Report on the Radio Testing

For

Renishaw Plc

on

RMP400(Q)

Report no. TRA-040822-45-02A

13 July 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-040822-45-02A
Issue: A

REPORT ON THE RADIO TESTING OF A
Renishaw Plc
RMP400(Q)
WITH RESPECT TO SPECIFICATION
FCC 47CFR 15.247 October 2017

TEST DATE: 2018-05-10 to 2018-05-25

Tested by: A Longley, A Wong & I Broadwell

Written by: A Tosif
Radio Test Engineer

Approved by: Digitally signed by John Charters
DN: cn=John Charters, o, ou=Element Materials Technology Ltd., email=john.charters@element.com, c=GB
Reason: I am approving this document
Date: 2018.07.13 10:09:54 +01'00'
J Charters
Department Manager - Radio

Date: 13 July 2018

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

1 Revision Record

Issue Number	*Issue Date*	*Revision History*
A	13 July 2018	Original

2 Summary

TEST REPORT NUMBER:	TRA-040822-45-02A
WORKS ORDER NUMBER:	TRA-040822-02
PURPOSE OF TEST:	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:	FCC 47CFR 15.247 October 2017
EQUIPMENT UNDER TEST (EUT):	RMP400(Q)
FCC IDENTIFIER:	KQGRMP400
EUT SERIAL NUMBER:	OTTR66, OTTR77 & OTVA43
MANUFACTURER/AGENT:	Renishaw Plc
ADDRESS:	New Mills Wooton Road, Charfield, Wotton Under Edge Gloucestershire GL12 8JR United Kingdom
CLIENT CONTACT:	Richard Warren ☎ 01453 524524 ✉ richard.warren@renishaw.com
ORDER NUMBER:	PU03445710
TEST DATE:	2018-05-10 to 2018-05-25
TESTED BY:	A Longley, A Wong & I Broadwell Element

2.1 Test Summary

Test Method and Description	*Requirement Clause 47CFR15*	*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	☐	*Note 1*
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*
20 dB emission bandwidth	15.247(a)(1) (i) and (ii)	☒	*Pass*
Out-of-band emissions	15.247(d)	☒	*Pass*

Specific Note:

1. The EUT is a battery powered equipment.

General 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-040822-45-02A presents the results of the Radio testing on a Renishaw Plc, RMP400(Q) to specification 47CFR15 Radio Frequency Devices.

The testing was carried out for Renishaw Plc 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.

ISED Registration Numbers:

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 - October 2017 - 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
ISED	Innovation, Science and Economic Development Canada (formerly 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: RMP400(Q)
- Serial Number: OTTR66, OTTR77 & OTVA43
- Model Number: RMP400(Q)

7.2 System Equipment

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

Not Applicable – No support/monitoring equipment required.

7.3 EUT Mode of Operation

7.3.1 Transmission

The mode of operation for transmitter tests was as follows.

The EUT was transmitting modulated carrier on the frequencies indicated.

7.3.2 Reception

The mode of operation for receiver tests was as follows.

The EUT was tuned to permanent receive mode on the frequencies indicated.

7.4 EUT Radio Parameters

Frequency of operation:	2403 MHz – 2481 MHz
Modulation type:	GFSK
Channel bandwidth:	1 MHz
Channel spacing:	1 MHz
Declared output power:	2 mW
Antenna type:	PCB slot antenna
Antenna gain:	-0.82 dBi
Nominal Supply Voltage:	7.2 Vdc

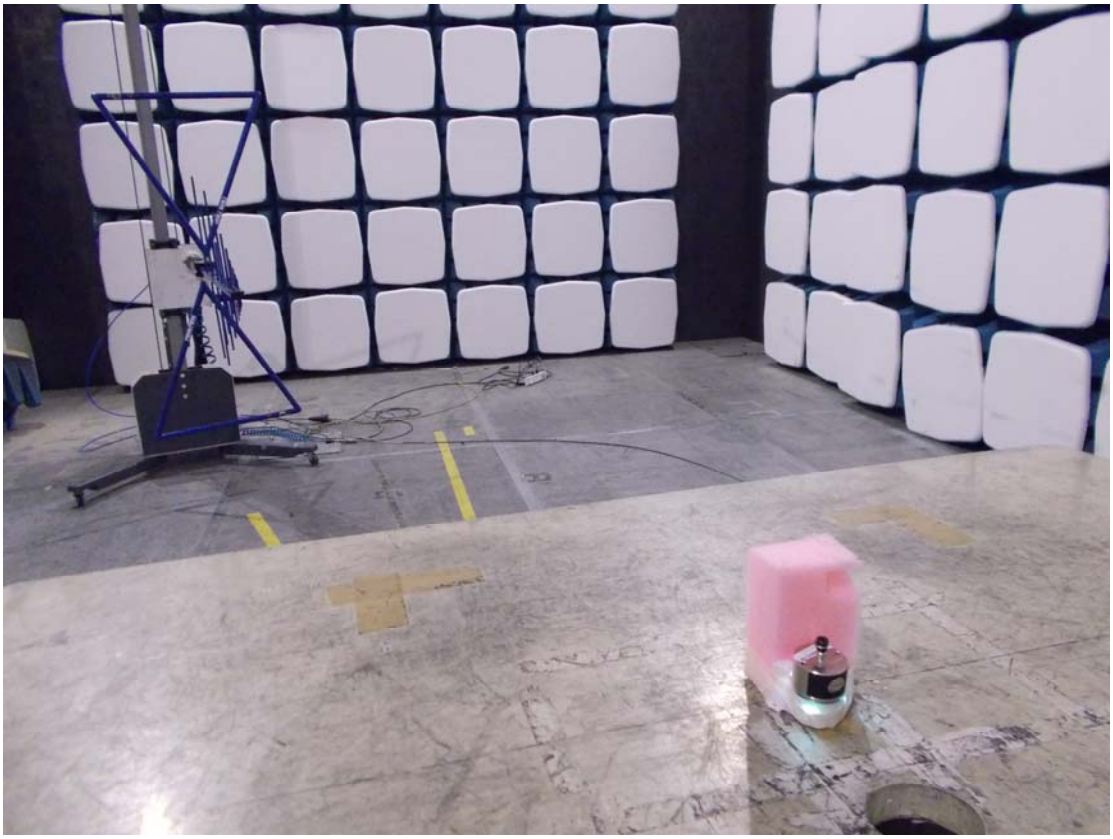
7.5 EUT Description

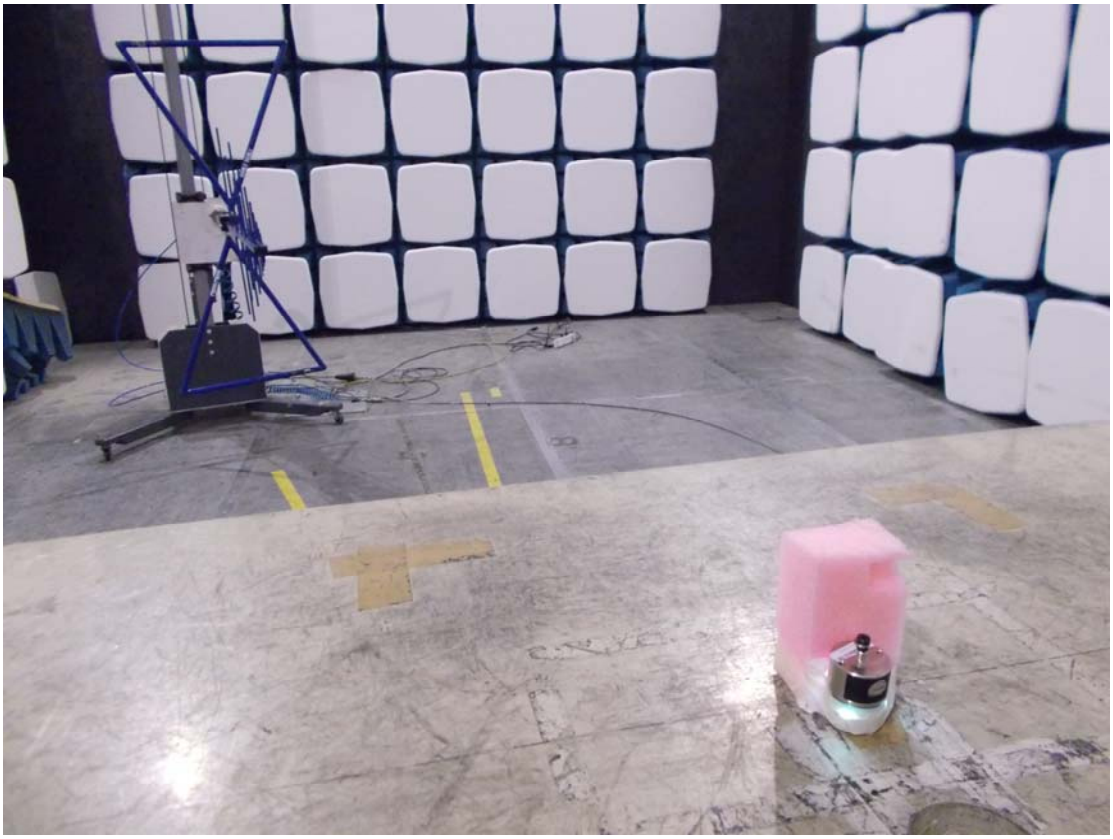
The EUT is a 40 mm radio strain gauge metrology probe for use on machine tools. It is powered from two 1/2 AA Lithium Thionyl Chloride batteries. It operates within the 2.4 GHz band using FHSS with GFSK modulation. Internally, the circuit uses 2 PIC microprocessors running at 4 MHz and a Nordic Semiconductor nRF2401AG radio transceiver which is clocked at 16 MHz. Standby timings are maintained with a 32.768 kHz crystal.

8 Modifications

No modifications were performed during this assessment.

9 EUT Test Setup Photographs





10 General Technical Parameters

10.1 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 7.2 V dc.

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.

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:	Wireless Laboratory 2
Test Standard and Clause:	ANSI C63.10-2013, Clause 6.5 and 6.6
Frequencies Measured:	2403 MHz, 2442 MHz & 2481 MHz
EUT Channel Bandwidths:	800 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: 39 % RH	20 % RH to 75 % RH (as declared)
Supply: 7.2 V dc	As declared

11.3 Test Limit

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

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

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

11.4 Test Method

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

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

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

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

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

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

$$FS = PR + CL + AF – PA + DC – CF$$

Where,

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

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

Figure i Test Setup

Duty Cycle Correction
The duty cycle correction factor, DC, was used to adjust peak emissions to give an average value and is calculated by:

$$DC = 20 \log (\text{duty ratio})$$

Where, duty ratio is total on-time divided by total off-time in the worst-case pulse train or 100 ms, whichever is longer.

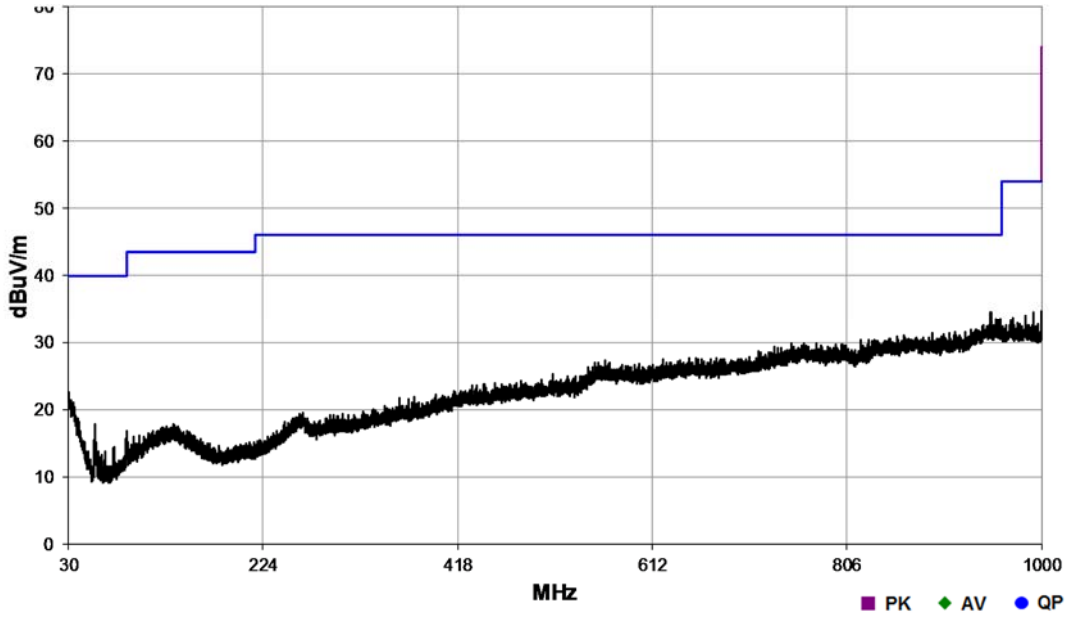
The measured duty ratio was 61%.

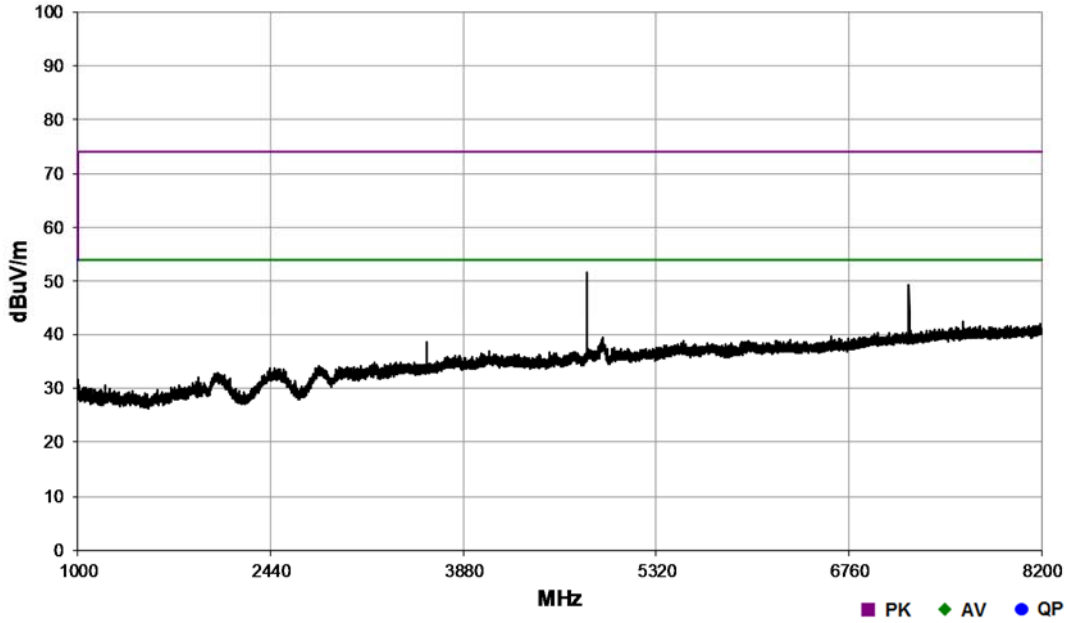
11.5 Test Equipment

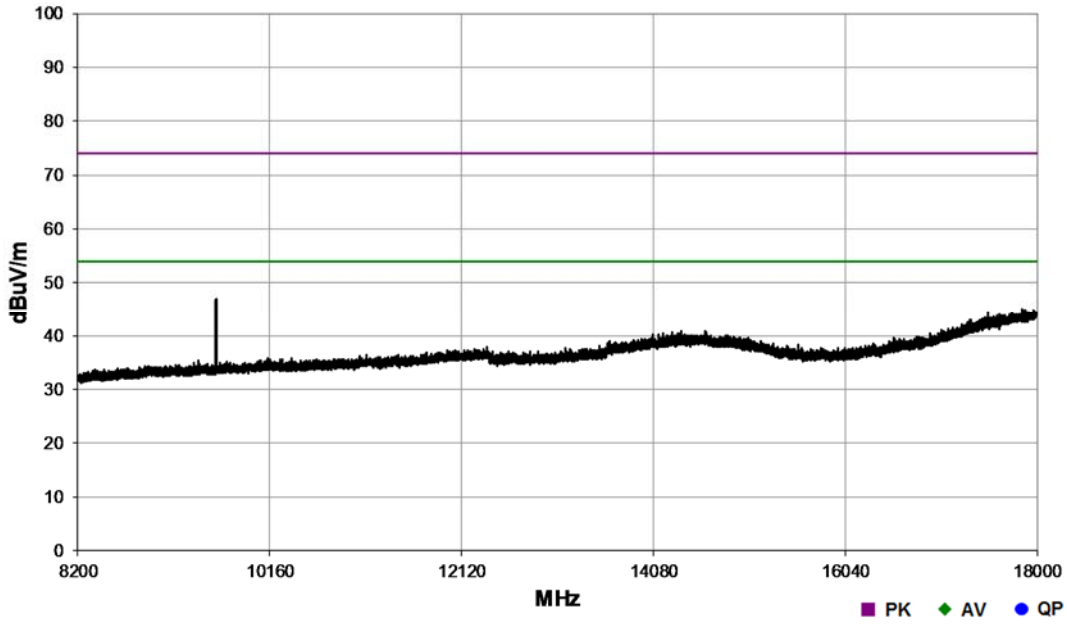
Equipment Description	*Manufacturer*	*Equipment Type*	*Element No*	*Due For Calibration*
Ferrite Lined Chamber	Rainford	ATS	REF886	2019-07-24
Spectrum Analyser	Agilent	N9030A	REF2167	2018-08-17
Horn Antenna	EMCO	3115	RFG129	2020-02-12
3115	EMCO	Horn Antenna	TRL128	2019-04-13
CBL6111B	Chase	Bilog Antenna	REF2218	2019-11-06
Pre-Amp (1 – 26.5GHz)	Agilent	8449B	REF913	2019-02-07
Pre-Amp (9kHz – 1GHz)	Sonoma	310	REF927	2018-06-30

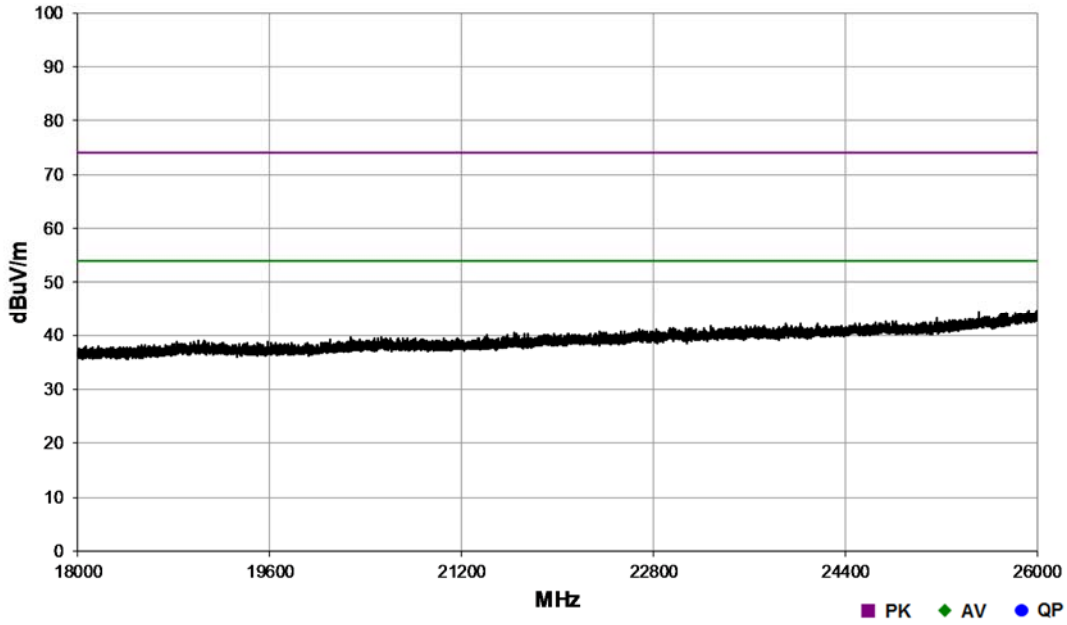
11.6 Test Results

Frequency: 2403 MHz								
Measurement	**Freq. (MHz)**	**Meas'd Emission (dBµV)**	**Factor (dB)**	**Duty Cycle Corr'n (dB)**	**Distance Extrap'n Factor (dB)**	**Field Strength (dBµV/m)**	**Field Strength (µV/m)**	**Limit (µV/m)**
Peak	4806.1	55.0	2.0	0.0	0.0	57.0	707.9	5000.0
Average	4806.1	55.0	2.0	-4.3	0.0	52.7	431.5	500.0
Peak	7209.1	49.8	5.9	0.0	0.0	55.7	609.5	5000.0
Average	7209.1	49.8	5.9	-4.3	0.0	51.4	371.5	500.0
Peak	9611.5	52.0	8.3	0.0	-9.5	50.8	346.7	5000.0
Average	9612.1	52.0	8.3	-4.3	-9.5	46.5	211.3	500.0

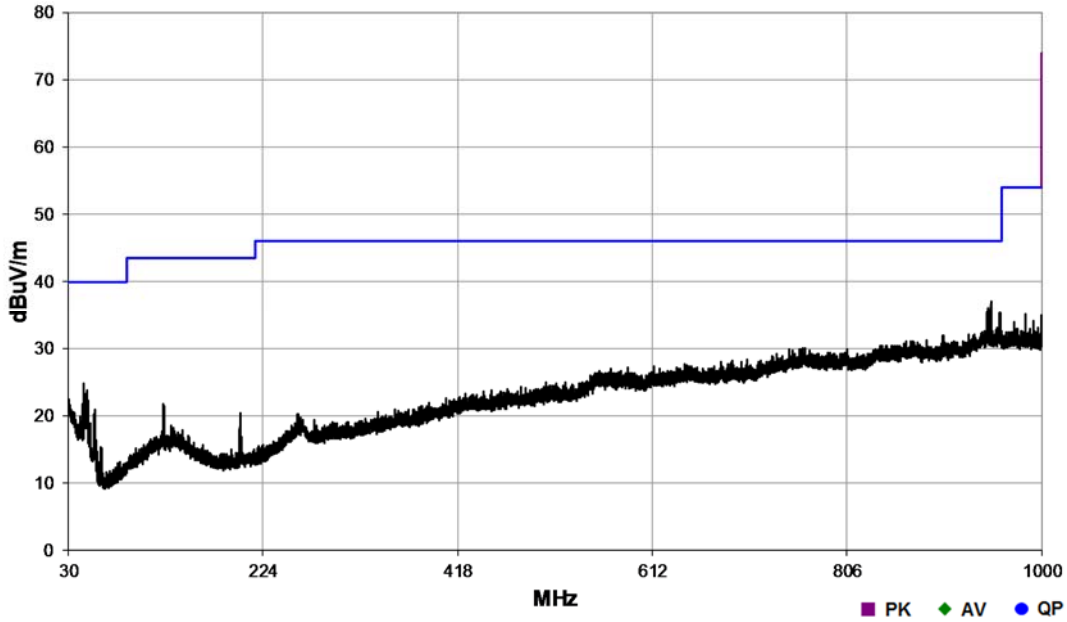


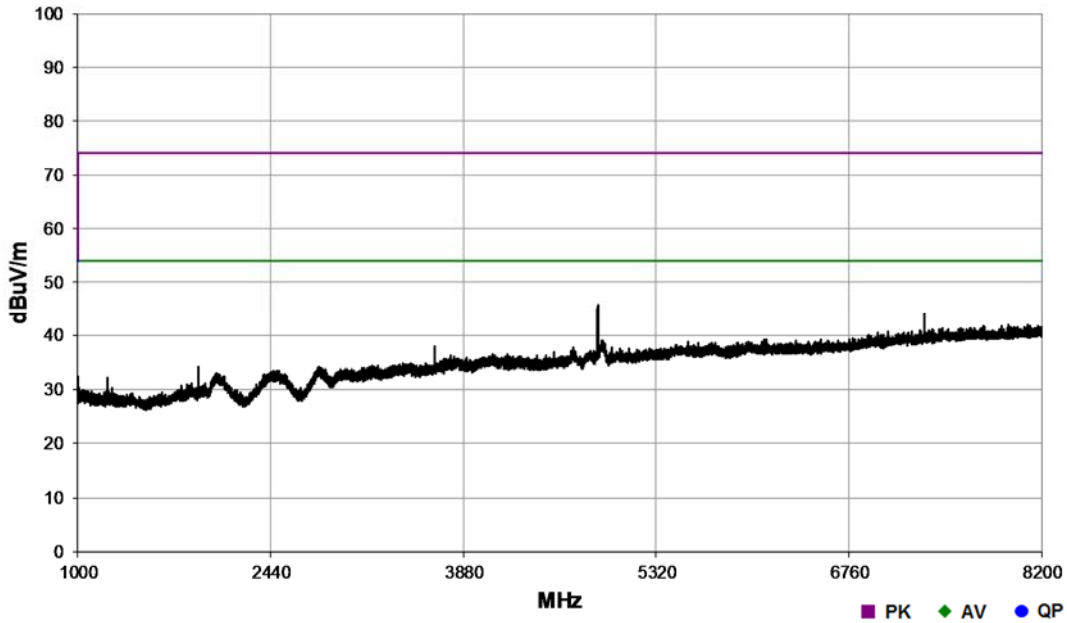


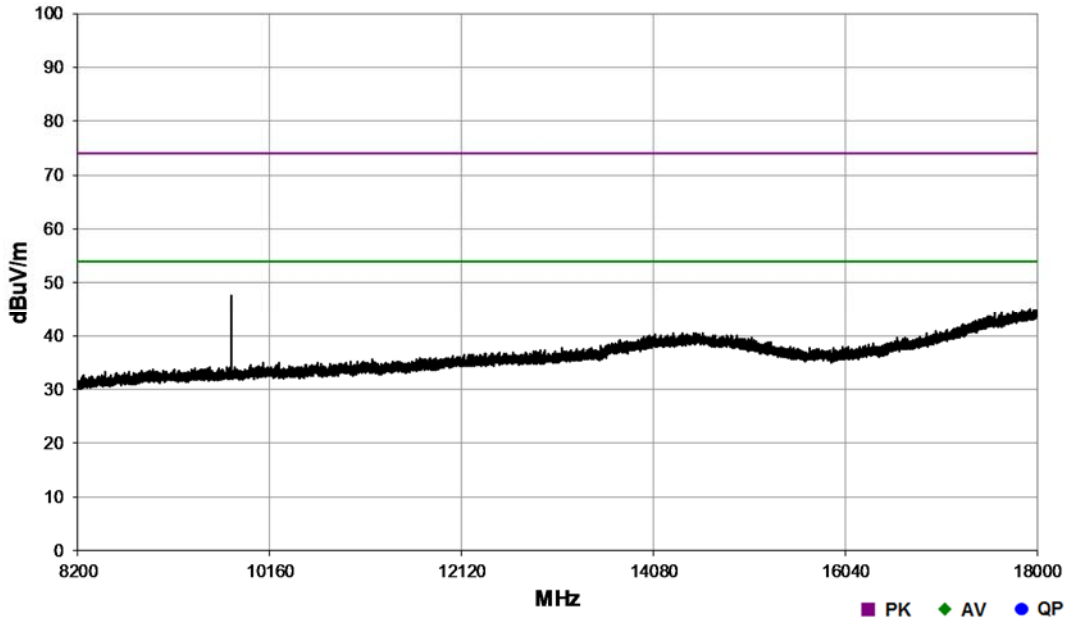

100
90
80
70
60
50
40
30
20
10
0
dBuV/m
8200
10160
12120
14080
16040
18000
MHz
PK
AV
QP

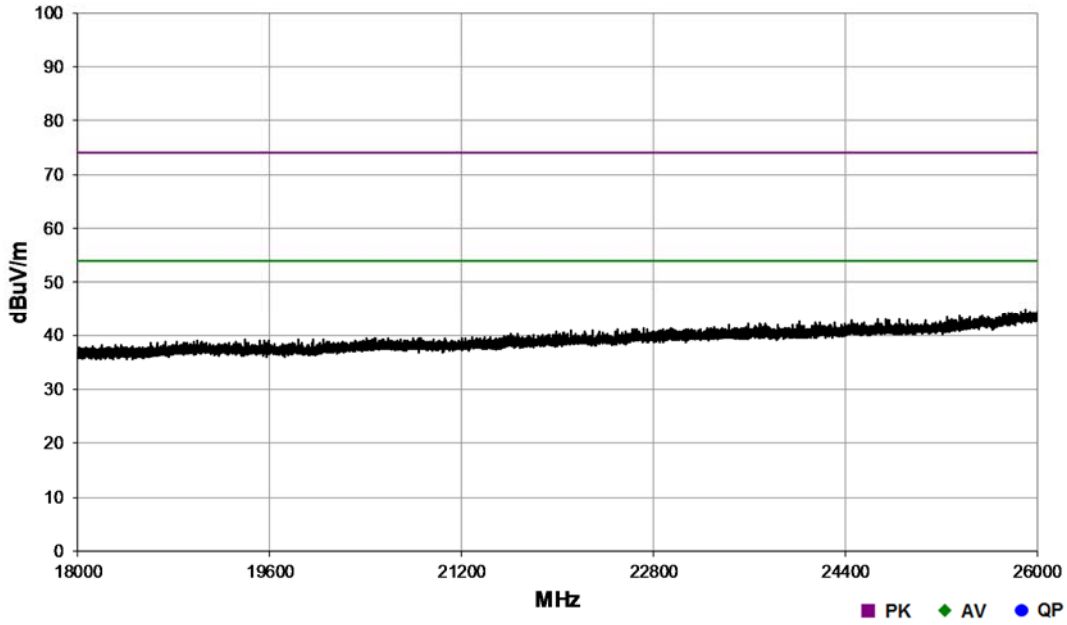

100
90
80
70
60
50
40
30
20
10
0
dBuV/m
18000
19600
21200
22800
24400
26000
MHz
PK
AV
QP

Frequency: 2442 MHz								
Measurement	***Freq. (MHz)***	***Meas'd Emission (dBµV)***	***Factor (dB)***	***Duty Cycle Corr'n (dB)***	***Distance Extrap'n Factor (dB)***	***Field Strength (dBµV/m)***	***Field Strength (µV/m)***	***Limit (µV/m)***
Peak	4884.1	50.0	2.3	0.0	0.0	52.3	412.1	5000.0
Average	4884.1	50.0	2.3	-4.3	0.0	48.0	251.2	500.0
Peak	7326.2	48.0	6.1	0.0	0.0	54.1	507.0	5000.0
Average	7326.1	48.0	6.1	-4.3	0.0	49.8	309.0	500.0
Peak	9768.1	53.2	8.3	0.0	-9.5	52.0	398.1	5000.0
Average	9768.1	53.2	8.3	-4.3	-9.5	47.7	242.7	500.0

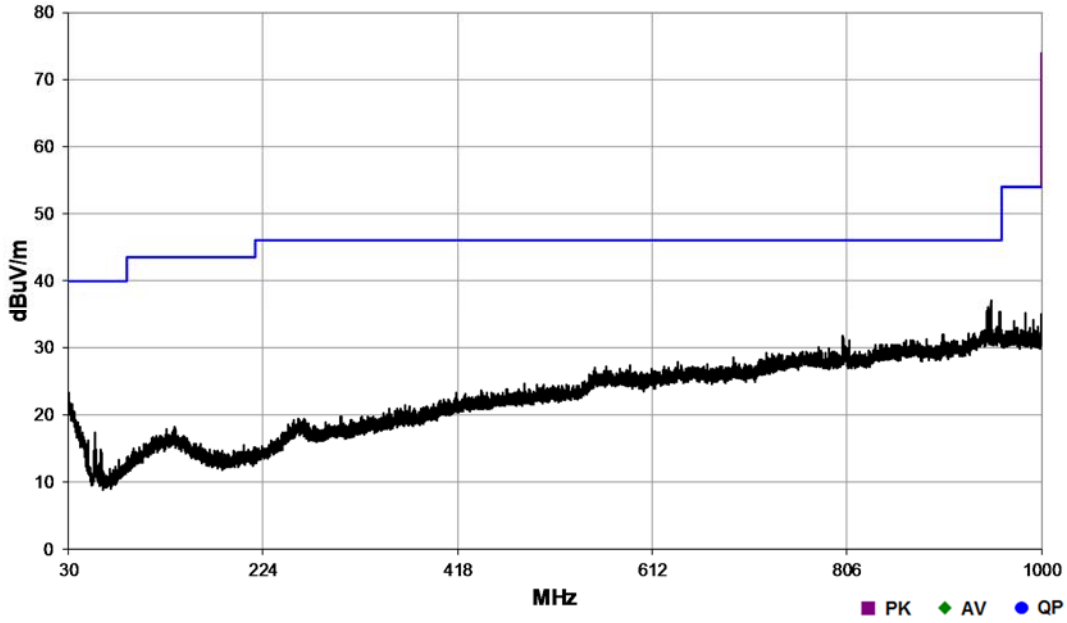


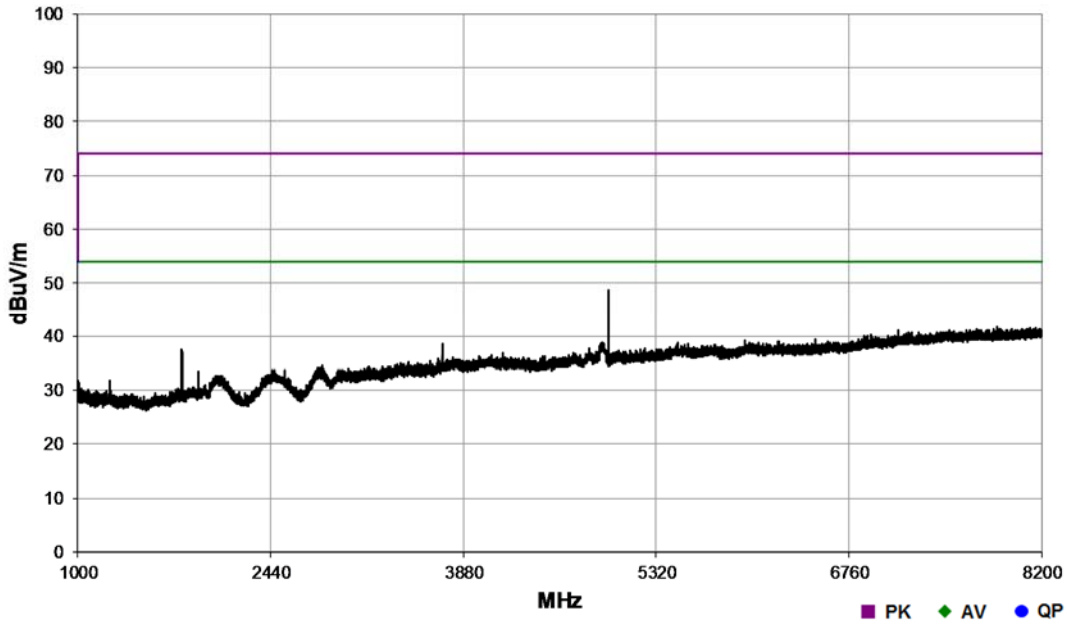


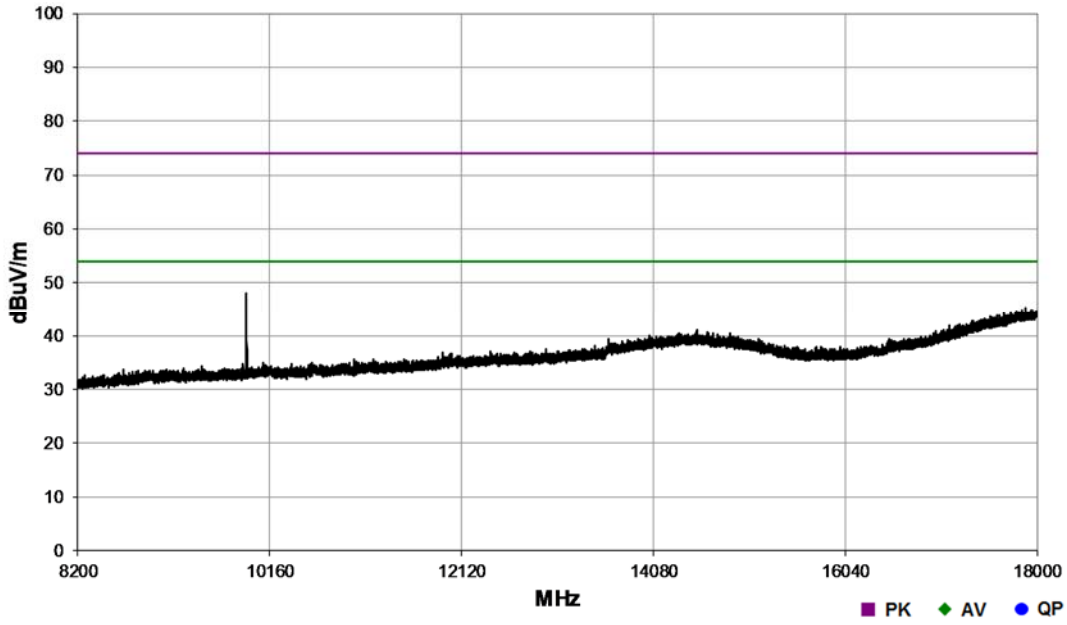

100
90
80
70
60
50
40
30
20
10
0
dBuV/m
8200
10160
12120
14080
16040
18000
MHz
PK
AV
QP

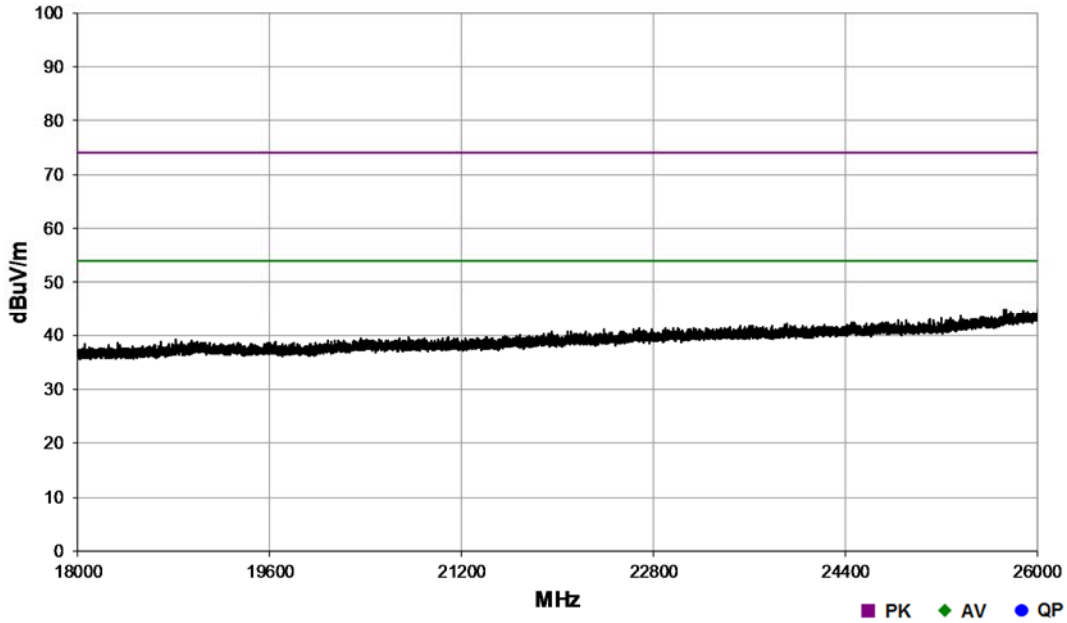

100
90
80
70
60
50
40
30
20
10
0
dBuV/m
18000
19600
21200
22800
24400
26000
MHz
PK
AV
QP

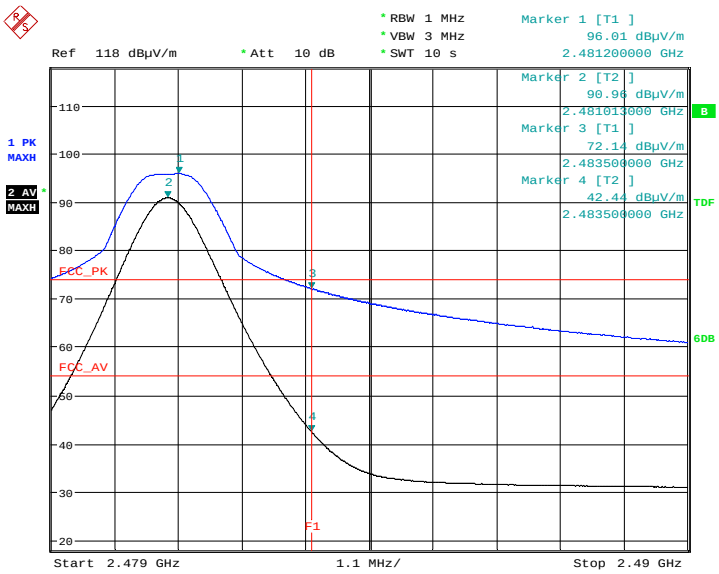
Frequency: 2481 MHz								
Measurement	***Freq. (MHz)***	***Meas'd Emission (dBµV)***	***Factor (dB)***	***Duty Cycle Corr'n (dB)***	***Distance Extrap'n Factor (dB)***	***Field Strength (dBµV/m)***	***Field Strength (µV/m)***	***Limit (µV/m)***
Peak	4962.0	51.8	2.4	0.0	0.0	54.2	512.9	5000.0
Average	4962.0	51.8	2.4	-4.3	0.0	49.9	312.6	500.0
Peak	9924.1	52.9	8.4	0.0	-9.5	51.8	389.0	5000.0
Average	9924.1	52.9	8.4	-4.3	-9.5	47.5	237.1	500.0



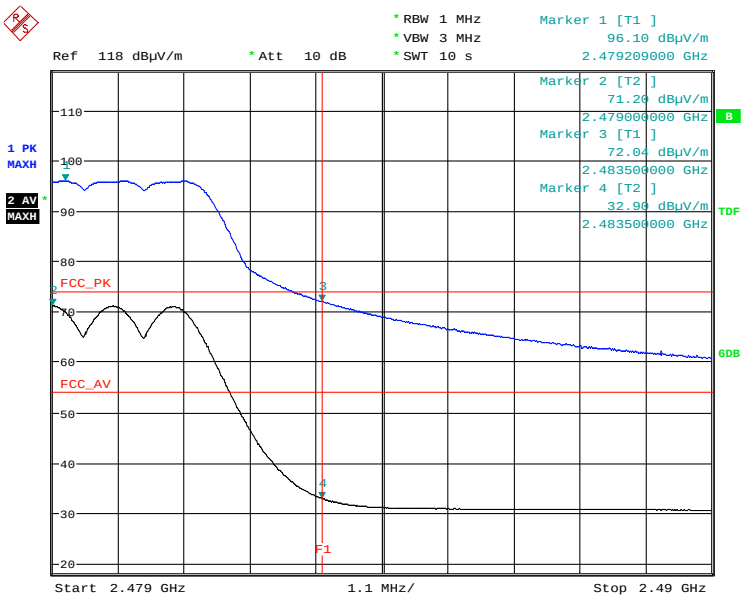



100
90
80
70
60
50
40
30
20
10
0
dBuV/m
8200
10160
12120
14080
16040
18000
MHz
PK
AV
QP


100
90
80
70
60
50
40
30
20
10
0
dBuV/m
18000
19600
21200
22800
24400
26000
MHz
PK
AV
QP


Ref 118 dBµV/m
* Att 10 dB
* RBW 1 MHz
* VBW 3 MHz
* SWT 10 s
Marker 1 [T1]
96.01 dBµV/m
2.481200000 GHz
Marker 2 [T2]
90.96 dBµV/m
2.481013000 GHz
Marker 3 [T1]
72.14 dBµV/m
2.483500000 GHz
Marker 4 [T2]
42.44 dBµV/m
2.483500000 GHz
1 PK
MAXH
2 AV
MAXH
FCC_PK
FCC_AV
B
TDF
6DB
Start 2.479 GHz
1.1 MHz/
Stop 2.49 GHz

Frequencies: All 2403 MHz–2481 MHz (Hopping)



Date: 24.MAY.2018 09:58:46

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 Hull
Test Chamber:	Wireless Laboratory 1
Test Standard and Clause:	ANSI C63.10-2013, Clause 7.8.2
EUT Frequencies Measured:	2440 & 2441 MHz (in hopping mode)
EUT 20 dB Bandwidth:	535 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: 7.2 V dc	As declared

12.3 Test Limit

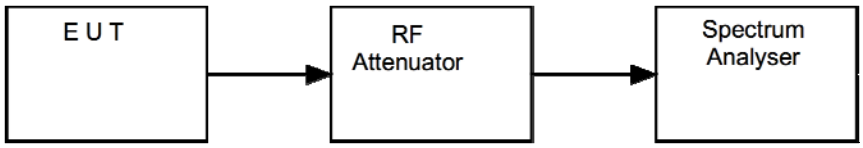
Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the -20 dB bandwidth of the hopping channel, whichever is greater. Alternatively, frequency hopping systems operating in the band 2400 to 2483.5 MHz may have hopping channel carrier frequencies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

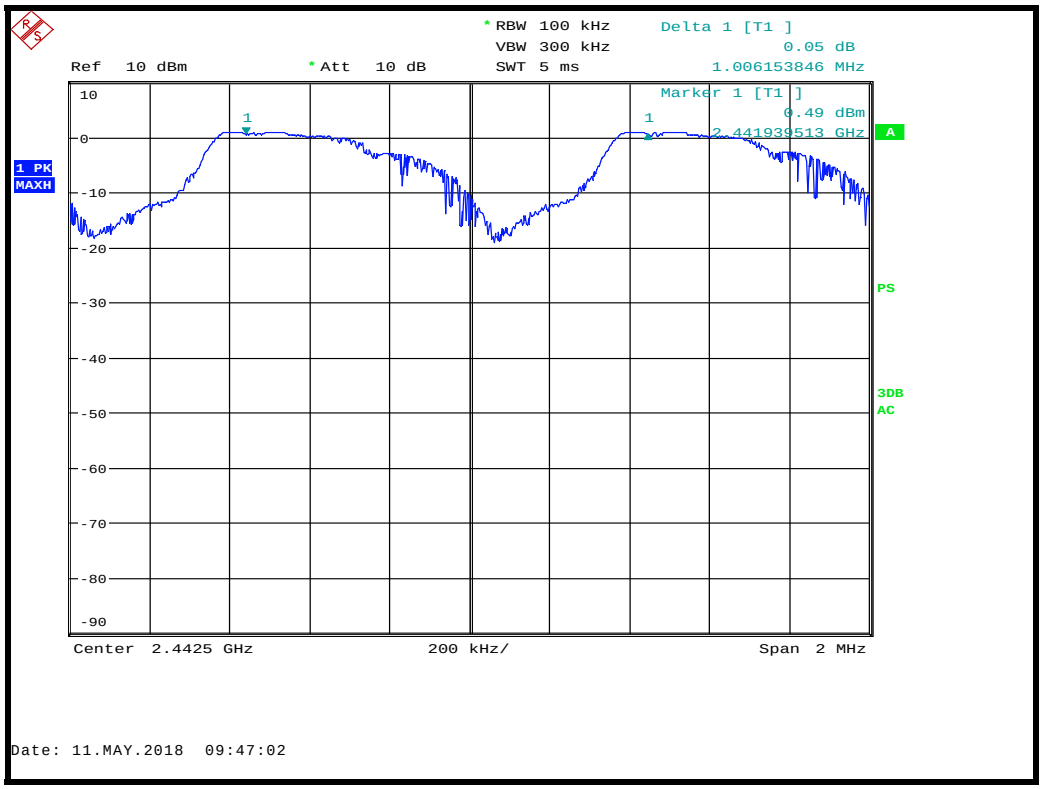


12.5 Test Equipment

Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
ESU40	R&S	Receiver	RFG701	2018-11-20

12.6 Test Results

Frequencies: 2440 & 2441 MHz (in hopping mode); Power setting: Nominal				
Data Rate	**$F1_c$ (MHz)**	**$F2_c$ (MHz)**	**Channel Separation, $F2_c - F1_c$ (kHz)**	**Result**
Single possible	2441.939513	2442.945667	1006.153846	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 Hull
Test Chamber:	Wireless Laboratory 1
Test Standard and Clause:	ANSI C63.10-2013, Clause 7.8.3
EUT Frequencies Measured:	All (2403 MHz – 2481 MHz), in hopping mode
EUT 20dB Bandwidth:	535 kHz
EUT Test Modulations:	Internal pattern generation – hopping enabled
Deviations From Standard:	None
Measurement BW:	200 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: 7.2 V dc	As declared

13.3 Test Limit

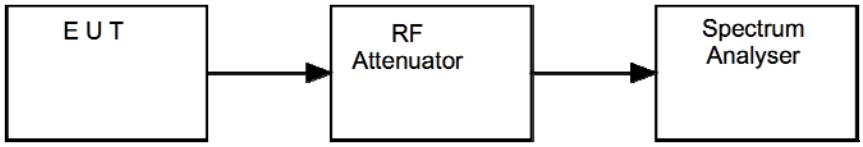
- For frequency hopping systems in the band 902 to 928 MHz: if the -20 dB bandwidth of the hopping channel is less than 250 kHz, the system shall use at least 50 hopping channels;
  If the -20 dB bandwidth of the hopping channel is 250 kHz or greater, the system shall use at least 25 hopping channels;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

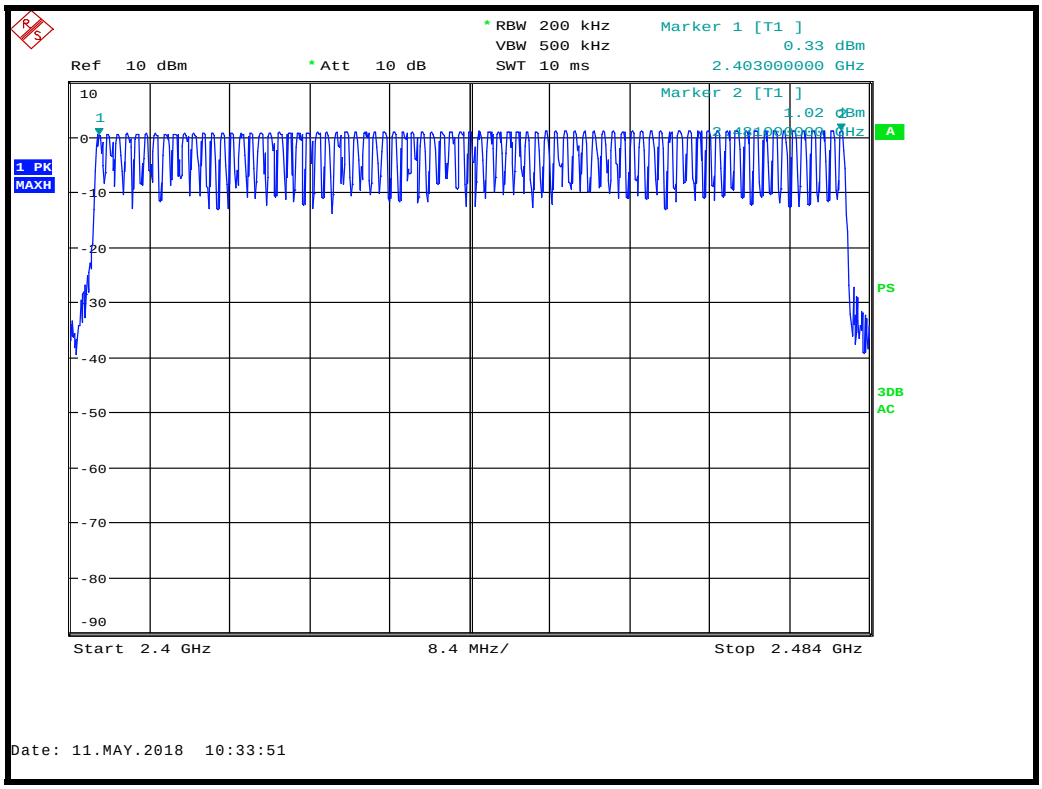


13.5 Test Equipment

Equipment Type	*Manufacturer*	*Equipment Description*	*Element No*	*Due For Calibration*
ESU40	R&S	Receiver	RFG701	2018-11-20

13.6 Test Results

Power setting: Nominal				
Data Rate	*Lowest channel, F_{CL} (MHz)*	*Highest channel, F_{CH} (MHz)*	*Number of channels observed*	*Result*
Single possible	2403	2481	79	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 Hull
Test Chamber:	Wireless Laboratory 1
Test Standard and Clause:	ANSI C63.10-2013, Clause 7.8.4
EUT Frequency Measured:	2442 MHz (in hopping mode)
EUT 20 dB bandwidth:	535 kHz
EUT Number of hopping channels:	79
EUT Test Modulations:	Internal pattern generation – hopping enabled
Deviations From Standard:	None
Measurement BW:	1 MHz
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: 7.2 V dc	As declared

14.3 Test Limit

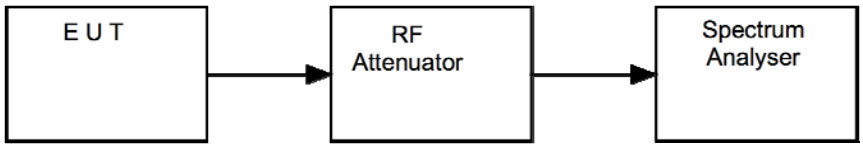
- For frequency hopping systems in the band 902 to 928 MHz: if the -20 dB bandwidth of the hopping channel is less than 250 kHz, the average time of occupancy on any channel shall not be greater than 0.4 seconds within a 20 second period;
  If the -20 dB bandwidth of the hopping channel is 250 kHz or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



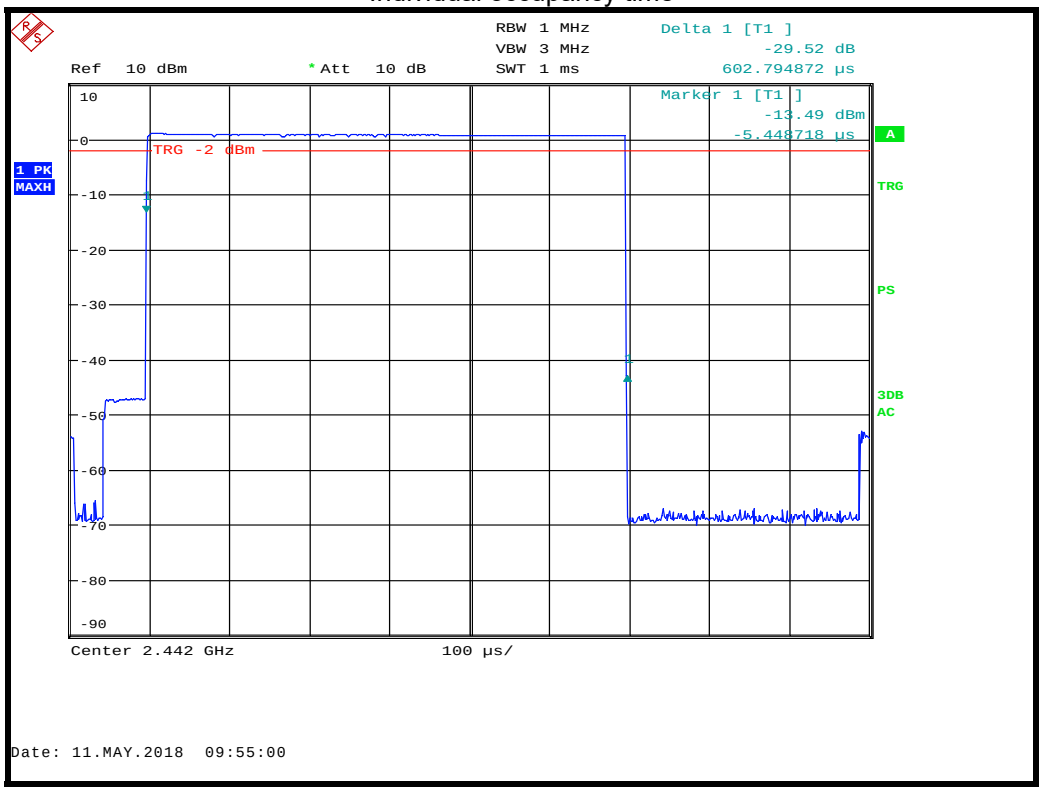
14.5 Test Equipment

Equipment Type	*Manufacturer*	*Equipment Description*	*Element No*	*Due For Calibration*
ESU40	R&S	Receiver	RFG701	2018-11-20

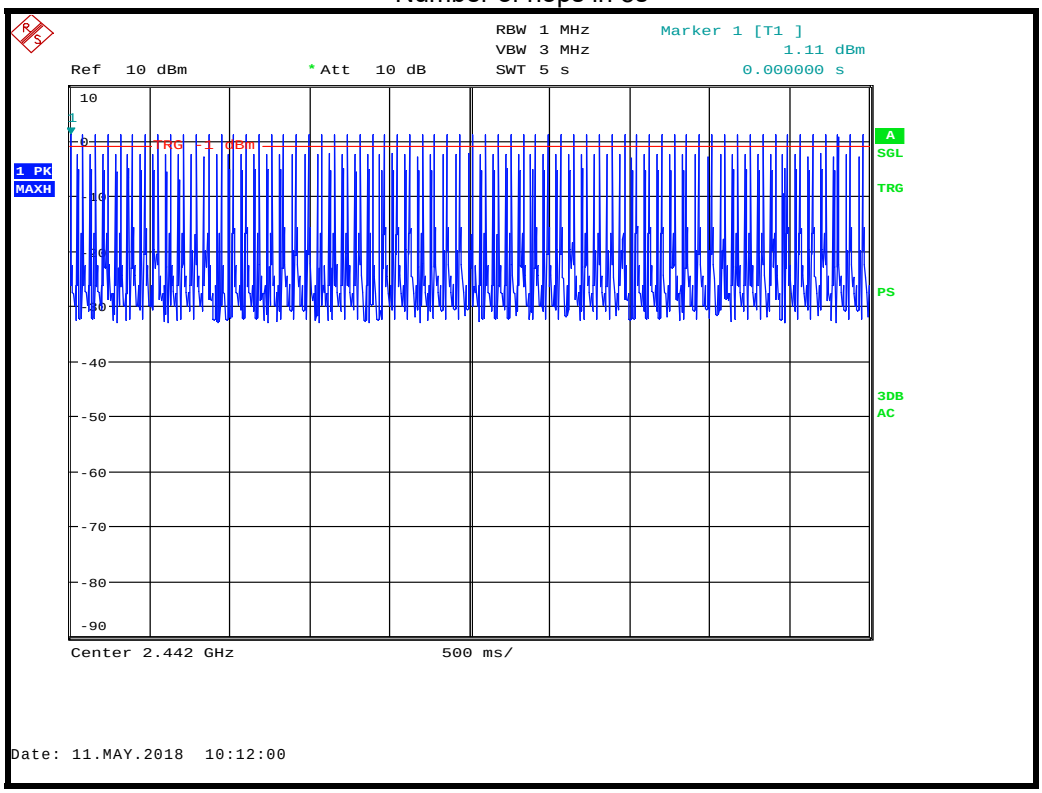
14.6 Test Results

Frequency: 2442 MHz (in hopping mode); Power setting: Nominal					
Data Rate	*Individual occupancy time (ms)*	*Observation period (s)*	*Number of hops observed*	*Average time of occupancy (s)*	*Result*
Single Possible	0.602794872	31.6	404.48	0.244	PASS

Individual occupancy time



Number of hops in 5s



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 Hull
Test Chamber:	Wireless Laboratory 1
Test Standard and Clause:	ANSI C63.10-2013, Clause 7.8.5
EUT Frequencies Measured:	2403 MHz, 2442 MHz & 2481 MHz
EUT Channel Bandwidths:	1 MHz
Deviations From Standard:	None
Measurement BW:	3 MHz
Spectrum Analyzer Video BW:	10 MHz
Measurement Detector:	Peak
Voltage Extreme Environment Test Range:	Mains Power = 85 % and 115 % of Nominal (FCC only requirement); Battery Power = new battery.

Environmental Conditions (Normal Environment)

Temperature: 23 °C	+15 ºC to +35 ºC (as declared)
Humidity: 32 % RH	20 % RH to 75 % RH (as declared)

15.3 Test Limit

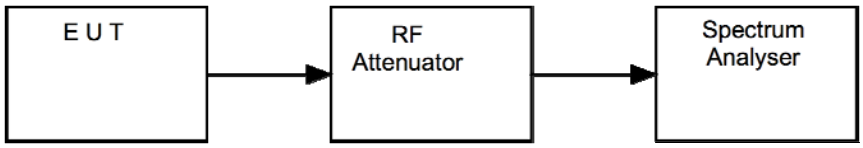
- For frequency hopping systems operating in the band 902 to 928 MHz, the maximum peak conducted output power shall not exceed 1 W, and the e.i.r.p. shall not exceed 4 W, if the hopset uses 50 or more hopping channels; the maximum peak conducted output power shall not exceed 0.25 W, and the e.i.r.p. 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 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*
ESU40	R&S	Receiver	RFG701	2018-11-20

15.6 Test Results

Power setting: Nominal						
Channel Frequency (MHz)	*Analyzer Level (dBm)*	*Cable loss (dB)*	*Maximum peak conducted output power (W)*	*Antenna gain (dBi)*	*E.I.R.P. (W)*	*Result*
2403	0.58	0	0.001143	-0.82	0.000946	PASS
2442	1.42	0	0.001387	-0.82	0.001148	PASS
2481	1.89	0	0.001545	-0.82	0.001279	PASS

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 Hull
Test Chamber:	Wireless Laboratory 1
Test Standard and Clause:	ANSI C63.10-2013, Clause 6.9
EUT Frequencies Measured:	2403 MHz, 2442 MHz & 2481 MHz
EUT Channel Bandwidths:	1 MHz
Deviations From Standard:	None
Measurement BW: (requirement: 1 % to 5 % OBW)	5 kHz
Spectrum Analyzer Video BW: (requirement at least 3x RBW)	20 kHz
Measurement Span: (requirement 2 to 5 times OBW)	2 MHz
Measurement Detector:	Peak

Environmental Conditions (Normal Environment)

Temperature: 23 °C	+15 ºC to +35 ºC (as declared)
Humidity: 32 % RH	20 % RH to 75 % RH (as declared)
Supply: 7.2 V dc	As declared

16.3 Test Limit

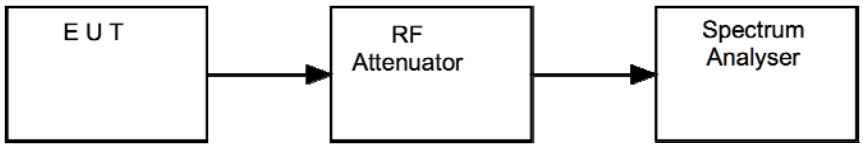
- For frequency hopping systems in the band 902 to 928 MHz: The maximum allowed -20 dB bandwidth of the hopping channel is 500 kHz.
- Frequency hopping systems operating in the band 5725 to 5850 MHz: The maximum -20 dB bandwidth of the hopping channel shall be 1 MHz

16.4 Test Method

With the EUT 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

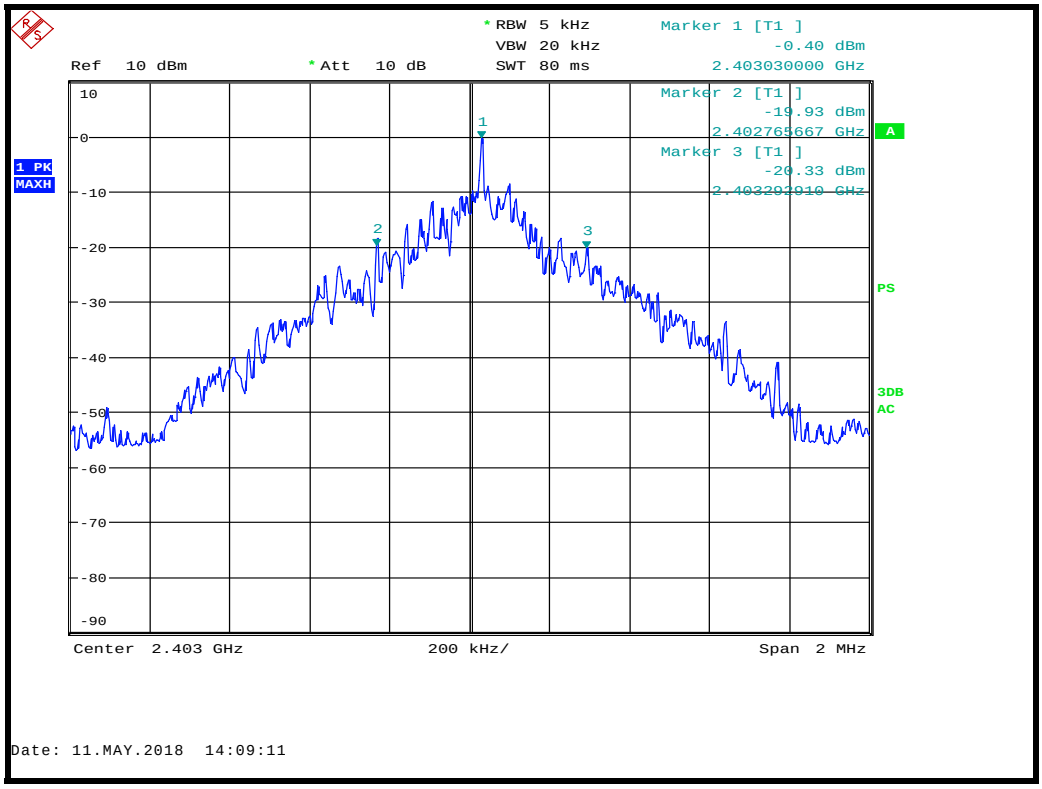


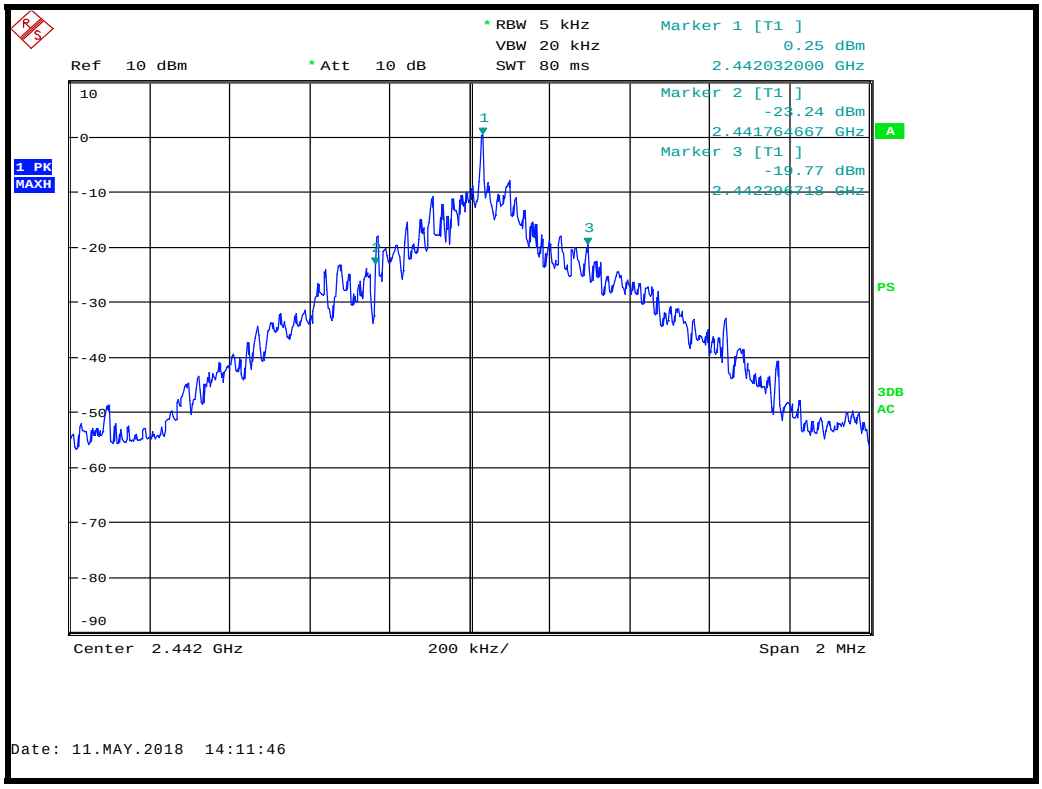
16.5 Test Equipment

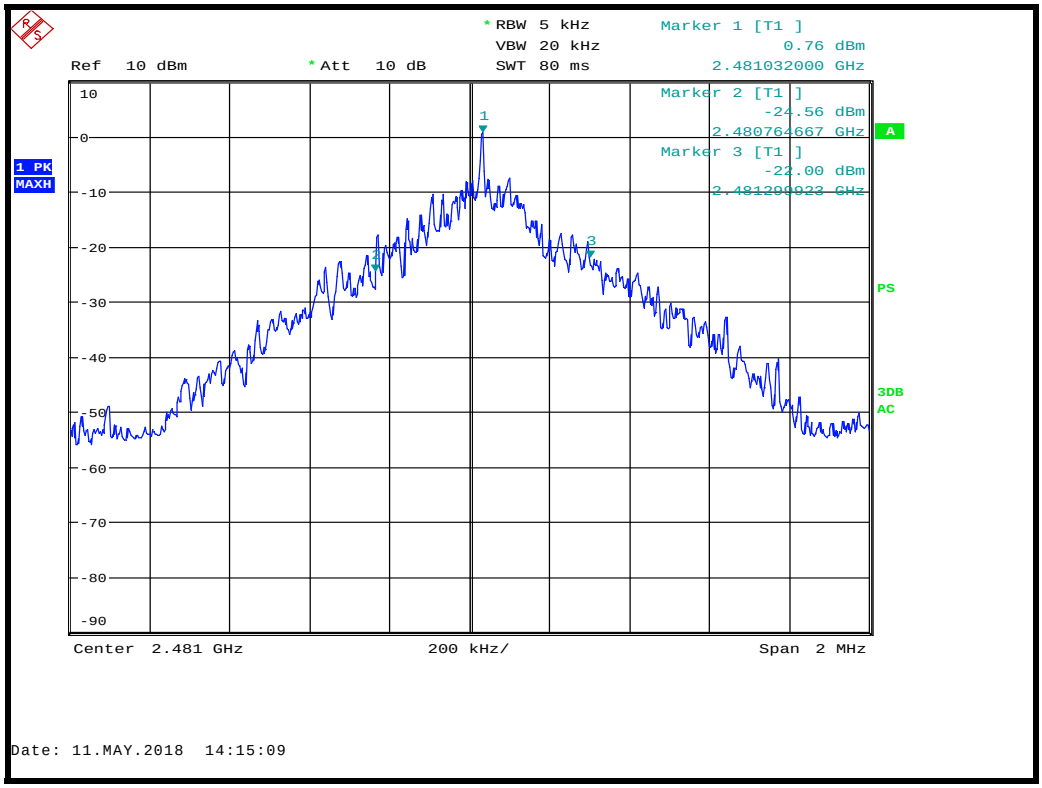
Equipment Type	*Manufacturer*	*Equipment Description*	*Element No*	*Due For Calibration*
ESU40	R&S	Receiver	RFG701	2018-11-20

16.6 Test Results

Power setting: Nominal				
Channel Frequency (MHz)	*F_L (MHz)*	*F_H (MHz)*	*20 dB Bandwidth (MHz)*	*Result*
2403	2402.765667	2403.292910	0.527243	PASS
2442	2441.764667	2442.296718	0.532051	PASS
2481	2480.764667	2481.299923	0.535256	PASS


RBW 5 kHz
VBW 20 kHz
SWT 80 ms
Marker 1 [T1]
-0.40 dBm
2.403030000 GHz
Marker 2 [T1]
-19.93 dBm
2.402765667 GHz
Marker 3 [T1]
-20.33 dBm
2.403293010 GHz
Ref 10 dBm
Att 10 dB
1 PK
MAXH
A
PS
3DB
AC
Center 2.403 GHz
200 kHz/
Span 2 MHz
Date: 11.MAY.2018 14:09:11


RBW 5 kHz
VBW 20 kHz
SWT 80 ms
Marker 1 [T1]
0.25 dBm
2.442032000 GHz
Marker 2 [T1]
-23.24 dBm
2.441764667 GHz
Marker 3 [T1]
-19.77 dBm
2.442296718 GHz
Ref 10 dBm
Att 10 dB
1 PK
MAXH
A
PS
3DB
AC
Center 2.442 GHz
200 kHz/
Span 2 MHz
Date: 11.MAY.2018 14:11:46


RBW 5 kHz
VBW 20 kHz
SWT 80 ms
Marker 1 [T1]
0.76 dBm
2.481032000 GHz
Marker 2 [T1]
-24.56 dBm
2.480764667 GHz
Marker 3 [T1]
-22.00 dBm
2.481200023 GHz
Ref 10 dBm
Att 10 dB
1 PK
MAXH
A
PS
3DB
AC
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
Center 2.481 GHz
200 kHz/
Span 2 MHz
Date: 11.MAY.2018 14:15:09

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 Hull
Test Chamber:	Wireless Laboratory 1
Test Standard and Clause:	ANSI C63.10-2013, Clause 7.8.8
EUT Frequencies Measured:	2403 MHz, 2442 MHz & 2481 MHz
EUT Channel Bandwidths:	1 MHz
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: 35 % RH	20 % RH to 75 % RH (as declared)
Supply: 7.2 V dc	As declared

17.3 Test Limits

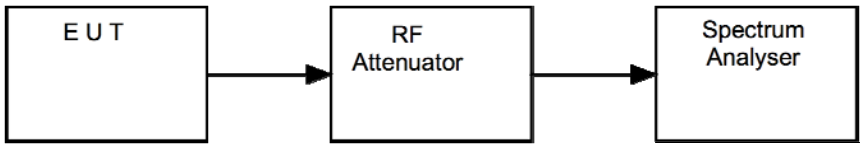
In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated device is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either 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), is not required.

17.4 Test Method

With the EUT 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

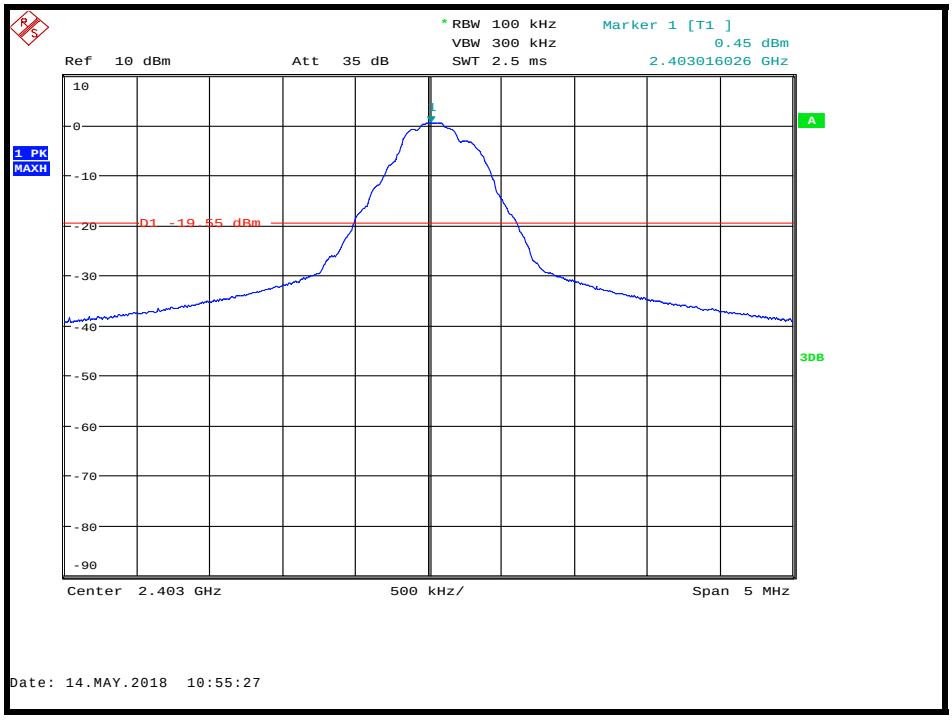


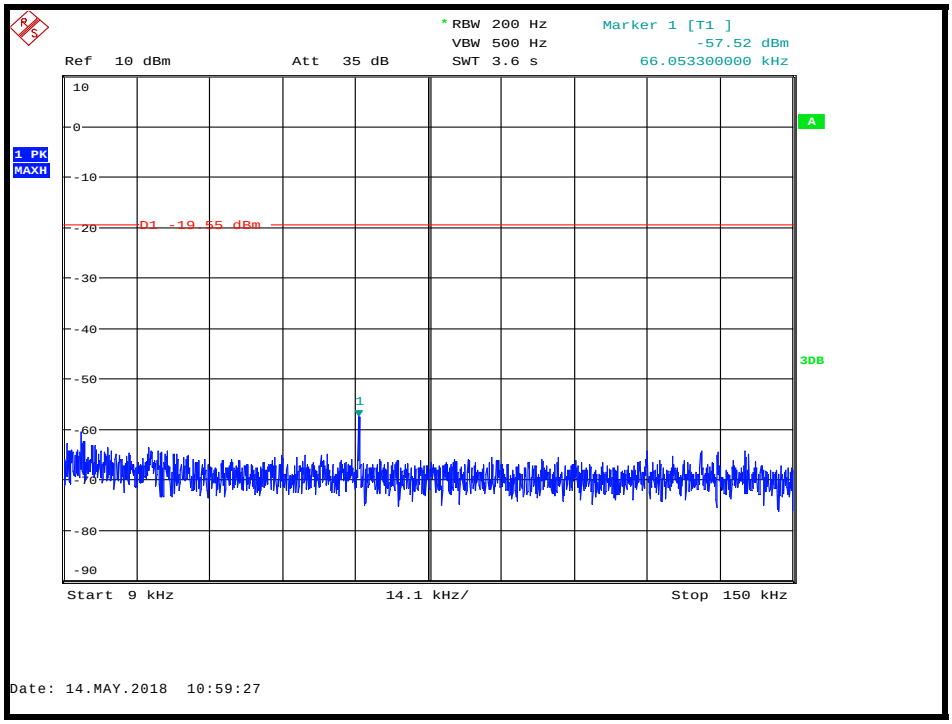
17.5 Test Equipment

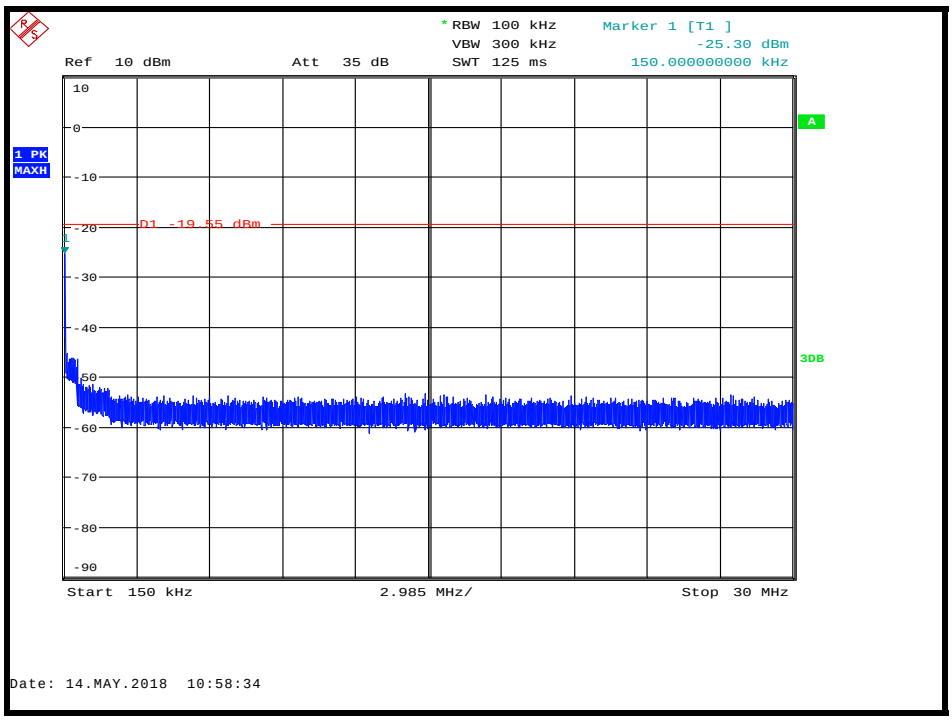
Equipment Type	*Manufacturer*	*Equipment Description*	*Element No*	*Due For Calibration*
ESU40	R&S	Receiver	RFG701	2018-11-20

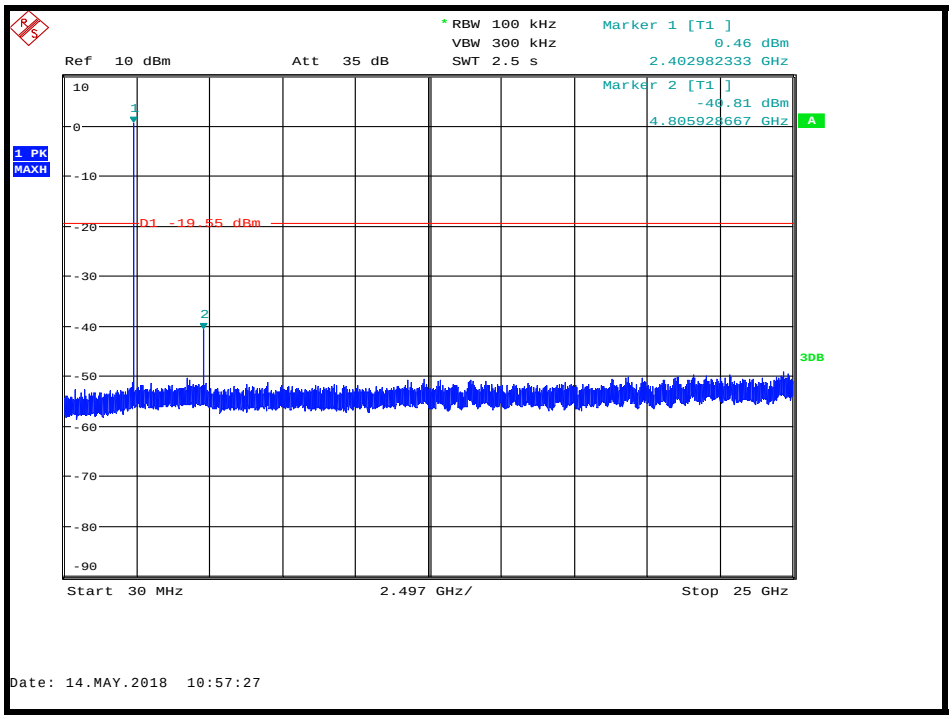
17.6 Test Results

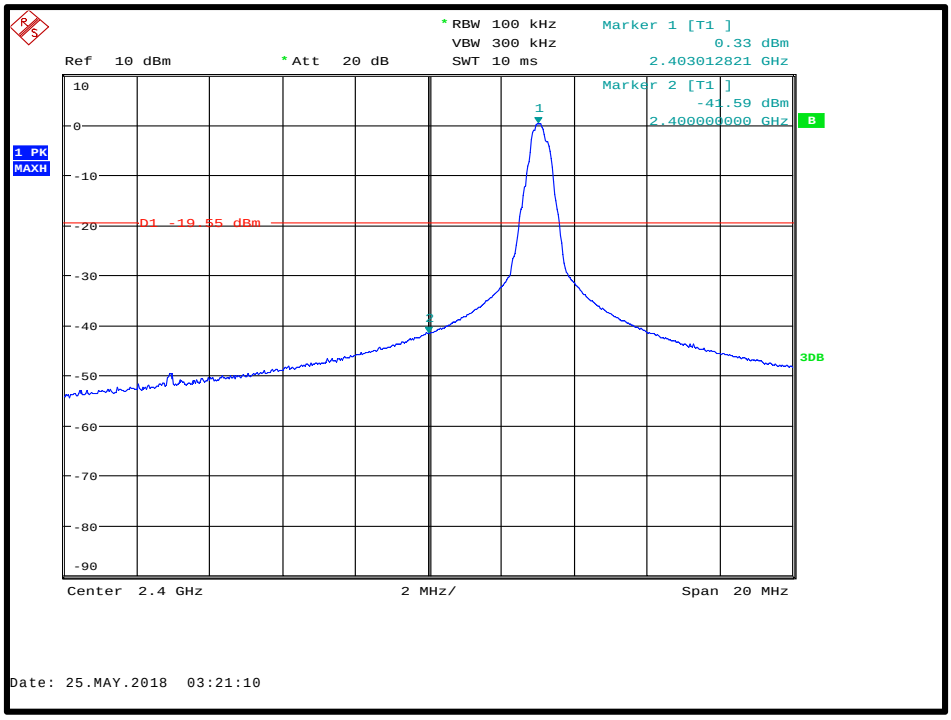
Data rate: Single possible; Power setting: Nominal						
Channel Frequency (MHz)	**Emission Frequency (MHz)**	**Analyzer Level (dBm)**	**Emission Level (dBm)**	**Limit (dBm)**	**Margin (dB)**	**Result**
2403	2403	0.45	0.45	N/A	N/A	PASS
2403	0.066	-57.52	-57.52	-19.55	-37.97	PASS
2403	0.150	-25.30	-25.30	-19.55	-5.75	PASS
2403	4805.929	-40.81	-40.81	-19.55	-21.26	PASS



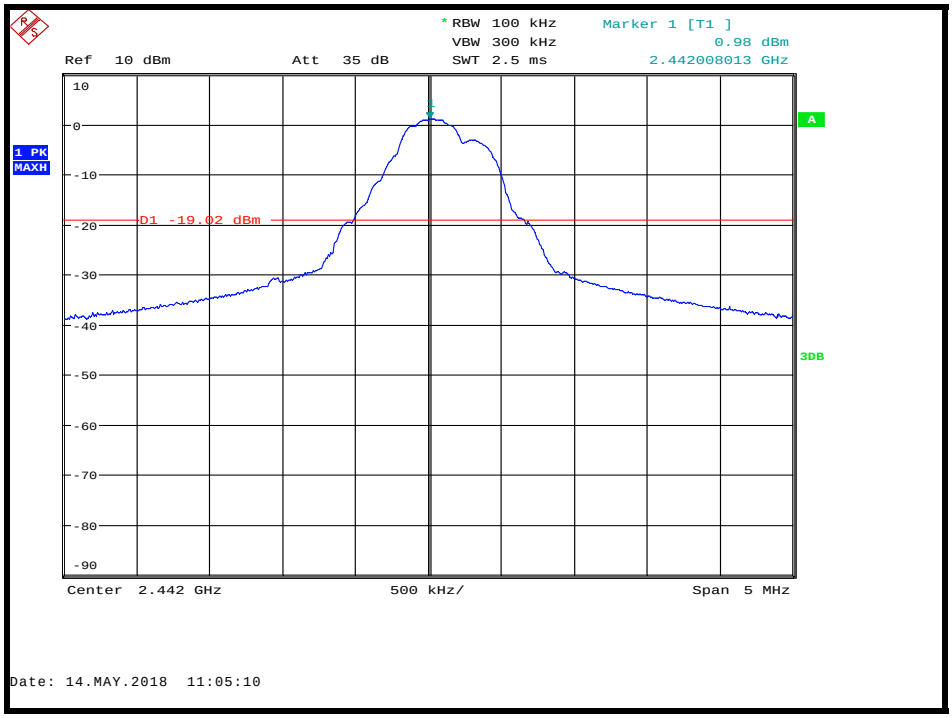


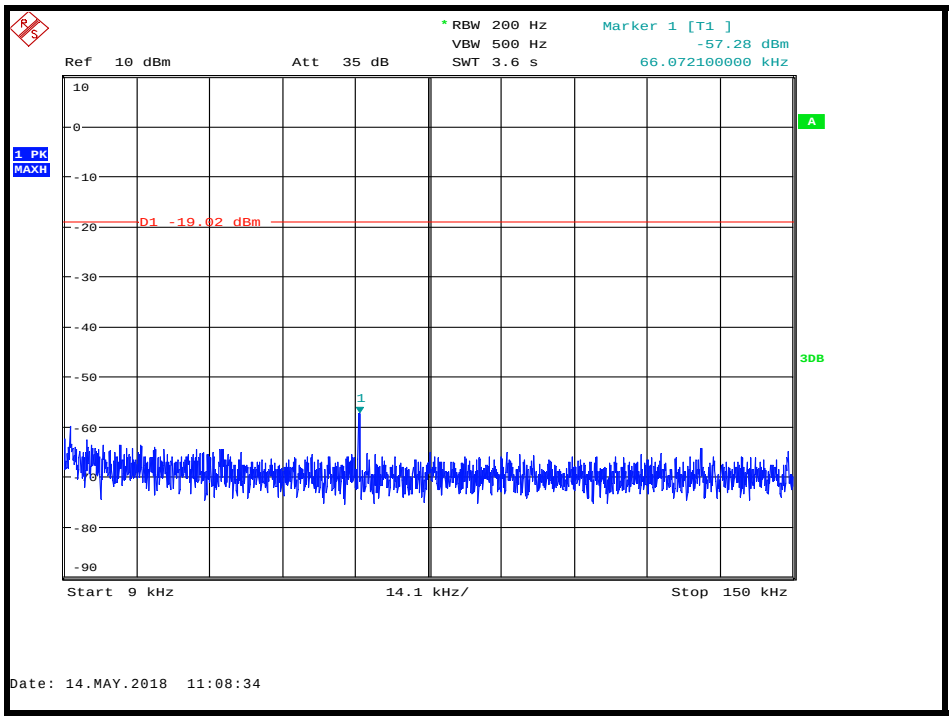

RBW 100 kHz
VBW 300 kHz
SWT 125 ms
Marker 1 [T1]
-25.30 dBm
150.000000000 kHz
Ref 10 dBm
Att 35 dB
1 PK
MAXH
A
3DB
D1 -19.5 dBm
Start 150 kHz
2.985 MHz/
Stop 30 MHz
Date: 14.MAY.2018 10:58:34

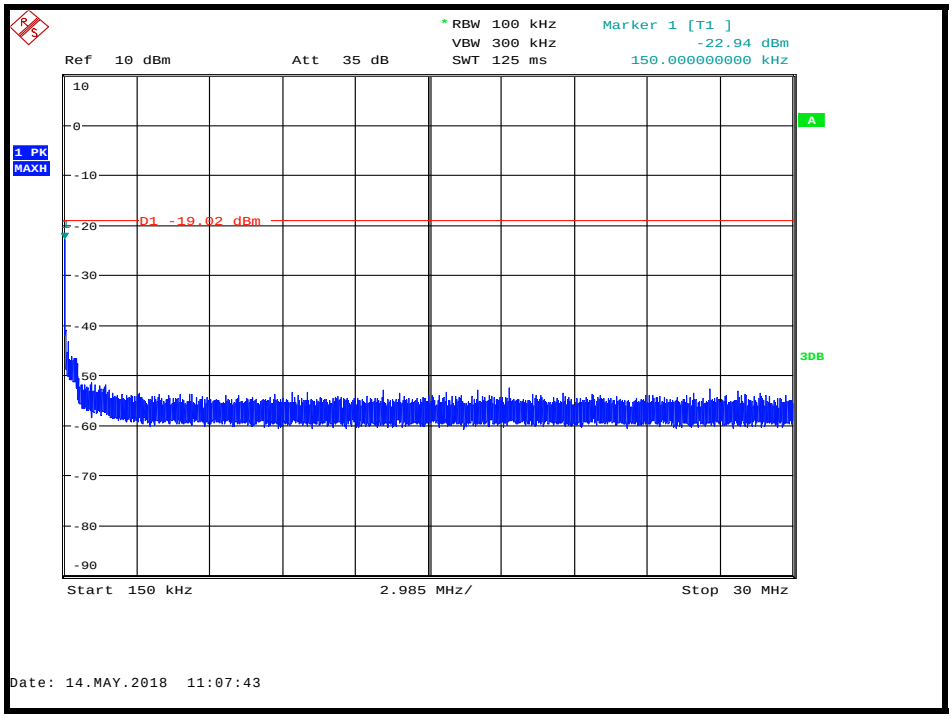

RBW 100 kHz
VBW 300 kHz
SWT 2.5 s
Marker 1 [T1]
0.46 dBm
2.402982333 GHz
Marker 2 [T1]
-40.81 dBm
4.805928667 GHz
Ref 10 dBm
Att 35 dB
1 PK
MAXH
A
3DB
D1 -19.5 dBm
Start 30 MHz
2.497 GHz/
Stop 25 GHz
Date: 14.MAY.2018 10:57:27

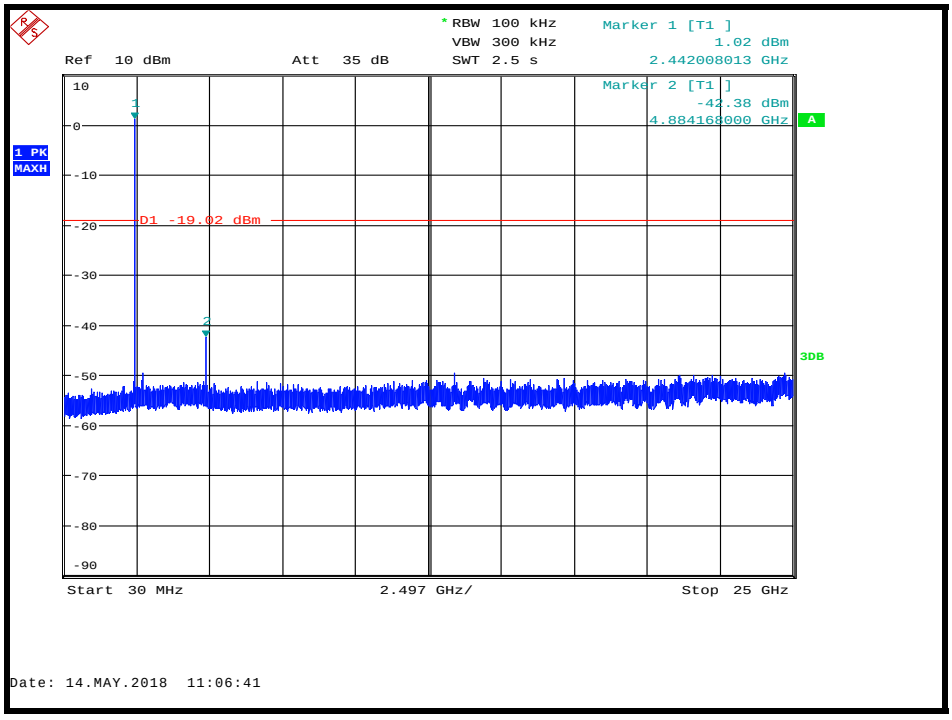

RBW 100 kHz
VBW 300 kHz
SWT 10 ms
Marker 1 [T1]
0.33 dBm
2.403012821 GHz
Marker 2 [T1]
-41.59 dBm
2.400000000 GHz
Ref 10 dBm
Att 20 dB
1 PK
MAXH
D1 -19.55 dBm
3DB
Center 2.4 GHz
2 MHz/
Span 20 MHz
Date: 25.MAY.2018 03:21:10

Data rate: Single possible; Power setting: Nominal						
Channel Frequency (MHz)	**Emission Frequency (MHz)**	**Analyzer Level (dBm)**	**Emission Level (dBm)**	**Limit (dBm)**	**Margin (dB)**	**Result**
2442	2442	0.98	0.98	N/A	N/A	PASS
2442	0.066	-57.28	-57.28	-19.02	-38.26	PASS
2442	150.000	-22.94	-22.94	-19.02	-3.92	PASS
2442	4884.168	-42.38	-42.38	-19.02	-23.36	PASS

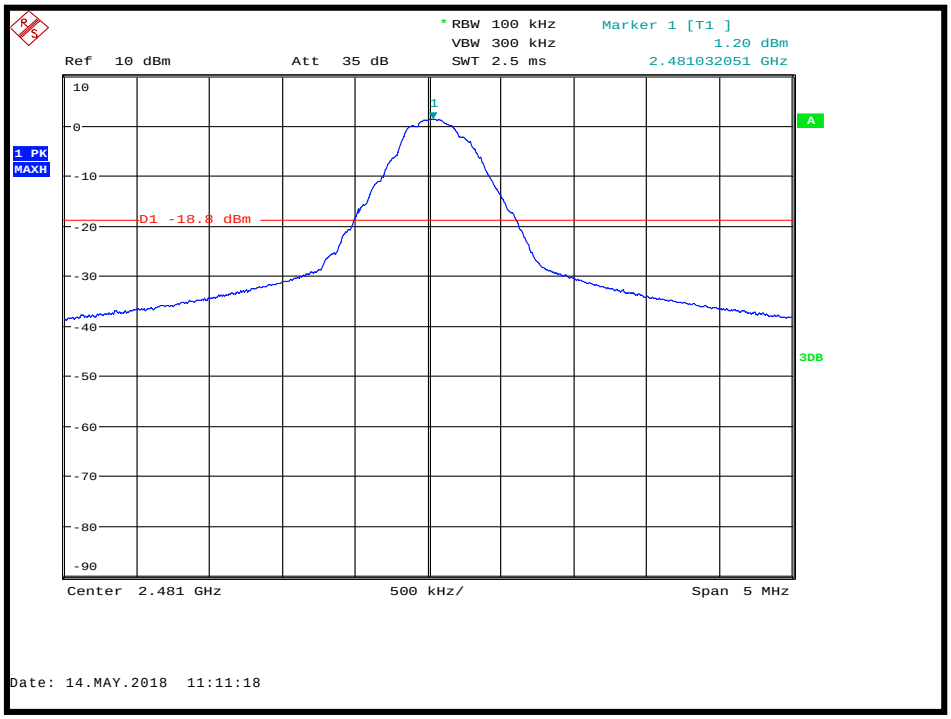


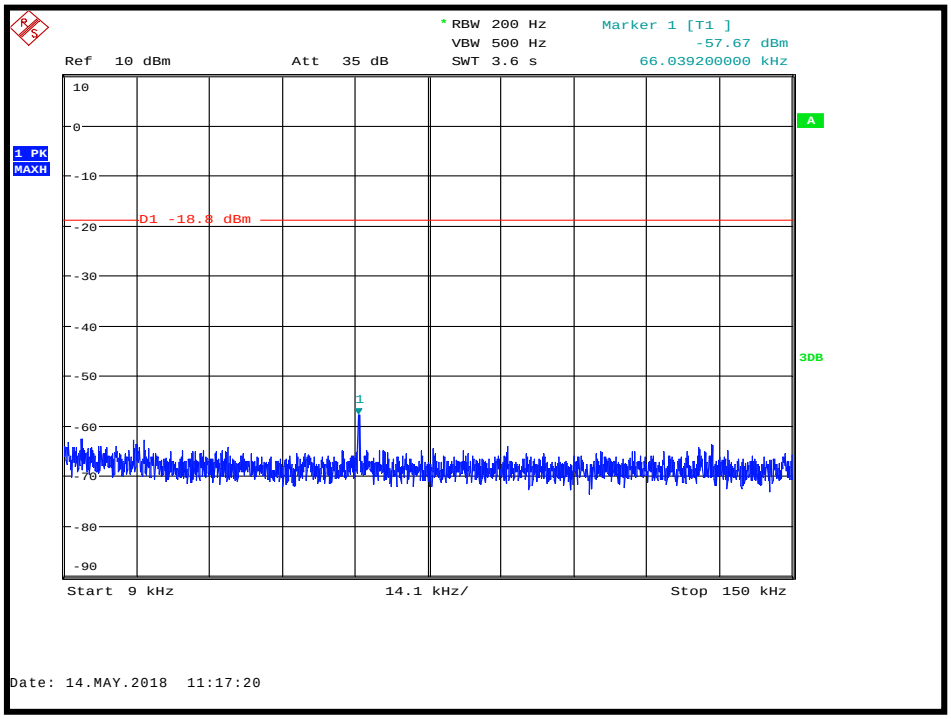


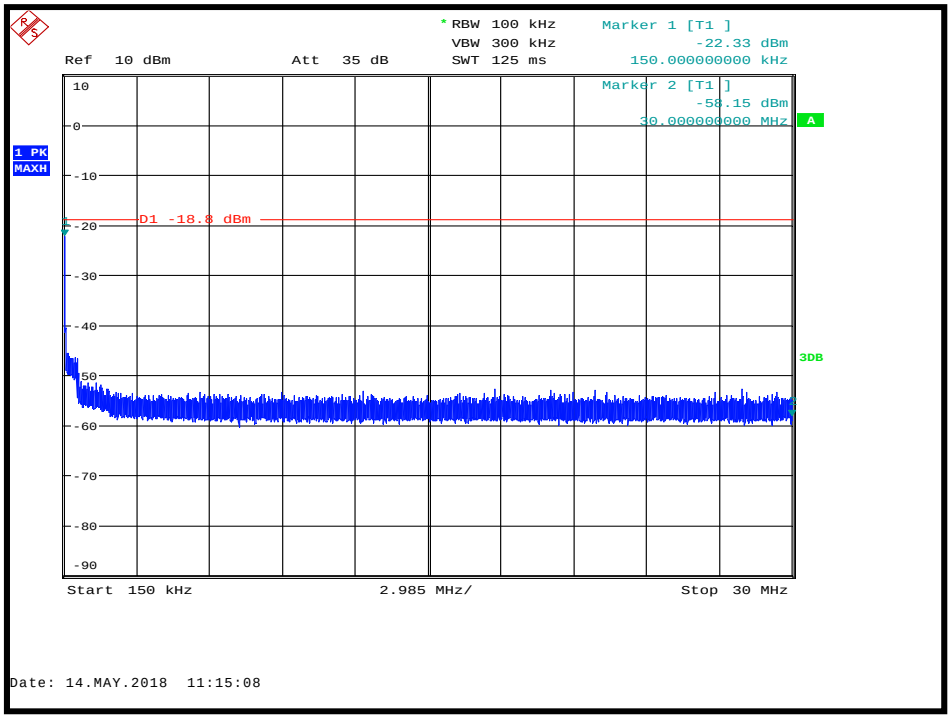

RBW 100 kHz
VBW 300 kHz
SWT 125 ms
Marker 1 [T1]
-22.94 dBm
150.000000000 kHz
Ref 10 dBm
Att 35 dB
1 PK
MAXH
D1 -19.02 dBm
A
3DB
Start 150 kHz
2.985 MHz/
Stop 30 MHz
Date: 14.MAY.2018 11:07:43

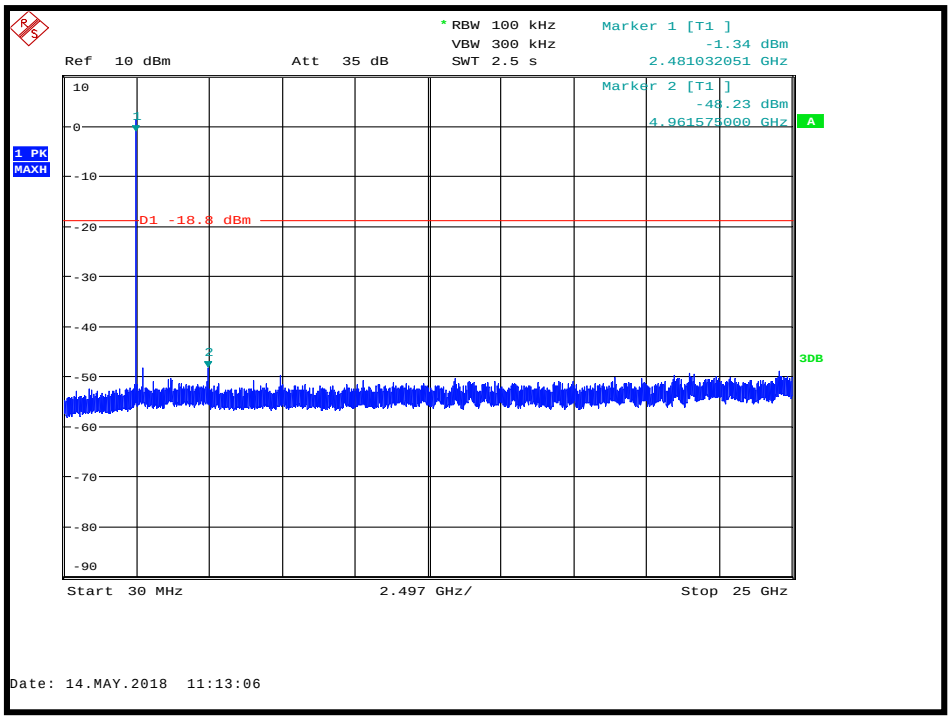

RBW 100 kHz
VBW 300 kHz
SWT 2.5 s
Marker 1 [T1]
1.02 dBm
2.442008013 GHz
Marker 2 [T1]
-42.38 dBm
4.884168000 GHz
Ref 10 dBm
Att 35 dB
1 PK
MAXH
D1 -19.02 dBm
A
3DB
Start 30 MHz
2.497 GHz/
Stop 25 GHz
Date: 14.MAY.2018 11:06:41

Data rate: Single possible; Power setting: Nominal						
Channel Frequency (MHz)	**Emission Frequency (MHz)**	**Analyzer Level (dBm)**	**Emission Level (dBm)**	**Limit (dBm)**	**Margin (dB)**	**Result**
2481	2481	1.20	1.20	N/A	N/A	PASS
2481	0.066	-57.67	-57.67	-18.8	-38.87	PASS
2481	150.000	-22.33	-22.33	-18.8	-3.53	PASS
2481	4961.575	-48.23	-48.23	-18.8	-29.43	PASS

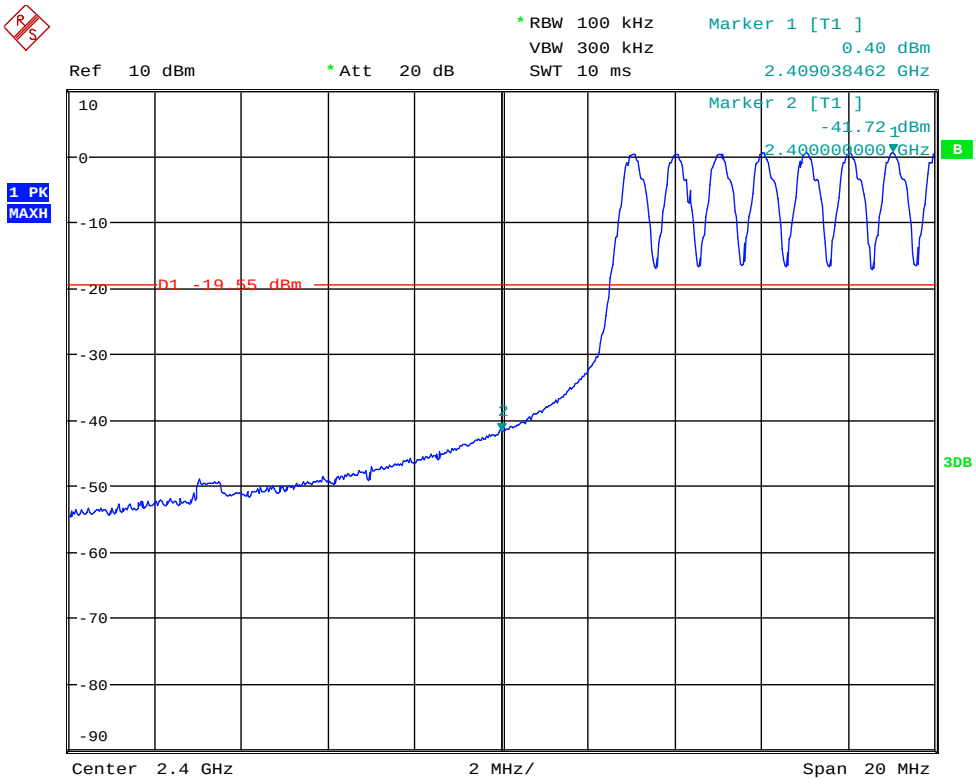





RBW 100 kHz
VBW 300 kHz
SWT 125 ms
Marker 1 [T1]
-22.33 dBm
150.000000000 kHz
Marker 2 [T1]
-58.15 dBm
30.000000000 MHz
Ref 10 dBm
Att 35 dB
1 PK
MAXH
D1 -18.8 dBm
3DB
Start 150 kHz
2.985 MHz/
Stop 30 MHz
Date: 14.MAY.2018 11:15:08


RBW 100 kHz
VBW 300 kHz
SWT 2.5 s
Marker 1 [T1]
-1.34 dBm
2.481032051 GHz
Marker 2 [T1]
-48.23 dBm
4.961575000 GHz
Ref 10 dBm
Att 35 dB
1 PK
MAXH
D1 -18.8 dBm
3DB
Start 30 MHz
2.497 GHz/
Stop 25 GHz
Date: 14.MAY.2018 11:13:06

Channels: All 2403 MHz–2481 MHz (Hopping); Data rate: Single possible; Power setting: Nominal



Date: 25.MAY.2018 03:42:49

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 MPE Calculation

Prediction of MPE limit at a given distance

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 centimeters 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 20 cm 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 the power density limit, as required under FCC rules.

Equation from IEEE C95.1

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

Where:

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

Result

Channel Frequency (MHz)	***EIRP (W)***	***Power density limit (S) (mW/cm^2)***	***Distance (R) cm required to be less than the power density limit***
2403	0.000946	1.00	0.28
2442	0.001148	1.00	0.31
2480	0.001279	1.00	0.32

Note: EIRP is calculated by adding maximum conducted power and antenna gain of -0.82 dBi