Report on the Radio Testing

For

Renishaw Plc

on

RMP600

Report no. TRA-046257-47-00B

2 September 2020

Report Number: TRA-046257-47-00B
Issue: B

REPORT ON THE RADIO TESTING OF A
Renishaw Plc
RMP600
WITH RESPECT TO SPECIFICATION
FCC 47CFR 15.247

TEST DATE: 30th July 2020 - 17th August 2020

Written by: D Moncayola, Radio Test Engineer

Approved by: J Charters, Lab Manager

Date: 2 September 2020

1 Revision Record

Issue Number	*Issue Date*	*Revision History*
A	2nd September 2020	Original
B	2 September 2020	Typographical Corrections

2 Summary

TEST REPORT NUMBER:	TRA-046257-47-00B
WORKS ORDER NUMBER:	TRA-046257-00
PURPOSE OF TEST:	USA: Testing of radio frequency equipment per the relevant authorization procedure of chapter 47 of CFR (code of federal regulations) Part 2, subpart J.
TEST SPECIFICATION(S):	47CFR15.247
EQUIPMENT UNDER TEST (EUT):	RMP600
EQUIPMENT VARIANTS:	RMP600QE
FCC IDENTIFIER:	KQGRMP600QE
EUT SERIAL NUMBER:	22AM74
MANUFACTURER/AGENT:	Renishaw Plc
ADDRESS:	New Mills Wotton Under Edge Gloucestershire GL12 8JR United Kingdom
CLIENT CONTACT:	Rich Warren ☎ 01453 523240 ✉ richard.warren@renishaw.com
TEST DATE:	30th July 2020 - 17th August 2020
TESTED BY:	D Winstanley S Garwell Element

2.1 Test Summary

Test Method and Description		*Requirement Clause47CFR15*	*Applicable to this equipment*	*Result / Note*
Radiated spurious emissions (restricted bands of operation and cabinet radiation)		15.205	☒	*Pass Note 4*
AC power line conducted emissions		15.207	☐	*Note 1*
Carrier frequency separation		15.247(a)(1)	☒	*Pass Note 2*
Number of hopping channels		15.247(a)(1) (i), (ii) and (iii)	☒	*Pass Note 2*
Average time of occupancy		15.247(a)(1) (i), (ii) and (iii)	☒	*Pass Note 2*
Maximum peak conducted output power		15.247 (a)(1), (b)(1) and (b)(2)	☒	*Pass Note 2*
Conducted carrier power	Peak	15.247(b)(3)	☐	*Pass Note 3*
	Max.		☒	
Power spectral density, conducted		15.247(e)	☒	*Pass Note 3*
20dB emission bandwidth		15.247(a)(1) (i) and (ii)	☒	*Pass Note 2*
Occupied bandwidth		15.247(a)(2)	☒	*Pass Note 3*
Out-of-band emissions		15.247(d)	☒	*Pass Note 4*

Notes:

1 Note applicable EUT is battery powered
2 Applicable for Mode 1 and Mode 2 – FHSS Operation
3 Applicable for Mode 2 – DTS operation
4 Applicable for Mode 1 and Mode 2 (both FHSS and DTS Operation) EUT uses same modulation techniques for both FHSS and DTS operation

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-046257-47-00B presents the results of the Radio testing on a Renishaw Plc, RMP600 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.

IC Registration Number(s):

Element Hull	3483A
Element North West	3930B

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

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

5 Test Specifications

5.1 Normative References

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

5.2 Deviations from Test Standards

There were no deviations from the test standard.

6 Glossary of Terms

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

7 Equipment Under Test

7.1 EUT Identification

- Name: RMP600
- Serial Number: 22AM74
- Model Number: RMP600QE
- Software Revision: Not Applicable
- Build Level / Revision Number: Production

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 contains selections for test menus for Mode 1 or Mode 2 and selection of normal operation.

These test menus allow the unit to be set to top, middle or bottom frequencies or hopping across all frequencies in either Mode 1 or Mode 2.

7.4 EUT Radio Parameters

7.4.1 General

Frequency of operation:	2403 MHz-2481 MHz
Modulation type(s):	Mode 1: 1 MBps Binary GFSK Frequency Hopping Mode 2: 2 MBps Binary GFSK Frequency Hopping Mode 2: 2 MBps Binary GFSK DSSS
Occupied channel bandwidth(s):	Mode 1: 1 MHz Mode 2: 2 MHz
Channel spacing:	Mode 1: 1 MHz Mode 2: 2 MHz
Declared output power(s):	Mode 1: 0dBm Mode 2: +4dBm
Antenna type:	Slot type
Antenna gain:	1.3 dBi
Nominal Supply Voltage:	3.0 Vdc

7.5 EUT Description

The EUT is a measuring probe, using the 2400 MHz - 2483.5 MHz frequency band, and uses frequency hopping.

Mode 1 uses FHSS operating over 79 channels.
Mode 2 uses DTS and FHSS over 39 channels. DTS mode is used during setup and FHSS mode in probe operation.

8 Modifications

No modifications were performed during this assessment.

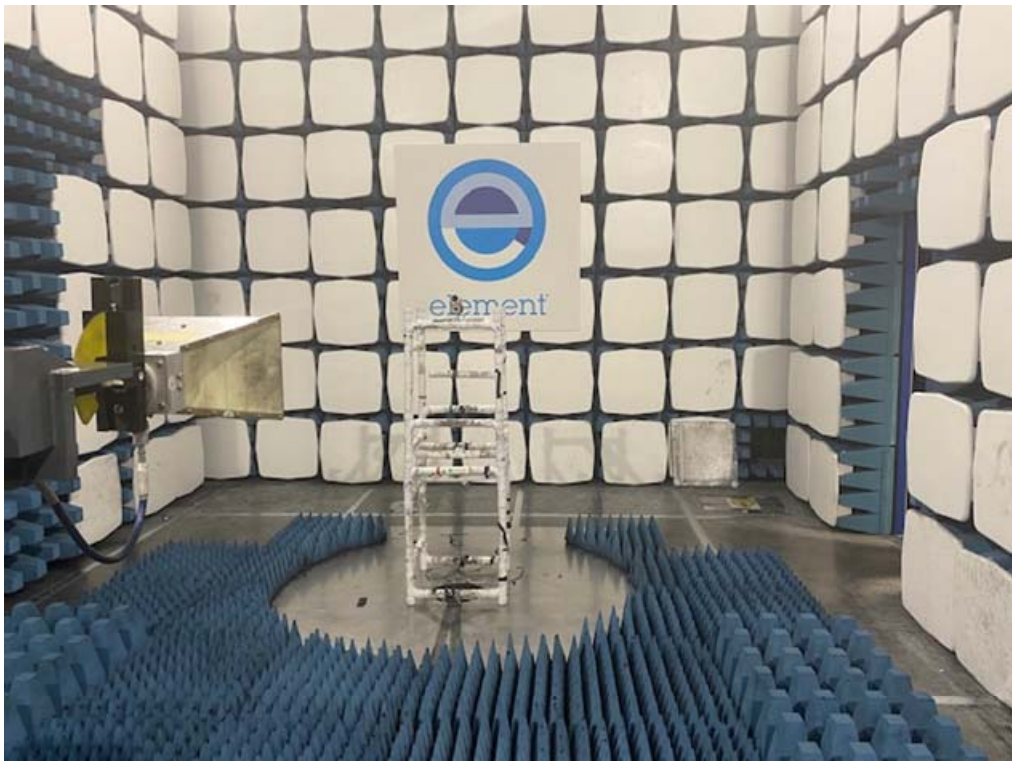
9 EUT Test Setup

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:



9.3 Measurement software

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

Element Emissions R5 (See Note)
Element Transmitter Bench Test (See Note)
ETS Lindgren EMPower V1.0.4.2

Note:

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

10 General Technical Parameters

10.1 Normal Conditions

The E U T was tested under the normal environmental conditions of the test laboratory, except where otherwise stated. The normal power source applied was approx. 3 Vdc from alkaline batteries

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 Skelmersdale
Test Chamber:	Chamber 3
Test Standard and Clause:	ANSI C63.10-2013, Clause 6.5 and 6.6
EUT Channels Measured:	Low / Mid / High
EUT Channel Bandwidths:	1 MHz / 2 MHz
Deviations From Standard:	None
Measurement BW:	30 MHz to 1 GHz: 120 kHz; Above 1 GHz: 1 MHz
Measurement Detector:	Up to 1 GHz: quasi-peak; Above 1 GHz: RMS average and Peak

Environmental Conditions (Normal Environment)

Temperature: 23 °C	+15 ºC to +35 ºC (as declared)
Humidity: 39 % RH	20 % RH to 75 % RH (as declared)
Supply: 3 V dc	

11.3 Test Limit

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

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

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

11.4 Test Method

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

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

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

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

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

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

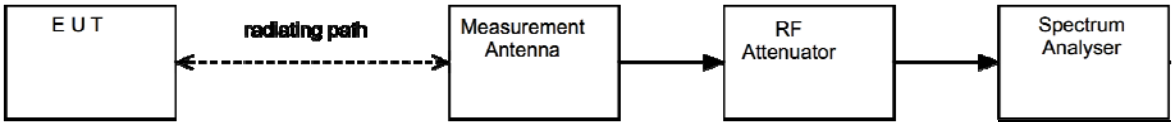
$$FS = PR + CL + AF – PA + DC – CF$$

Where,

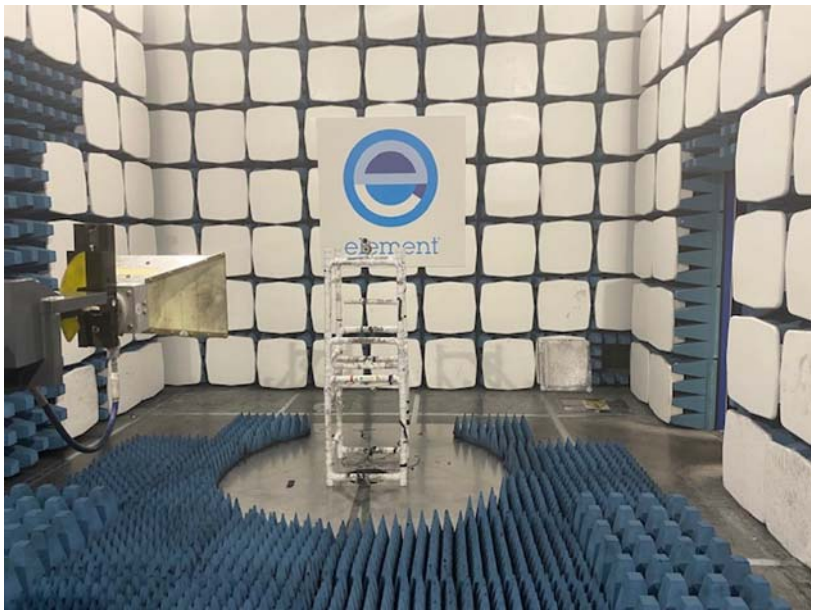
PR is the power recorded on the receiver / spectrum analyzer in dBµV;
CL is the cable loss in dB;
AF is the test antenna factor in dB/m;
PA is the pre-amplifier gain in dB (where used);
DC is the duty correction factor in dB (where used, e.g. harmonics of pulsed fundamental);
CF is the distance factor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

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

Figure i Test Setup



11.5 Test Set-up Photographs

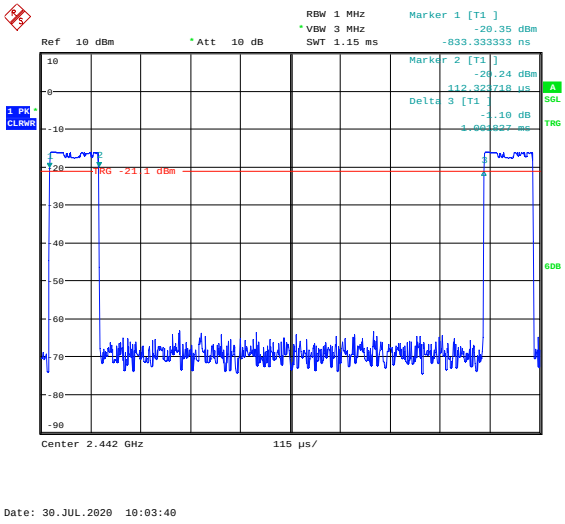


11.6 Test Equipment

Equipment Description	*Manufacturer*	*Equipment Type*	*Element No*	*Due For Calibration*
Spectrum Analyser	R&S	FSU26	REF909	2021-07-09
Bilog	Chase	CBL611/A	U573	2021-09-19
PreAmp	Watkins Johnson	6201-69	U372	2021-02-26
8449B	Agilent	Pre Amp	L572	2020-10-15
1-18GHz Horn	EMCO	3115	L139	2021-07-16

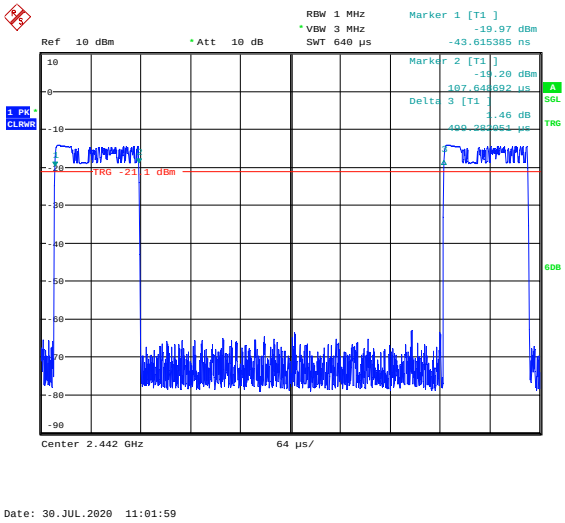
11.7 Test Results

Duty cycle correction Mode 1



Duty Cycle Correction= 20log (1/D)= 20 log (T/T_{on})= 19.2
Where D is the duty cycle= T_{on}/T

Duty cycle correction Mode 2

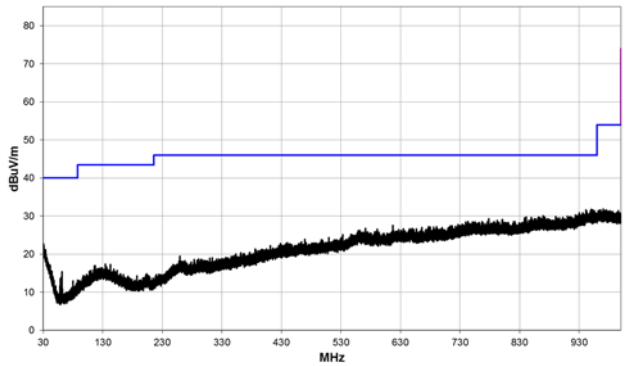


Duty Cycle Correction= 20log (1/D)= 20 log (T/T_{on})= 13.3

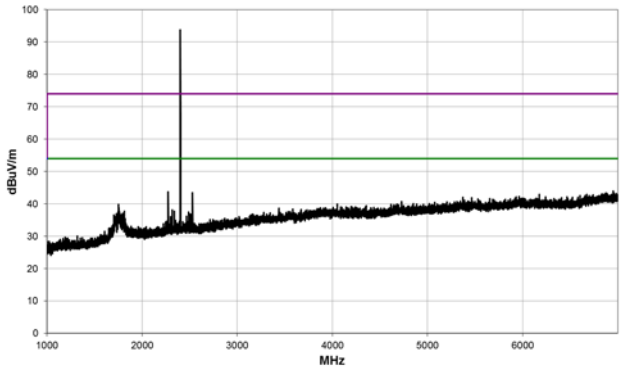
Where D is the duty cycle= T_{on}/T

11.8 Test Results – RMP600QE

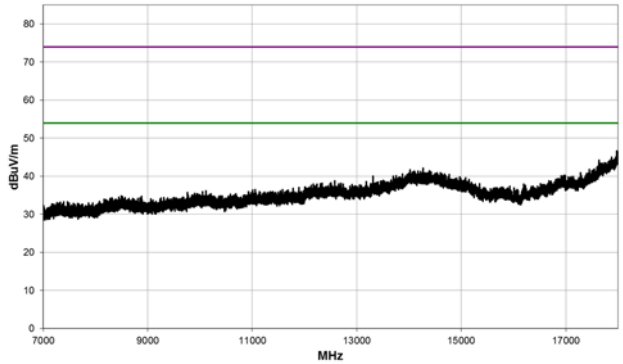
2403 MHz – 1 Mbps



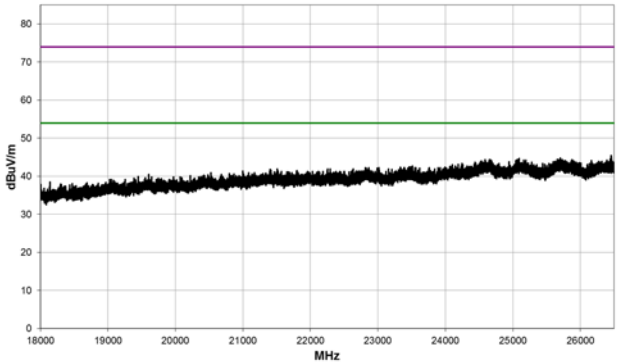
30 MHz to 1 GHz



1 GHz to 7 GHz



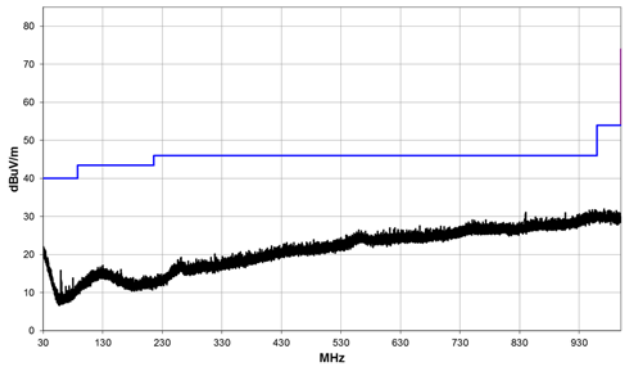
7 GHz to 18 GHz



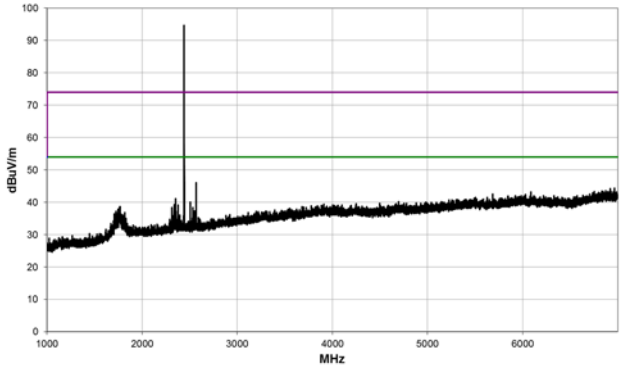
18 GHz to 26.5 GHz

Freq (MHz)	Amplitude (dBuV)	Factor (dB)	Antenna Height (meters)	Azimuth (degrees)	Duty Cycle Correction Factor (dB)	External Attenuation (dB)	Polarity/ Transducer Type	Detector	Distance Adjustment (dB)	Adjusted (dBuV/m)	Spec. Limit (dBuV/m)	Compared to Spec. (dB)	Comments
2275.087	34.4	-4.2	1.27	-0.1	19.2	0.0	Horz	AV	0.0	49.4	54.0	-4.6	Pass
2274.995	59.8	-4.2	1.27	-0.1		0.0	Horz	PK	0.0	55.6	74.0	-18.4	Pass
2275.187	52.2	-4.2	1.25	177.0		0.0	Vert	PK	0.0	48.0	74.0	-26.0	Pass

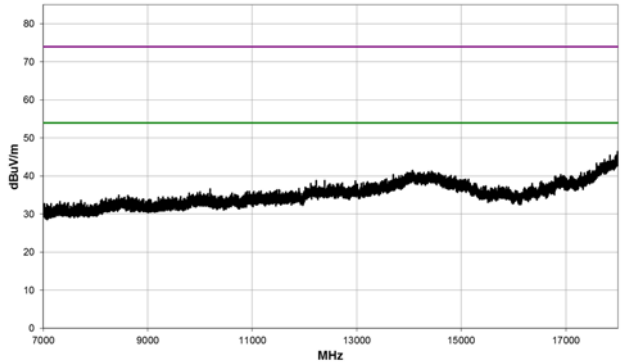
2442 MHz – 1 Mbps



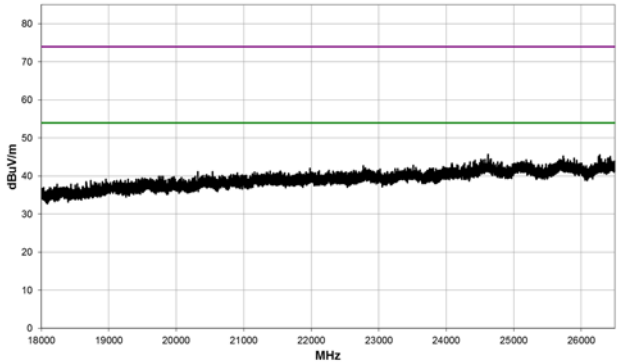
30 MHz to 1 GHz



1 GHz to 7 GHz



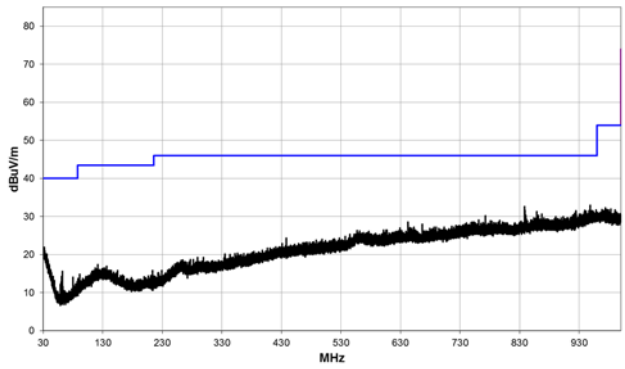
7 GHz to 18 GHz



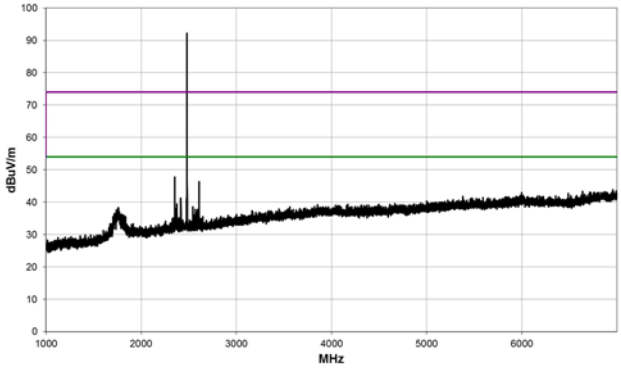
18 GHz to 26.5 GHz

Freq (MHz)	Amplitude (dBuV)	Factor (dB)	Antenna Height (meters)	Azimuth (degrees)	Duty Cycle Correction Factor (dB)	External Attenuation (dB)	Polarity/ Transducer Type	Detector	Distance Adjustment (dB)	Adjusted (dBuV/m)	Spec. Limit (dBuV/m)	Compared to Spec. (dB)	Comments
2351.887	56.4	-3.8	2.13	261.9		0.0	Horz	PK	0.0	52.6	74.0	-21.4	Pass
2352.770	47.5	-3.8	1.5	327.1		0.0	Vert	PK	0.0	43.7	74.0	-30.3	Pass

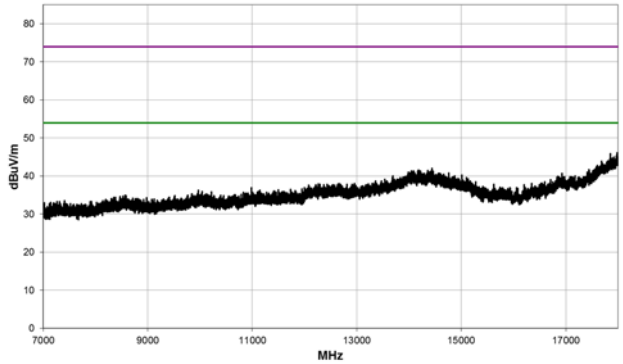
2481 MHz – 1 Mbps



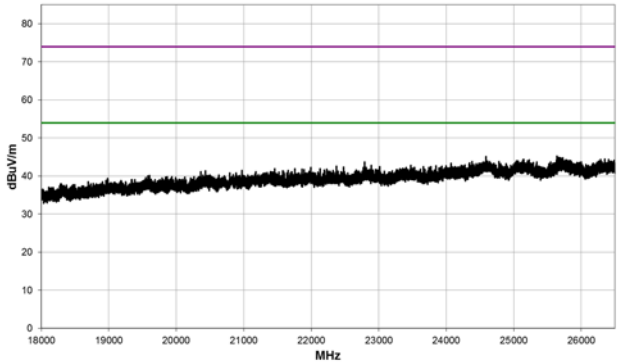
30 MHz to 1 GHz



1 GHz to 7 GHz

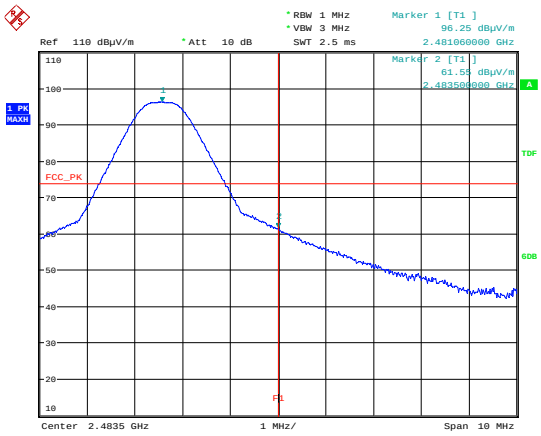


7 GHz to 18 GHz

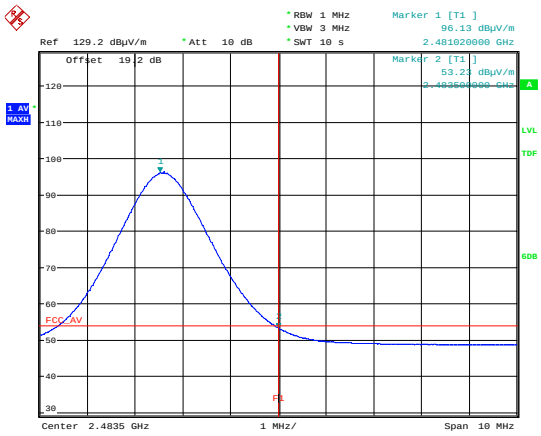


18 GHz to 26.5 GHz

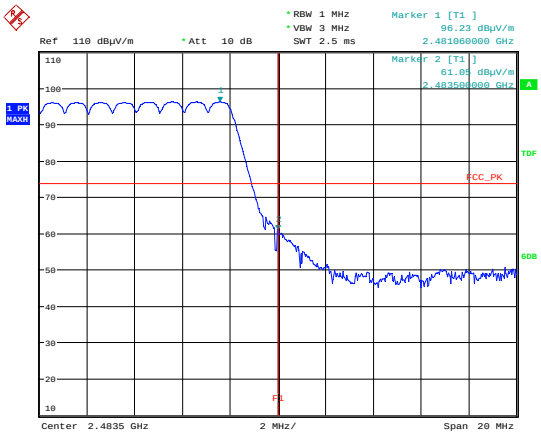
Freq (MHz)	Amplitude (dBuV)	Factor (dB)	Antenna Height (meters)	Azimuth (degrees)	Duty Cycle Correction Factor (dB)	External Attenuation (dB)	Polarity/ Transducer Type	Detector	Distance Adjustment (dB)	Adjusted (dBuV/m)	Spec. Limit (dBuV/m)	Compared to Spec. (dB)	Comments
2353.103	34.6	-3.8	1.5	270.1	19.2	0.0	Horz	AV	0.0	50.0	54.0	-4.0	Pass
2352.953	60.1	-3.8	1.5	270.1		0.0	Horz	PK	0.0	56.3	74.0	-17.7	Pass
2353.137	49.4	-3.8	1.11	203.9		0.0	Vert	PK	0.0	45.6	74.0	-28.4	Pass



2481 MHz Upper Band Edge Plot – Peak

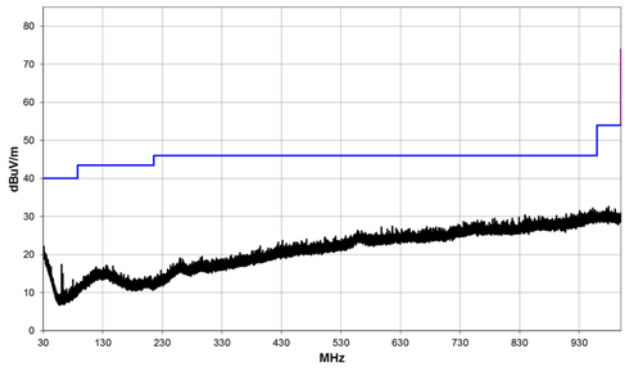


2481 MHz Upper Band Edge Plot – Average

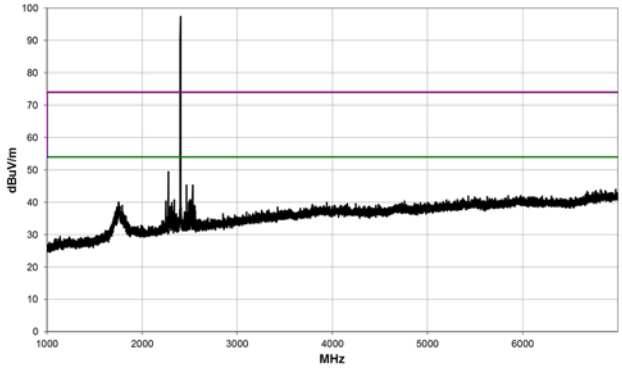


2481 MHz Upper Band Edge Plot – All Hopping

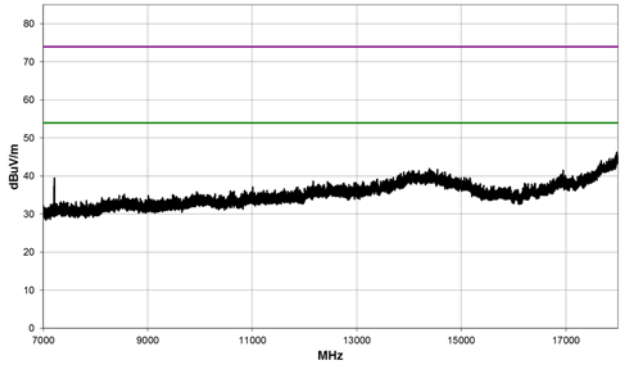
2404 MHz – 2 Mbps



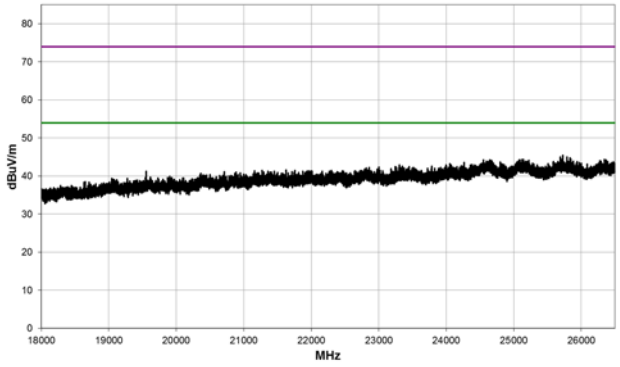
30 MHz to 1 GHz



1 GHz to 7 GHz



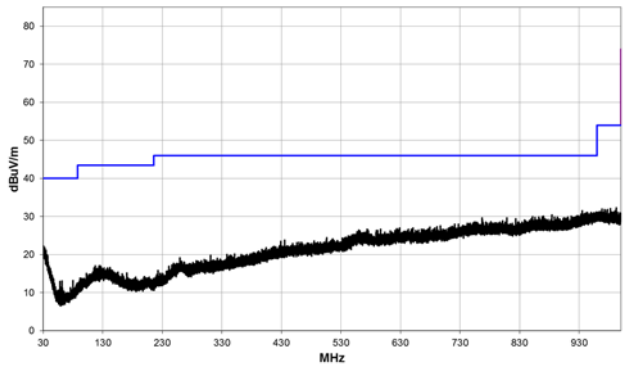
7 GHz to 18 GHz



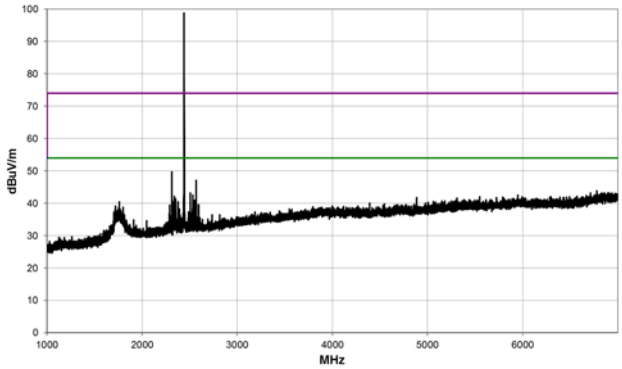
18 GHz to 26.5 GHz

Freq (MHz)	Amplitude (dBuV)	Factor (dB)	Antenna Height (meters)	Azimuth (degrees)	Duty Cycle Correction Factor (dB)	External Attenuation (dB)	Polarity/ Transducer Type	Detector	Distance Adjustment (dB)	Adjusted (dBuV/m)	Spec. Limit (dBuV/m)	Compared to Spec. (dB)	Comments
2276.103	37.0	-4.2	2.1	4.0	13.3	0.0	Horz	AV	0.0	46.1	54.0	-7.9	Pass
2276.120	61.9	-4.2	2.1	4.0		0.0	Horz	PK	0.0	57.7	74.0	-16.3	Pass
2276.228	53.1	-4.2	1.1	319.0		0.0	Vert	PK	0.0	48.9	74.0	-25.1	Pass

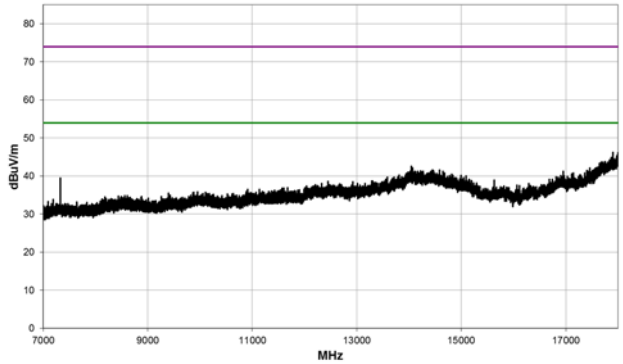
2442 MHz – 2 Mbps



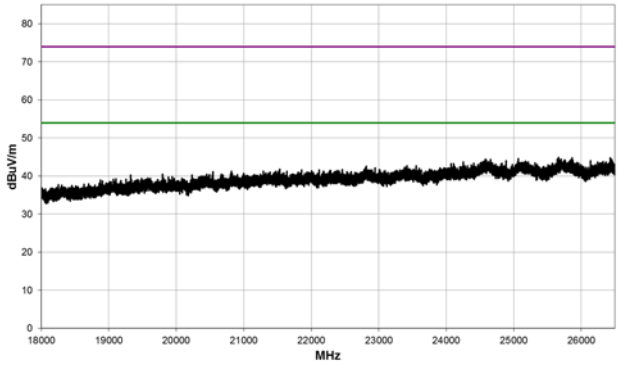
30 MHz to 1 GHz



1 GHz to 7 GHz



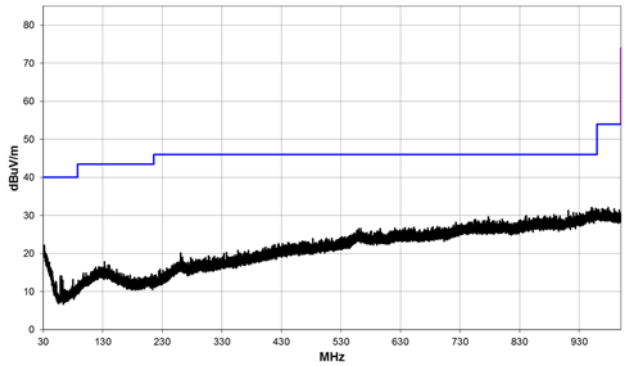
7 GHz to 18 GHz



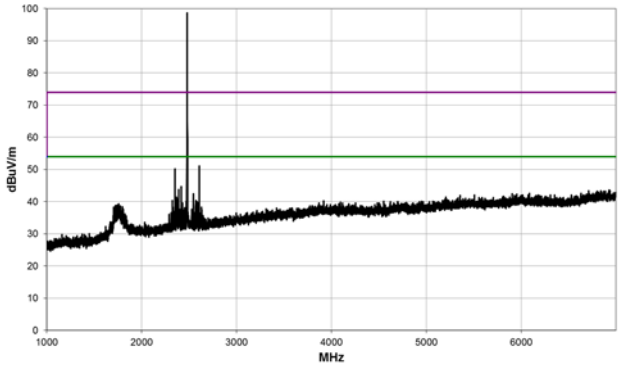
18 GHz to 26.5 GHz

Freq (MHz)	Amplitude (dBuV)	Factor (dB)	Antenna Height (meters)	Azimuth (degrees)	Duty Cycle Correction Factor (dB)	External Attenuation (dB)	Polarity/ Transducer Type	Detector	Distance Adjustment (dB)	Adjusted (dBuV/m)	Spec. Limit (dBuV/m)	Compared to Spec. (dB)	Comments
2314.087	36.4	-4.0	1.5	185.0	13.3	0.0	Horz	AV	0.0	45.7	54.0	-8.3	Pass
2313.728	61.7	-4.0	1.5	185.0		0.0	Horz	PK	0.0	57.7	74.0	-16.3	Pass
2313.687	53.0	-4.0	1.05	318.0		0.0	Vert	PK	0.0	49.0	74.0	-25.0	Pass
7327.07	53.10	7.50	1.85	194.00		0.00	Vert	PK	-9.50	51.10	74.00	-22.90	Pass
7325.70	49.40	7.50	1.60	24.10		0.00	Horz	PK	-9.50	47.40	74.00	-26.60	Pass

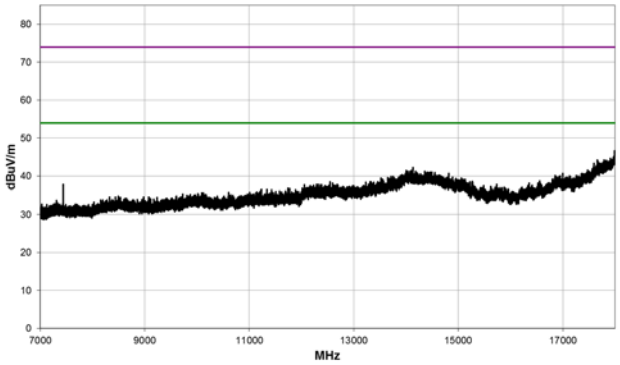
2480 MHz – 2 Mbps



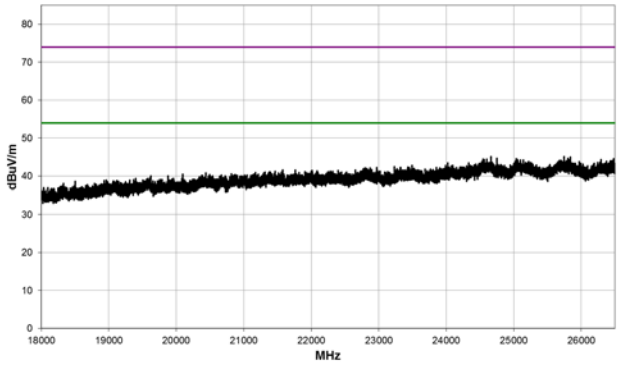
30 MHz to 1 GHz



1 GHz to 7 GHz

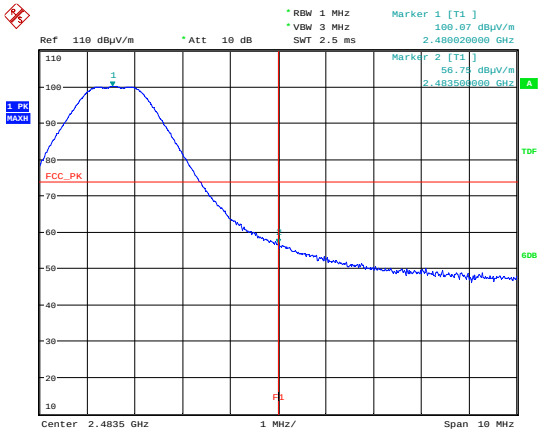


7 GHz to 18 GHz

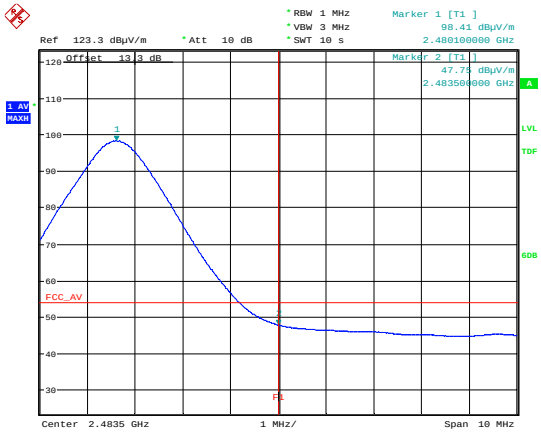


18 GHz to 26.5 GHz

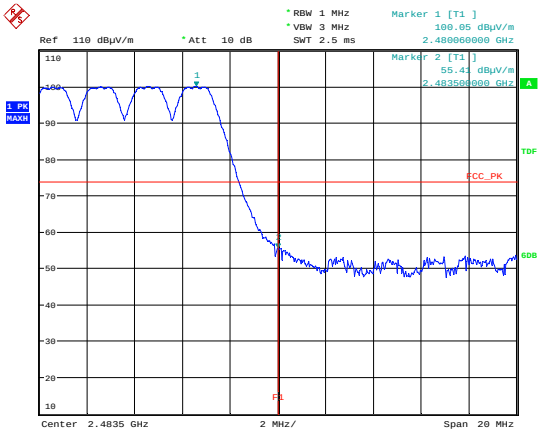
Freq (MHz)	Amplitude (dBuV)	Factor (dB)	Antenna Height (meters)	Azimuth (degrees)	Duty Cycle Correction Factor (dB)	External Attenuation (dB)	Polarity/ Transducer Type	Detector	Distance Adjustment (dB)	Adjusted (dBuV/m)	Spec. Limit (dBuV/m)	Compared to Spec. (dB)	Comments
2352.070	37.2	-3.8	1.5	264.0	13.3	0.0	Horz	AV	0.0	46.7	54.0	-7.3	Pass
2351.837	62.4	-3.8	1.5	264.0		0.0	Horz	PK	0.0	58.6	74.0	-15.4	Pass
2351.862	52.0	-3.8	1.5	202.1		0.0	Vert	PK	0.0	48.2	74.0	-25.8	Pass
7441.22	52.60	7.60	1.91	191.00		0.00	Vert	PK	-9.50	50.70	74.00	-23.30	Pass
7440.14	48.80	7.60	1.50	169.00		0.00	Horz	PK	-9.50	46.90	74.00	-27.10	Pass



2481 MHz Upper Band Edge Plot – Peak



2481 MHz Upper Band Edge Plot – Average



2481 MHz Upper Band Edge Plot – All Hopping

12 Carrier frequency separation

12.1 Definition

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

12.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Radio Laboratory
Test Standard and Clause:	ANSI C63.10-2013, Clause 7.8.2
EUT Channels / Frequencies Measured:	Mode 1: 2403 to 2481 MHz Mode 2: 2404 to 2480 MHz
EUT Test Modulations:	Internal pattern generation – hopping enabled
Deviations From Standard:	None
Measurement BW:	100 kHz
Measurement Detector:	Peak

Environmental Conditions (Normal Environment)

Temperature: 23 °C	+15 ºC to +35 ºC (as declared)
Humidity: 29 % RH	20 % RH to 75 % RH (as declared)
Supply: 3.0 Vdc	

12.3 Test Limit

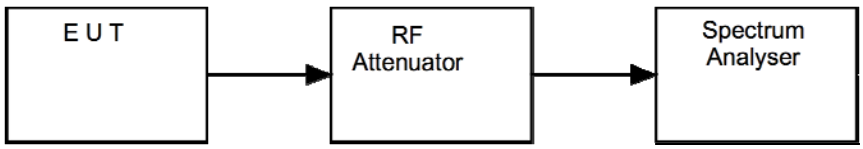
Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the -20 dB bandwidth of the hopping channel, whichever is greater. Alternatively, frequency hopping systems operating in the band 2400 to 2483.5 MHz may have hopping channel carrier frequencies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

12.4 Test Method

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

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

Figure iii Test Setup



12.5 Test Equipment

Equipment Description	*Manufacturer*	*Equipment Type*	*Element No*	*Due For Calibration*
Spectrum Analyser	R&S	FSU26	REF909	2021-07-09

12.6 Test Results

Mode 1: 1MBps		
Data Rate	*Channel Separation, $F2_c - F1_c$ (kHz)*	*Result*
1 MBps	1001.5	PASS

Mode 2: 2MBps		
Data Rate	*Channel Separation, $F2_c - F1_c$ (kHz)*	*Result*
2 MBps	2002	PASS

Mode 1:

07:07:29 07.08.2020

Mode 2:

06:48:37 07.08.2020

13 Number of hopping frequencies

13.1 Definition

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

13.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Radio Laboratory
Test Standard and Clause:	ANSI C63.10-2013, Clause 7.8.3
EUT Channels / Frequencies Measured:	All; 2400 – 2483.5 MHz
EUT Test Modulations:	Internal pattern generation – hopping enabled
Deviations From Standard:	None
Measurement Detector:	Peak

Environmental Conditions (Normal Environment)

Temperature: 23 °C	+15 ºC to +35 ºC (as declared)
Humidity: 29 % RH	20 % RH to 75 % RH (as declared)
Supply: 3.0 V dc	

13.3 Test Limit

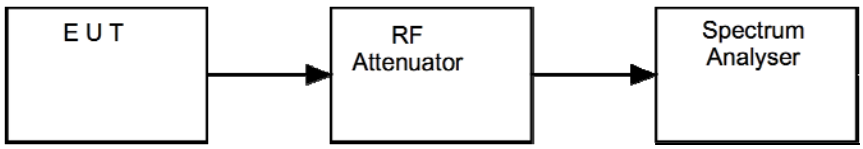
- For frequency hopping systems in the band 902 to 928 MHz: if the -20 dB bandwidth of the hopping channel is less than 250 kHz, the system shall use at least 50 hopping channels; If the -20 dB bandwidth of the hopping channel is 250 kHz or greater, the system shall use at least 25 hopping channels;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

13.4 Test Method

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

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

Figure iv Test Setup



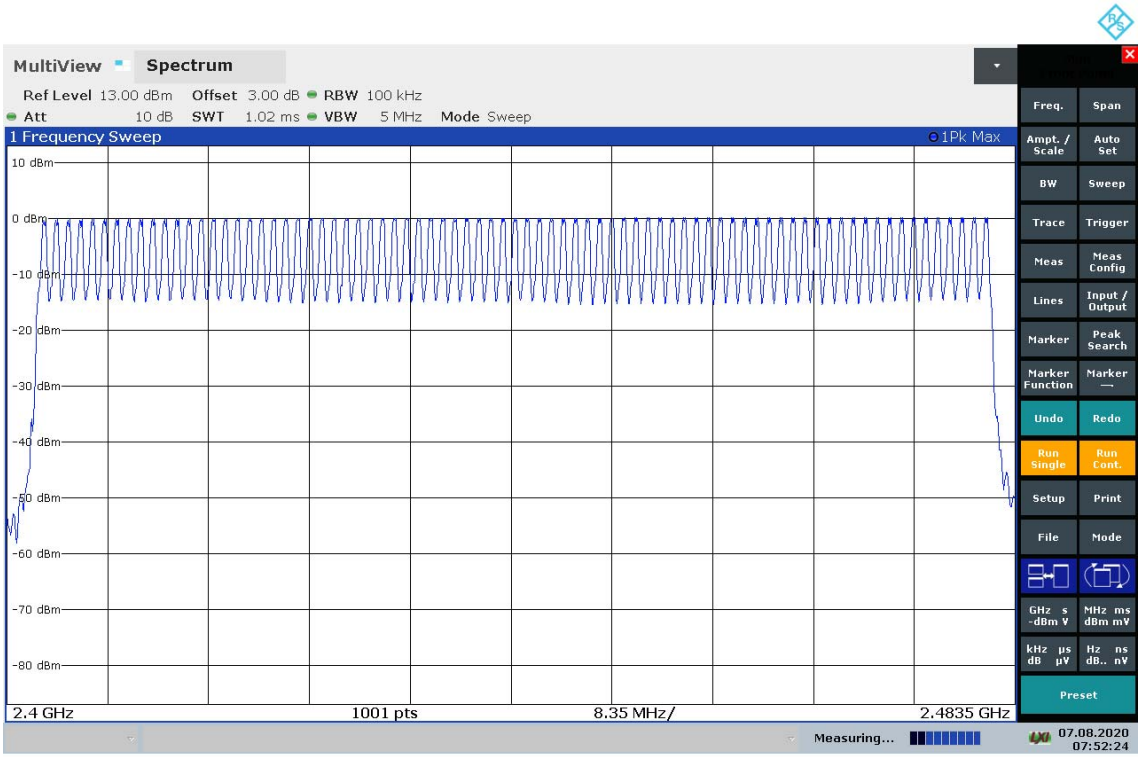
13.5 Test Equipment

Equipment Description	*Manufacturer*	*Equipment Type*	*Element No*	*Due For Calibration*
Spectrum Analyser	R&S	FSU26	REF909	2021-07-09

13.6 Test Results

Data Rate	*Lowest channel, F_{CL} (MHz)*	*Highest channel, F_{CH} (MHz)*	*Number of channels observed*	*Result*
1 MBps	2403.0 MHz	2481.0 MHz	79	PASS
2 MBps	2404.0 MHz	2480.0 MHz	39	PASS

Mode 1:



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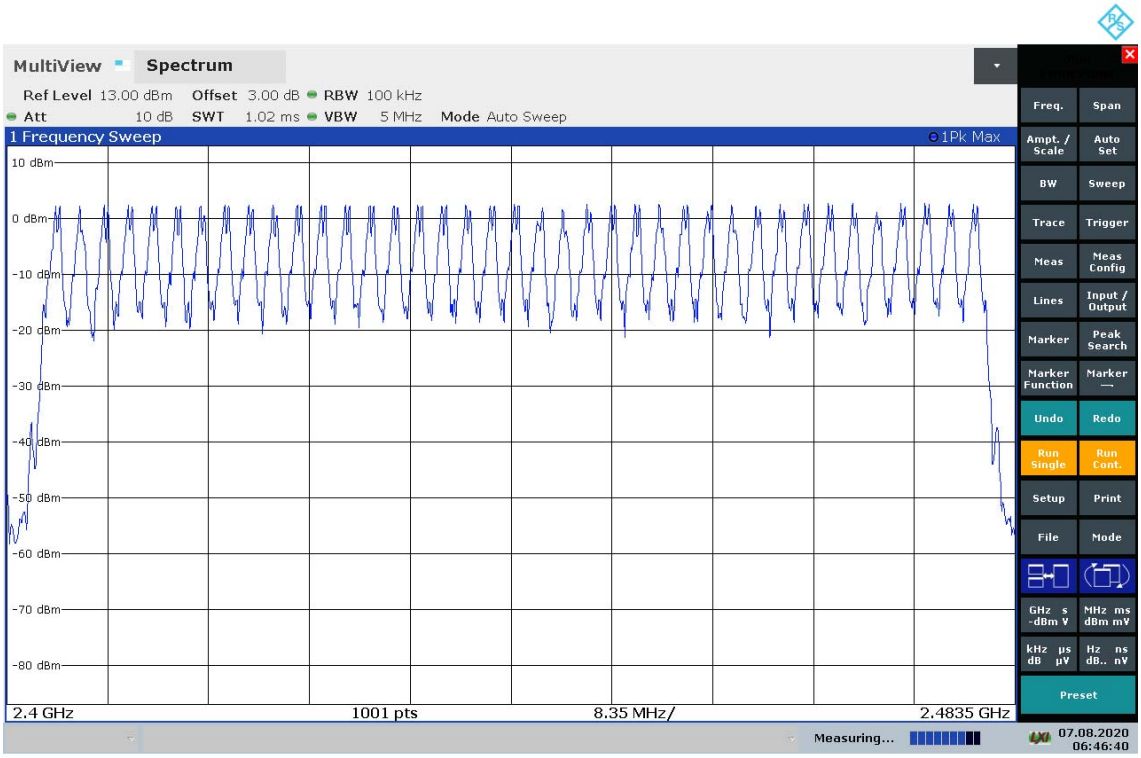
Mode 2:



06:46:41 07.08.2020

14 Average channel occupancy

14.1 Definition

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

14.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Radio Laboratory
Test Standard and Clause:	ANSI C63.10-2013, Clause 7.8.4
Frequencies Measured:	2440 MHz
EUT Number of hopping channels:	Mode 1: 79 Mode 2: 39
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: 30 % RH	20 % RH to 75 % RH (as declared)
Supply: 3.0 Vdc	

14.3 Test Limit

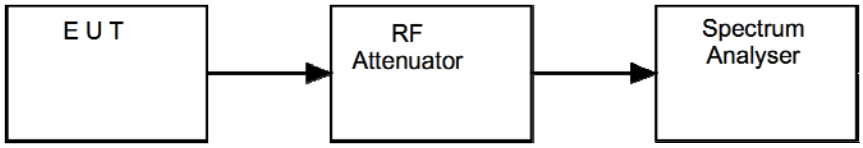
- For frequency hopping systems in the band 902 to 928 MHz: if the -20 dB bandwidth of the hopping channel is less than 250 kHz, the average time of occupancy on any channel shall not be greater than 0.4 seconds within a 20 second period;
  If the -20 dB bandwidth of the hopping channel is 250 kHz or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

14.4 Test Method

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

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

Figure v Test Setup

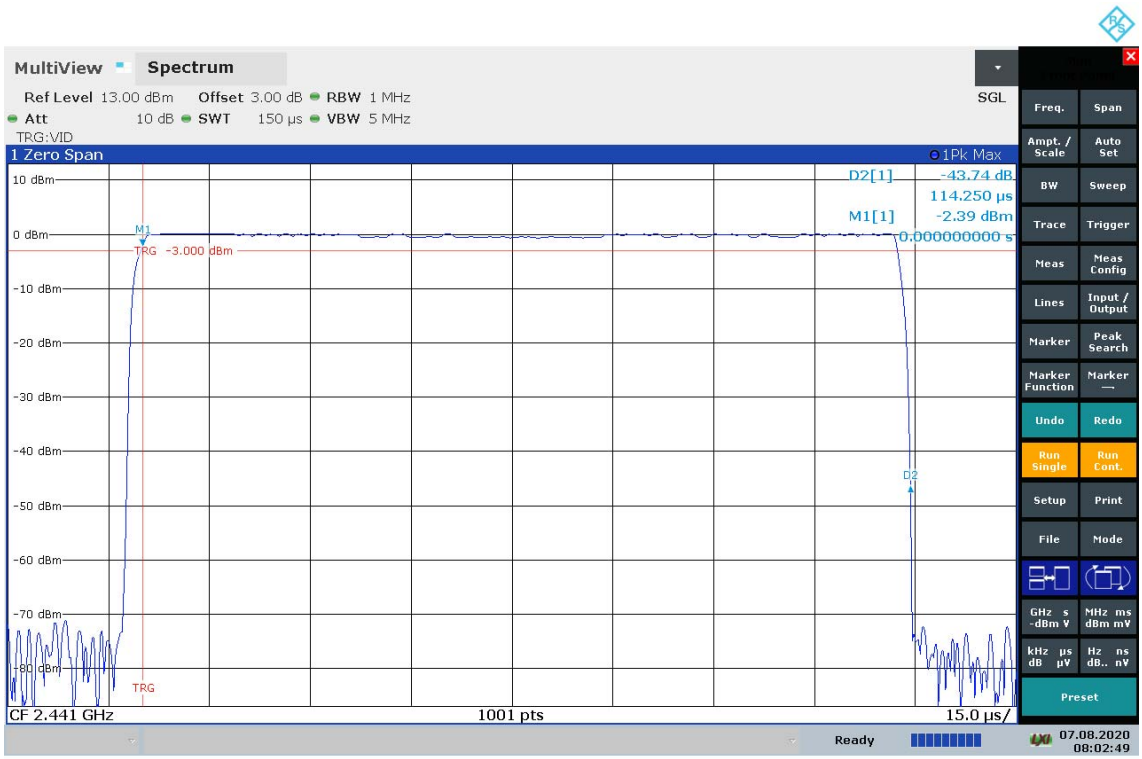


14.5 Test Equipment

Equipment Description	*Manufacturer*	*Equipment Type*	*Element No*	*Due For Calibration*
Spectrum Analyser	R&S	FSU26	REF909	2021-07-09

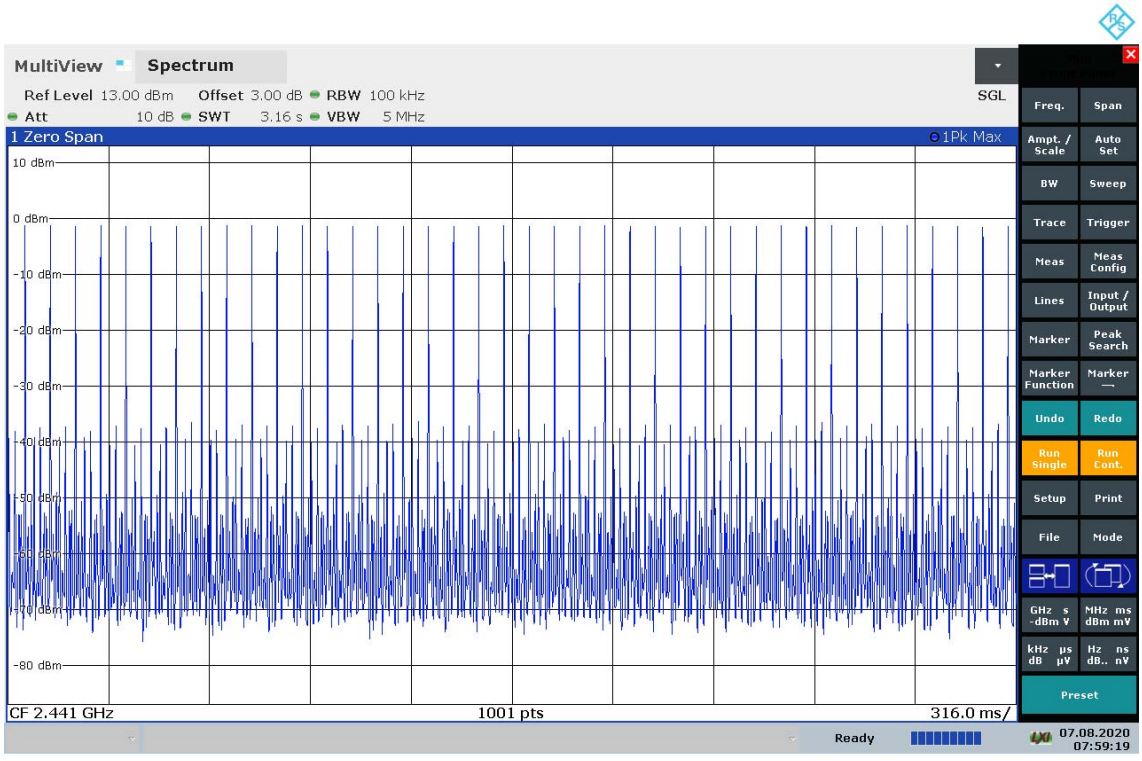
14.6 Test Results

Mode 1: 1MBps					
Data Rate	**Individual occupancy time (ms)**	**Observation period (s)**	**Number of hops observed**	**Average time of occupancy (s)**	**Result**
1MBps	0.11425	31.6	400	0.0457	PASS

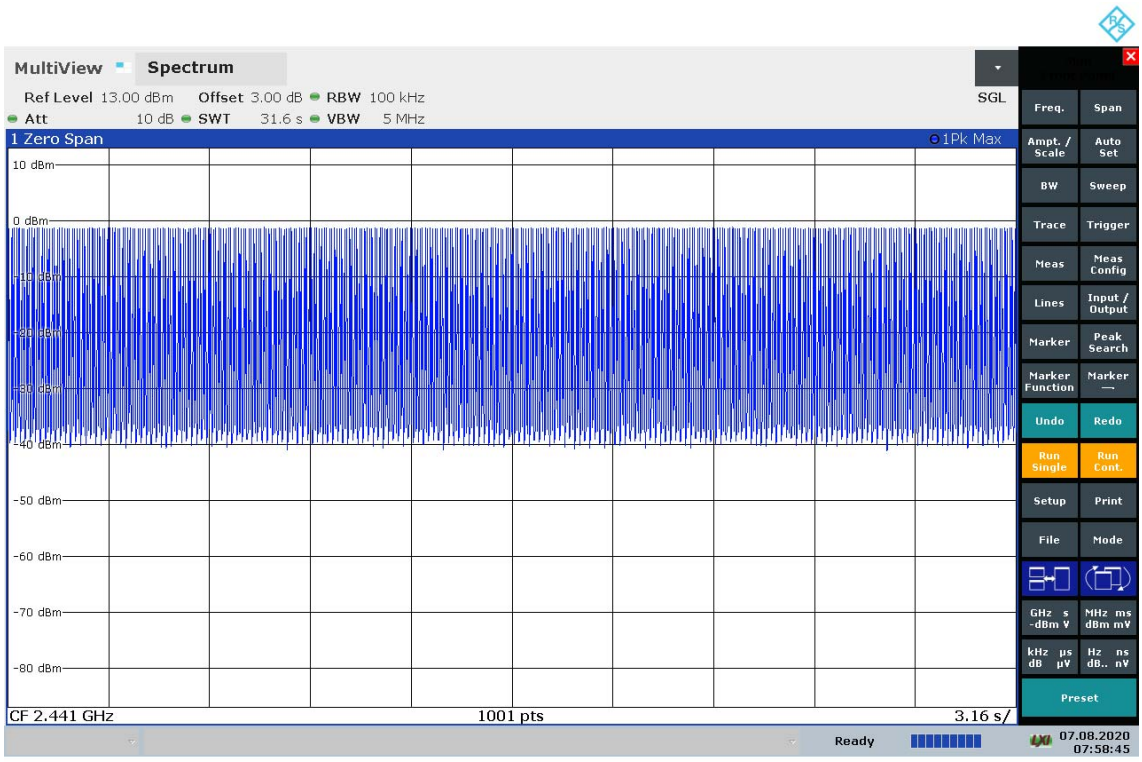


08:02:49 07.08.2020

TX On



07:59:20 07.08.2020

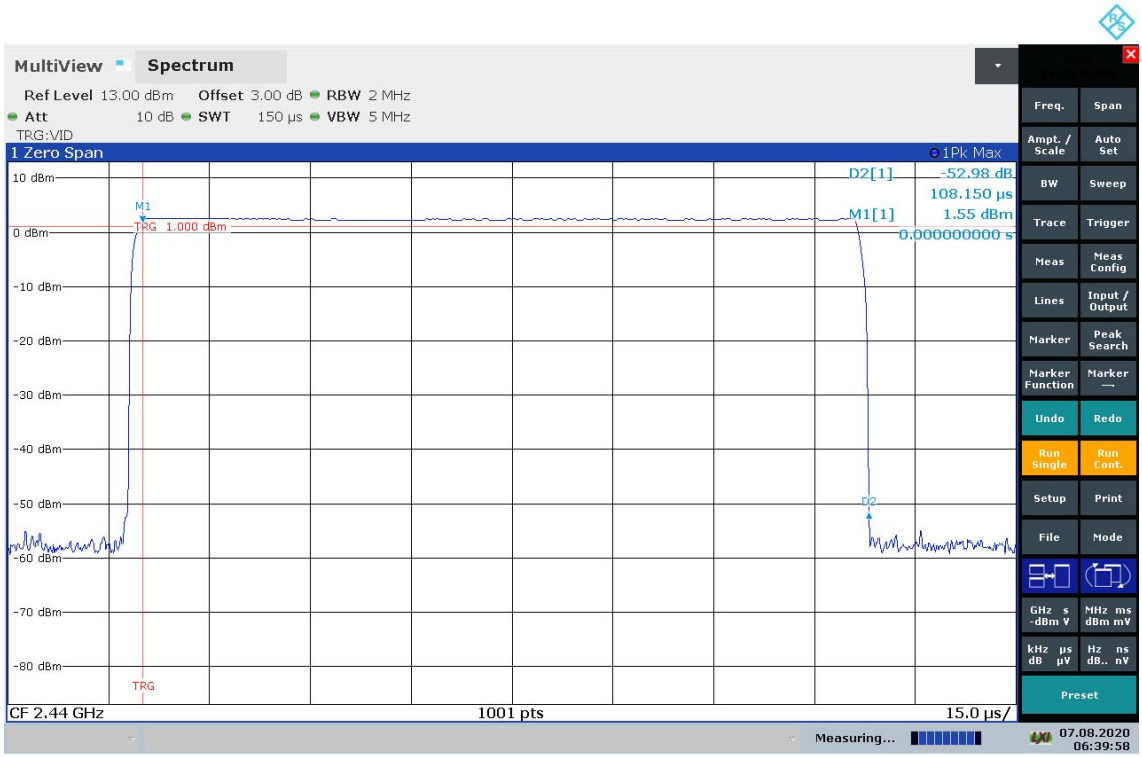


07:58:45 07.08.2020

Number of Transmissions in measurement period

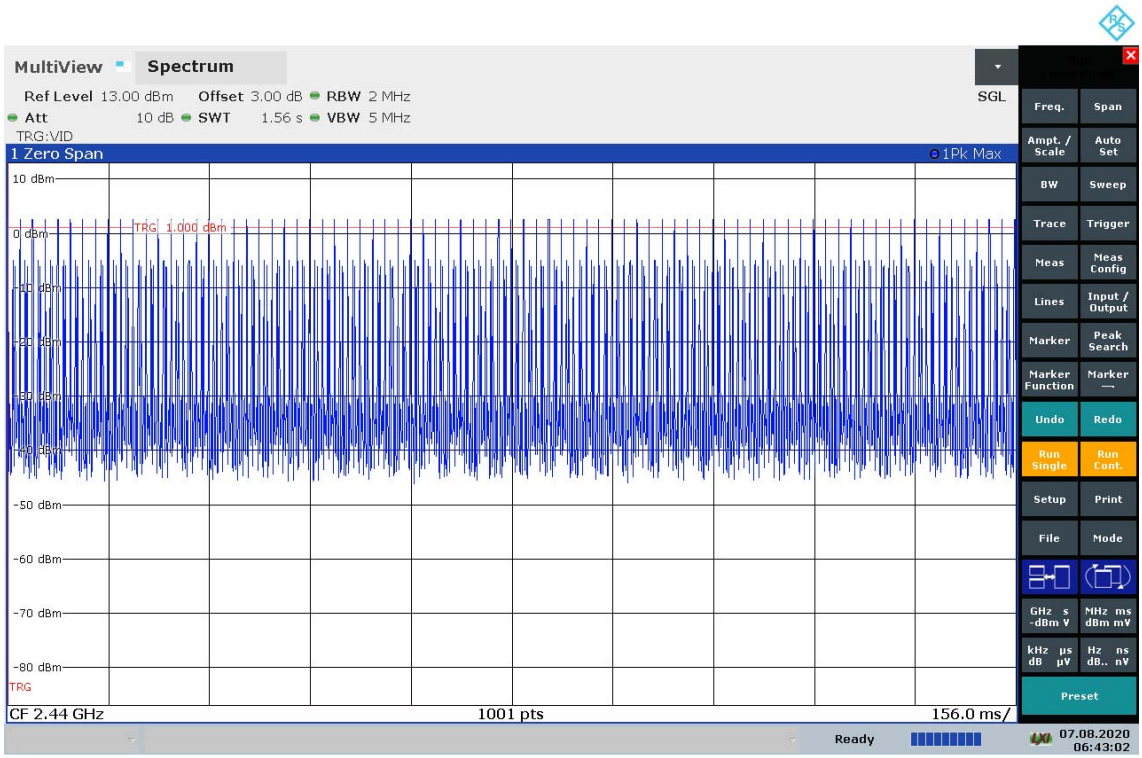
Number of transmissions in a 3.16 second period = 40
Number of transmissions in a 31.6 second period = 40 * 10 = 400

Mode 2: 2MBps					
Data Rate	***Individual occupancy time (ms)***	***Observation period (s)***	***Number of hops observed***	***Average time of occupancy (s)***	***Result***
2MBps	0.10815	15.6	800	0.08652	PASS



06:39:58 07.08.2020

TX On



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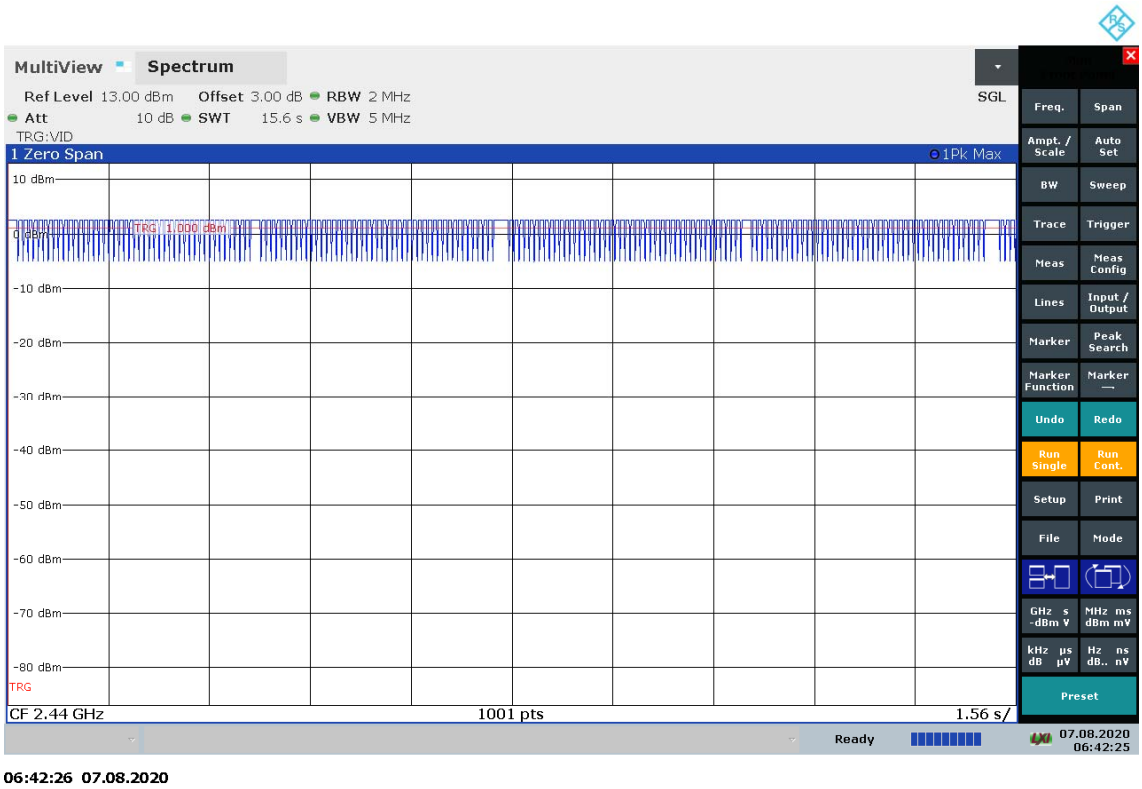


06:42:26 07.08.2020

Number of Transmissions in measurement period

Number of transmissions in a 1.56 second period = 80
Number of transmissions in a 15.6 second period = 80 * 10 = 800

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.

The maximum conducted output power is defined as the total transmit power delivered to all antennas and antenna elements averaged across all symbols in the signaling alphabet when the transmitter is operating at its maximum power control level.

15.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Radio Laboratory
Test Standard and Clause:	ANSI C63.10-2013, Clause 7.8.5
Frequencies Measured:	Mode 1: 2403 MHz / 2442 MHz/ 2481 MHz – hopping disabled. Mode 2: 2404 MHz / 2442 MHz/ 2480 MHz – hopping disabled / DTS
EUT Channel Bandwidths:	Mode 1: 1 MHz Mode 2: 2 MHz
Deviations From Standard:	None
Measurement BW:	Mode 1: 1 MHz Mode 2: 2 MHz
Spectrum Analyzer Video BW:	Mode 1: 3 MHz Mode 2: 5 MHz
Measurement Detector:	Peak
Voltage Extreme Environment Test Range:	Battery Power = new battery.

Environmental Conditions (Normal Environment)

Temperature: 23 °C	+15 ºC to +35 ºC (as declared)
Humidity: 29 % 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.

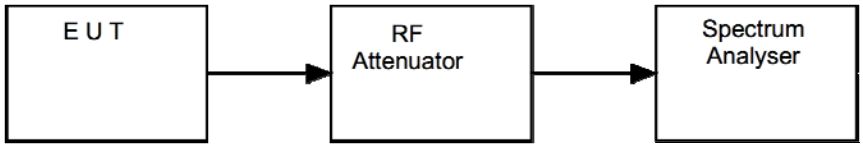
- For systems employing digital modulation techniques operating in the bands 902 to 928 MHz, 2400 to 2483.5 MHz and 5725 to 5850 MHz, the maximum peak conducted output power shall not exceed 1 W.

15.4 Test Method

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

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

Figure vi Test Setup

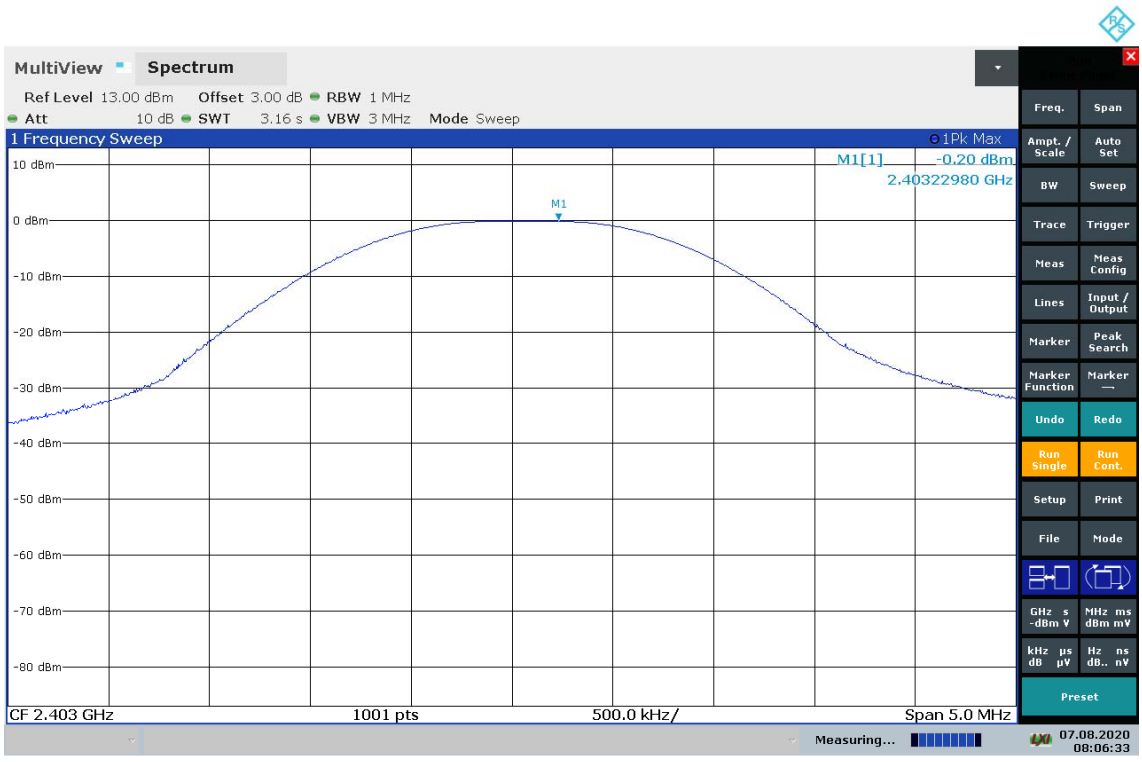


15.5 Test Equipment

Equipment Description	*Manufacturer*	*Equipment Type*	*Element No*	*Due For Calibration*
Spectrum Analyser	R&S	FSU26	REF909	2021-07-09

15.6 Test Results

Mode 1: 1 Mbps					
Channel Frequency (MHz)	Maximum Peak Conducted Output power (dBm)	Maximum peak conducted output power (W)	Antenna gain (dBi)	E.I.R.P. (W)	Result
2403	-0.20	0.0010	1.3	0.0013	PASS
2442	0.05	0.0010	1.3	0.0014	PASS
2481	0.31	0.0011	1.3	0.0014	PASS



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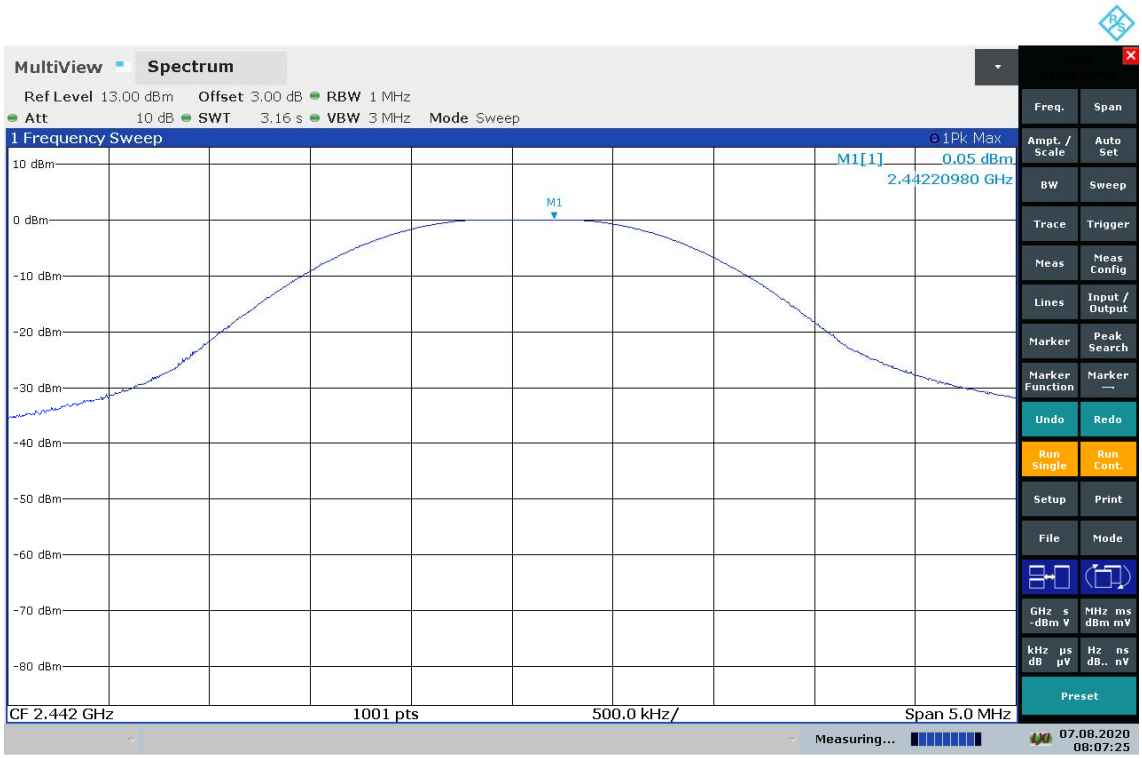
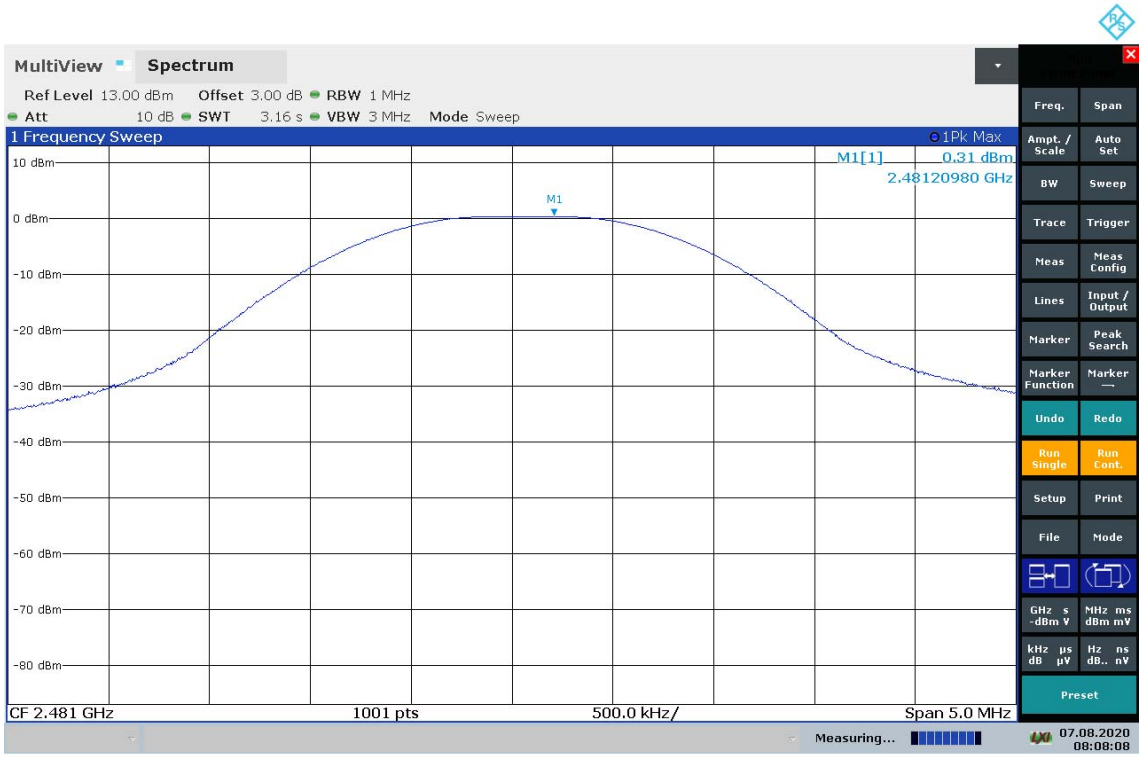
2403



08:07:25 07.08.2020

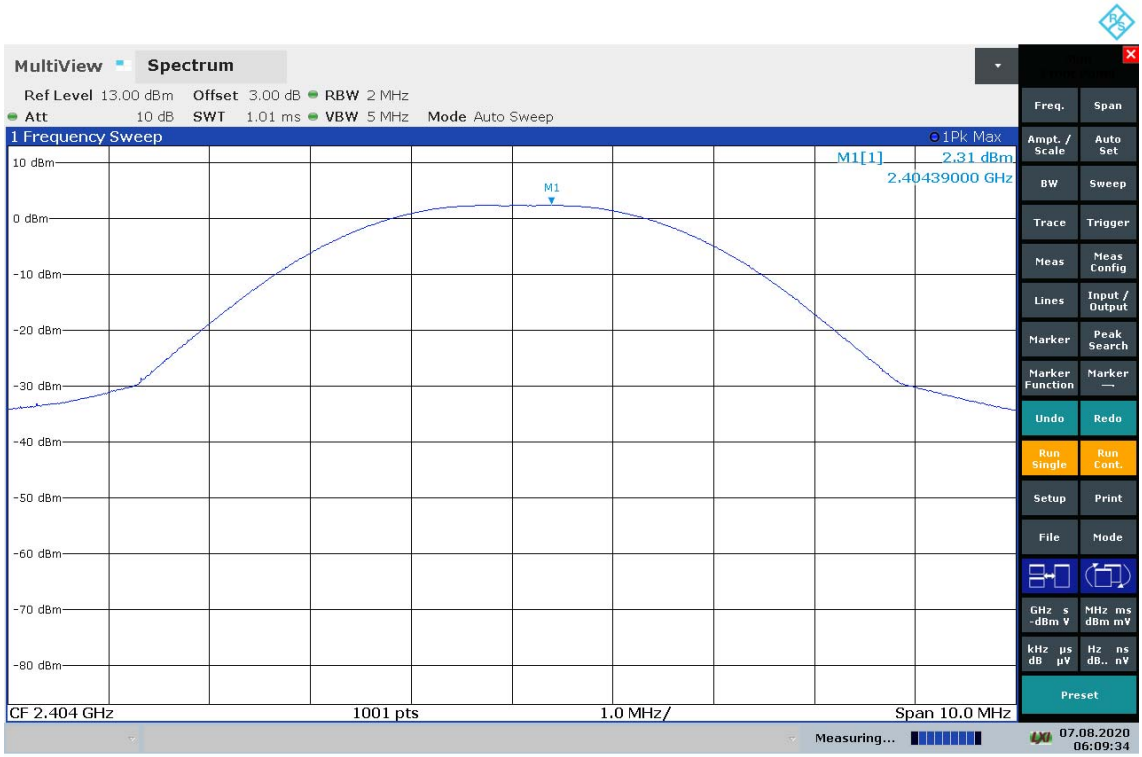
2442



08:08:09 07.08.2020

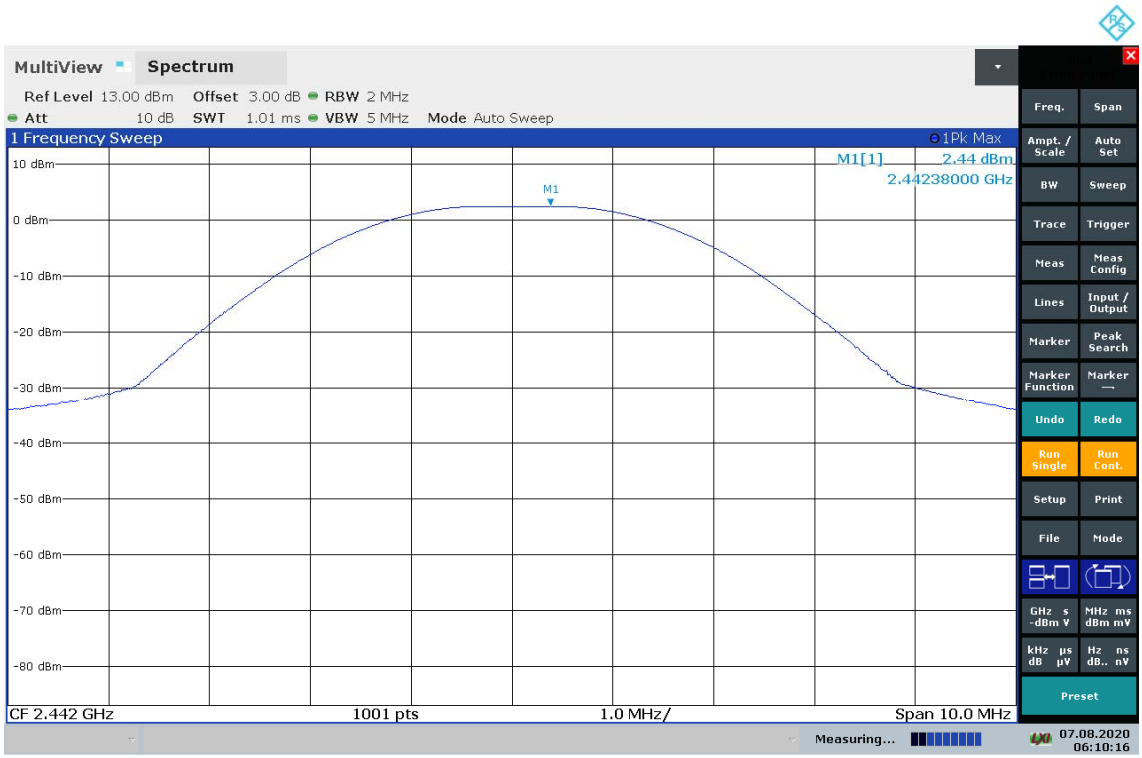
2481

Mode 2: 2 Mbps					
Channel Frequency (MHz)	***Maximum Peak Conducted Output power (dBm)***	***Maximum peak conducted output power (W)***	***Antenna gain (dBi)***	***E.I.R.P. (W)***	***Result***
2404	2.31	0.0017	1.3	0.0023	PASS
2442	2.44	0.0018	1.3	0.0024	PASS
2480	2.90	0.0019	1.3	0.0026	PASS



06:09:35 07.08.2020

2404



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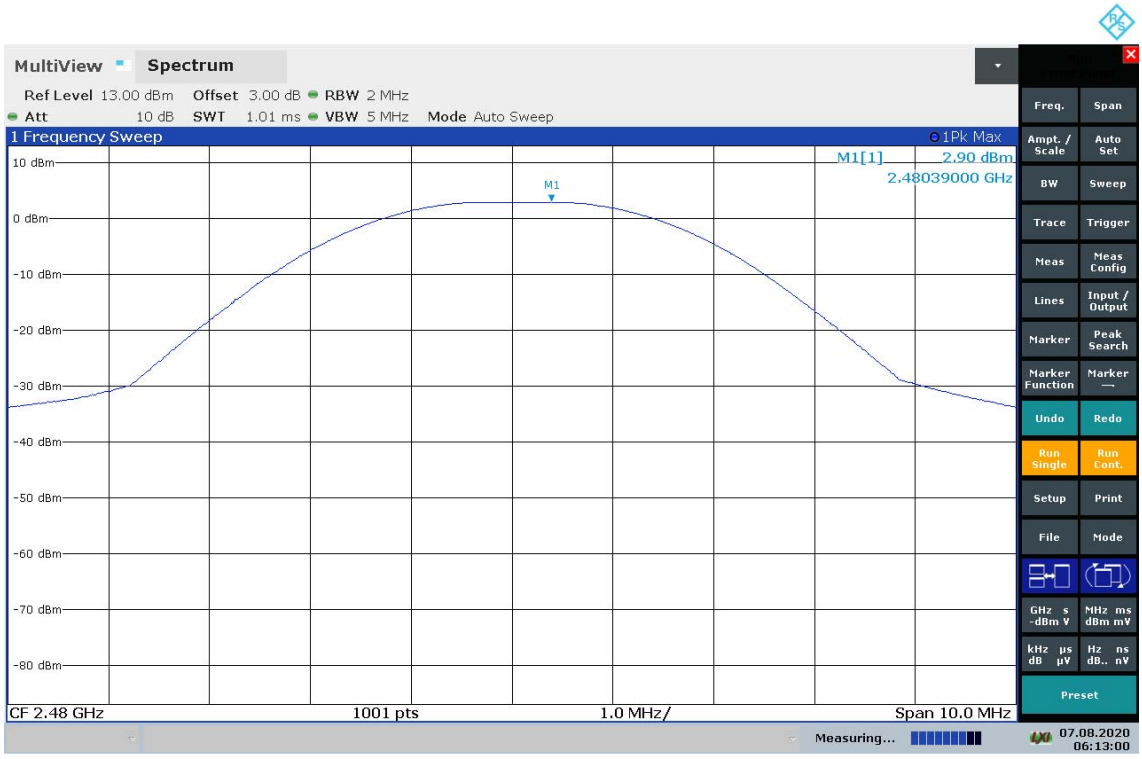
2442



06:13:00 07.08.2020

2480

16 Power spectral density

16.1 Definition

The power per unit bandwidth.

16.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Radio Laboratory
Test Standard and Clause:	ANSI C63.10-2013, Clause 11.10
EUT Channels / Frequencies Measured:	2404 MHz / 2442 MHz / 2480 MHz
EUT Channel Bandwidths:	2 MHz
Deviations From Standard:	None
Measurement BW:	100 kHz
Spectrum Analyzer Video BW: (requirement at least 3x RBW)	300 kHz
Measurement Span: (requirement 1.5 times Channel BW)	1.3 MHz
Measurement Detector:	Peak

Environmental Conditions (Normal Environment)

Temperature: 22 °C	+15 ºC to +35 ºC (as declared)
Humidity: 32 % RH	20 % RH to 75 % RH (as declared)

16.3 Test Limit

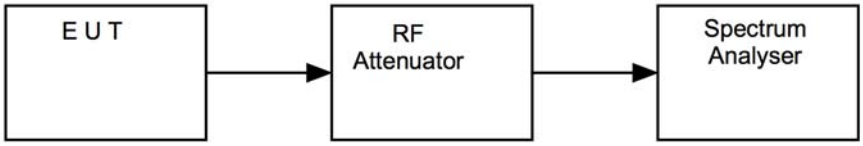
The transmitter power spectral density conducted from the transmitter to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.

16.4 Test Method

With the EUT setup as per section 9 of this report and connected as per Figure vi, the peak emission of the EUT was measured on a spectrum analyser, with path losses taken into account.

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

Figure vi Test Setup

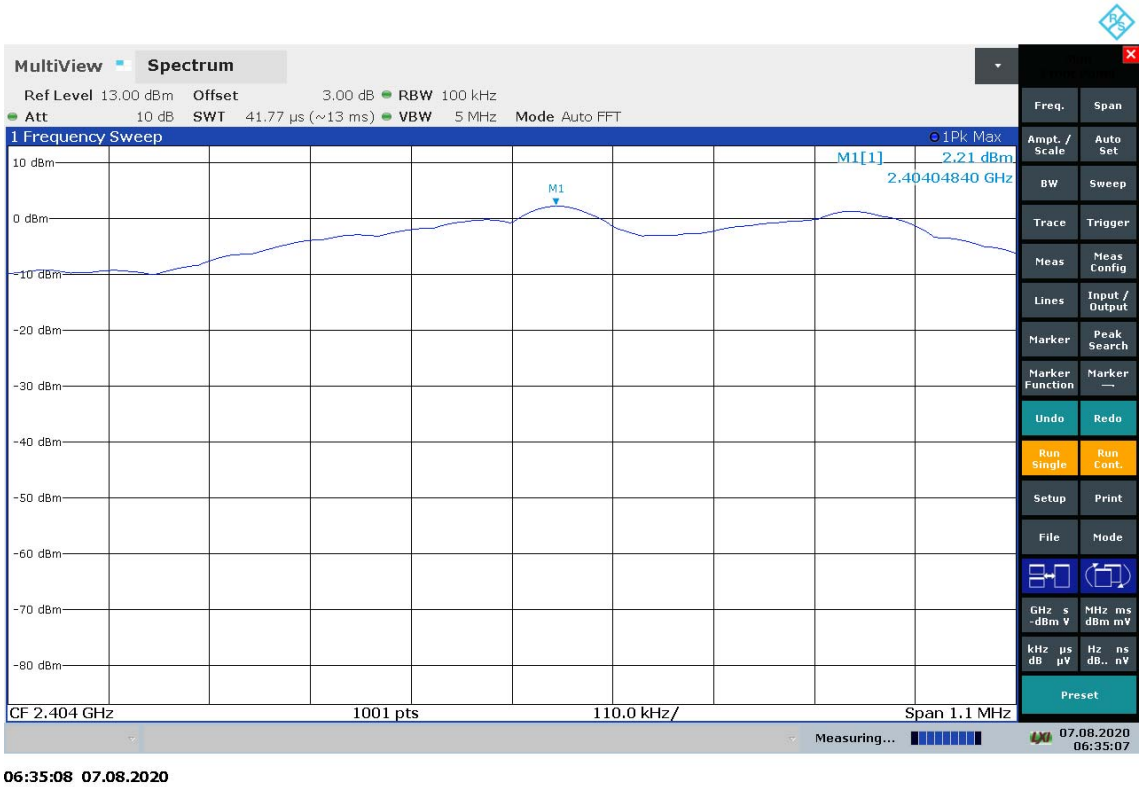


16.5 Test Equipment

Equipment Description	*Manufacturer*	*Equipment Type*	*Element No*	*Due For Calibration*
Spectrum Analyser	R&S	FSU26	REF909	2021-07-09

16.6 Test Results

Mode 2: 2 Mbps				
Channel Frequency (MHz)	**Analyzer Level (dBm)**	**Cable loss (dB)**	**Power (dBm)**	**Result**
2404	-0.79	3.00	2.21	PASS
2442	-0.53	3.00	2.47	PASS
2480	-0.28	3.00	2.72	PASS



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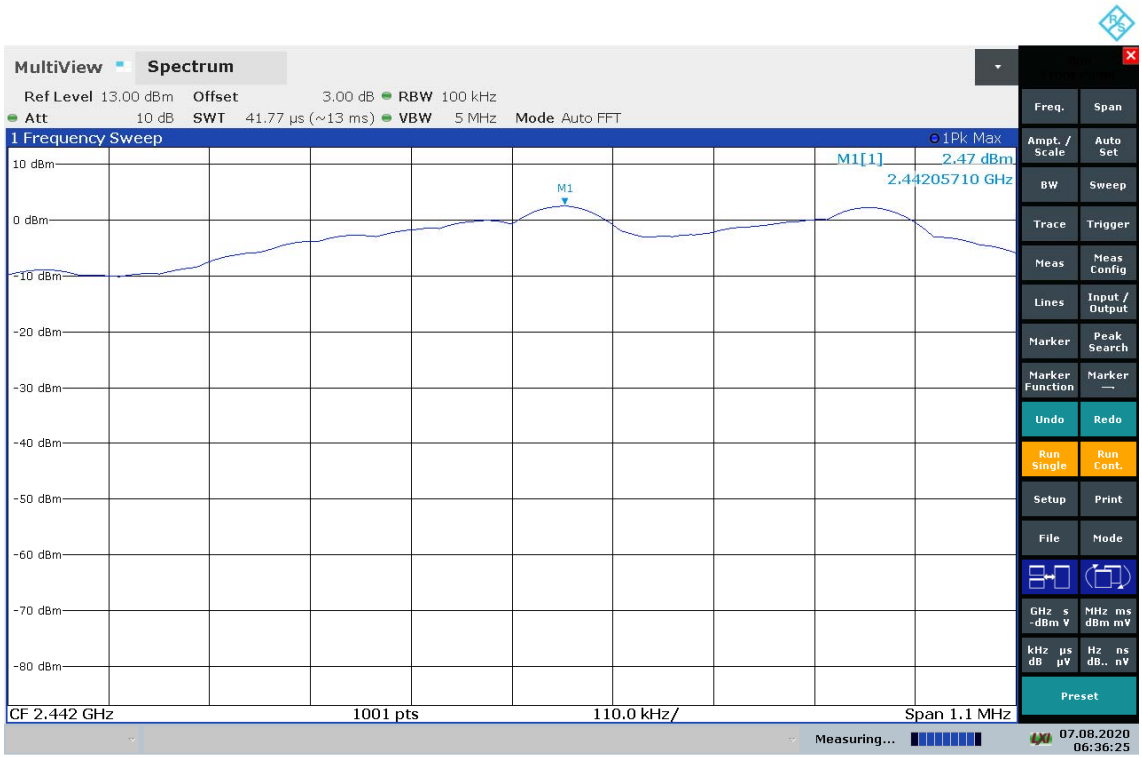

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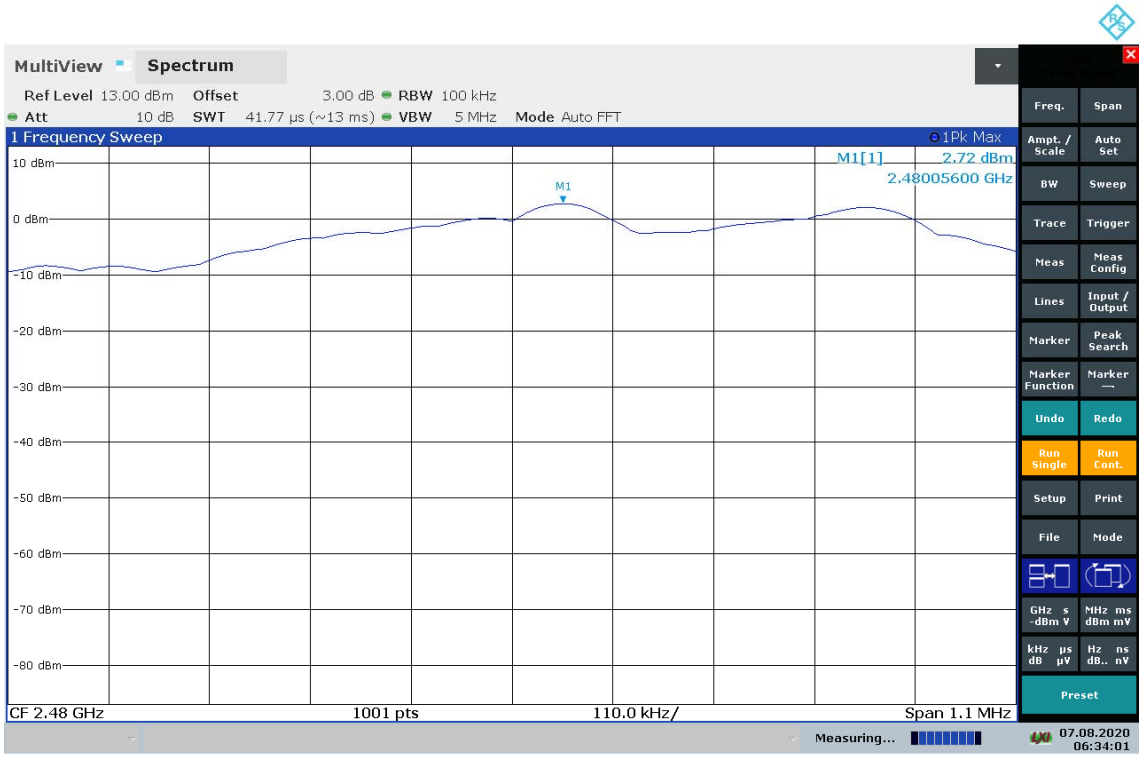
Middle



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Top

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 Skelmersdale
Test Chamber:	Radio Laboratory
Test Standard and Clause:	ANSI C63.10-2013, Clause 11.8
Frequencies Measured:	Mode 1: 2403 MHz 2442 MHz / 2481 MHz – hopping stopped. Mode 2: 2404 MHz 2442 MHz / 2480 MHz – hopping stopped / DTS
EUT Channel Bandwidths:	Mode 1: 1 MHz Mode 2: 2 MHz
EUT Test Modulations:	Mode 1: 1MBps Binary GFSK Mode 2: 1MBps Binary GFSK
Deviations From Standard:	None
Measurement BW:	30 kHz / 100 kHz
Spectrum Analyzer Video BW:	100 kHz / 1 MHz
Measurement Span: (requirement 2 to 5 times OBW)	3 MHz / 5 MHz
Measurement Detector:	Peak

Environmental Conditions (Normal Environment)

Temperature: 23 °C	+15 ºC to +35 ºC (as declared)
Humidity: 29 % RH	20 % RH to 75 % RH (as declared)
Supply: 3.0 Vdc	

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

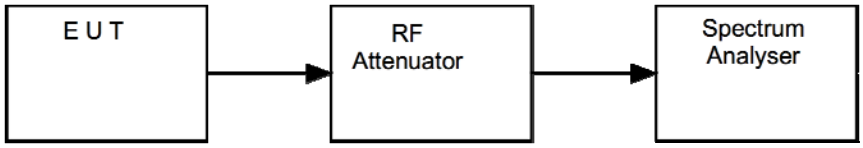
- For DTS the minimum -6 dB bandwidth shall be at least 500 kHz.

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 Description	*Manufacturer*	*Equipment Type*	*Element No*	*Due For Calibration*
Spectrum Analyser	R&S	FSU26	REF909	2021-07-09

17.6 Test Results

Mode 1: 1 Mbps 20 dB Bandwidth				
Channel Frequency (MHz)	**F_L (MHz)**	**F_H (MHz)**	**20dB Bandwidth (kHz)**	**Result**
2403.0	2402.530500	2403.5694	1038.9	PASS
2442.0	2441.535500	2442.5794	1043.9	PASS
2481.0	2480.535500	2481.5844	1048.9	PASS

2403

08:26:37 07.08.2020

2442

08:11:08 07.08.2020

2481

Mode 2: 2Mbps 20 dB Bandwidth				
Channel Frequency (MHz)	**F_L (MHz)**	**F_H (MHz)**	**20dB Bandwidth (kHz)**	**Result**
2404.0	2403.325700	2404.9041	1578.4	PASS
2442.0	2441.325700	2442.8991	1573.4	PASS
2480.0	2479.325700	2480.9041	1578.4	PASS

04:44:37 07.08.2020

2404

05:12:22 07.08.2020

2442

05:09:38 07.08.2020

2480

Mode 2: 2 Mbps 6 dB DTS bandwidth				
Channel Frequency (MHz)	**F_L (MHz)**	**F_H (MHz)**	**6dB Bandwidth (kHz)**	**Result**
2404.0	2403.780200	2404.4895	709.3	PASS
2442.0	2441.795200	2442.4895	694.3	PASS
2480.0	2479.795200	2480.4895	694.3	PASS

2404

03:50:31 07.08.2020

2442

03:51:27 07.08.2020

2480

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 Skelmersdale
Test Chamber:	Radio Laboratory
Test Standard and Clause:	ANSI C63.10-2013, Clause 7.8.8 ANSI C63.10-2013, Clause 11.11
Frequencies Measured:	Mode 1: 2403 MHz/2442 MHz/2481 MHz Mode 2: 2404 MHz/2442 MHz/2480 MHz
EUT Channel Bandwidths:	Mode 1: 1 MHz Mode 2: 2 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 25 GHz

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: 3.0 Vdc	

18.3 Test Limits

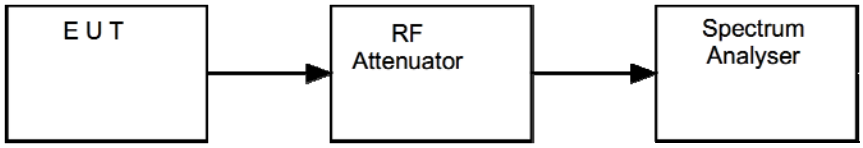
In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated device is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either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

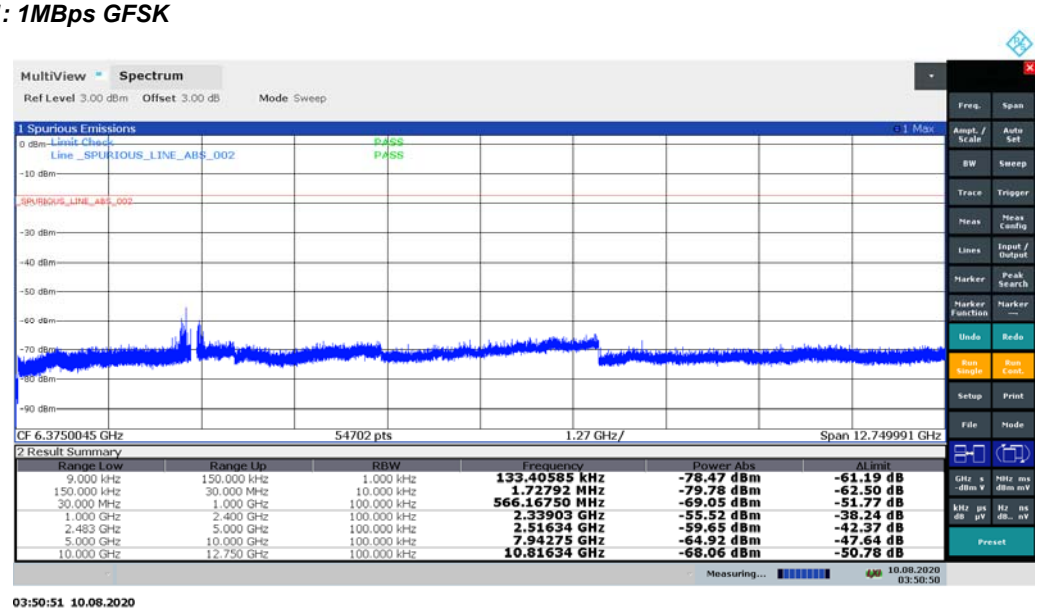


18.5 Test Equipment

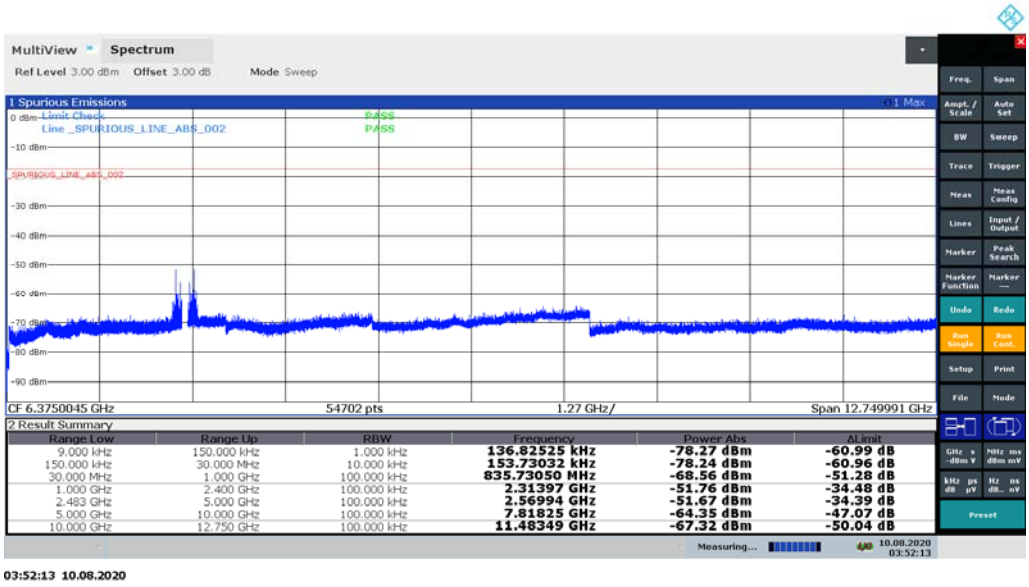
Equipment Description	*Manufacturer*	*Equipment Type*	*Element No*	*Due For Calibration*
Spectrum Analyser	R&S	FSU26	REF909	2021-07-09

18.6 Test Results

Mode 1: 1MBps GFSK



Bottom



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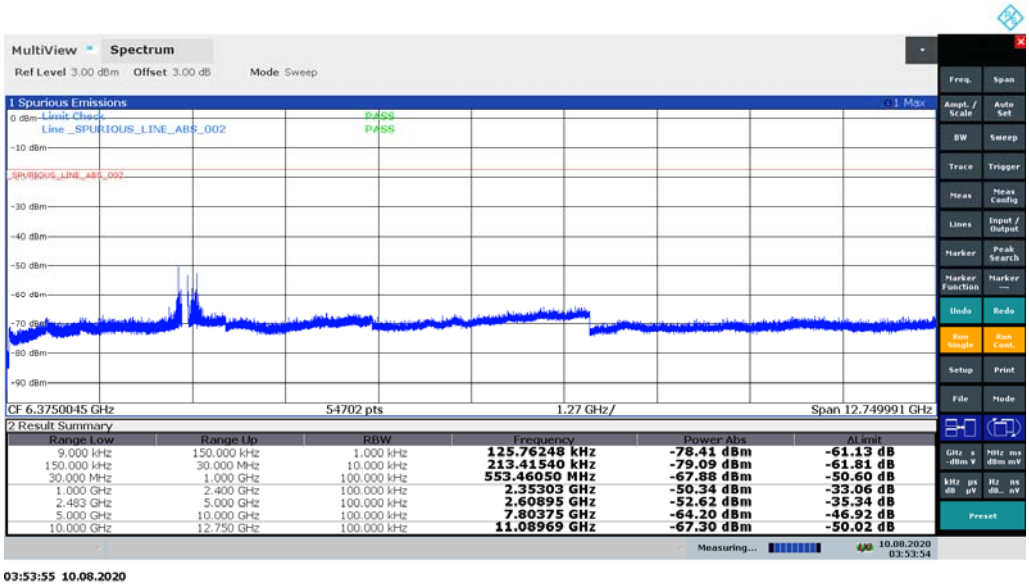
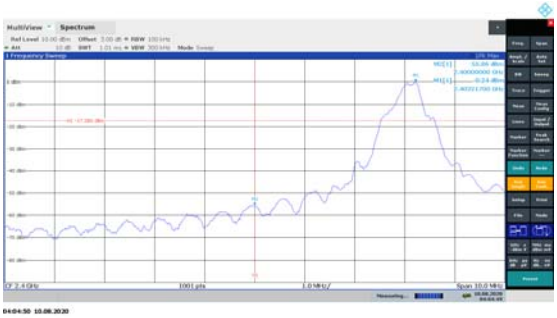
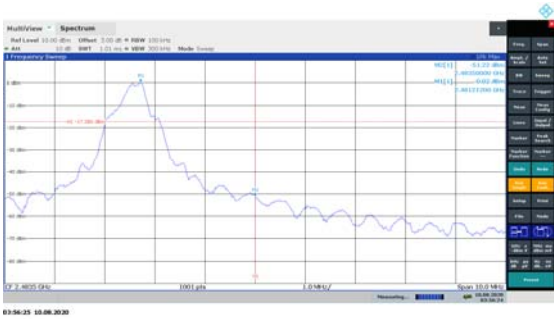


Top

Band edge Mode 1:



Lower band edge single hopping channel

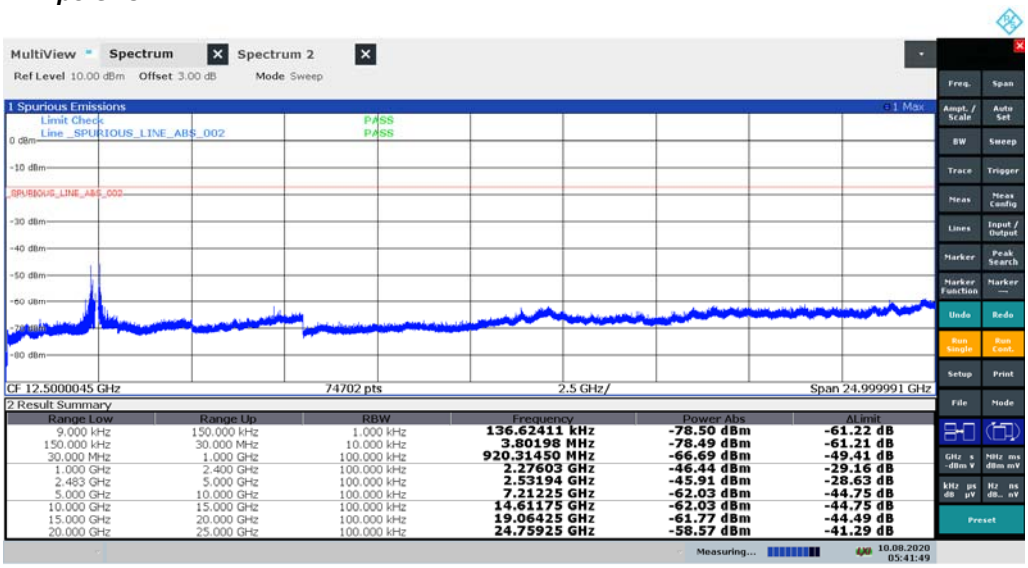


Upper band edge single hopping channel

Lower band edge hopping channel

Upper band edge hopping channel

Mode 2: 2MBps GFSK



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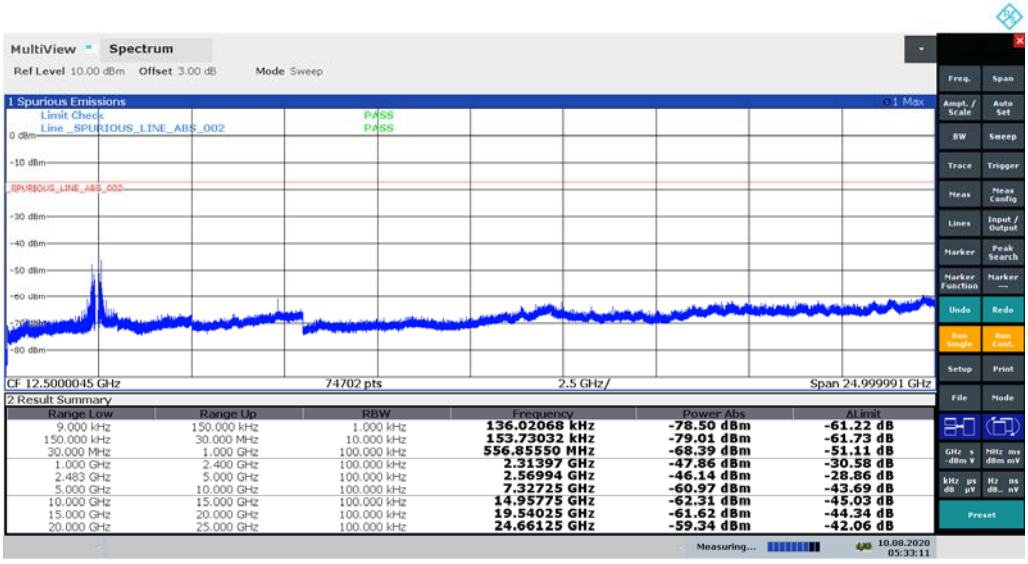
Bottom



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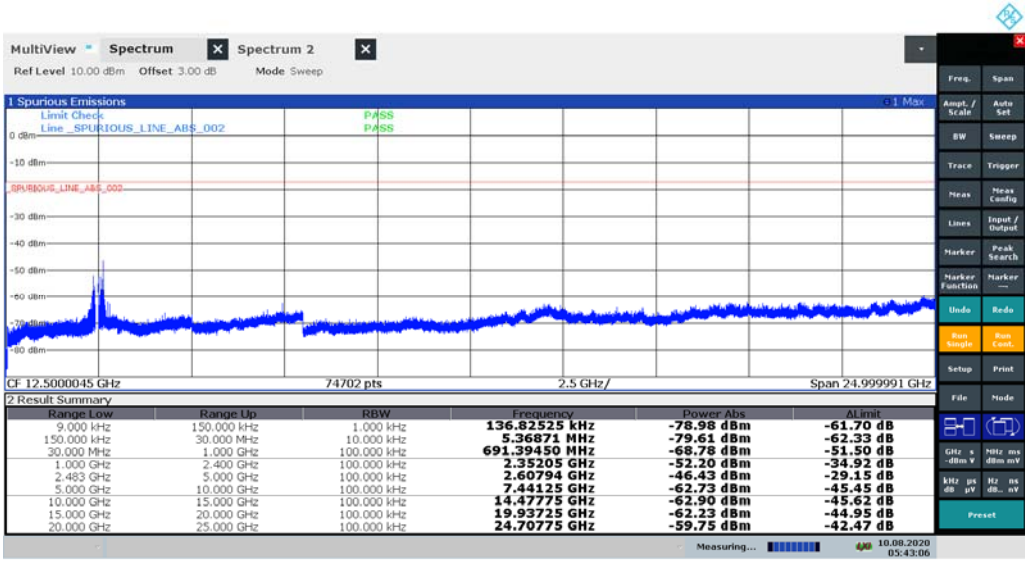
Middle



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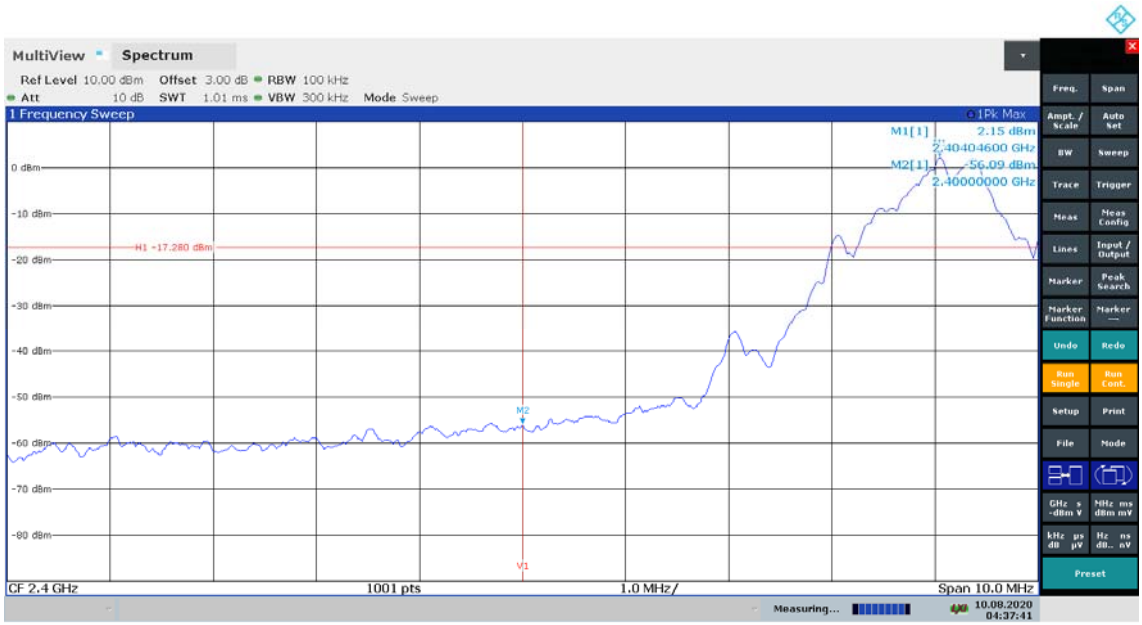
Top

Band edge Mode 2:



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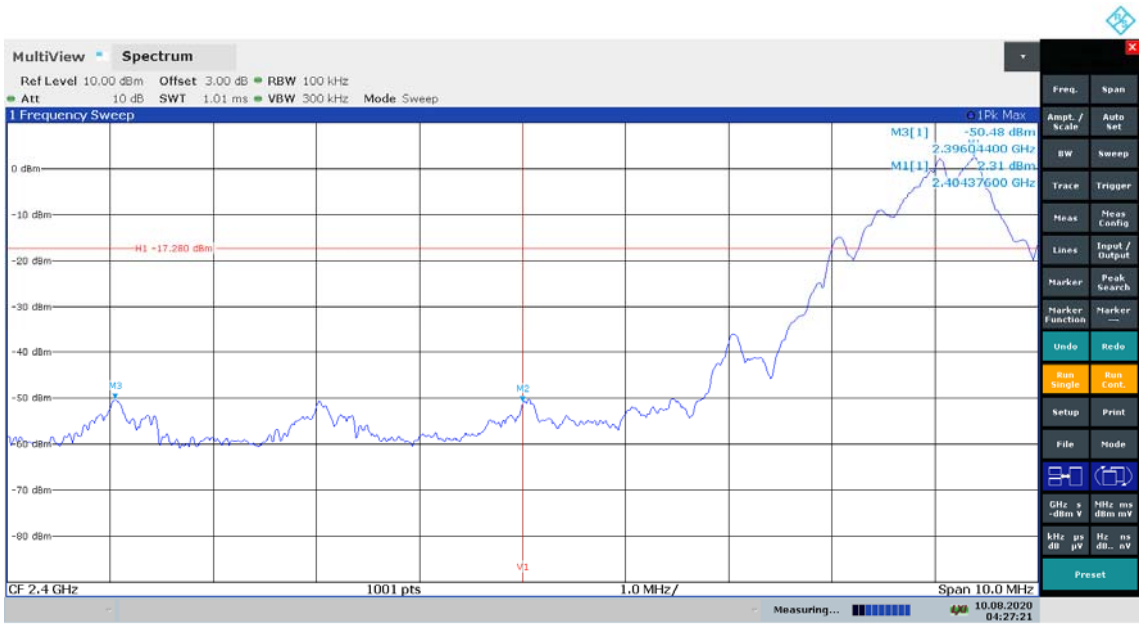
Lower band edge single hopping channel

04:39:51 10.08.2020

Upper band edge single hopping channel



04:27:21 10.08.2020

Lower band edge hopping channel

04:41:45 10.08.2020

Upper band edge hopping channel

19 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) = **4.75 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 %**

[8] Radiated RF power out-of-band

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

[9] Power spectral density

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

[10] ERP / EIRP

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

20 RF Exposure

KDB 447498

Section 4.3 General SAR test reduction and exclusion guidance

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

In the frequency range below 100 MHz to 6 GHz and test separation distance of 50mm, the SAR Test Exclusion Threshold for operation in the 2400 – 2483.5 MHz band will be determined as follows

SAR Exclusion Threshold (SARET)

SAR Exclusion Threshold = Step 1 + Step 2

Step 1

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

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

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

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

For Distances Greater than 50 mm Step 2 applies

Step 2

$$(TSD^{B} – 50mm) * 10\}$$

Where:

TSD^{B}	=	Min Test separation Distance (mm) = 50

Operating Frequency 2.403 GHz

SARET = [(3.0 x 50) / √2.402] + { (50 – 50) * 10 }
SARET = [150 / 1.55] + (0 * 10 }
SARET = 96.77mW

Operating Frequency 2.442 GHz

SARET = [(3.0 x 50) / √2.442] + { (50 – 50) * 10 }
SARET = [150 / 1.56] + (0 * 10 }
SARET = 96.15mW

Operating Frequency 2.481 GHz

SARET = [(3.0 x 50) / √2.481] + { (50 – 50) * 10 }
SARET = [150 / 1.57] + (0 * 10 }
SARET = 95.54mW

Mode 1				
Evaluation Frequency	2403	2442	2481	MHz
SAR Exclusion Threshold	96.77	96.15	95.54	Watts
Conducted Power	-0.2	0.05	0.31	dBm
Antenna Gain	1.3	1.3	1.3	dBi
EIRP	1.29	1.36	1.45	mW
SAR Evaluation	***Exempt***			

Therefore standalone SAR evaluation for general population exposure conditions by measurement or numerical simulation is not required.

Operating Frequency 2.404 GHz

SARET = [(3.0 x 50) / √2.404] + { (50 – 50) * 10 }
SARET = [150 / 1.55] + (0 * 10 }
SARET = 96.77mW

Operating Frequency 2.440 GHz

SARET = [(3.0 x 50) / √2.44] + { (50 – 50) * 10 }
SARET = [150 / 1.56] + (0 * 10 }
SARET = 96.15mW

Operating Frequency 2.480 GHz

SARET = [(3.0 x 50) / √2.48] + { (50 – 50) * 10 }
SARET = [150 / 1.57] + (0 * 10 }
SARET = 95.54mW

Mode 2				
Evaluation Frequency	2404	2440	2480	MHz
SAR Exclusion Threshold	96.77	96.15	95.54	Watts
Conducted Power	2.31	2.44	2.90	dBm
Antenna Gain	1.3	1.3	1.3	dBi
EIRP	2.30	2.37	2.63	mW
SAR Evaluation	***Exempt***			

Therefore standalone SAR evaluation for general population exposure conditions by measurement or numerical simulation is not required.