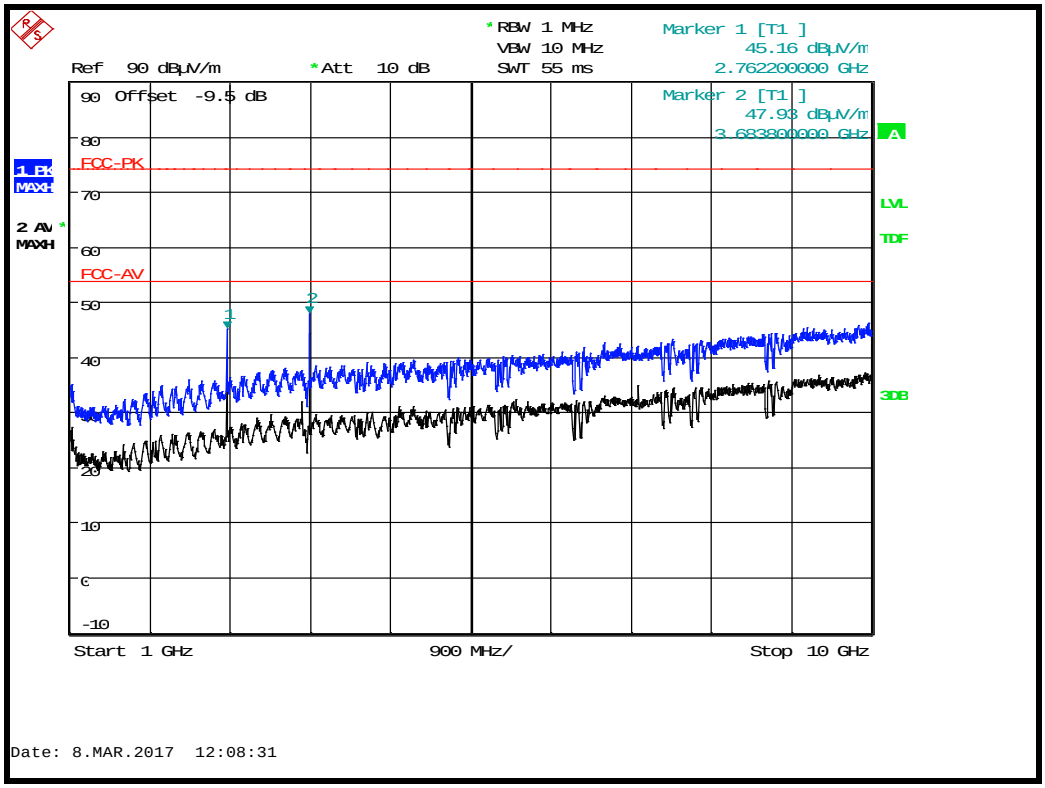



RBW 1 MHz
VBW 10 MHz
SWT 55 ms
Marker 1 [T1]
46.29 dBµV/m
2.746000000 GHz
Marker 2 [T1]
42.56 dBµV/m
1.829800000 GHz
Marker 3 [T1]
42.39 dBµV/m
3.660400000 GHz
Marker 4 [T1]
42.54 dBµV/m
5.491000000 GHz
Ref 90 dBµV/m
Att 10 dB
90 Offset -9.5 dB
FCC-PK
FCC-AV
1 PK MAXH
2 AV MAXH
A
LVL
TDF
3DB
Start 1 GHz
900 MHz/
Stop 10 GHz
Date: 8.MAR.2017 11:54:15

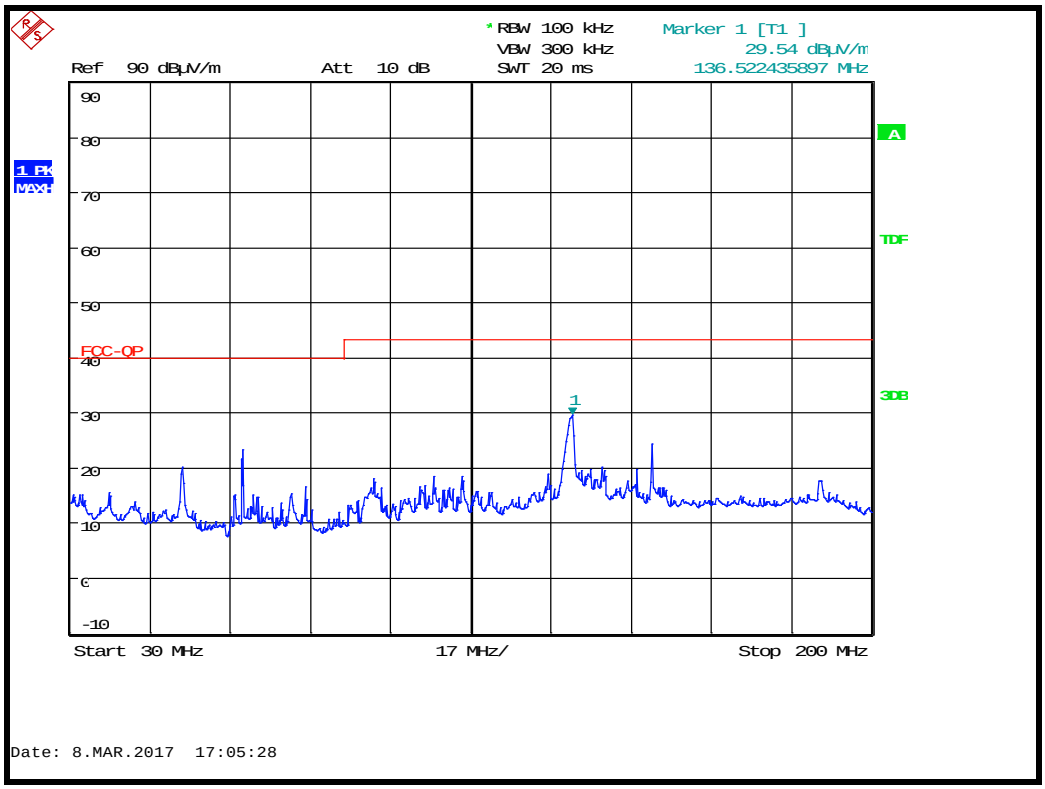
Channel 29 : 921.00

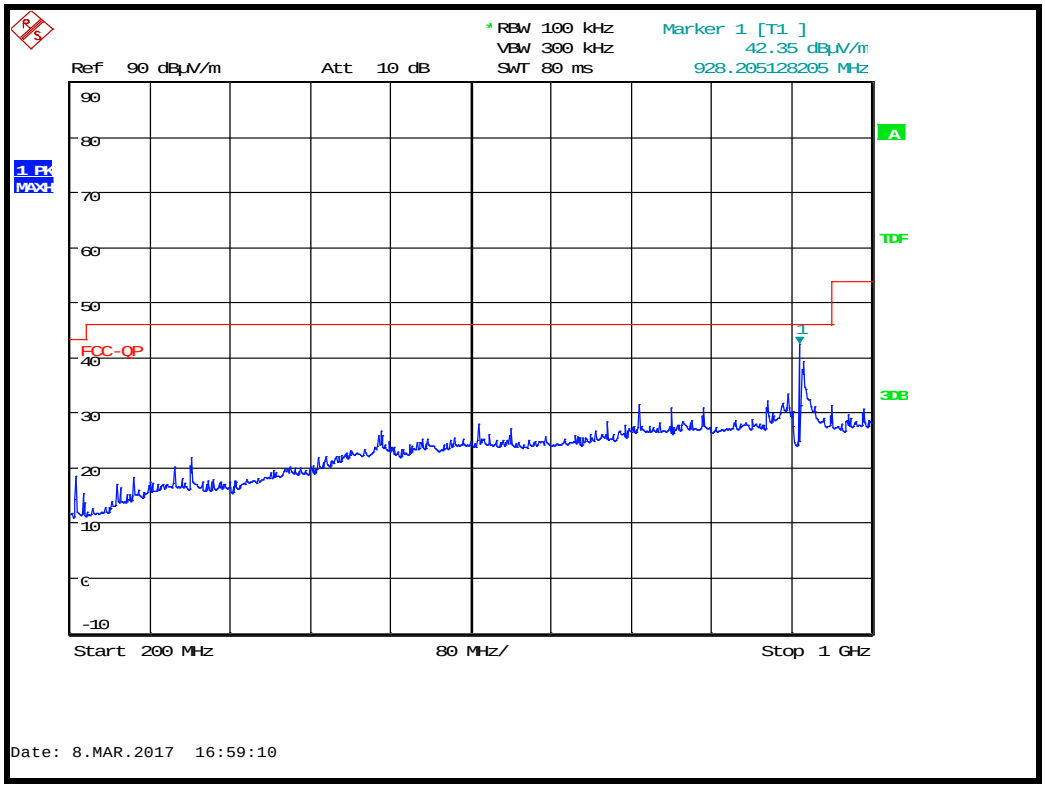


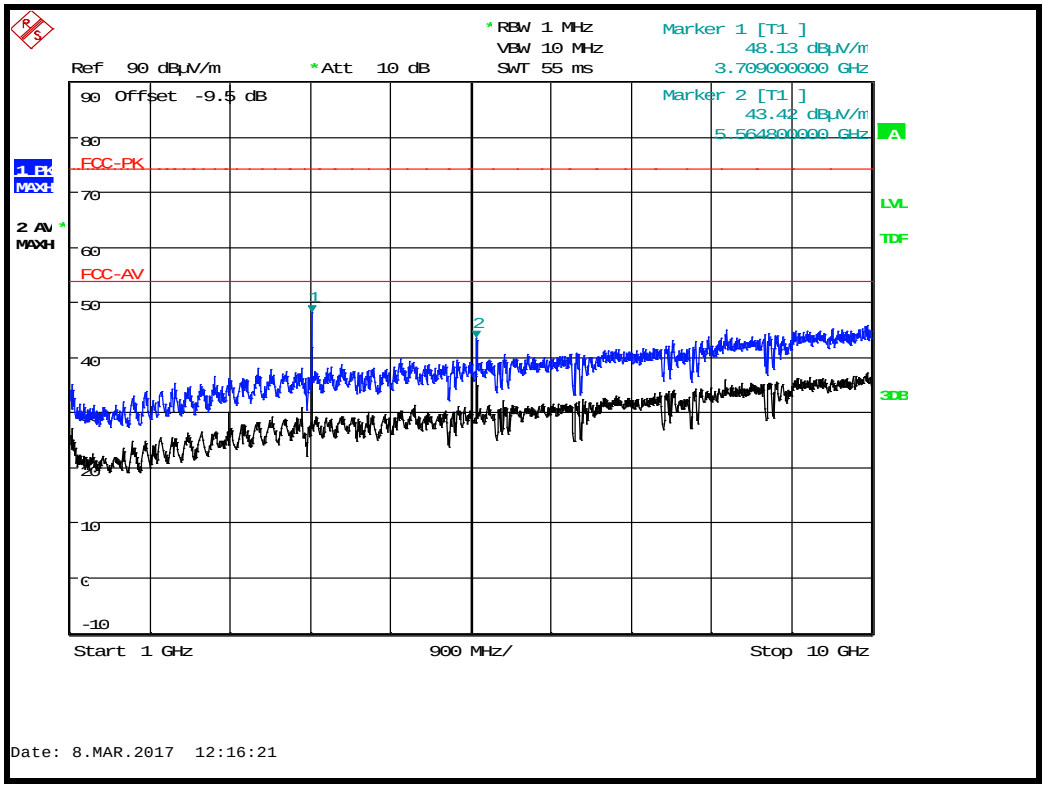



RBW 1 MHz
VBW 10 MHz
SWT 55 ms
Marker 1 [T1]
45.16 dBµV/m
2.762200000 GHz
Marker 2 [T1]
47.93 dBµV/m
3.683800000 GHz
Ref 90 dBµV/m
Att 10 dB
90 Offset -9.5 dB
FCC-PK
FCC-AV
1 PK MAXH
2 AV MAXH
A
LVL
TDF
3DB
Start 1 GHz
900 MHz/
Stop 10 GHz
Date: 8.MAR.2017 12:08:31

Channel 55 : 927.50






RBW 1 MHz
VBW 10 MHz
SWT 55 ms
Marker 1 [T1]
48.13 dBµV/m
3.709000000 GHz
Marker 2 [T1]
43.42 dBµV/m
5.564800000 GHz
Ref 90 dBµV/m
Att 10 dB
90 Offset -9.5 dB
FCC-PK
FCC-AV
1 PK MAXH
2 AV MAXH
A
LVL
TDF
3DB
Start 1 GHz
900 MHz/
Stop 10 GHz
Date: 8.MAR.2017 12:16:21

High Power; Channel: 915.25 MHz										
Detector	**Freq. (MHz)**	**Meas'd Emission (dBµV)**	**Cable Loss (dB)**	**Antenna Factor (dB/m)**	**Pre-amp Gain (dB)**	**Duty Cycle Corr'n (dB)**	**Distance Extrap'n Factor (dB)**	**Field Strength (dBµV/m)**	**Field Strength (µV/m)**	**Limit (µV/m)**
QP	136.52	46.30	1.3	12.7	32.5	0	0	27.8	24.55	150
Pk	2745.81	57.56	3.8	29.3	35.3	0	-9.5	45.80	194.98	5000
Av	2745.81	55.40	3.8	29.3	35.3	0	-9.5	43.64	152.05	500

High Power; Channel: 921.00 MHz										
Detector	**Freq. (MHz)**	**Meas'd Emission (dBµV)**	**Cable Loss (dB)**	**Antenna Factor (dB/m)**	**Pre-amp Gain (dB)**	**Duty Cycle Corr'n (dB)**	**Distance Extrap'n Factor (dB)**	**Field Strength (dBµV/m)**	**Field Strength (µV/m)**	**Limit (µV/m)**
QP	136.52	46.30	1.3	12.7	32.5	0	0	27.8	24.55	150
Pk	2763.01	57.43	4.2	29.4	35.3	0	-9.5	46.16	203.24	5000
Av	2763.01	55.01	4.2	29.4	35.3	0	-9.5	43.74	153.82	500
Pk	3684.02	57.18	4.6	31.6	35.4	0	-9.5	48.48	265.46	5000
Av	3684.02	54.78	4.6	31.6	35.4	0	-9.5	46.08	201.37	500

High Power; Channel: 927.50 MHz										
Detector	**Freq. (MHz)**	**Meas'd Emission (dBµV)**	**Cable Loss (dB)**	**Antenna Factor (dB/m)**	**Pre-amp Gain (dB)**	**Duty Cycle Corr'n (dB)**	**Distance Extrap'n Factor (dB)**	**Field Strength (dBµV/m)**	**Field Strength (µV/m)**	**Limit (µV/m)**
QP	136.52	46.30	1.3	12.7	32.5	0	0	27.8	24.55	150
Pk	3710.02	56.52	4.6	31.7	35.4	0	-9.5	47.92	248.89	5000
Av	3710.02	54.19	4.6	31.7	35.4	0	-9.5	45.59	190.33	500

12 AC power-line conducted emissions

12.1 Definition

Line-to-ground radio-noise voltage that is conducted from all of the EUT current-carrying power input terminals that are directly (or indirectly via separate transformers or power supplies) connected to a public power network.

12.2 Test Parameters

Test Location:	Element Hull
Test Chamber:	Lab 5
Test Standard and Clause:	ANSI C63.10-2013, Clause 6.2
EUT Channels / Frequencies Measured:	Mid
EUT Modulation:	LoRa and GSM active
Deviations From Standard:	None
Measurement BW:	9 kHz
Measurement Detectors:	Quasi-Peak and Average, RMS

Environmental Conditions (Normal Environment)

Temperature: 21 °C	+15 ºC to +35 ºC (as declared)
Humidity: 34 % RH	20 % RH to 75 % RH (as declared)
Supply: 110 V dc	

Test Limit

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

Table 3 – AC Power Line Conducted Emission Limits

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

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

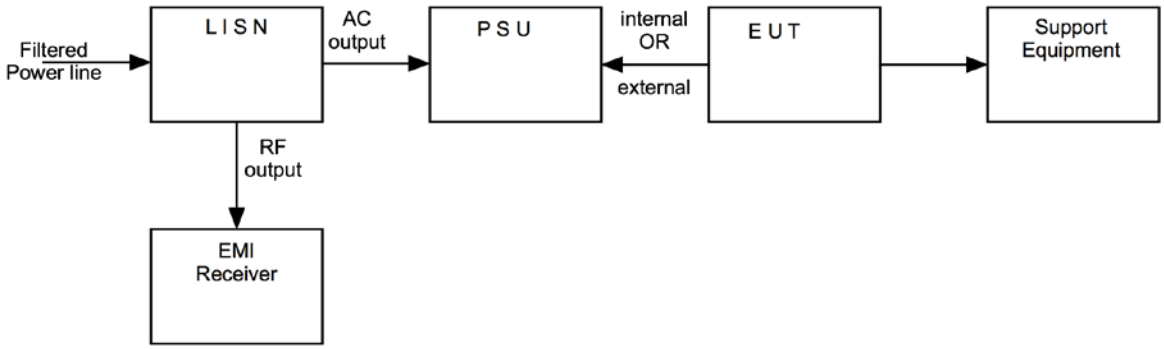
12.3 Test Method

With the EUT setup in a screened room, as per section 9 of this report and connected as per Figure ii, the power line emissions were measured on a spectrum analyzer / EMI receiver.

AC power line conducted emissions from the EUT are checked first by preview scans with peak and average detectors covering both live and neutral lines. A spectrum analyzer is used to determine if any periodic emissions are present.

Formal measurements using the correct detector(s) and bandwidth are made on frequencies identified from the preview scans. Final measurements were performed with EUT set at its maximum duty in transmit and receive modes.

Figure ii Test Setup

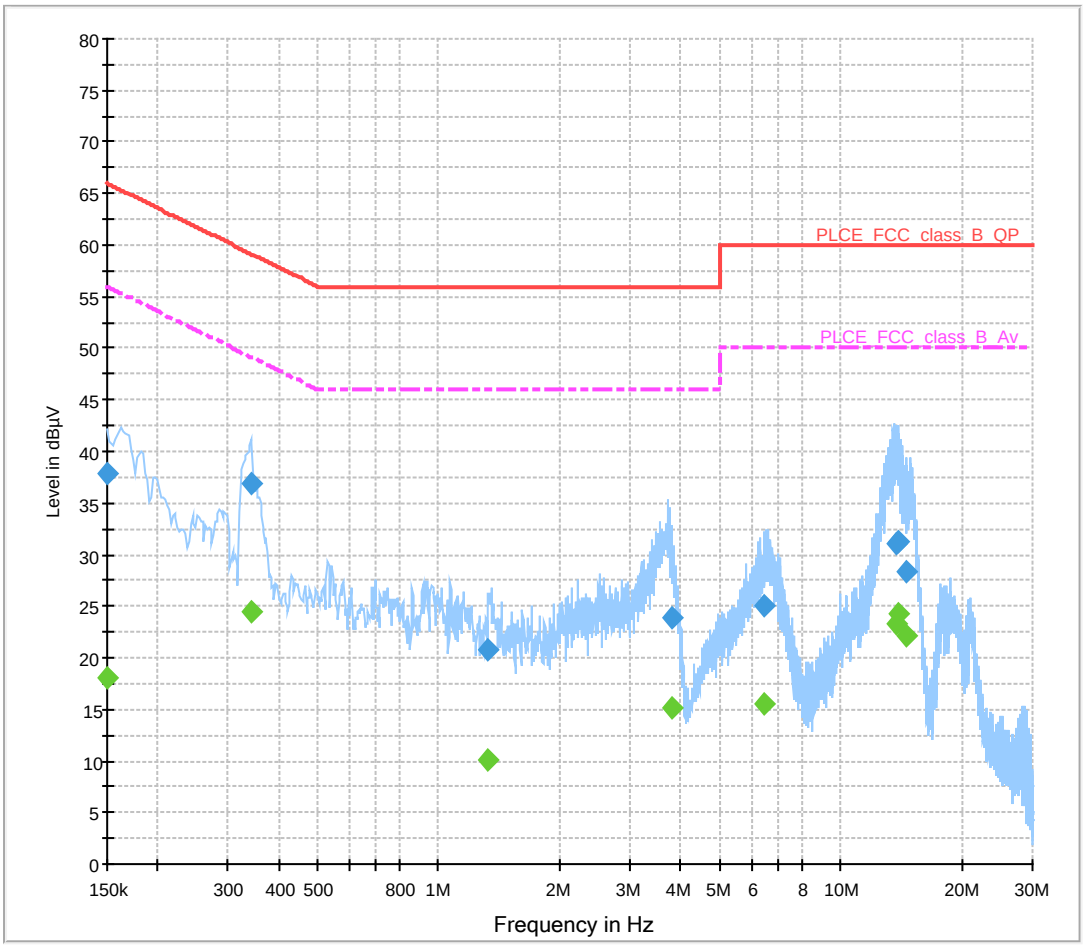


12.4 Test Set-up Photograph

12.5 Test Equipment

Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
ESH3-Z2	R&S	Pulse Limiter	RFG680	14/06/2017
ESH3-Z5	R&S	LISN	RFG189	02/08/2017
ESCI7	R&S	Measuring Receiver	RFG715	06/10/2017

12.6 Test Results



Frequency (MHz)	QuasiPeak (dBµV)	Meas. Time (ms)	Bandwidth (kHz)	PE	Line	Corr. (dB)	Margin (dB)	Limit (dBµV)
0.150000	37.8	15000.0	0.200	GND	N	0.2	28.2	66.0
0.340650	36.9	15000.0	9.000	GND	L1	0.3	22.3	59.2
1.320600	20.8	15000.0	9.000	GND	N	0.3	35.2	56.0
3.796400	23.8	15000.0	9.000	GND	N	0.4	32.2	56.0
6.470000	25.1	15000.0	9.000	GND	N	0.5	34.9	60.0
13.781500	31.1	15000.0	9.000	GND	L1	1.3	28.9	60.0
13.977500	31.4	15000.0	9.000	GND	L1	1.4	28.6	60.0
14.579000	28.4	15000.0	9.000	GND	L1	1.4	31.6	60.0

Frequency (MHz)	Average (dBµV)	Meas. Time (ms)	Bandwidth (kHz)	PE	Line	Corr. (dB)	Margin (dB)	Limit (dBµV)
0.150000	18.1	15000.0	9.000	GND	N	0.2	37.9	56.0
0.340650	24.4	15000.0	9.000	GND	L1	0.3	24.8	49.2
1.320600	10.1	15000.0	9.000	GND	N	0.3	35.9	46.0
3.796400	15.1	15000.0	9.000	GND	N	0.4	30.9	46.0
6.470000	15.5	15000.0	9.000	GND	N	0.5	34.5	50.0
13.781500	23.3	15000.0	9.000	GND	L1	1.3	26.7	50.0
13.977500	24.2	15000.0	9.000	GND	L1	1.4	25.8	50.0
14.579000	22.2	15000.0	9.000	GND	L1	1.4	27.8	50.0

13 Carrier frequency separation

13.1 Definition

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

13.2 Test Parameters

Test Location:	Element Hull
Test Chamber:	Lab 4
Test Standard and Clause:	ANSI C63.10-2013, Clause 7.8.2
EUT Channels / Frequencies Measured:	All; 2405 to 2480 MHz
EUT 20dB Bandwidth:	148 kHz
EUT Test Modulations:	Internal pattern generation – hopping enabled
Deviations From Standard:	None
Measurement BW:	4.3 kHz
Measurement Detector:	Peak

Environmental Conditions (Normal Environment)

Temperature: 22 °C	+15 ºC to +35 ºC (as declared)
Humidity: 33 % RH	20 % RH to 75 % RH (as declared)
Supply: 6 V dc	

13.3 Test Limit

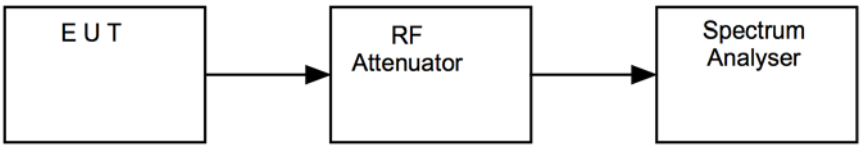
Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the -20 dB bandwidth of the hopping channel, whichever is greater. Alternatively, frequency hopping systems operating in the band 2400 to 2483.5 MHz may have hopping channel carrier frequencies that are separated by 25 kHz or two-thirds of the -20 dB bandwidth of the hopping channel, whichever is greater, provided that the systems operate with an output power no greater than 0.125 W.

13.4 Test Method

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

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

Figure iii Test Setup

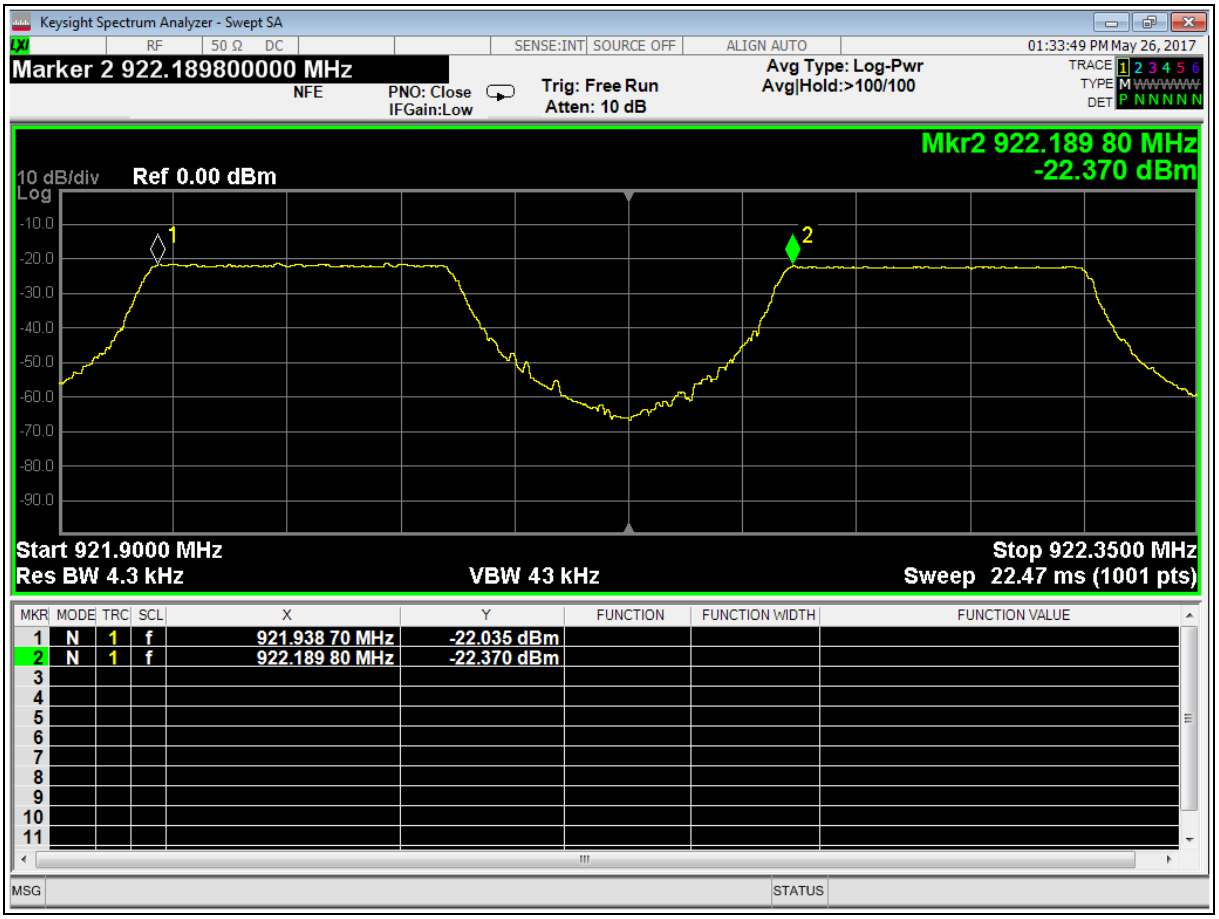


13.5 Test Equipment

Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
N9030A	Agilent	Spectrum Analyser	REF2167	19/04/2018

13.6 Test Results

Channel #: 33 & 34; Modulation: LoRa; Power setting: 0x0F				
Data Rate	***$F1_c$ (MHz)***	***$F2_c$ (MHz)***	***Channel Separation, $F2_c - F1_c$ (kHz)***	***Result***
LoRa	921.93870	922.18980	251.1	PASS


Keysight Spectrum Analyzer - Swept SA
RF
50 Ω DC
SENSE:INT
SOURCE OFF
ALIGN AUTO
01:33:49 PM May 26, 2017
Marker 2 922.189800000 MHz
NFE
PNO: Close
IFGain:Low
Trig: Free Run
Atten: 10 dB
Avg Type: Log-Pwr
Avg|Hold:>100/100
TRACE 1 2 3 4 5 6
TYPE M
DET P N N N N N
Mkr2 922.189 80 MHz
-22.370 dBm
10 dB/div
Log
Ref 0.00 dBm
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
-80.0
-90.0
1
2
Start 921.9000 MHz
Res BW 4.3 kHz
VBW 43 kHz
Stop 922.3500 MHz
Sweep 22.47 ms (1001 pts)
MKR MODE TRC SCL X Y FUNCTION FUNCTION WIDTH FUNCTION VALUE
1 N 1 f 921.938 70 MHz -22.035 dBm
2 N 1 f 922.189 80 MHz -22.370 dBm
3
4
5
6
7
8
9
10
11
MSG
STATUS

14 Number of hopping frequencies

14.1 Definition

The total number of hopping frequencies (the centre frequencies defined within the hopping sequence of a FHSS equipment) which are randomly sequenced in order to spread the transmission.

14.2 Test Parameters

Test Location:	Element Hull
Test Chamber:	Lab 4
Test Standard and Clause:	ANSI C63.10-2013, Clause 7.8.3
EUT Channels / Frequencies Measured:	All; 2405 – 2480 MHz
EUT 20dB Bandwidth:	148 kHz
EUT Test Modulations:	Internal pattern generation – hopping enabled
Deviations From Standard:	None
Measurement BW:	100 kHz
Measurement Detector:	Peak

Environmental Conditions (Normal Environment)

Temperature: 22 °C	+15 ºC to +35 ºC (as declared)
Humidity: 33 % RH	20 % RH to 75 % RH (as declared)
Supply: 6 V dc	

14.3 Test Limit

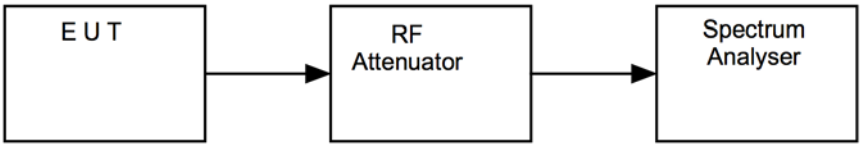
- For frequency hopping systems in the band 902 to 928 MHz: if the -20 dB bandwidth of the hopping channel is less than 250 kHz, the system shall use at least 50 hopping channels;
  If the -20 dB bandwidth of the hopping channel is 250 kHz or greater, the system shall use at least 25 hopping channels;
- Frequency hopping systems operating in the band 2400 to 2483.5 MHz shall use at least 15 hopping channels;
- Frequency hopping systems operating in the band 5725 to 5850 MHz shall use at least 75 hopping channels.

14.4 Test Method

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

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

Figure iv Test Setup

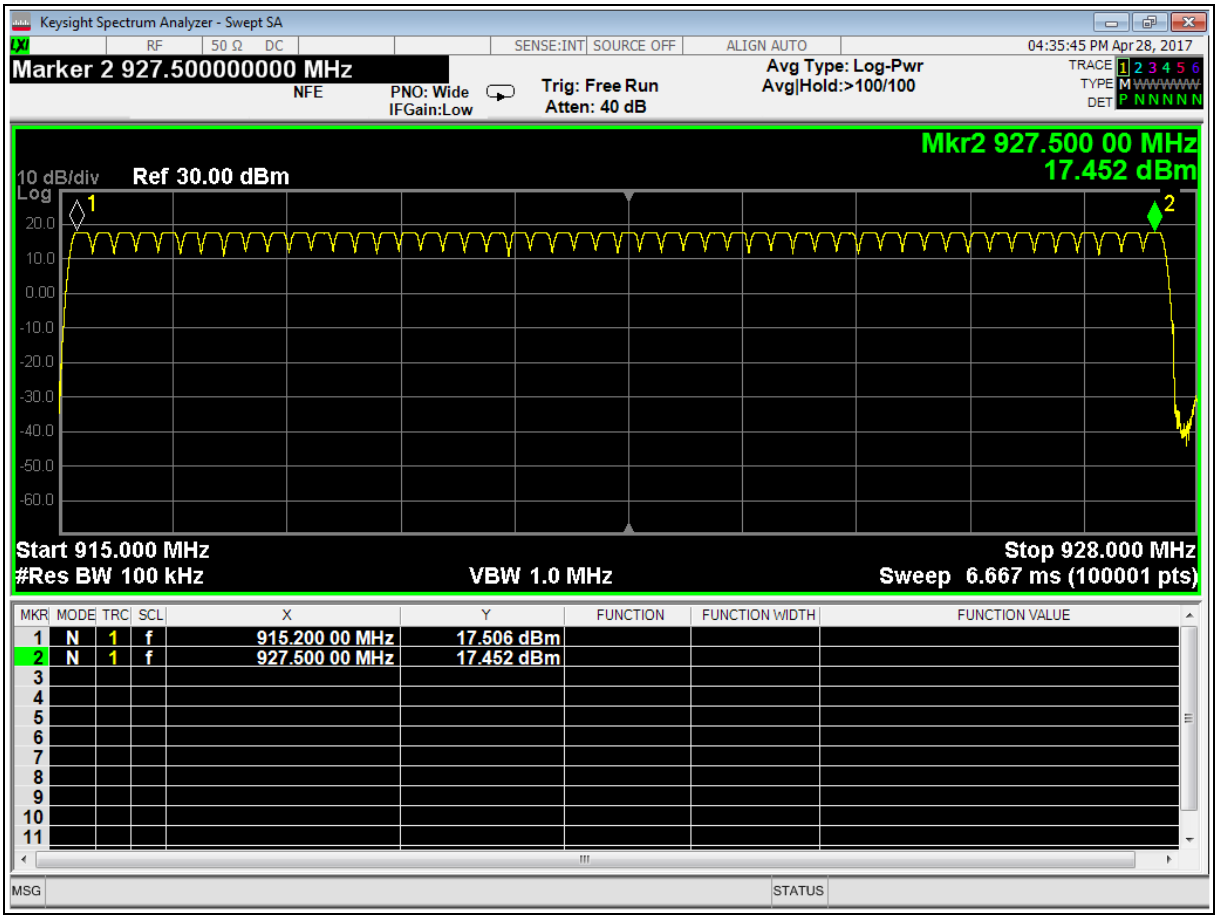


14.5 Test Equipment

Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
N9030A	Agilent	Spectrum Analyser	REF2167	19/04/2018

14.6 Test Results

Modulation: LoRa ; Power setting: .0x0F				
Data Rate	***Lowest channel, F_{CL} (MHz)***	***Highest channel, F_{CH} (MHz)***	***Number of channels observed***	***Result***
LoRa	915.200	927.500	50	PASS


Keysight Spectrum Analyzer - Swept SA
RF
50 Ω DC
SENSE:INT
SOURCE OFF
ALIGN AUTO
04:35:45 PM Apr 28, 2017
Marker 2 927.500000000 MHz
NFE
PNO: Wide
IFGain:Low
Trig: Free Run
Atten: 40 dB
Avg Type: Log-Pwr
Avg|Hold:>100/100
TRACE 1 2 3 4 5 6
TYPE M
DET P N N N N N
Mkr2 927.500 00 MHz
17.452 dBm
10 dB/div
Log
Ref 30.00 dBm
20.0
10.0
0.00
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
Start 915.000 MHz
#Res BW 100 kHz
VBW 1.0 MHz
Stop 928.000 MHz
Sweep 6.667 ms (100001 pts)
MKR MODE TRC SCL X Y FUNCTION FUNCTION WIDTH FUNCTION VALUE
1 N 1 f 915.200 00 MHz 17.506 dBm
2 N 1 f 927.500 00 MHz 17.452 dBm
3
4
5
6
7
8
9
10
11
MSG
STATUS

15 Average channel occupancy

15.1 Definition

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

15.2 Test Parameters

Test Location:	Element Hull
Test Chamber:	Lab 4
Test Standard and Clause:	ANSI C63.10-2013, Clause 7.8.4
EUT Channels / Frequencies Measured:	Mid
EUT 20dB bandwidth:	148 kHz
EUT Number of hopping channels:	50
EUT Test Modulations:	Internal pattern generation – hopping enabled
Deviations From Standard:	None
Measurement BW:	100 kHz
Measurement Detector:	Peak

Environmental Conditions (Normal Environment)

Temperature: 22 °C	+15 ºC to +35 ºC (as declared)
Humidity: 33 % RH	20 % RH to 75 % RH (as declared)
Supply: 6 V dc	

15.3 Test Limit

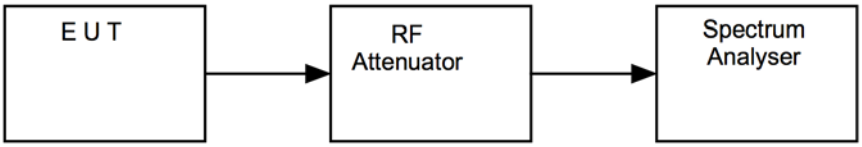
- For frequency hopping systems in the band 902 to 928 MHz: if the -20 dB bandwidth of the hopping channel is less than 250 kHz, the average time of occupancy on any channel shall not be greater than 0.4 seconds within a 20 second period;
  If the -20 dB bandwidth of the hopping channel is 250 kHz or greater, the average time of occupancy on any channel shall not be greater than 0.4 seconds within a 10 second period;
- Frequency hopping systems operating in the band 2400 to 2483.5 MHz: The average time of occupancy on any channel shall not be greater than 0.4 seconds within a period of 0.4 seconds, multiplied by the number of hopping channels employed;
- Frequency hopping systems operating in the band 5725 to 5850 MHz: The average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 30 second period.

15.4 Test Method

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

The measurements were performed with EUT set at its maximum duty. A number of hops were observed to confirm consistency of the dwell time / observe the worst case. All modulation schemes, data rates and power settings were used to observe the worst-case configuration.

Figure v Test Setup

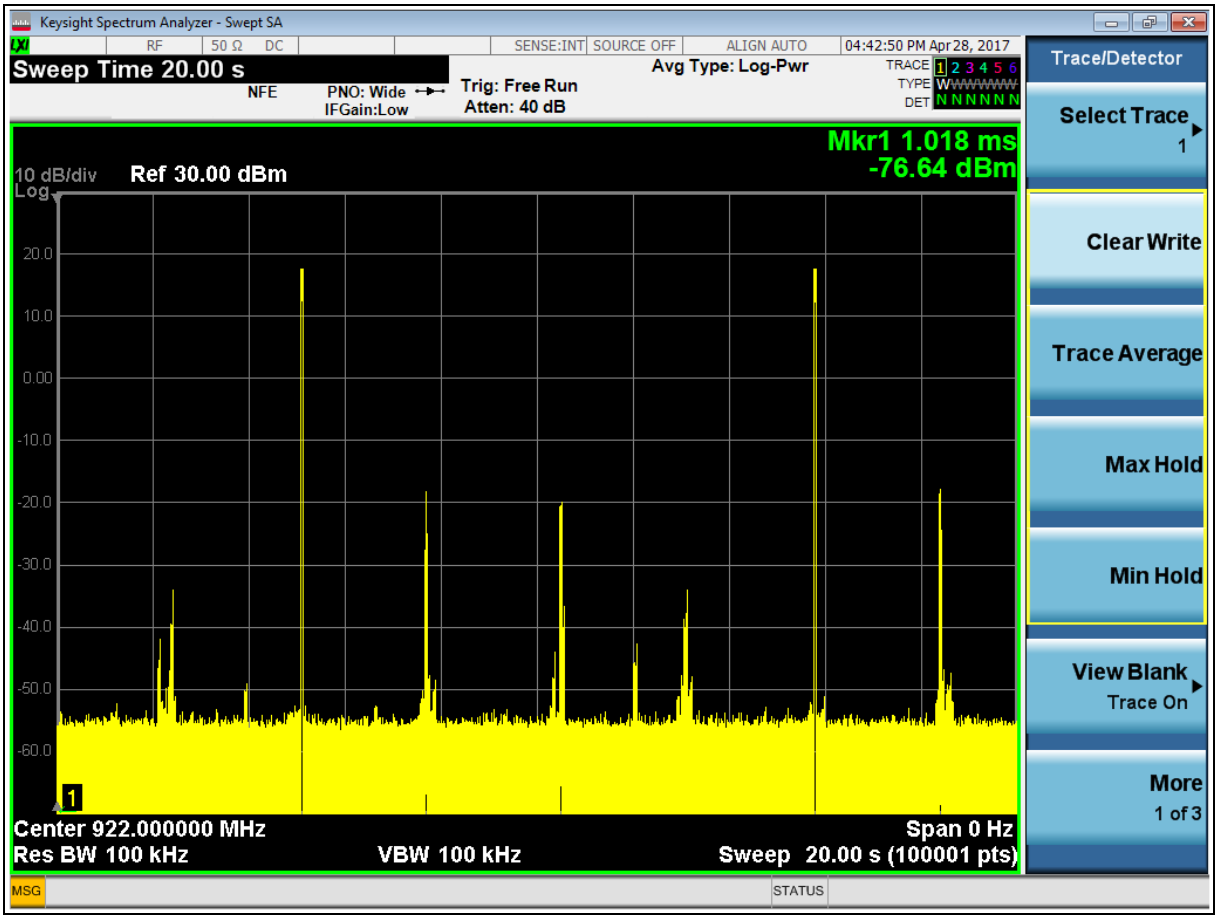


15.5 Test Equipment

Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
N9030A	Agilent	Spectrum Analyser	REF2167	19/04/2018

15.6 Test Results

Modulation: LoRa; Power setting: .0x0F					
Data Rate	***Individual occupancy time (s)***	***Observation period (s)***	***Number of hops observed***	***Average time of occupancy (s)***	***Result***
LoRa	0.052	20	2	0.104	PASS


Keysight Spectrum Analyzer - Swept SA
RF
50 Ω DC
SENSE:INT
SOURCE OFF
ALIGN AUTO
04:42:50 PM Apr 28, 2017
Sweep Time 20.00 s
NFE
PNO: Wide
IFGain:Low
Trig: Free Run
Atten: 40 dB
Avg Type: Log-Pwr
TRACE 1 2 3 4 5 6
TYPE W
DET N N N N N
Mkr1 1.018 ms
-76.64 dBm
10 dB/div
Log
Ref 30.00 dBm
20.0
10.0
0.00
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
Center 922.000000 MHz
Res BW 100 kHz
VBW 100 kHz
Span 0 Hz
Sweep 20.00 s (100001 pts)
MSG
STATUS
Trace/Detector
Select Trace
1
Clear Write
Trace Average
Max Hold
Min Hold
View Blank
Trace On
More
1 of 3

16 Maximum peak conducted output power

16.1 Definition

The maximum peak conducted output power is defined as the maximum power level measured with a peak detector using a filter with width and shape of which is sufficient to accept the signal bandwidth.

16.2 Test Parameters

Test Location:	Element Hull
Test Chamber:	Lab 4
Test Standard and Clause:	ANSI C63.10-2013, Clause 7.8.5
EUT Channels / Frequencies Measured:	Low / Mid / High – hopping disabled.
EUT Channel Bandwidths:	200 kHz
Deviations From Standard:	None
Measurement BW:	3 kHz
Spectrum Analyzer Video BW:	10 kHz
Measurement Detector:	Peak
Voltage Extreme Environment Test Range:	Mains Power = 85 % and 115 % of Nominal (FCC only requirement); Battery Power = new battery.

Environmental Conditions (Normal Environment)

Temperature: 22 °C	+15 ºC to +35 ºC (as declared)
Humidity: 33 % RH	20 % RH to 75 % RH (as declared)

16.3 Test Limit

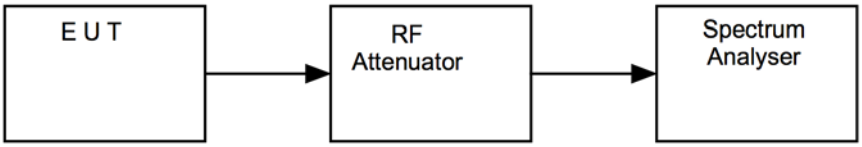
- For frequency hopping systems operating in the band 902 to 928 MHz, the maximum peak conducted output power shall not exceed 1 W, and the e.i.r.p. shall not exceed 4 W, if the hopset uses 50 or more hopping channels;
  the maximum peak conducted output power shall not exceed 0.25 W, and the e.i.r.p. shall not exceed 1 W, if the hopset uses less than 50 hopping channels.
- For frequency hopping systems operating in the band 2400 to 2483.5 MHz and employing at least 75 hopping channels, the maximum peak conducted output power shall not exceed 1 W;
  for all other frequency hopping systems in the band, the maximum peak conducted output power shall not exceed 0.125 W. The e.i.r.p. shall not exceed 4 W.
- For frequency hopping systems operating in the band 5725 to 5850 MHz, the maximum peak conducted output power shall not exceed 1 W. The e.i.r.p. shall not exceed 4 W.
- Point-to-point systems in the bands 2400-2483.5 MHz and 5725 to 5850 MHz are permitted to have an e.i.r.p. higher than 4 W provided that the higher e.i.r.p. is achieved by employing higher gain directional antennas and not higher transmitter output powers.

16.4 Test Method

With the EUT setup as per section 9 of this report and connected as per Figure vi, the resolution bandwidth of the spectrum analyser was increased above the EUT occupied bandwidth and the peak emission data noted.

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

Figure vi Test Setup



16.5 Test Equipment

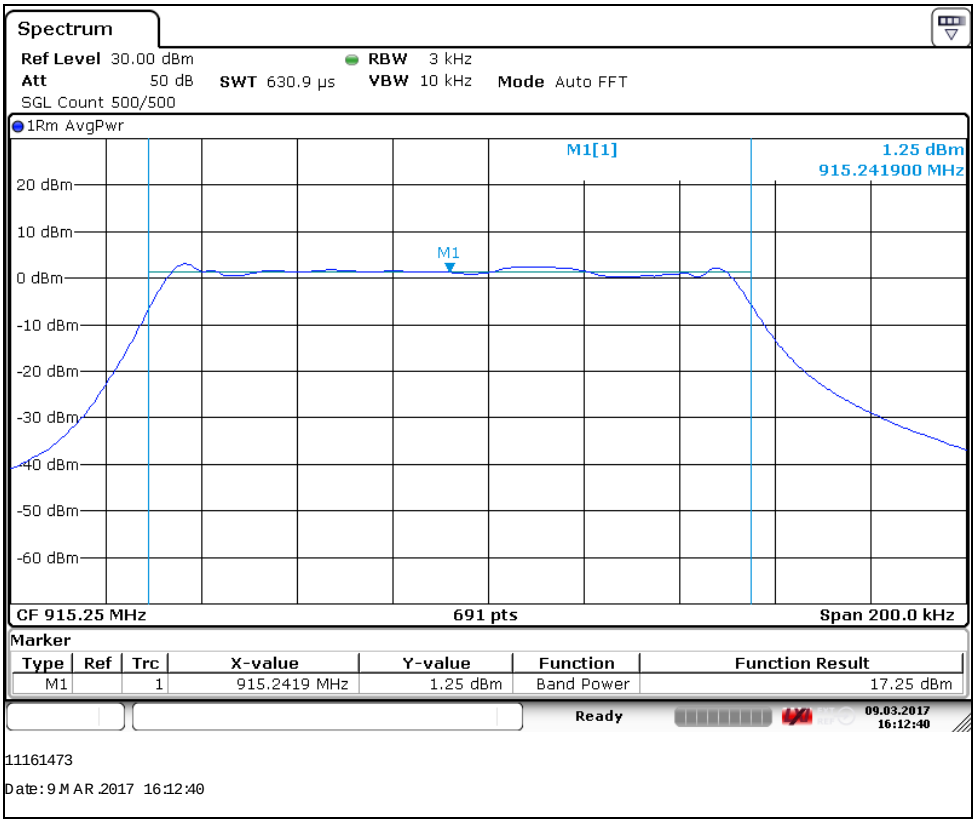
Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
FSV	Rohde & Schwarz	Spectrum Analyser	N/A	07/06/2017

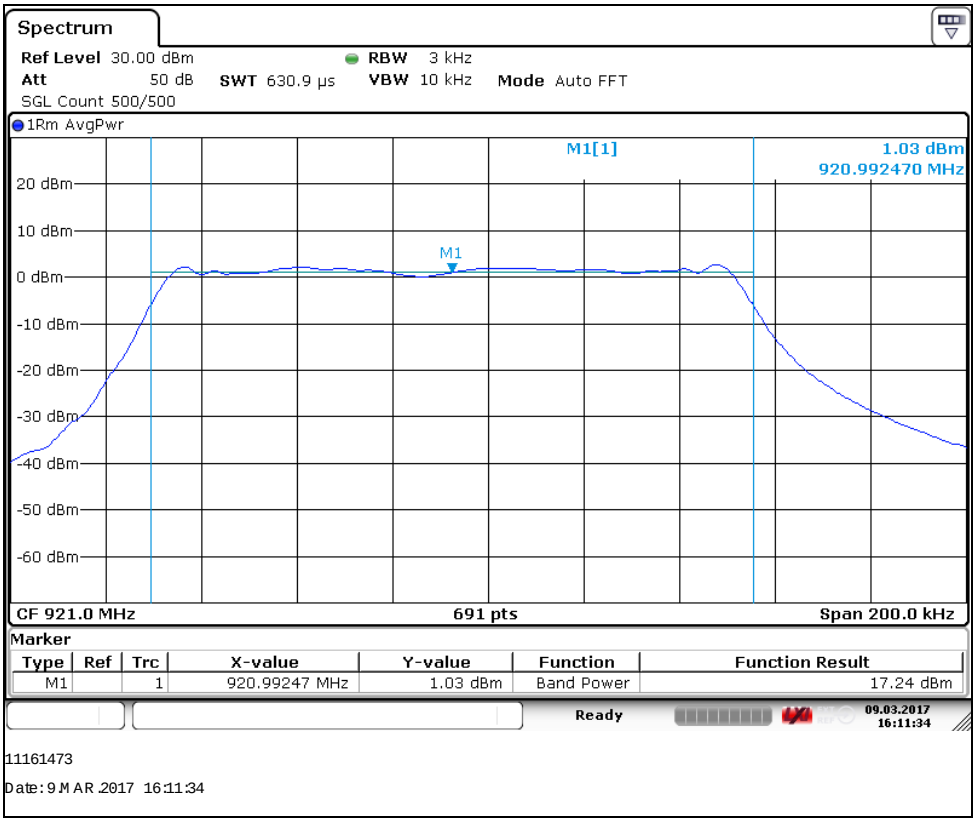
16.6 Test Results

Modulation: LoRa; Data rate: LoRa; Power setting: 0x0F						
Channel Frequency (MHz)	***Analyzer Level (dBm)***	***Cable loss (dB)***	***Maximum peak conducted output power (W)***	***Antenna gain (dBi)***	***E.I.R.P. (W)***	***Result***
915.25	1.25	0	0.001333	6 (max)	0.005309	PASS
921.00	1.03	0	0.001268	6 (max)	0.005047	PASS
927.50	1.25	0	0.001333	6 (max)	0.005309	PASS

Antennas used by all three products covered by this report were < 6 dBi gain, 6 dBi was used as a worst case to cover all products.

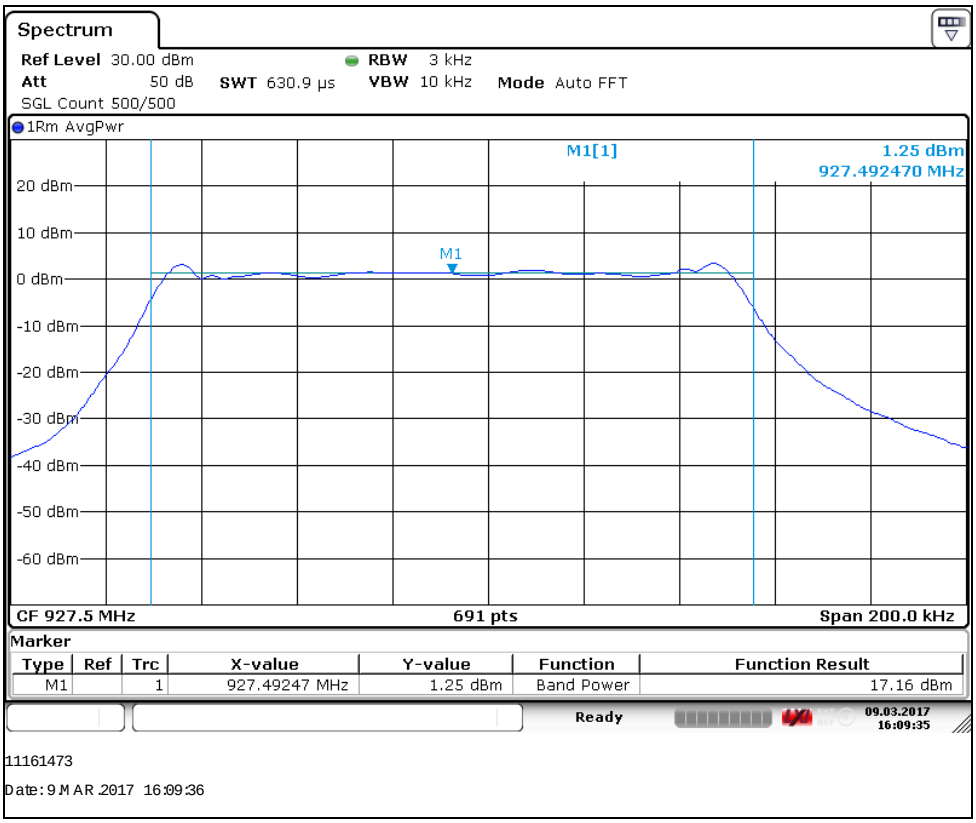
Measurements were made using the AVGSA-1 method detailed in 558074 D01 DTS Meas Guidance v04





11161473

Date: 9.MAR.2017 16:11:34



11161473

Date: 9.MAR.2017 16:09:36

17 Occupied Bandwidth

17.1 Definition

The emission bandwidth (x dB) is defined as the frequency range between two points, one above and one below the carrier frequency, at which the spectral density of the emission is attenuated x dB below the maximum in-band spectral density of the modulated signal.

17.2 Test Parameters

Test Location:	Element Hull
Test Chamber:	Lab 4
Test Standard and Clause:	ANSI C63.10-2013, Clause 6.9
EUT Channels / Frequencies Measured:	Low / Mid / High – hopping stopped.
EUT Channel Bandwidths:	
EUT Test Modulations:	LoRa
Deviations From Standard:	None
Measurement BW: (requirement: 1 % to 5 % OBW)	100 kHz (DSSS), 4.7 (FHSS)
Spectrum Analyzer Video BW: (requirement at least 3x RBW)	, 47 (FHSS)
Measurement Span: (requirement 2 to 5 times OBW)	1 MHz
Measurement Detector:	Peak

Environmental Conditions (Normal Environment)

Temperature: 21 °C	+15 ºC to +35 ºC (as declared)
Humidity: 32 % RH	20 % RH to 75 % RH (as declared)
Supply: 6 V dc	

17.3 Test Limit

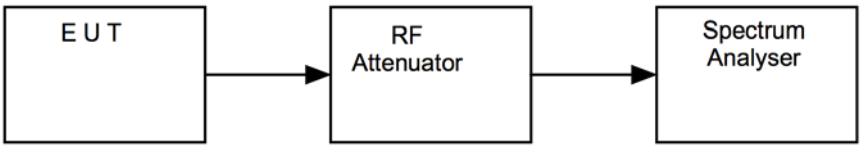
- For frequency hopping systems in the band 902 to 928 MHz: The maximum allowed -20 dB bandwidth of the hopping channel is 500 kHz.
- Frequency hopping systems operating in the band 5725 to 5850 MHz: The maximum -20 dB bandwidth of the hopping channel shall be 1 MHz

17.4 Test Method

With the EUT setup as per section 9 of this report and connected as per Figure vii, the bandwidth of the EUT was measured on a spectrum analyser.

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

Figure vii Test Setup

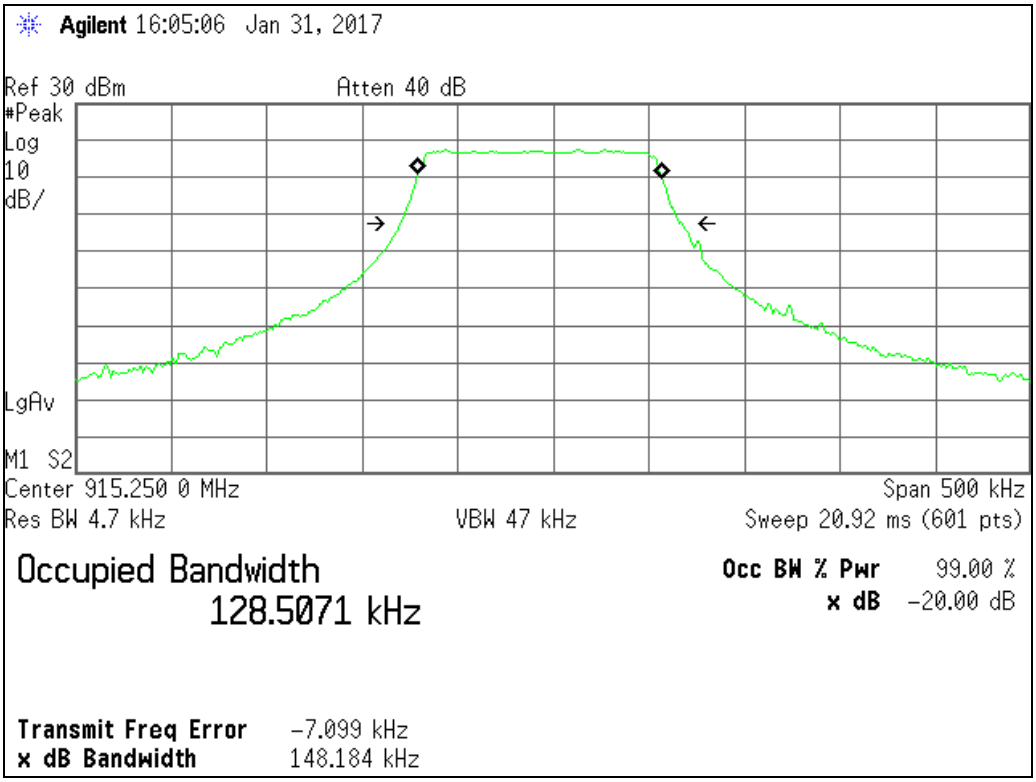


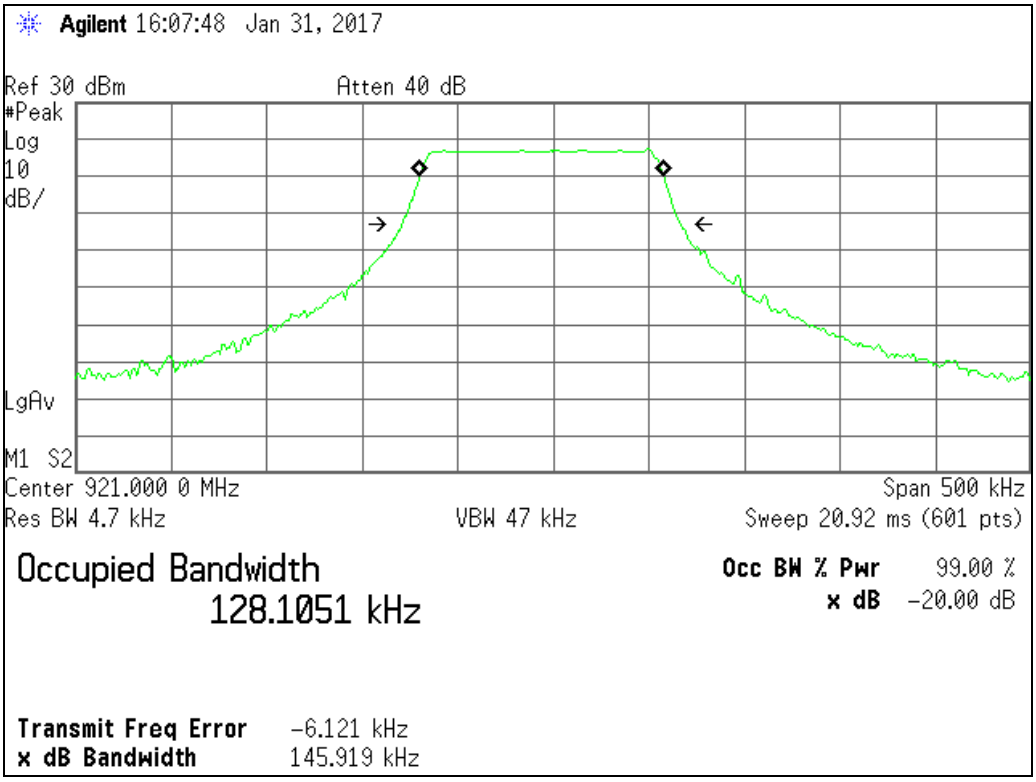
17.5 Test Equipment

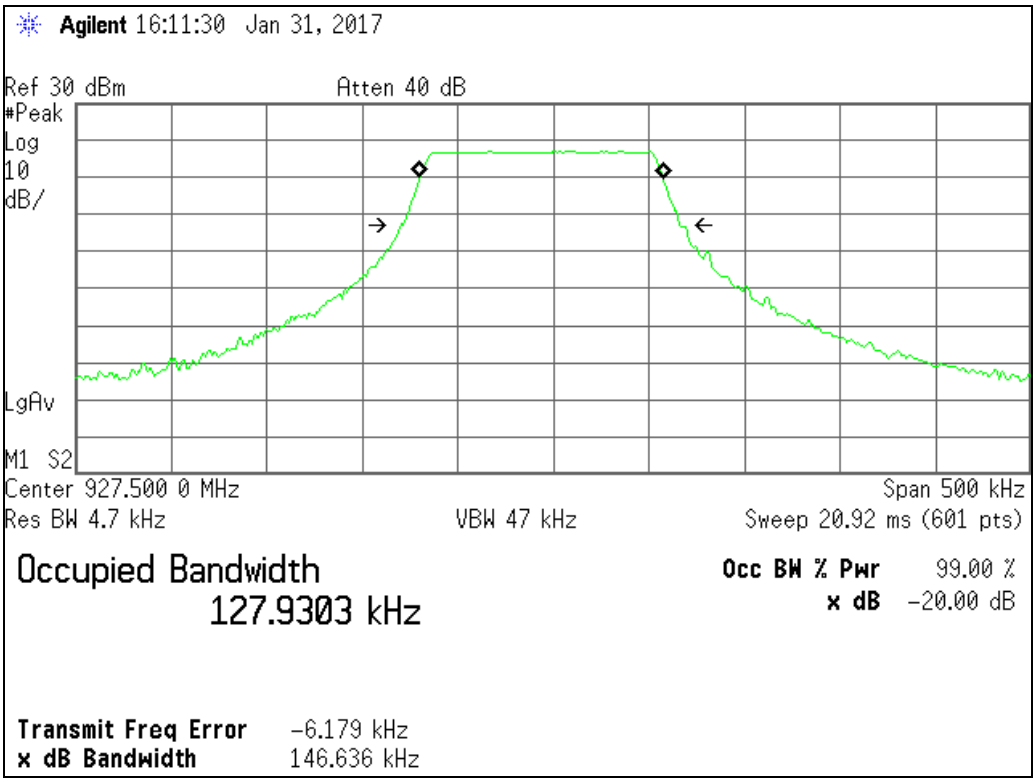
Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
E4440A	Agilent	Spectrum Analyser	REF837	22/06/2017

17.6 Test Results

Hybrid: FHSS requirement			
Modulation: LoRa; Data rate: LoRa; Power setting: 0x0F			
Channel Frequency (MHz)	***99% Bandwidth (kHz)***	***20dB Bandwidth (kHz)***	***Result***
915.25	128.5071	148.1840	PASS
921.00	128.1051	145.9190	PASS
927.50	127.9303	146.636	PASS




Agilent 16:07:48 Jan 31, 2017
Ref 30 dBm
Atten 40 dB
#Peak
Log
10
dB/
LgAv
M1 S2
Center 921.000 0 MHz
Span 500 kHz
Res BW 4.7 kHz
VBW 47 kHz
Sweep 20.92 ms (601 pts)
Occupied Bandwidth
128.1051 kHz
Occ BW % Pwr 99.00 %
x dB -20.00 dB
Transmit Freq Error -6.121 kHz
x dB Bandwidth 145.919 kHz


Agilent 16:11:30 Jan 31, 2017
Ref 30 dBm
Atten 40 dB
#Peak
Log
10
dB/
LgAv
M1 S2
Center 927.500 0 MHz
Span 500 kHz
Res BW 4.7 kHz
VBW 47 kHz
Sweep 20.92 ms (601 pts)
Occupied Bandwidth
127.9303 kHz
Occ BW % Pwr 99.00 %
x dB -20.00 dB
Transmit Freq Error -6.179 kHz
x dB Bandwidth 146.636 kHz

18 Out-of-band and conducted spurious emissions

18.1 Definition

Out-of-band emission.
Emission on a frequency or frequencies immediately outside the necessary bandwidth that results from the modulation process but excluding spurious emissions.

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

18.2 Test Parameters

Test Location:	Element Hull
Test Chamber:	Lab 4
Test Standard and Clause:	ANSI C63.10-2013, Clause 7.8.8
EUT Channels / Frequencies Measured:	Low / Mid / High
EUT Channel Bandwidths:	200 kHz
Deviations From Standard:	None
Measurement BW:	100 kHz
Spectrum Analyzer Video BW: (requirement at least 3x RBW)	300 kHz
Measurement Detector:	Peak
Measurement Range:	30 MHz to 26.5 GHz

Environmental Conditions (Normal Environment)

Temperature: 22 °C	+15 ºC to +35 ºC (as declared)
Humidity: 33 % RH	20 % RH to 75 % RH (as declared)
Supply: 6V dc	

18.3 Test Limits

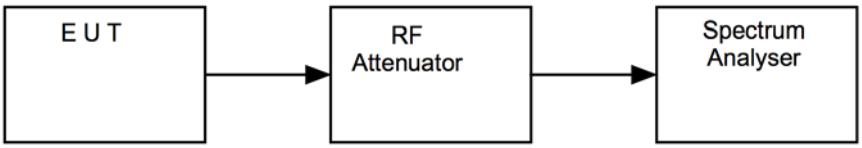
In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated device is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided that the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of root-mean-square averaging over a time interval, the attenuation required shall be 30 dB instead of 20 dB. Attenuation below the general field strength limits specified in FCC 47CFR15.209(a) / RSS-Gen is not required.

18.4 Test Method

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

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

Figure viii Test Setup



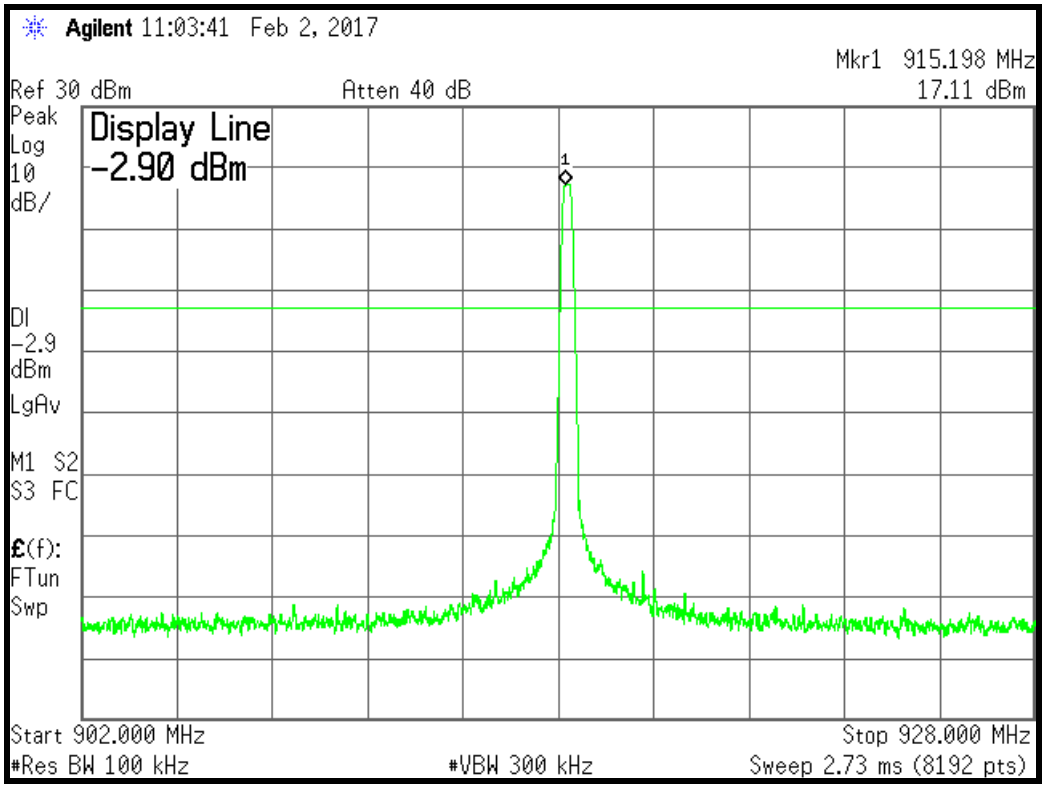
18.5 Test Equipment

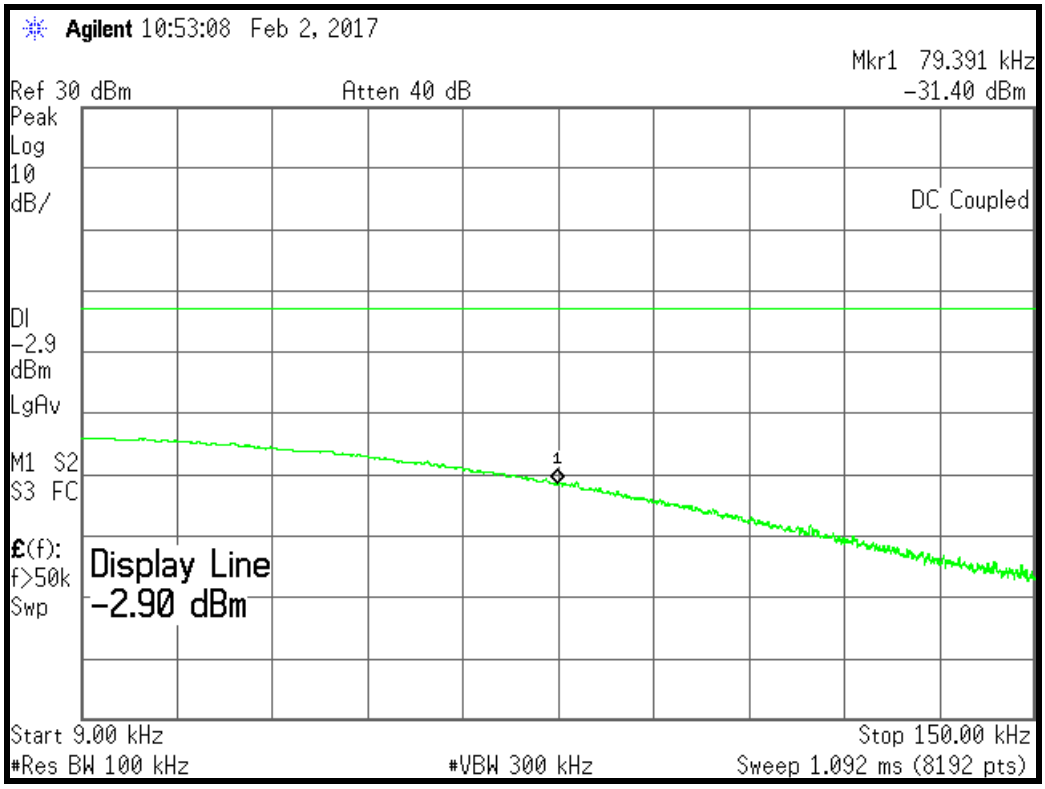
Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
E4440A	Agilent	Spectrum Analyser	REF837	22/06/2017

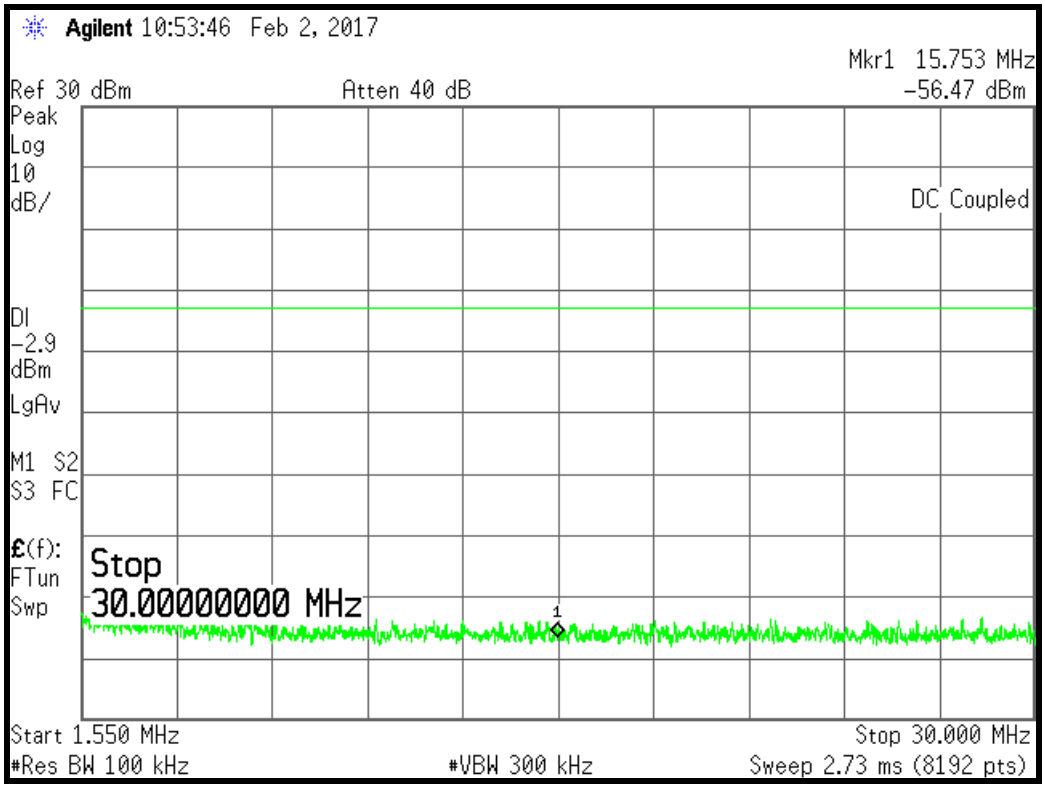
18.6 Test Results

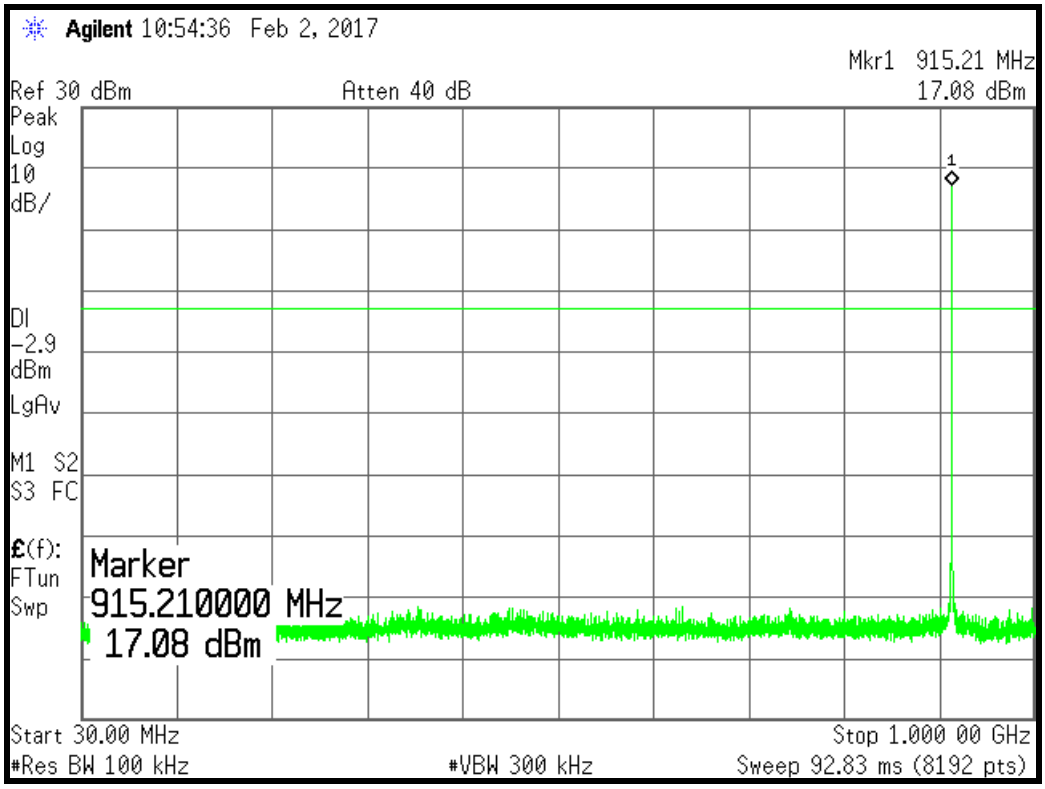
Modulation: LoRa; Data rate: LoRa; Power setting: 0x0F						
Channel Frequency (MHz)	***Emission Frequency (MHz)***	***Analyzer Level (dBm)***	***Emission Level (dBm)***	***Limit (dBm)***	***Margin (dB)***	***Result***
915.25	915.217	17.11	17.11	N/A	N/A	PASS

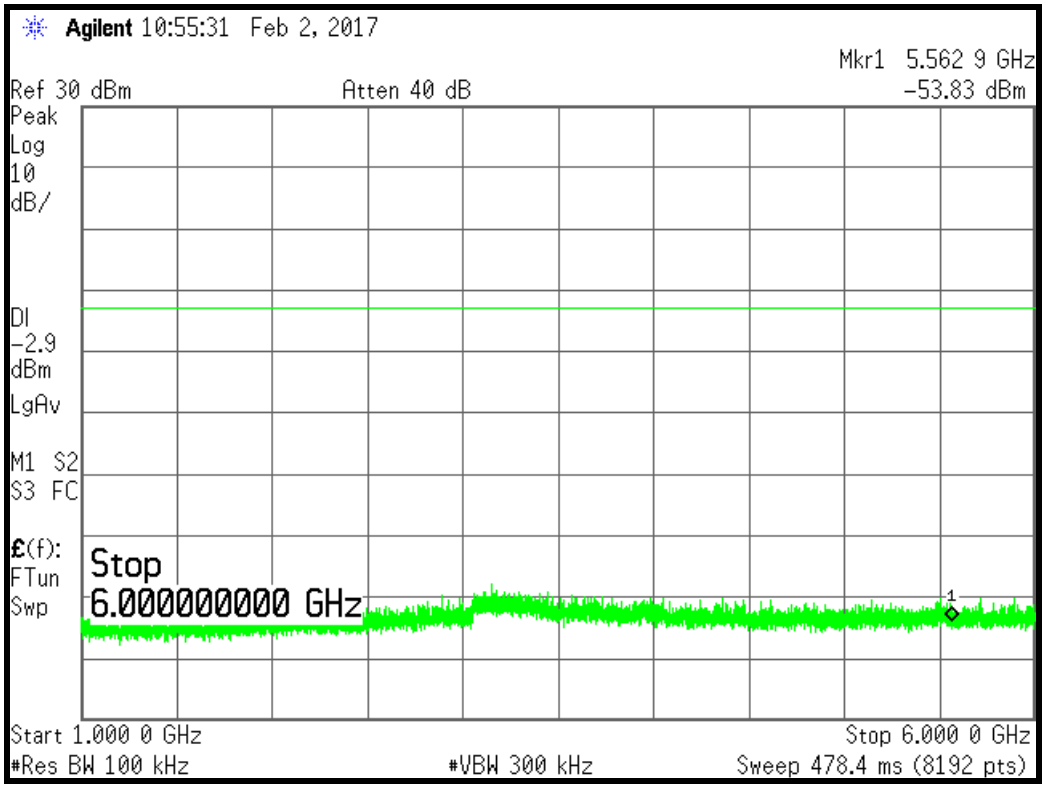
Plots show limit line 20 dB below the peak fundamental, all spurious signals are > 20dB below this limit and so also comply with a limit line 30 dB below the peak fundamental. (Average PSD measurements were made due to the Hybrid mode).

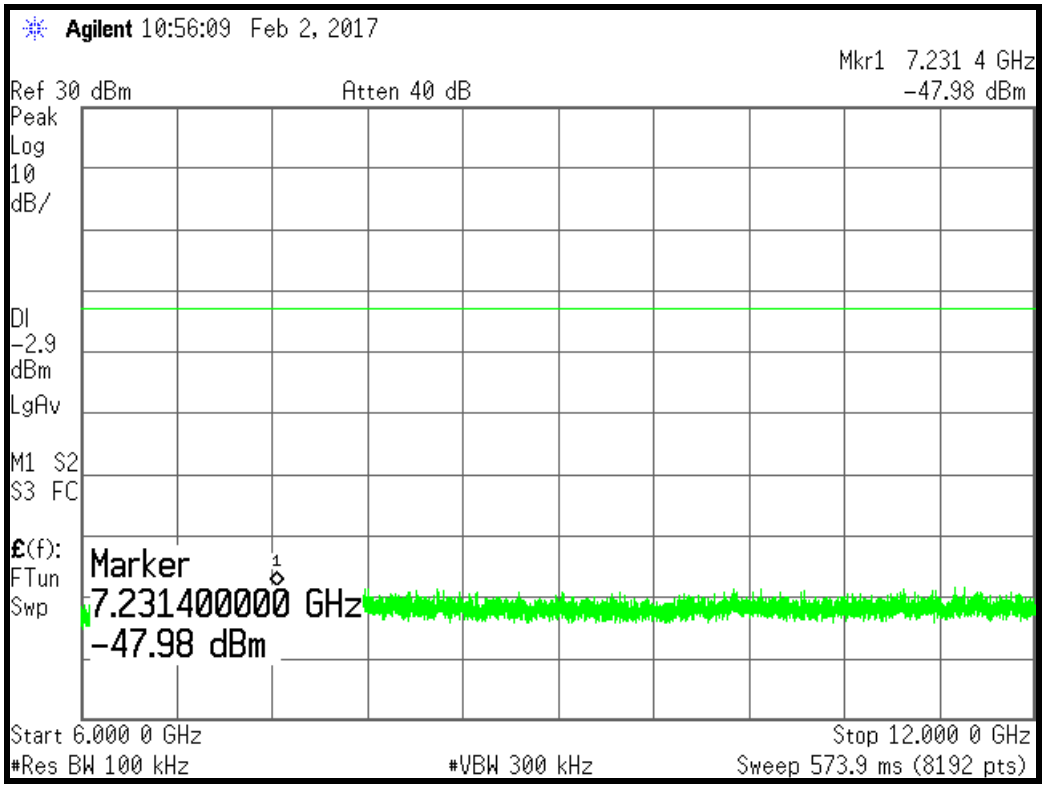



Agilent 10:53:08 Feb 2, 2017
Mkr1 79.391 kHz
Ref 30 dBm
Atten 40 dB
-31.40 dBm
Peak
Log
10
dB/
DC Coupled
Dl
-2.9
dBm
LgAv
M1 S2
S3 FC
£(f):
f>50k
Swp
Display Line
-2.90 dBm
Start 9.00 kHz
Stop 150.00 kHz
#Res BW 100 kHz
#VBW 300 kHz
Sweep 1.092 ms (8192 pts)


Agilent 10:53:46 Feb 2, 2017
Mkr1 15.753 MHz
Ref 30 dBm
Atten 40 dB
-56.47 dBm
Peak
Log
10
dB/
DC Coupled
Dl
-2.9
dBm
LgAv
M1 S2
S3 FC
£(f):
FTun
Swp
Stop
30.00000000 MHz
Start 1.550 MHz
Stop 30.000 MHz
#Res BW 100 kHz
#VBW 300 kHz
Sweep 2.73 ms (8192 pts)

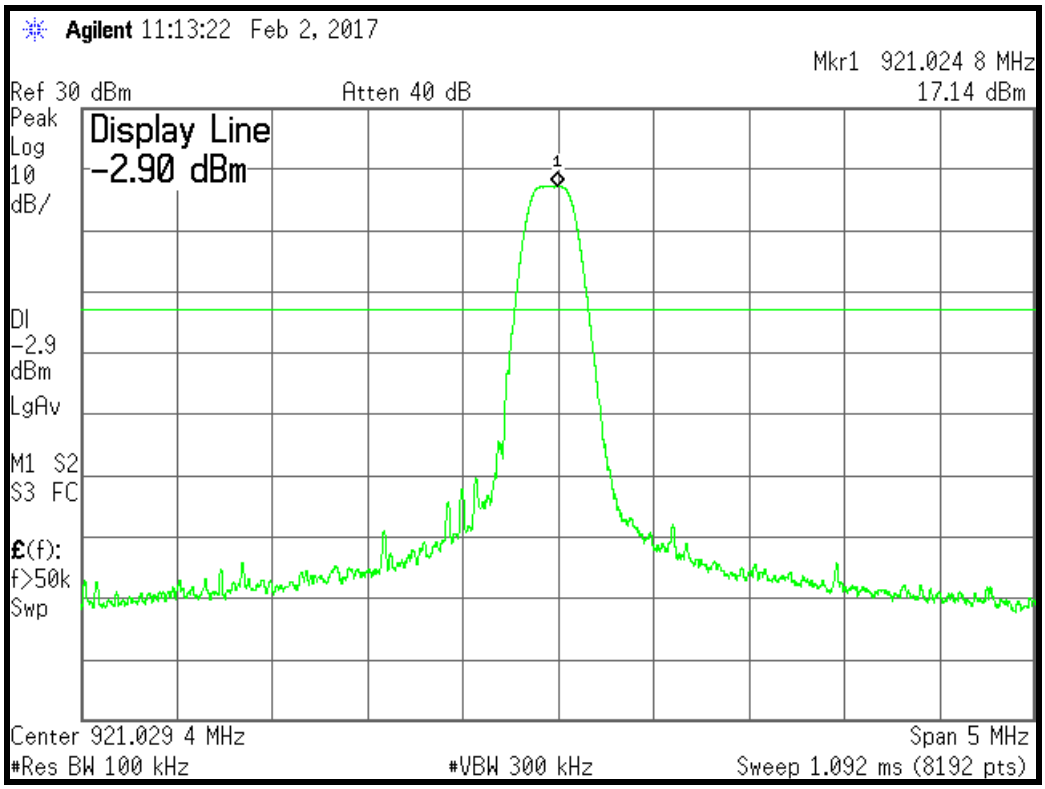

Agilent 10:54:36 Feb 2, 2017
Mkr1 915.21 MHz
Ref 30 dBm
Atten 40 dB
17.08 dBm
Peak
Log
10
dB/
Dl
-2.9
dBm
LgAv
M1 S2
S3 FC
£(f):
FTun
Swp
Marker
915.210000 MHz
17.08 dBm
Start 30.00 MHz
Stop 1.000 00 GHz
#Res BW 100 kHz
#VBW 300 kHz
Sweep 92.83 ms (8192 pts)

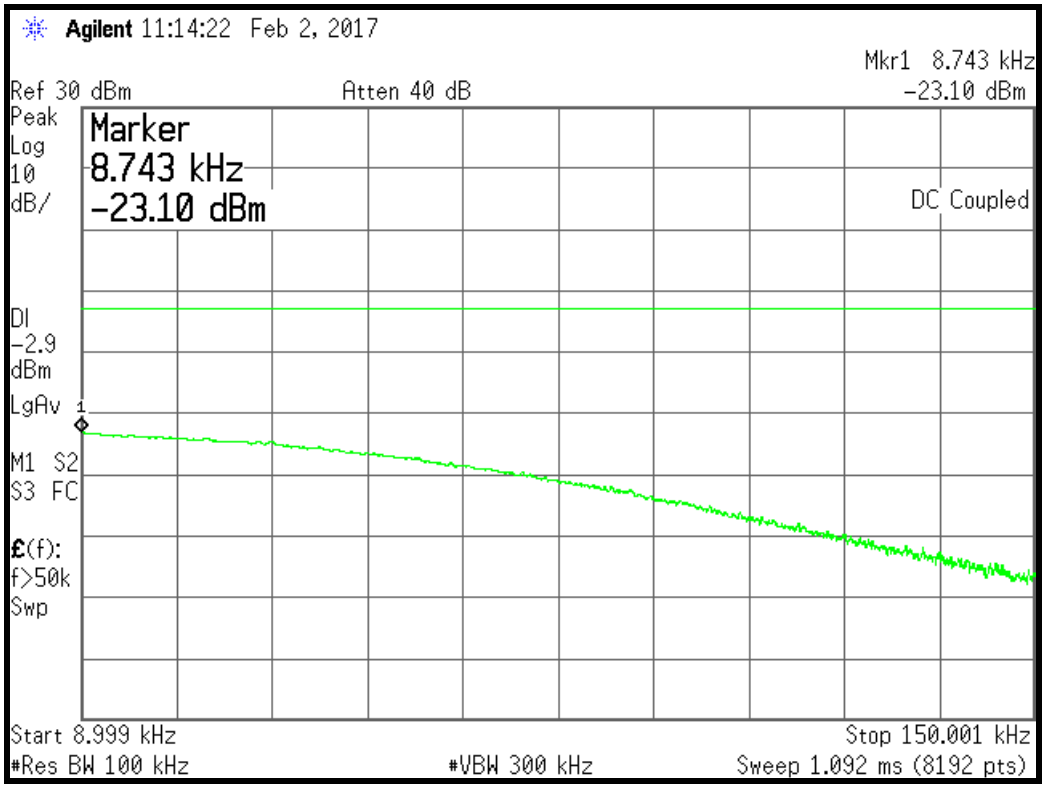

Agilent 10:55:31 Feb 2, 2017
Mkr1 5.562 9 GHz
Ref 30 dBm
Atten 40 dB
-53.83 dBm
Peak
Log
10
dB/
Dl
-2.9
dBm
LgAv
M1 S2
S3 FC
£(f):
FTun
Swp
Stop
6.000000000 GHz
Start 1.000 0 GHz
Stop 6.000 0 GHz
#Res BW 100 kHz
#VBW 300 kHz
Sweep 478.4 ms (8192 pts)

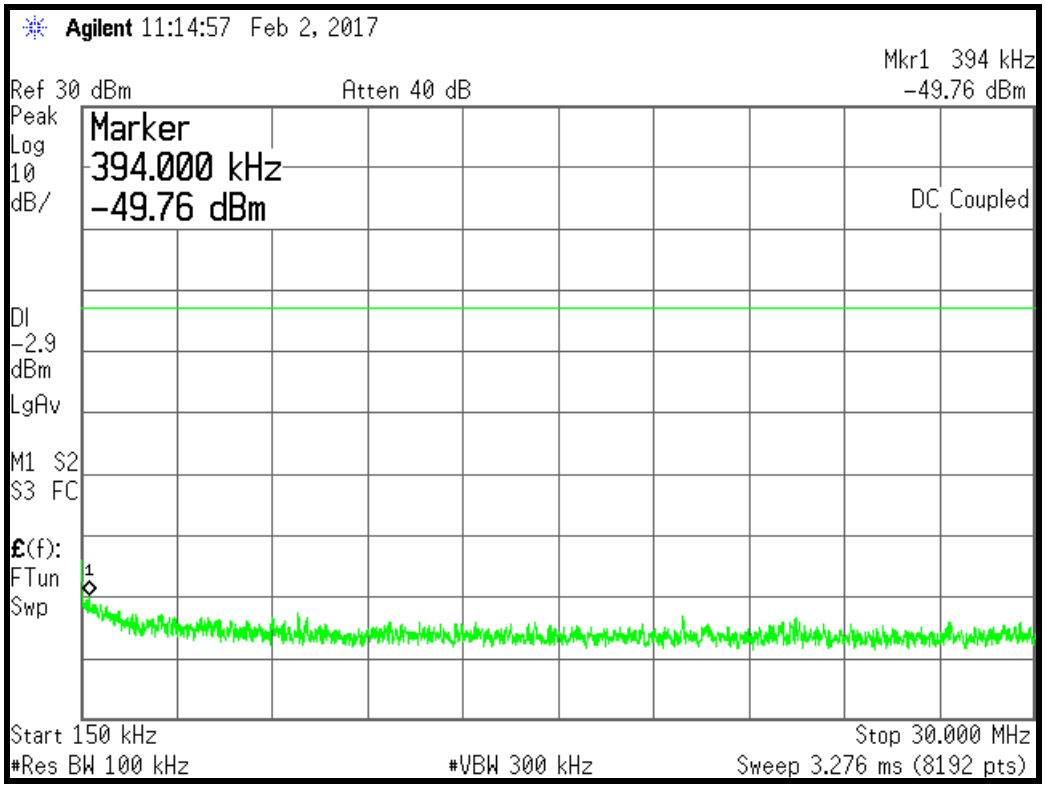

Agilent 10:56:09 Feb 2, 2017
Mkr1 7.231 4 GHz
Ref 30 dBm
Atten 40 dB
-47.98 dBm
Peak
Log
10
dB/
Dl
-2.9
dBm
LgAv
M1 S2
S3 FC
£(f):
FTun
Swp
Marker 1
7.231400000 GHz
-47.98 dBm
Start 6.000 0 GHz
Stop 12.000 0 GHz
#Res BW 100 kHz
#VBW 300 kHz
Sweep 573.9 ms (8192 pts)

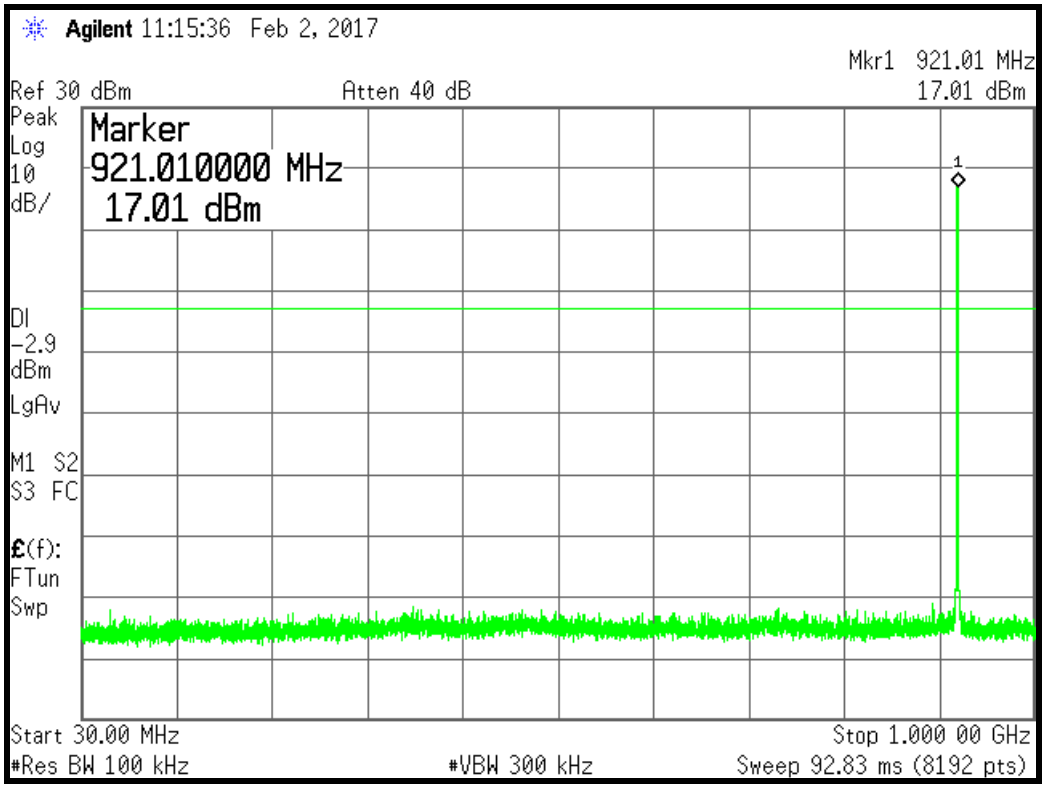
Modulation: LoRa; Data rate: LoRa; Power setting: 0x0F						
Channel Frequency (MHz)	***Emission Frequency (MHz)***	***Analyzer Level (dBm)***	***Emission Level (dBm)***	***Limit (dBm)***	***Margin (dB)***	***Result***
921.00	921.0248	17.14.9	17.14	N/A	N/A	PASS

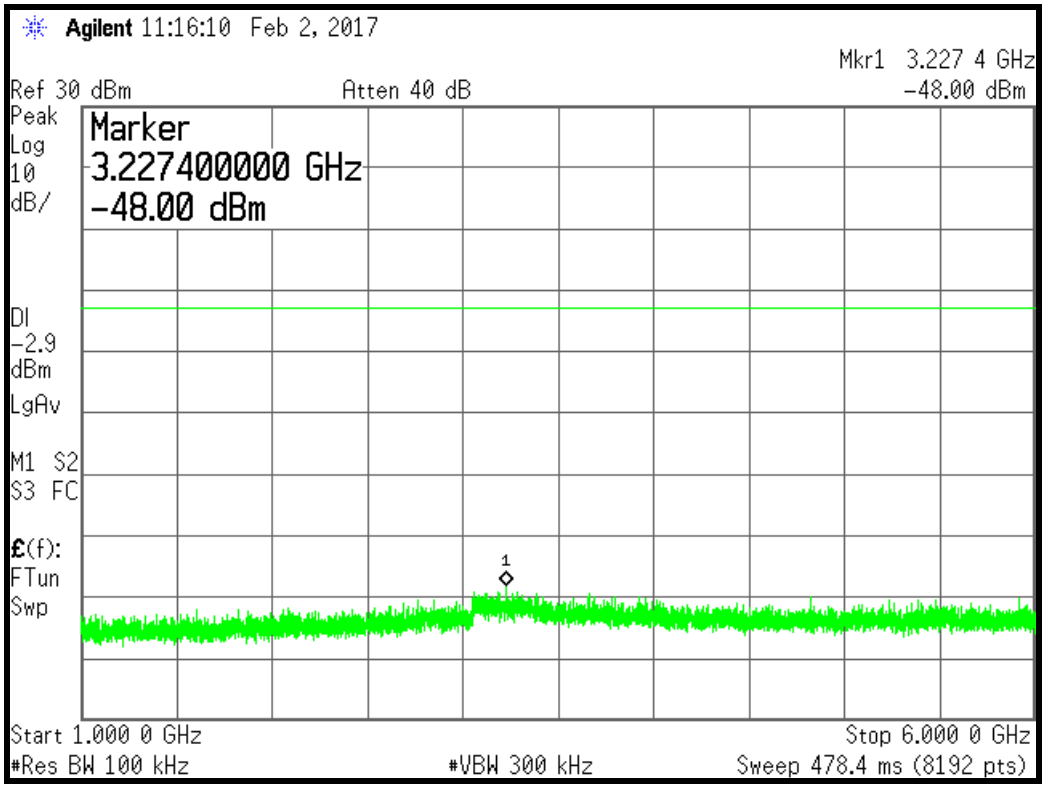
Plots show limit line 20 dB below the peak fundamental, all spurious signals are > 20dB below this limit and so also comply with a limit line 30 dB below the peak fundamental. (Average PSD measurements were made due to the Hybrid mode).

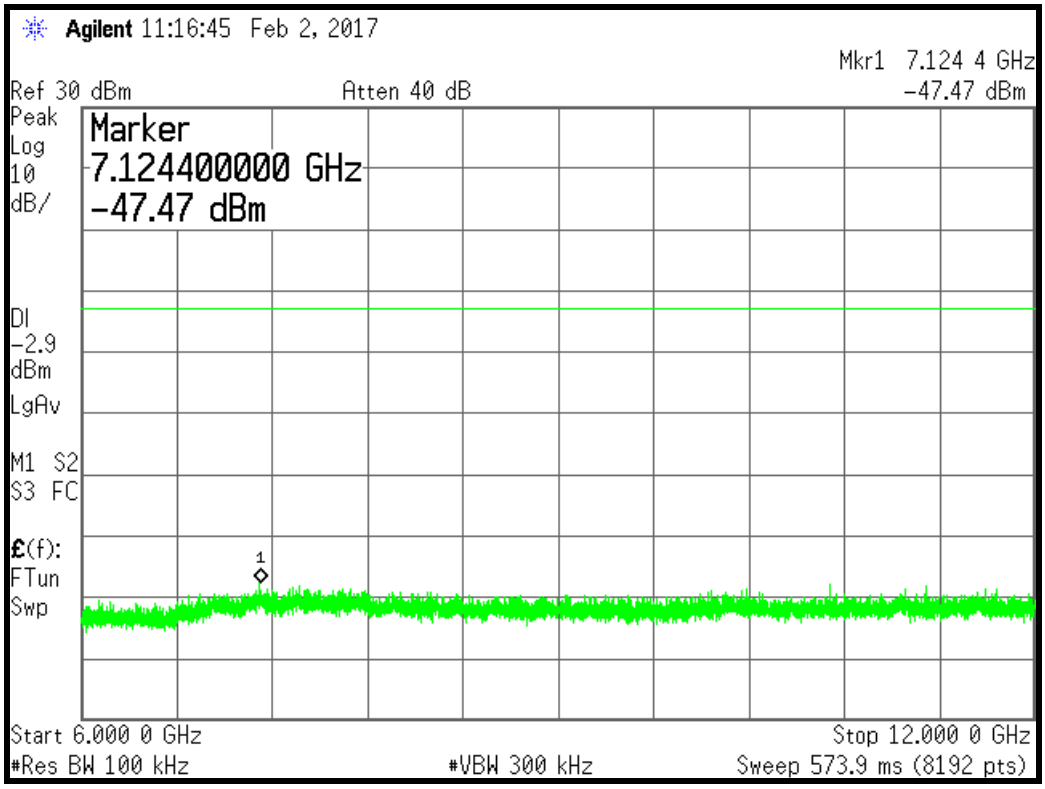



Agilent 11:14:22 Feb 2, 2017
Mkr1 8.743 kHz
Ref 30 dBm
Atten 40 dB
-23.10 dBm
Peak
Log
10
dB/
Marker
8.743 kHz
-23.10 dBm
DC Coupled
Dl
-2.9
dBm
LgAv
1
M1 S2
S3 FC
£(f):
f>50k
Swp
Start 8.999 kHz
Stop 150.001 kHz
#Res BW 100 kHz
#VBW 300 kHz
Sweep 1.092 ms (8192 pts)


Agilent 11:14:57 Feb 2, 2017
Mkr1 394 kHz
Ref 30 dBm
Atten 40 dB
-49.76 dBm
Peak
Log
10
dB/
Marker
394.000 kHz
-49.76 dBm
DC Coupled
Dl
-2.9
dBm
LgAv
M1 S2
S3 FC
£(f):
FTun
Swp
1
Start 150 kHz
Stop 30.000 MHz
#Res BW 100 kHz
#VBW 300 kHz
Sweep 3.276 ms (8192 pts)

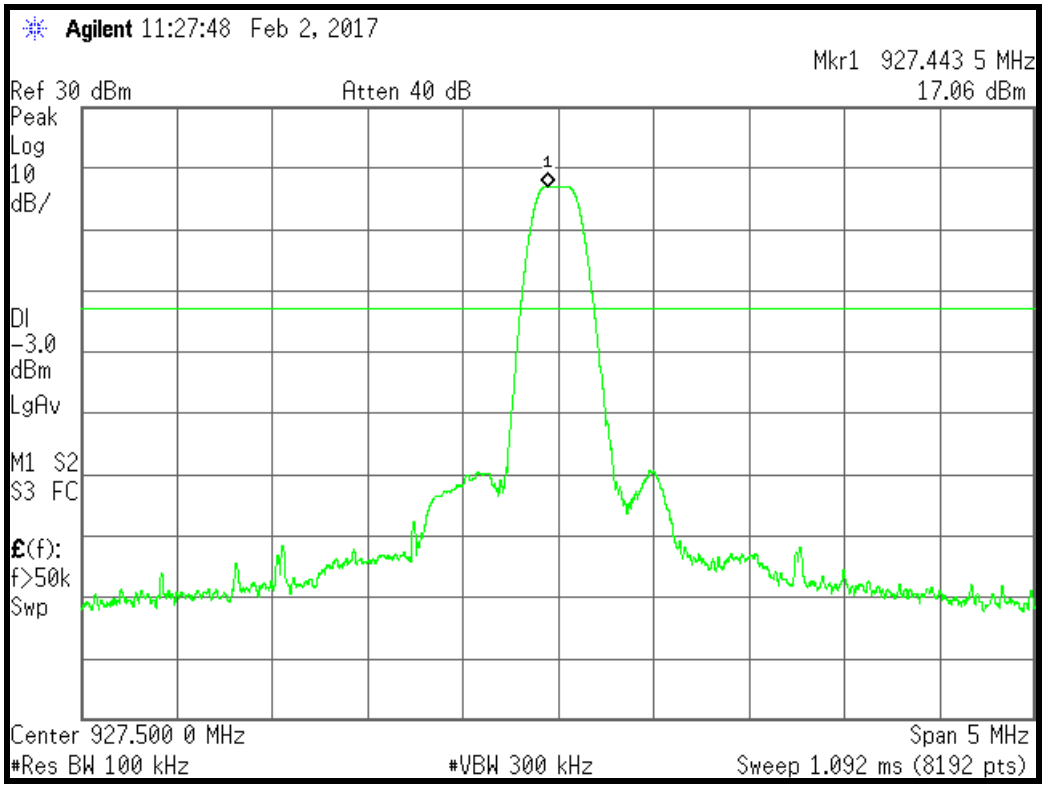

Agilent 11:15:36 Feb 2, 2017
Mkr1 921.01 MHz
17.01 dBm
Ref 30 dBm
Atten 40 dB
Peak
Log
10
dB/
Marker
921.010000 MHz
17.01 dBm
Dl
-2.9
dBm
LgAv
M1 S2
S3 FC
£(f):
FTun
Swp
Start 30.00 MHz
Stop 1.000 00 GHz
#Res BW 100 kHz
#VBW 300 kHz
Sweep 92.83 ms (8192 pts)

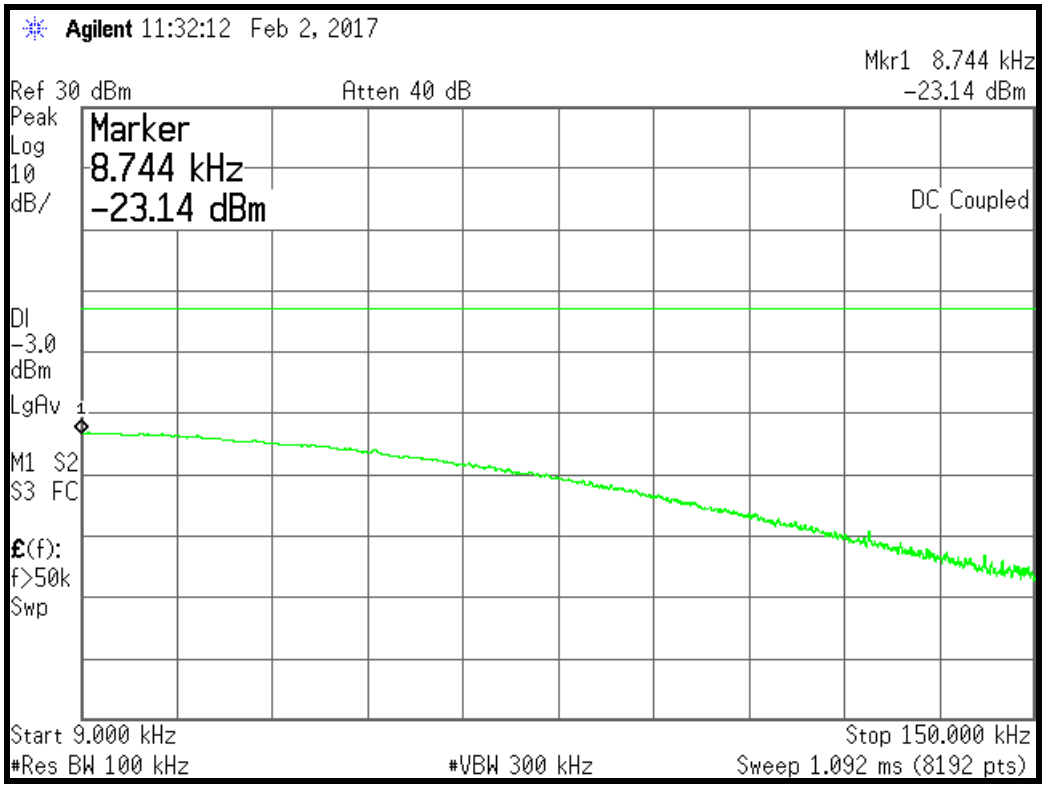

Agilent 11:16:10 Feb 2, 2017
Mkr1 3.227 4 GHz
-48.00 dBm
Ref 30 dBm
Atten 40 dB
Peak
Log
10
dB/
Marker
3.227400000 GHz
-48.00 dBm
Dl
-2.9
dBm
LgAv
M1 S2
S3 FC
£(f):
FTun
Swp
Start 1.000 0 GHz
Stop 6.000 0 GHz
#Res BW 100 kHz
#VBW 300 kHz
Sweep 478.4 ms (8192 pts)

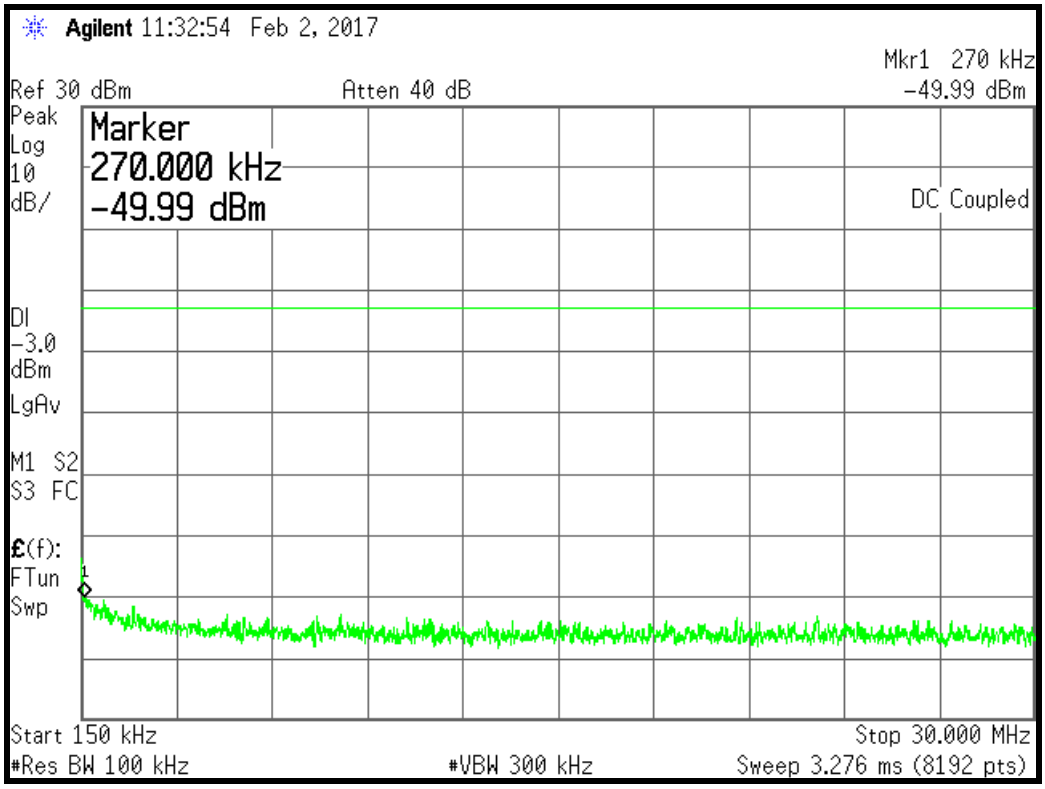

Agilent 11:16:45 Feb 2, 2017
Mkr1 7.124 4 GHz
Ref 30 dBm
Atten 40 dB
-47.47 dBm
Peak
Log
10
dB/
Marker
7.124400000 GHz
-47.47 dBm
Dl
-2.9
dBm
LgAv
M1 S2
S3 FC
£(f):
FTun
Swp
Start 6.000 0 GHz
Stop 12.000 0 GHz
#Res BW 100 kHz
#VBW 300 kHz
Sweep 573.9 ms (8192 pts)

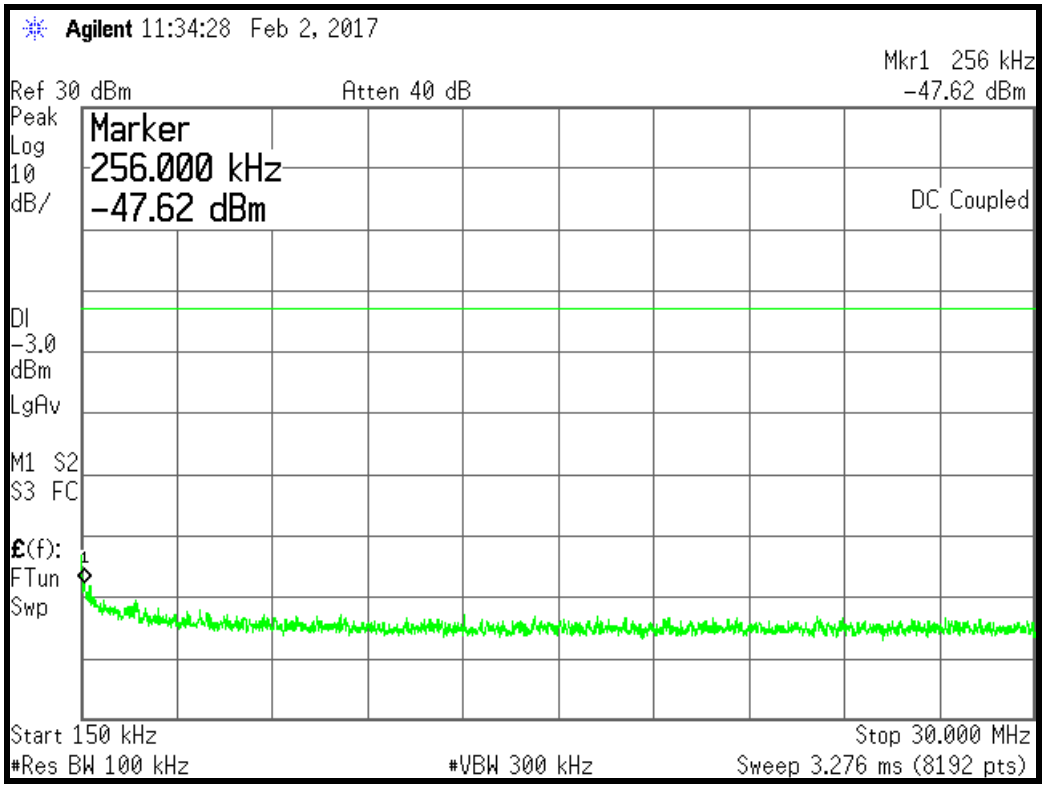
Modulation: LoRa; Data rate: LoRa; Power setting: 0x0F						
Channel Frequency (MHz)	***Emission Frequency (MHz)***	***Analyzer Level (dBm)***	***Emission Level (dBm)***	***Limit (dBm)***	***Margin (dB)***	***Result***
927.50	927.4435	17.06	17.06	N/A	N/A	PASS

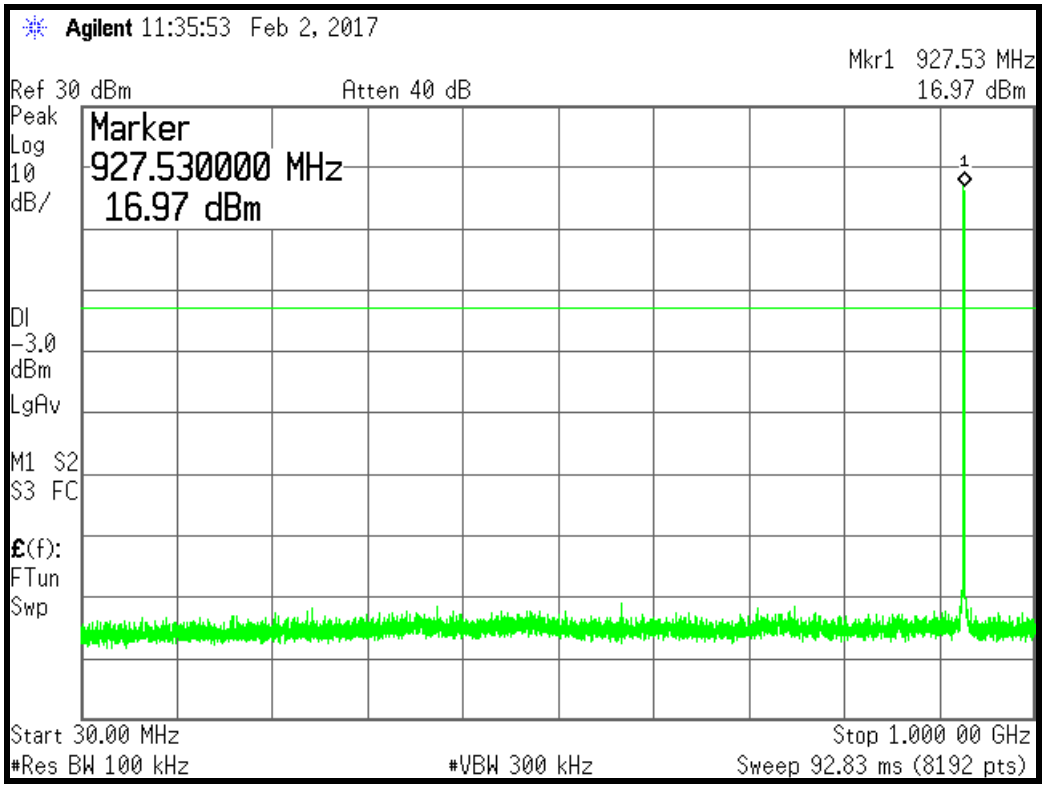
Plots show limit line 20 dB below the peak fundamental, all spurious signals are > 20dB below this limit and so also comply with a limit line 30 dB below the peak fundamental. (Average PSD measurements were made due to the Hybrid mode).

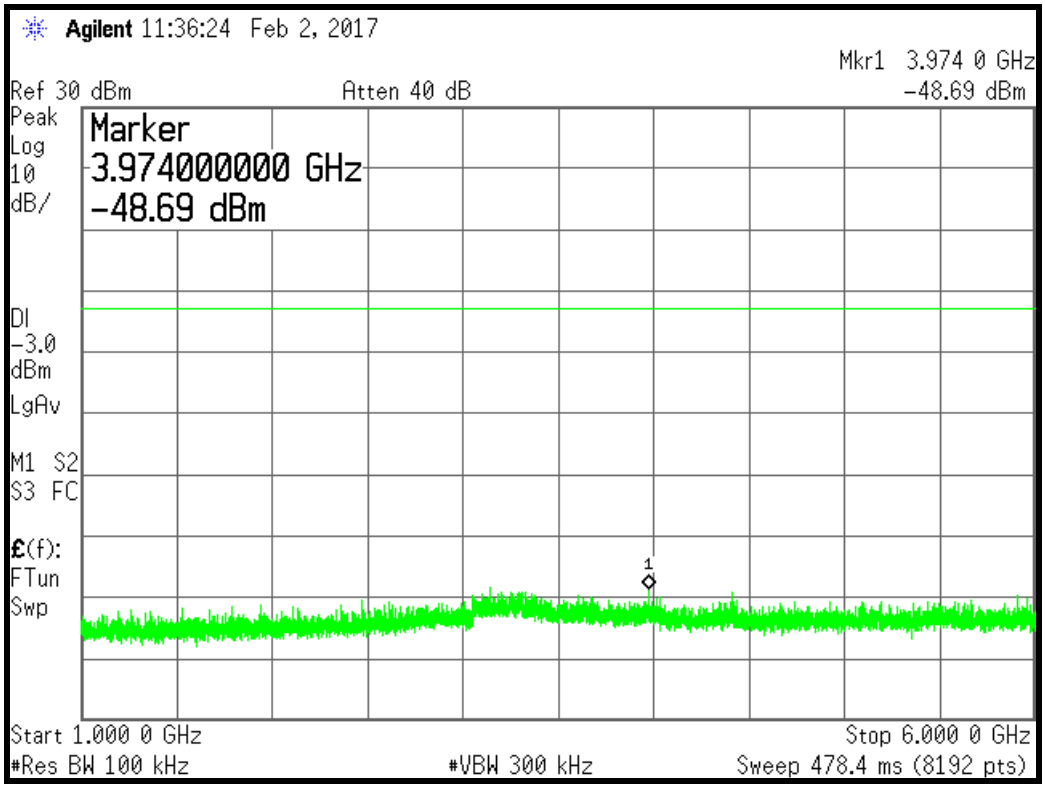


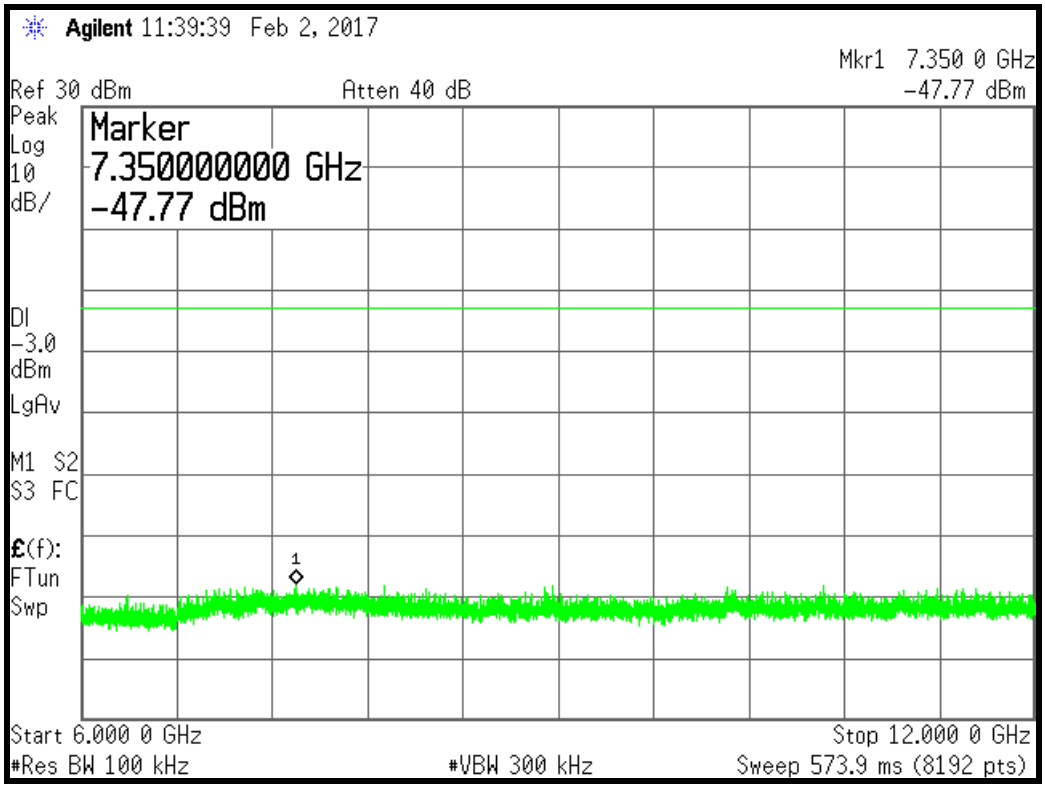

Agilent 11:32:12 Feb 2, 2017
Mkr1 8.744 kHz
Ref 30 dBm
Atten 40 dB
-23.14 dBm
Peak
Log
10
dB/
Marker
8.744 kHz
-23.14 dBm
DC Coupled
Dl
-3.0
dBm
LgAv
M1 S2
S3 FC
£(f):
f>50k
Swp
Start 9.000 kHz
Stop 150.000 kHz
#Res BW 100 kHz
#VBW 300 kHz
Sweep 1.092 ms (8192 pts)

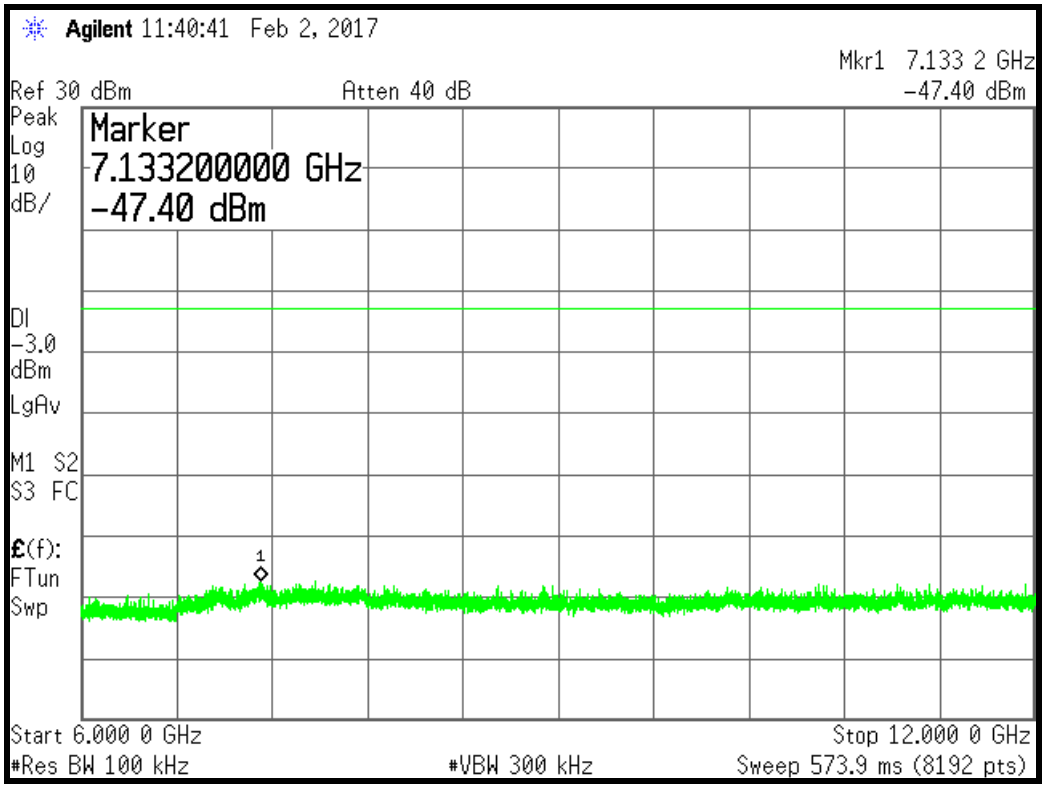

Agilent 11:32:54 Feb 2, 2017
Mkr1 270 kHz
Ref 30 dBm
Atten 40 dB
-49.99 dBm
Peak
Log
10
dB/
Marker
270.000 kHz
-49.99 dBm
DC Coupled
Dl
-3.0
dBm
LgAv
M1 S2
S3 FC
£(f):
FTun
Swp
Start 150 kHz
Stop 30.000 MHz
#Res BW 100 kHz
#VBW 300 kHz
Sweep 3.276 ms (8192 pts)


Agilent 11:34:28 Feb 2, 2017
Mkr1 256 kHz
-47.62 dBm
Ref 30 dBm
Atten 40 dB
Peak
Log
10
dB/
Marker
256.000 kHz
-47.62 dBm
DC Coupled
Dl
-3.0
dBm
LgAv
M1 S2
S3 FC
£(f):
FTun
Swp
Start 150 kHz
Stop 30.000 MHz
#Res BW 100 kHz
#VBW 300 kHz
Sweep 3.276 ms (8192 pts)

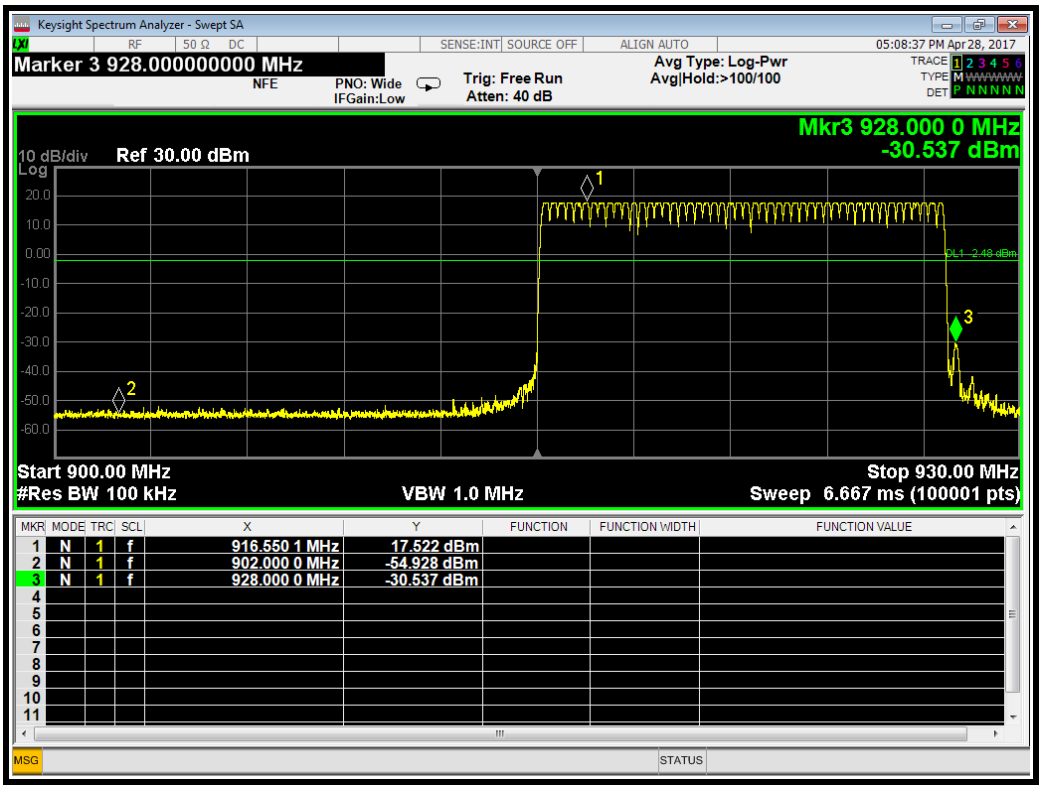

Agilent 11:35:53 Feb 2, 2017
Mkr1 927.53 MHz
16.97 dBm
Ref 30 dBm
Atten 40 dB
Peak
Log
10
dB/
Marker
927.530000 MHz
16.97 dBm
Dl
-3.0
dBm
LgAv
M1 S2
S3 FC
£(f):
FTun
Swp
Start 30.00 MHz
Stop 1.000 00 GHz
#Res BW 100 kHz
#VBW 300 kHz
Sweep 92.83 ms (8192 pts)


Agilent 11:36:24 Feb 2, 2017
Mkr1 3.974 0 GHz
Ref 30 dBm
Atten 40 dB
-48.69 dBm
Peak
Log
10
dB/
Marker
3.974000000 GHz
-48.69 dBm
Dl
-3.0
dBm
LgAv
M1 S2
S3 FC
£(f):
FTun
Swp
1
Start 1.000 0 GHz
Stop 6.000 0 GHz
#Res BW 100 kHz
#VBW 300 kHz
Sweep 478.4 ms (8192 pts)


Agilent 11:39:39 Feb 2, 2017
Mkr1 7.350 0 GHz
Ref 30 dBm
Atten 40 dB
-47.77 dBm
Peak
Log
10
dB/
Marker
7.350000000 GHz
-47.77 dBm
Dl
-3.0
dBm
LgAv
M1 S2
S3 FC
£(f):
FTun
Swp
1
Start 6.000 0 GHz
Stop 12.000 0 GHz
#Res BW 100 kHz
#VBW 300 kHz
Sweep 573.9 ms (8192 pts)


Agilent 11:40:41 Feb 2, 2017
Mkr1 7.133 2 GHz
Ref 30 dBm
Atten 40 dB
-47.40 dBm
Peak
Log
10
dB/
Marker
7.133200000 GHz
-47.40 dBm
Dl
-3.0
dBm
LgAv
M1 S2
S3 FC
£(f):
FTun
Swp
1
Start 6.000 0 GHz
Stop 12.000 0 GHz
#Res BW 100 kHz
#VBW 300 kHz
Sweep 573.9 ms (8192 pts)

Hopping mode Band Edge plot showing both Band Edges:



19 Power spectral density

19.1 Definition

The power per unit bandwidth.

19.2 Test Parameters

Test Location:	Element Hull
Test Chamber:	Lab 4
Test Standard and Clause:	ANSI C63.10-2013, Clause 11.10
EUT Channels / Frequencies Measured:	Low / Mid / High
EUT Channel Bandwidths:	200 kHz
Deviations From Standard:	None
Measurement BW:	3 kHz
Spectrum Analyzer Video BW: (requirement at least 3x RBW)	10 kHz
Measurement Span: (requirement 1.5 times Channel BW)	400 kHz
Measurement Detector:	Peak

Environmental Conditions (Normal Environment)

Temperature: 22 °C	+15 ºC to +35 ºC (as declared)
Humidity: 33 % RH	20 % RH to 75 % RH (as declared)
Supply: 6V dc	

19.3 Test Limit

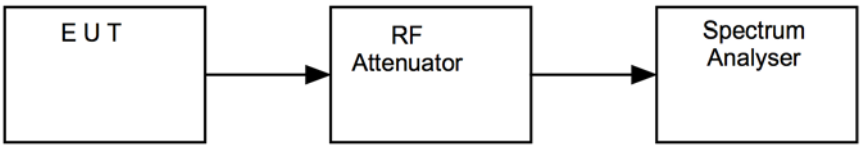
The transmitter power spectral density conducted from the transmitter to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.

19.4 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



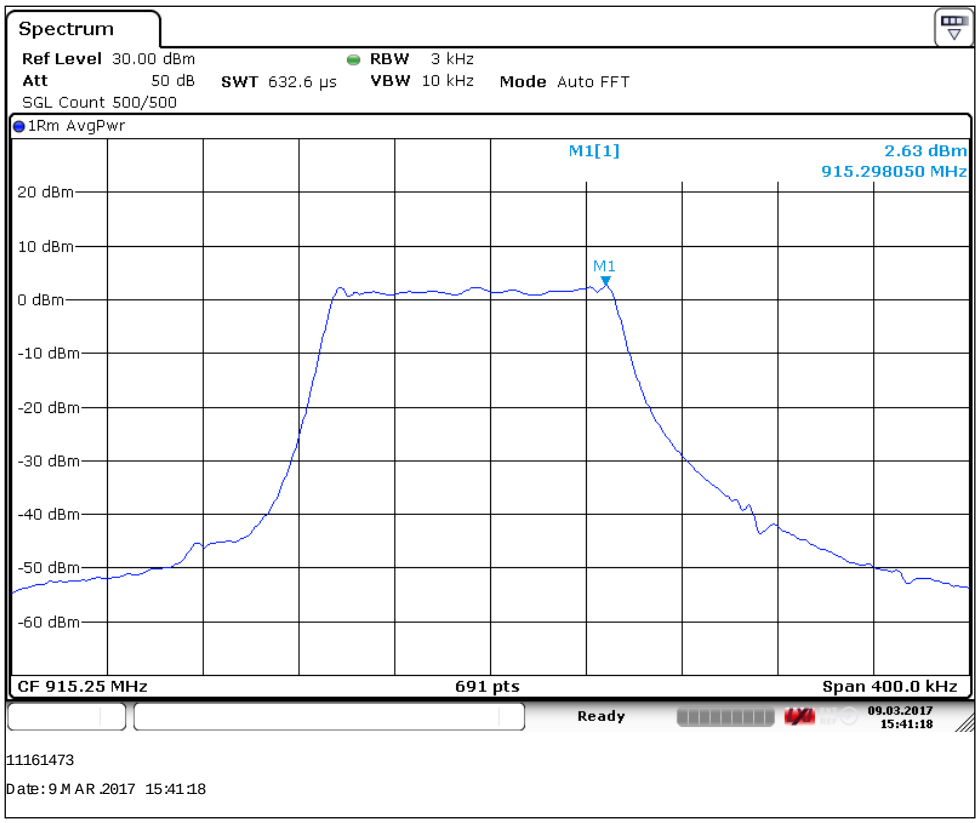
19.5 Test Equipment

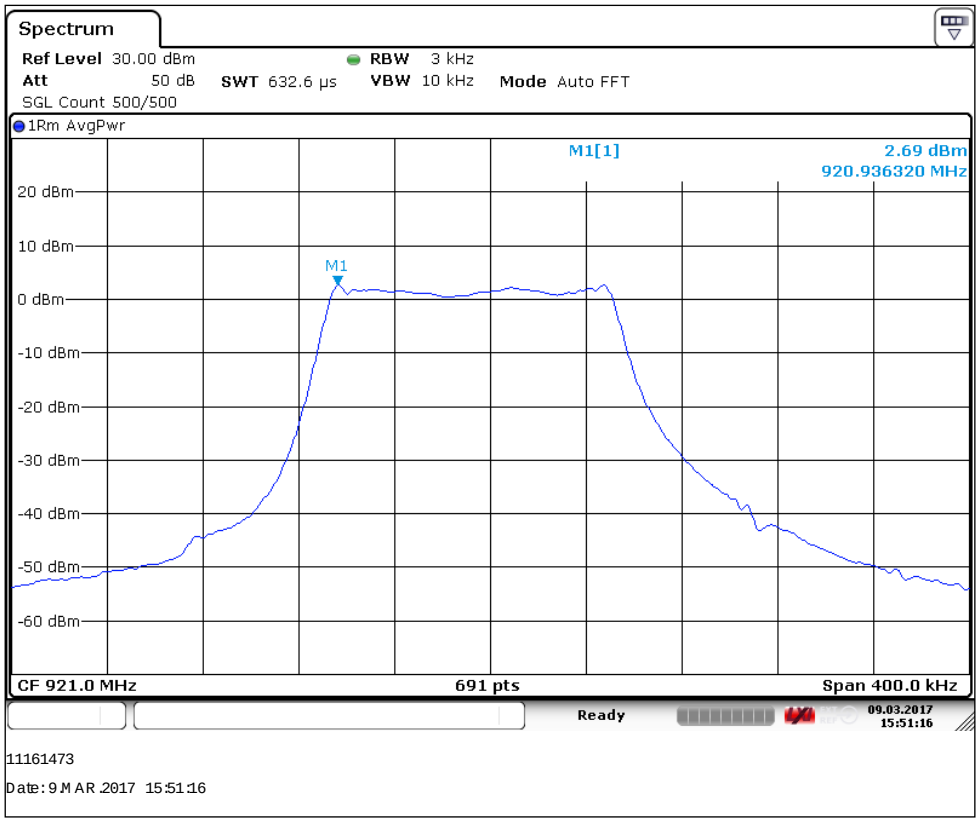
Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
FSV	Rohde & Schwarz	Spectrum Analyser	N/A	07/06/2017

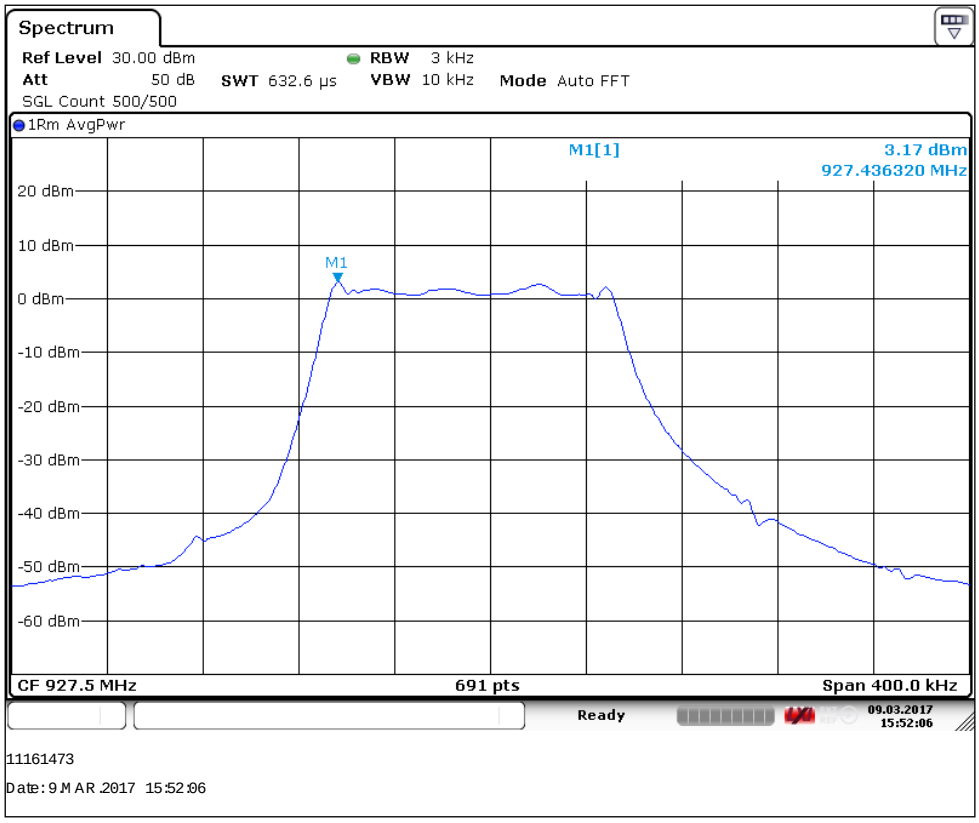
19.6 Test Results

Modulation: LoRa; Data rate: LoRa; Power setting: 0x0F				
Channel Frequency (MHz)	***Analyzer Level (dBm)***	***Cable loss (dB)***	***Power (dBm)***	***Result***
915.25	2.63	0	2.63	PASS
921.00	2.69	0	2.69	PASS
927.5	3.17	0	3.17	PASS

Measurements were made using the AVGPSD-1 method detailed in 558074 D01 DTS Meas Guidance v04




Spectrum
Ref Level 30.00 dBm
RBW 3 kHz
Att 50 dB
SWT 632.6 µs
VBW 10 kHz
Mode Auto FFT
SGL Count 500/500
1Rm AvgPwr
M1[1]
2.69 dBm
920.936320 MHz
20 dBm
10 dBm
0 dBm
-10 dBm
-20 dBm
-30 dBm
-40 dBm
-50 dBm
-60 dBm
M1
CF 921.0 MHz
691 pts
Span 400.0 kHz
Ready
09.03.2017
15:51:16
11161473
Date: 9.MAR.2017 15:51:16


Spectrum
Ref Level 30.00 dBm
RBW 3 kHz
Att 50 dB
SWT 632.6 µs
VBW 10 kHz
Mode Auto FFT
SGL Count 500/500
1Rm AvgPwr
M1[1]
3.17 dBm
927.436320 MHz
20 dBm
10 dBm
0 dBm
-10 dBm
-20 dBm
-30 dBm
-40 dBm
-50 dBm
-60 dBm
M1
CF 927.5 MHz
691 pts
Span 400.0 kHz
Ready
09.03.2017
15:52:06
11161473
Date: 9.MAR.2017 15:52:06

20 Measurement Uncertainty

Calculated Measurement Uncertainties

All statements of uncertainty are expanded standard uncertainty using a coverage factor of 1.96 to give a 95 % confidence:

[1] Radiated spurious emissions

Uncertainty in test result (30 MHz to 1 GHz) = **4.6 dB**
Uncertainty in test result (1 GHz to 18 GHz) = **4.7 dB**

[2] AC power line conducted emissions

Uncertainty in test result = **3.4 dB**

[3] Occupied bandwidth

Uncertainty in test result = **15.5 %**

[4] Conducted carrier power

Uncertainty in test result (Power Meter) = **1.08 dB**

[5] Conducted / radiated RF power out-of-band

Uncertainty in test result – up to 8.1 GHz = **3.31 dB**
Uncertainty in test result – 8.1 GHz to 15.3 GHz = **4.43 dB**
Uncertainty in test result (30 MHz to 1 GHz) = **4.6 dB**
Uncertainty in test result (1 GHz to 18 GHz) = **4.7 dB**

[6] Frequency separation

Uncertainty in test result (Spectrum Analyser) = **3.6 kHz**

[7] Accumulated channel occupancy time

Uncertainty in test result = **7.98 %**

21 RF Exposure

MPE Calculation

As per KDB 447498

47 CFR §§1.1307 and 2.1091

2.1091 Radio frequency radiation exposure evaluation: Portable devices.

For purposes of these requirements mobile devices are defined by the FCC as transmitters designed to be used in other than fixed locations and to generally be used in such a way that a separation distance of at least 20 centimetres is normally maintained between radiating structures and the body of the user or nearby persons. These devices are normally evaluated for exposure potential with relation to the MPE limits. As the 20cm separation specified under FCC rules may not be achievable under normal operation of the EUT, an RF exposure calculation is needed to show the minimum distance required to be less than 0.6mW/cm^2 power density limit, as required under FCC rules

Prediction of MPE limit at a given distance

Equation from KDB 447498 D01

$$S = \frac{1.64ERP}{4\pi R^2} \quad \text{re-arranged } R = \sqrt{\frac{1.64ERP}{S4\pi}}$$

where:

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

Result:

Prediction Frequency (MHz)	Maximum ERP (mW)	Power density limit (S) (mW/cm^2)	Distance (R) cm required to be less than 0.6mW/cm^2 (cm)
927.5	3.24	0.6	0.84

Prediction Frequency (MHz)	Maximum Conducted power (mW)	Power density limit (S) (mW/cm^2)	Distance (R) cm required to be less than 0.6mW/cm^2 (cm)
927.5	1.33	0.6	0.54