Report on the Radio Testing

For

Ocado Innovation Limited

on

RCOM Base Station

Report no. TRA-048486-45-04A

15th September 2021

RF930

Report Number: TRA-048486-45-04A
Issue: A

REPORT ON THE RADIO TESTING OF A
Ocado Innovation Limited
RCOM Base Station
WITH RESPECT TO SPECIFICATION
FCC 47CFR Subpart E

TEST DATE: 2021-07-12 to 2021-08-17

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Adobe Acrobat version: 2021.005.20060

Date: 15th September 2021

Disclaimers:

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

RF930

1 Revision Record

Issue Number	*Issue Date*	*Revision History*
A	15th September 2021	Original

2 Summary

TEST REPORT NUMBER:	TRA-048486-45-04A
WORKS ORDER NUMBER:	TRA-048486-02
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:	47CFR15 Subpart E
EQUIPMENT UNDER TEST (EUT):	RCOM Base Station
FCC IDENTIFIER:	2AGHF-RCOMBS002
EUT SERIAL NUMBER:	P3631-BS-A3070
MANUFACTURER/AGENT:	Ocado Innovation Limited
ADDRESS:	Trident Place, Hatfield Business Park, Mosquito Way, Hatfield, Hertfordshire, AL10 9UL United Kingdom
CLIENT CONTACT:	Ed Briggs ☎ 07557 860903 ✉ Ed.Briggs@Ocado.com
ORDER NUMBER:	IT-200528
TEST DATE:	2021-07-12 to 2021-08-17
TESTED BY:	D Garvey, A Longley 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*
Occupied bandwidth	15.407(a)	☒	*Note 2*
Output power	15.407(a)	☒	*PASS*
Power spectral density	15.407(a)	☒	*PASS*
Conducted RF power out-of-band	15.407(b)	☒	*PASS*
Duty Cycle	15.35(c)	☒	*Note 3*
TPC	15.407(h1)	☐	*Note 4*
DFS	15.407(h2)	☐	*Note 5*

Notes:

Note 1: EUT was DC powered.
Note 2: No limits are defined in the standard. Bandwidth is required to calculate the power limits.
Note 3: No limits are defined in the standard. Duty Cycle is required for correction factors for power measurements.
Note 4: Not applicable if TPC not implemented.
Note 5: DFS tests on this device are detailed in Element test report TRA-048486-45-06A.

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).

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4 Introduction

This report TRA-048486-45-04A presents the results of the Radio testing on a Ocado Innovation Limited, RCOM Base Station to specification 47CFR15 Radio Frequency Devices.

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

☒	Element Hull Unit E South Orbital Trading Park Hedon Road Hull HU9 1NJ UK	☐	Element Skelmersdale Unit 1 Pendle Place Skelmersdale West Lancashire WN8 9PN UK

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

FCC Site Listing:
The test laboratory is accredited for the above sites under the US-EU MRA,

Designation number(s):

Element Hull	UK2007
Element Skelmersdale	UK2020

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.
- FCC KDB Publication 905462 D02 v01r02 – Compliance measurement procedures for unlicensed-national information infrastructure devices operating in the 5250-5350 MHz and 5470-5725 MHz bands incorporating dynamic frequency selection.
- 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.
- KDB 789033 D02 General UNII Test Procedures New Rules v02r01

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
CAC	Channel Availability Check
CFR	Code of Federal Regulations
CW	Continuous Wave
dB	decibel
dBm	dB relative to 1 milliwatt
DC	Direct Current
DFS	Dynamic Frequency Selection
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 (now ISED)
ISED	Innovation, Science and Economic Development Canada
ITU	International Telecommunication Union
LBT	Listen Before Talk
LE-LAN	Licence-Exempt Local Area Network
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
PSD	Power Spectral Density
RF	Radio Frequency
RH	Relative Humidity
RMS	Root Mean Square
Rx	receiver
s	second
SVSWR	Site Voltage Standing Wave Ratio
TPC	Transmitter Power Control
Tx	transmitter
UKAS	United Kingdom Accreditation Service
U-NII	Unlicensed-National Information Infrastructure
V	volt
W	watt
Ω	ohm

7 Equipment Under Test

7.1 EUT Identification

- Name: RCOM Base Station
- Serial Number: P3631-BS-A3070
- Model Number: Base Station
- Software Revision: v10.0.73
- Build Level / Revision Number: A.3

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.

Lenovo Laptop and Netgear Ethernet Switch

7.3 EUT Mode of Operation

7.3.1 Transmission

The EUT was set to transmit on the required channels.

7.3.2 Reception

The EUT was set to receive mode on the required channels.

7.4 EUT Radio Frequency Parameters

Frequency of operation:	5470 MHz – 5725 MHz
Modulation type:	OFDM
Channel bandwidth:	10 MHz
Channel spacing:	10 MHz
Declared output power:	25 dBm EIRP
Antenna type and gain:	14.5 dBi gain 120 degree sector
Nominal Supply Voltage:	24 Vdc

7.5 EUT Description

The EUT is part of a point to multipoint short range radio communications system, identified as RCOM, which operates in the frequency band 5470MHz to 5725MHz. The wireless part of this system comprises of two parts, the BS – Base Station (EUT) and the BCM – Bot Control Module. One Base Station can be connected to many BCMs at any one time. The purpose of this radio system is to provide a low data rate, bi-directional, wireless connection to a large number of low speed factory floor machineries which transport goods, in a controlled manner, around the facility. These machineries are unmanned and the purpose of the wireless connection is to issue commands to the machineries and relay status information back, from each of the machineries, to a central point in the factory.

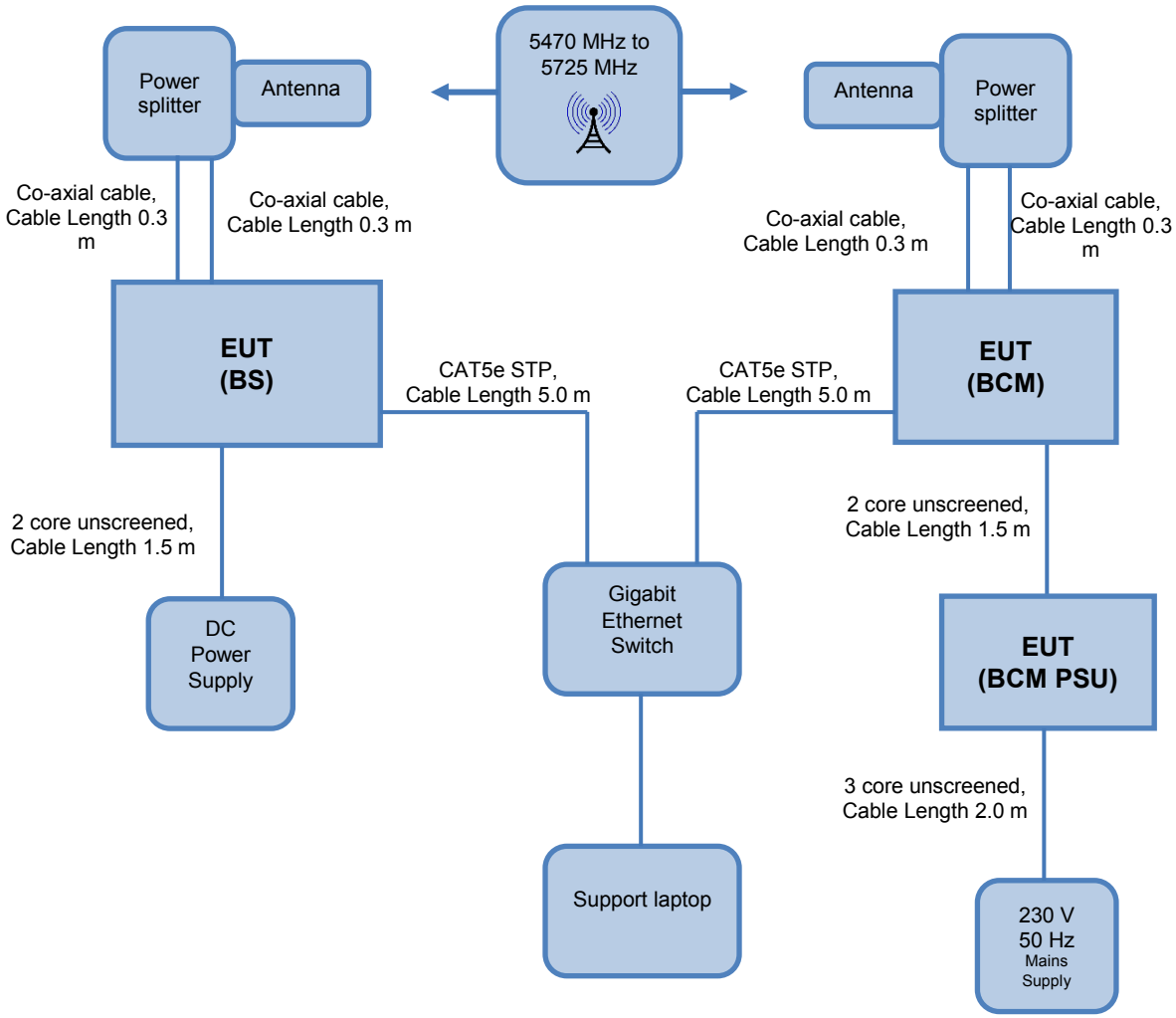
8 Modifications

No modifications were performed during this assessment.

9 EUT Test Setup

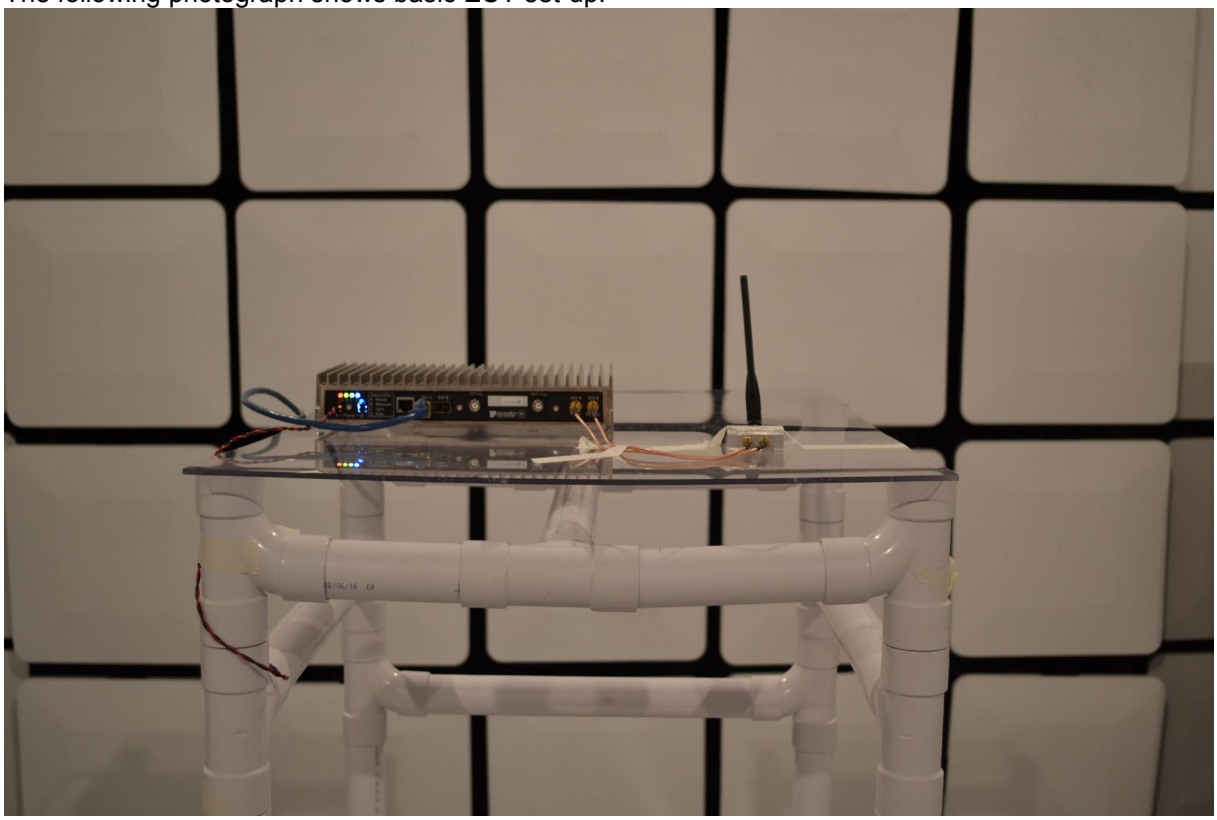
9.1 Block Diagram

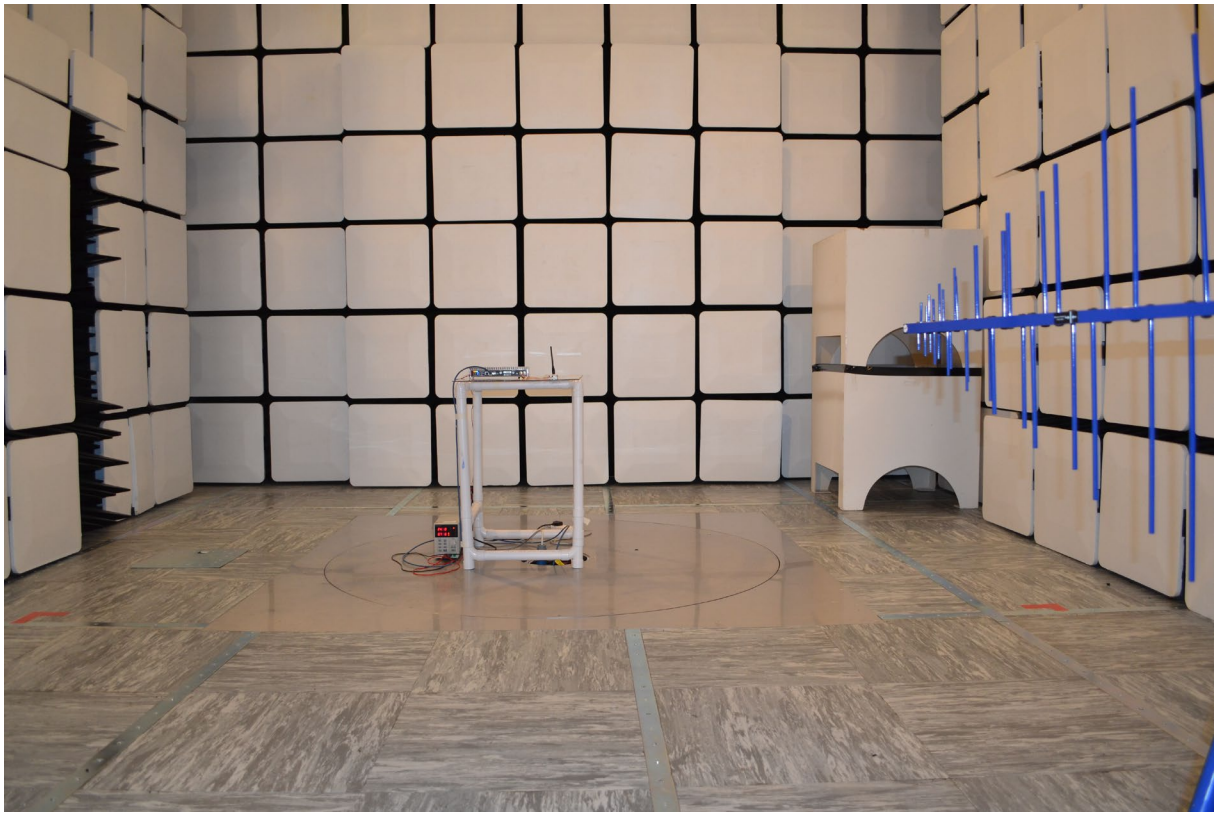
The following diagram shows basic EUT interconnections with cable type and cable lengths identified:

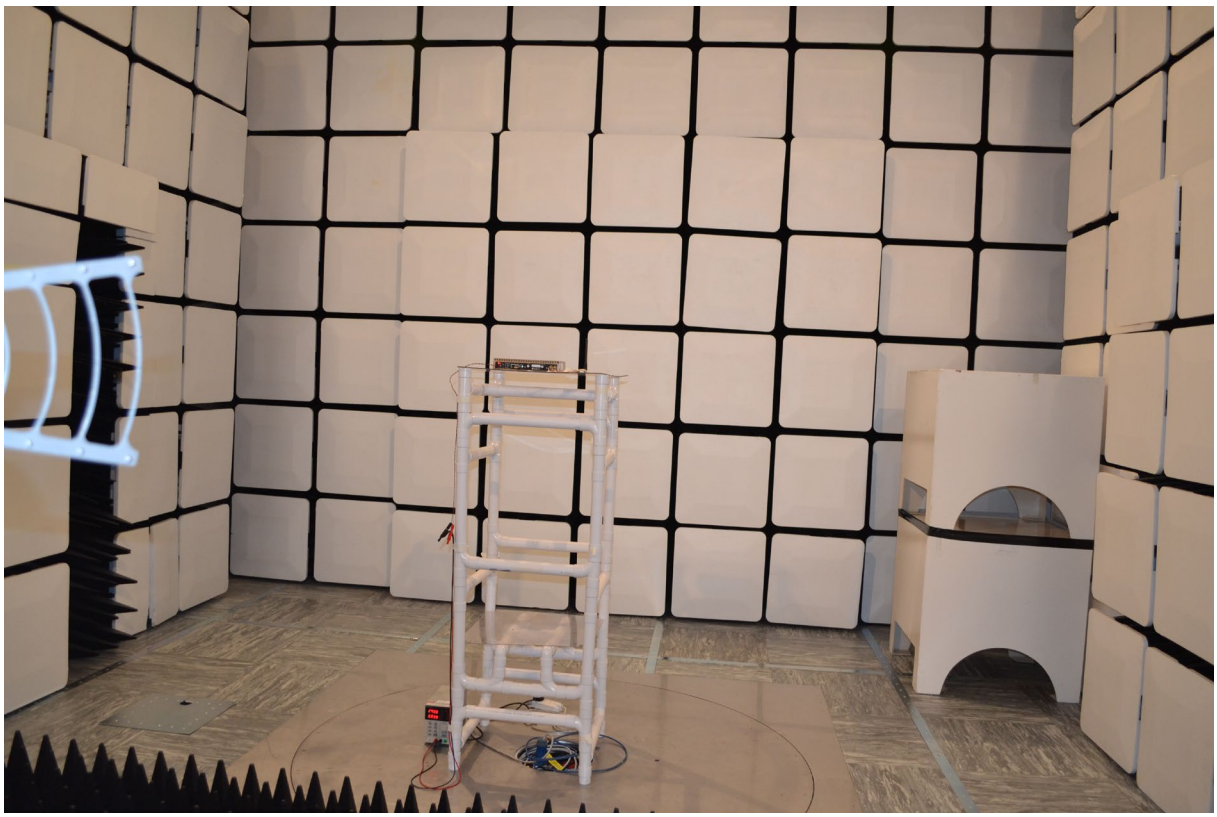


9.2 General Set-up Photograph

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)

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 EUT was tested under the normal environmental conditions of the test laboratory, except where otherwise stated. The normal power source applied was 24 Vdc powered from a bench top power supply connected to 110 Vac, 60 Hz from the mains.

10.2 Varying Test Conditions

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

	Category	***Nominal***	***Variation***
☐	Mains	110V ac +/-2%	85% and 115%
☒	Battery	24 Vdc	N/A

Full Battery power was simulated using a bench-top DC source.

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 Lab 3
Test Standard and Clause:	ANSI C63.10-2013, Clause 6.5 and 6.6
EUT Channels / Frequencies Measured:	0 / 11 / 23 – 5482.5 MHz / 5592.5 MHz / 5712.5 MHz
EUT Channel Bandwidths:	10 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: 21 °C	+15 ºC to +35 ºC (as declared)
Humidity: 45 %RH	20%RH to 75%RH (as declared)
Supply: 24 Vdc	230Vac +/-10% (as declared)

Test Limits
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 3m)*
30-88	100
88-216	150
216-960	200
Above 960	500

Limits from 15.407:
(b) Undesirable emission limits. … the maximum emissions outside of the frequency bands of operation shall be attenuated in accordance with the following limits:
(3) For transmitters operating in the 5.47-5.725 GHz band: All emission outside of the 5.47-5.725 GHz band shall not exceed and e.i.r.p. of -27 dBm/MHz.

11.3 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 100kHz 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:

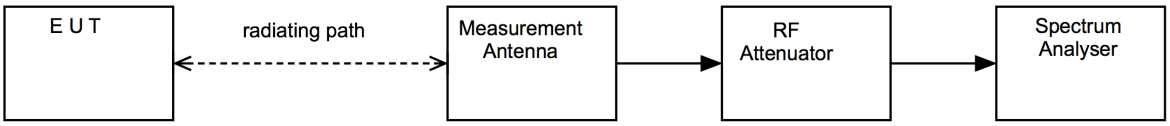
$$FS = PR + CL + AF - PA + DC - CF$$

Where,

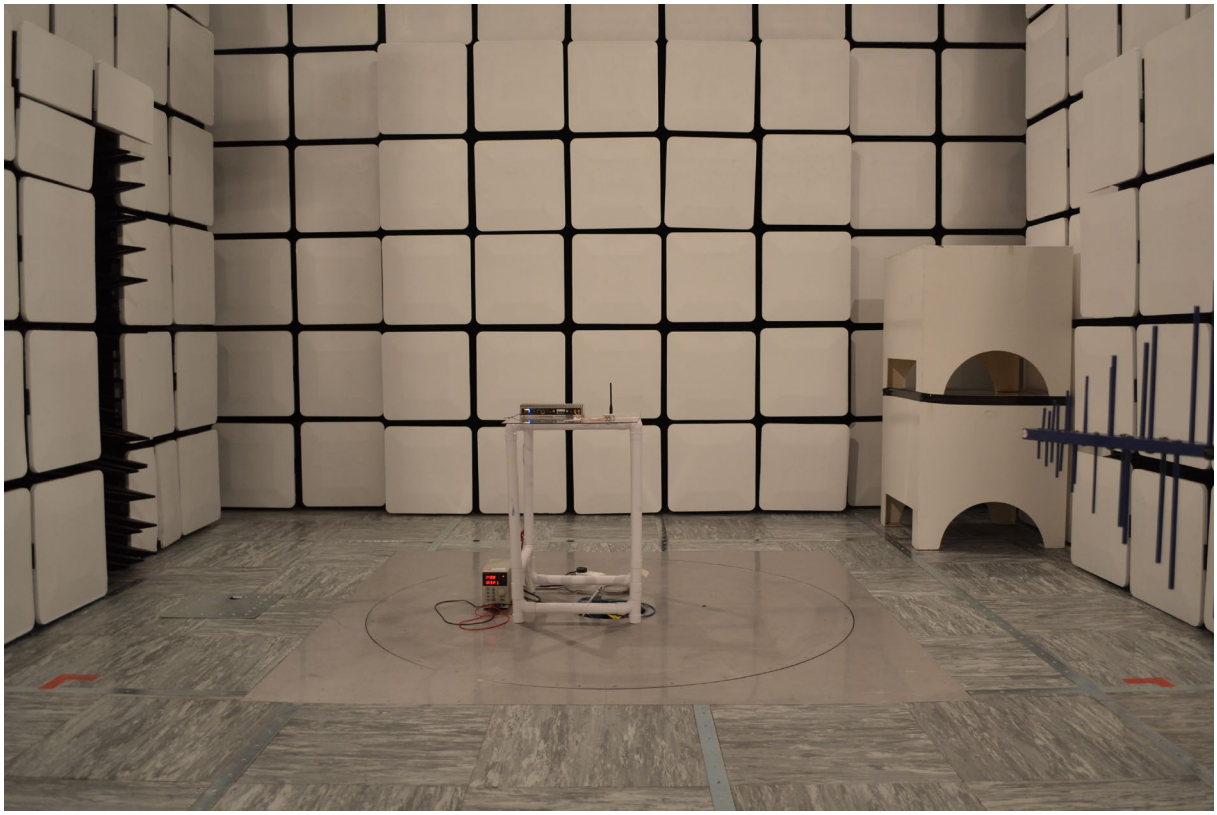
PR is the power recorded on the receiver / spectrum analyzer in dBµV;
CL is the cable loss in dB;
AF is the test antenna factor in dB/m;
PA is the pre-amplifier gain in dB (where used);
DC is the duty correction factor in dB (where used, e.g. where average detector on pulsed harmonic understates the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

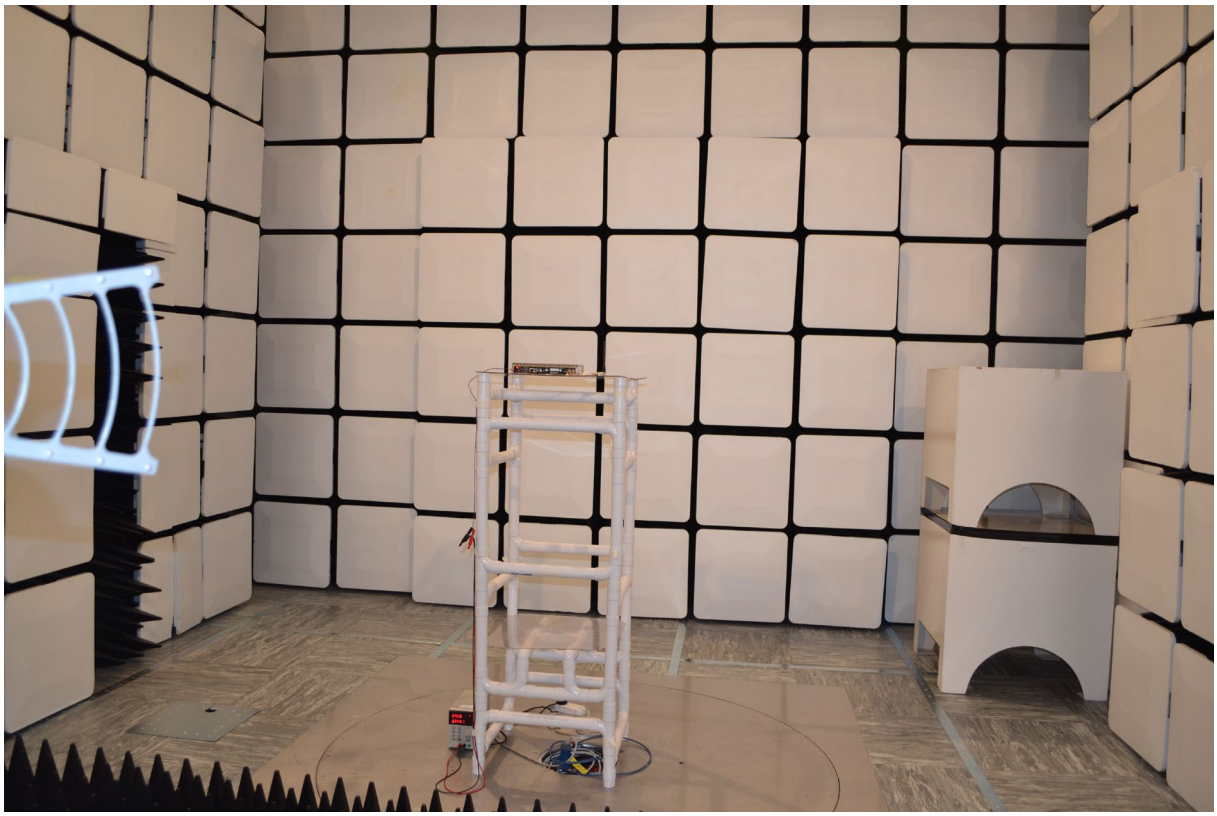
This field strength value is then compared with the regulatory limit.

Figure i Test Setup



Test Setup Photograph(s)





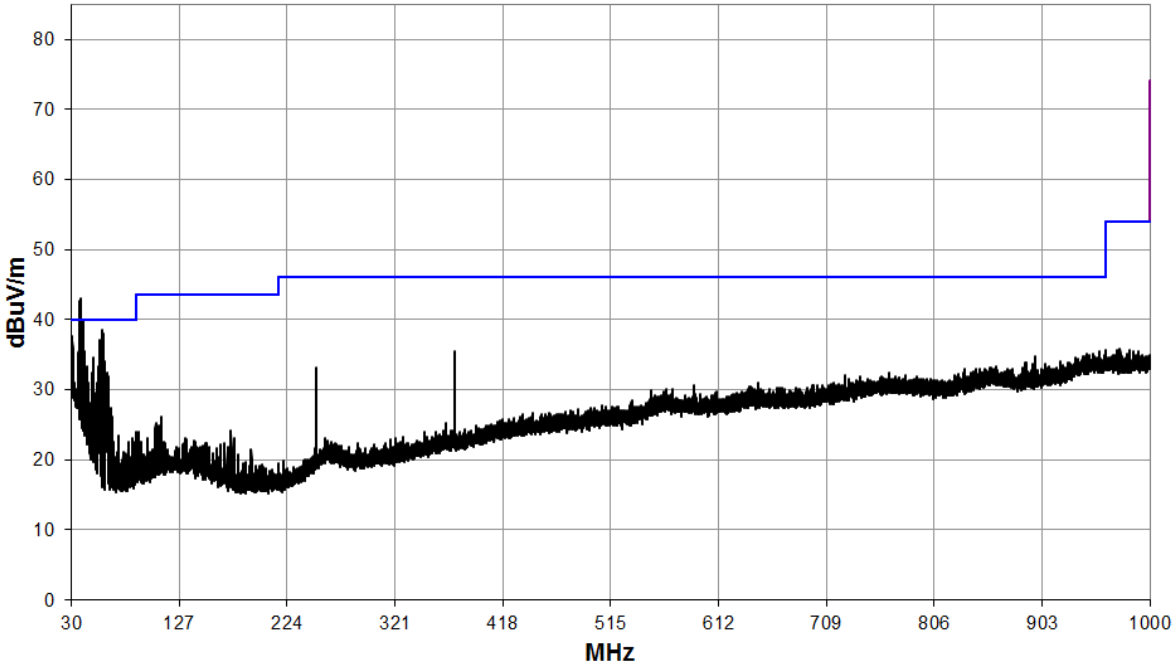
11.4 Test Equipment

Equipment Description	*Manufacturer*	*Equipment Type*	*Element No*	*Due For Calibration*
Ferrite Lined Chamber	Rainford	Chamber	REF2259	2022-08-03
EMI Test Receiver	R&S	ESW26	REF2235	2021-08-31
ESU40	R&S	Receiver	RFG701	2022-04-26
Bilog Antenna	Chase	CBL6111B	REF2218	2021-10-23
LB-10180-NF	A Info Inc	Horn Antenna	REF2241	2022-07-13
LB-90-25-C2-SF	A Info Inc	Horn Antenna	REF2243	2022-07-17
LB-62-25-C-SF	A Info Inc	Horn Antenna	REF2244	2022-07-17
LB-180400-25-C-KF	A Info Inc	Horn Antenna	REF2246	2022-07-28
Emissions R5	Element	Radiated Test Software	REF9000	Cal not required

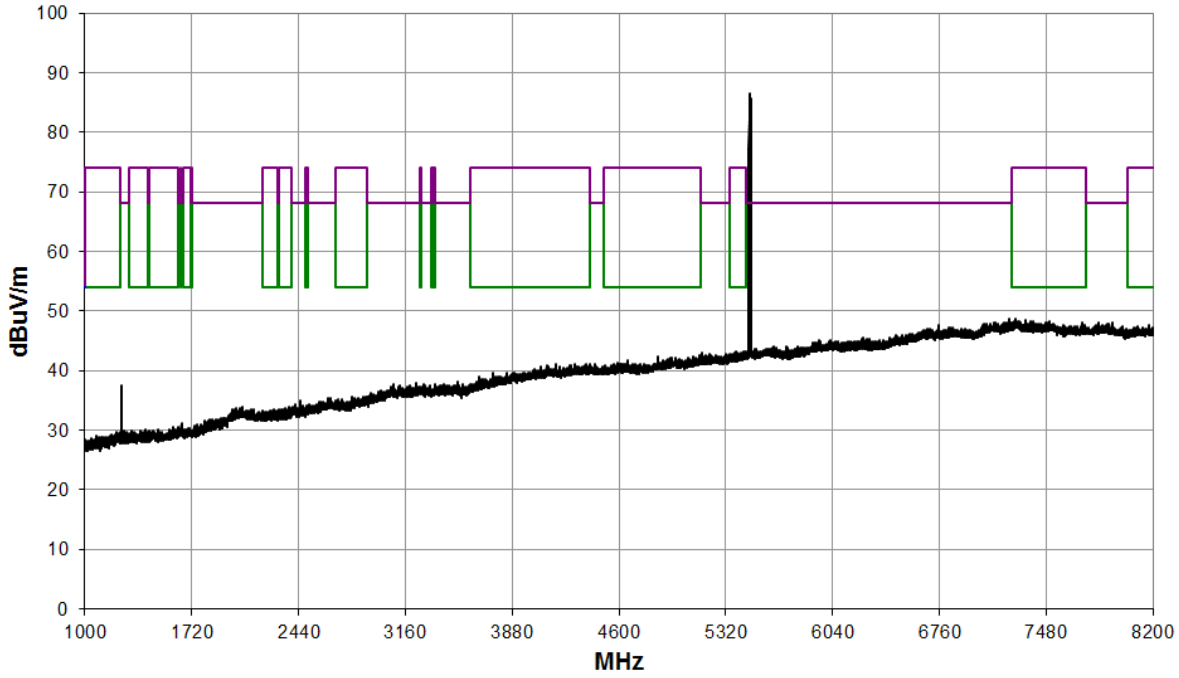
11.5 Test Results

Channel: 0; Frequency: 5482.5 MHz										
Detector	***Freq. (MHz)***	***Meas'd Emission (dBµV)***	***Cable Loss (dB)***	***Antenna Factor (dB/m)***	***Pre-amp Gain (dB)***	***Duty Cycle Corr'n (dB)***	***Field Strength (dBµV/m)***	***Distance Extrap'n Factor (dB)***	***Field Strength (µV/m)***	***Limit (µV/m)***
QP	31.1	1.1	0.7	24.6	0.0	0.0	26.4	0.0	20.9	40.0
QP	40.5	-0.2	0.7	19.7	0.0	0.0	20.4	0.0	10.5	40.0
QP	58.2	7.6	0.9	12.5	0.0	0.0	21.0	0.0	11.2	40.0
QP	375.0	5.9	2.7	20.4	0.0	0.0	29.0	0.0	28.2	46.0

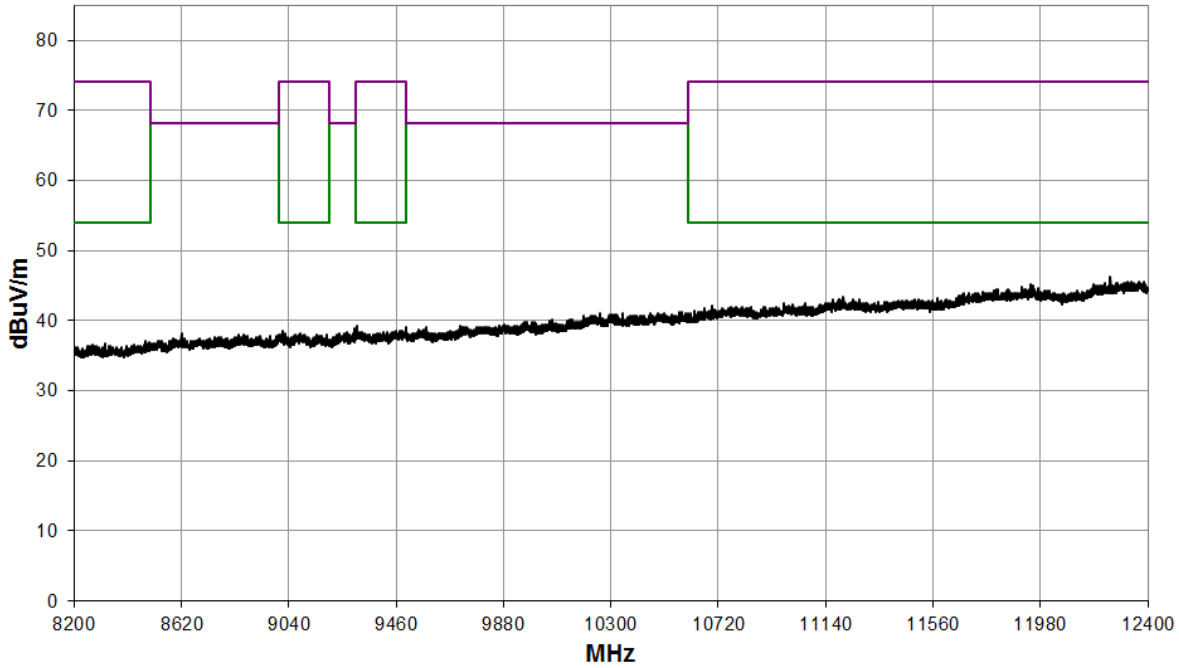
30 MHz to 1 GHz



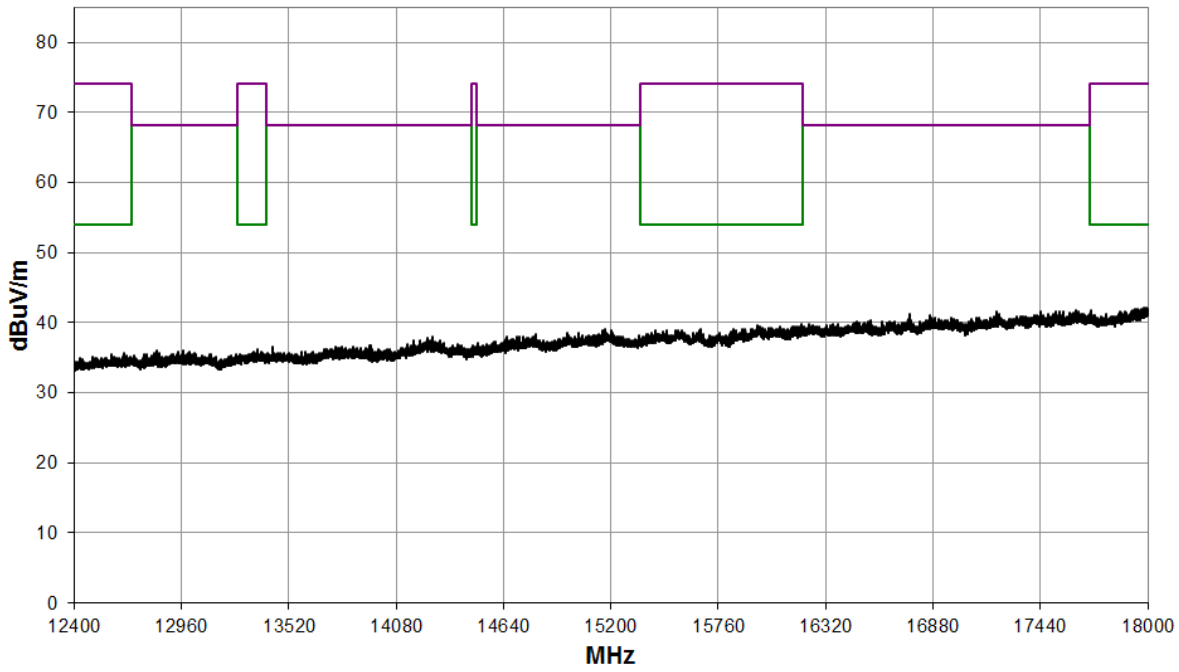
1 GHz to 8.2 GHz



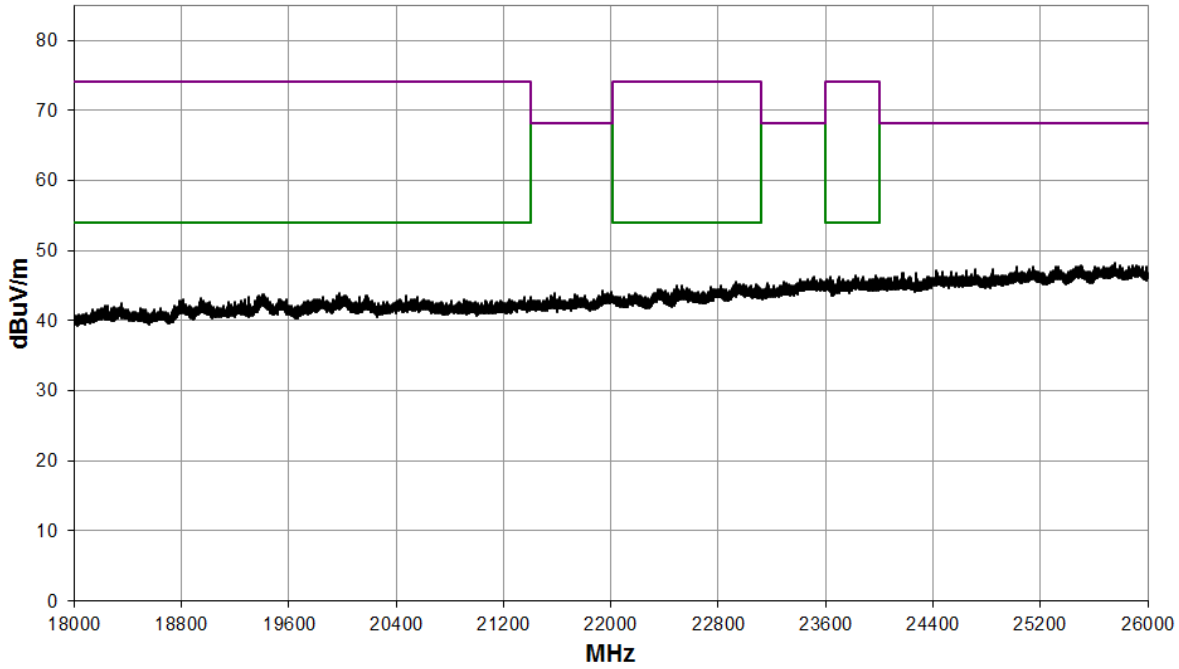
8.2 GHz to 12.4 GHz



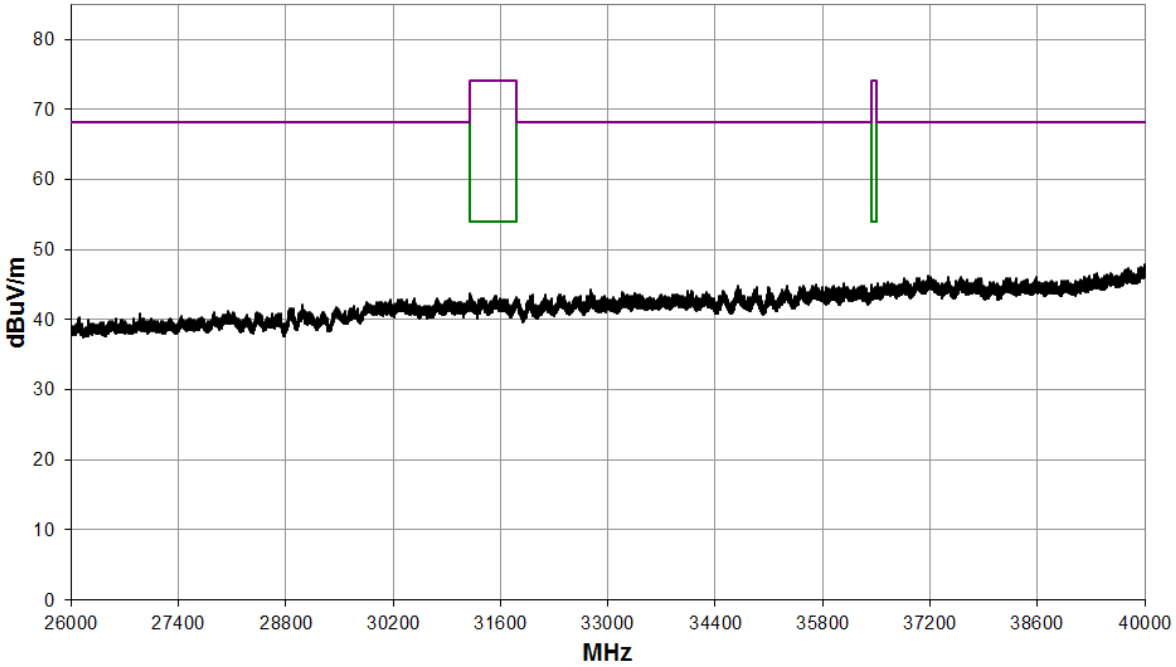
12.4 GHz to 18 GHz



18 GHz to 26 GHz

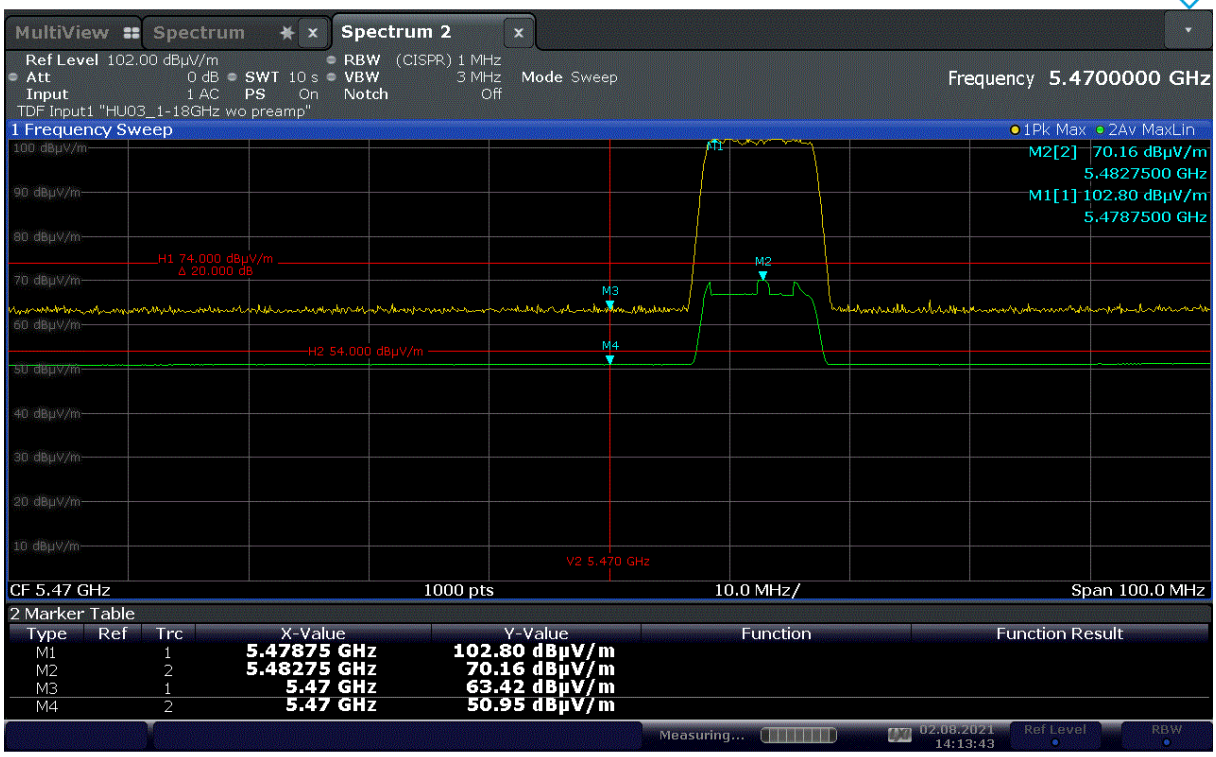


26 GHz to 40 GHz



Band Edge

Element



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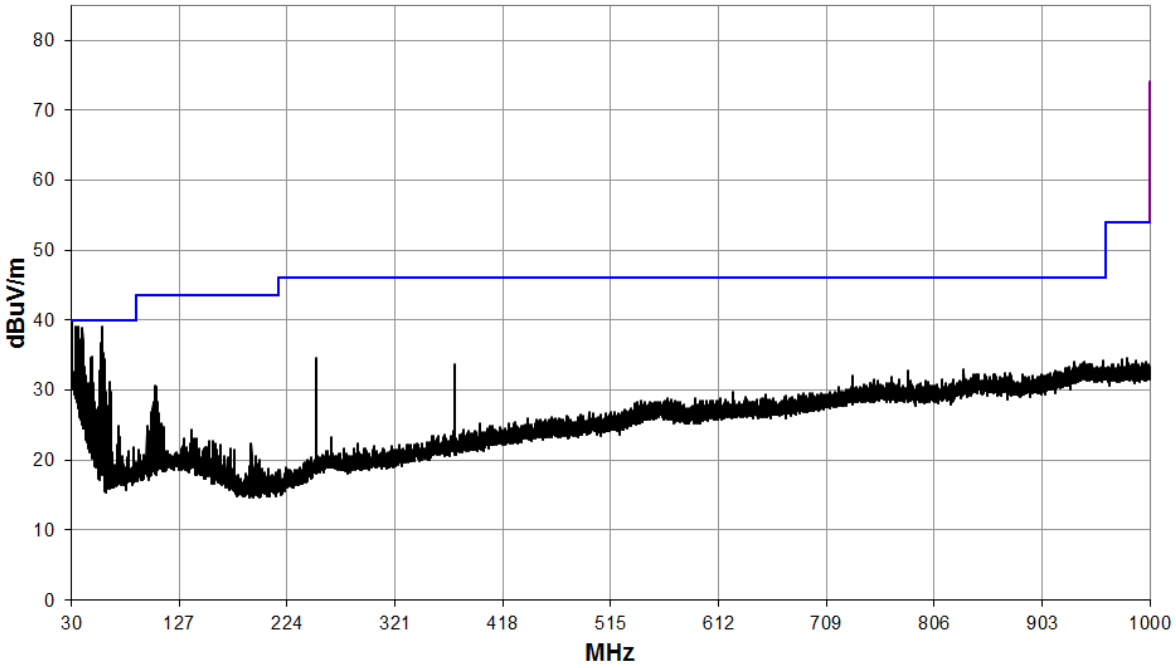
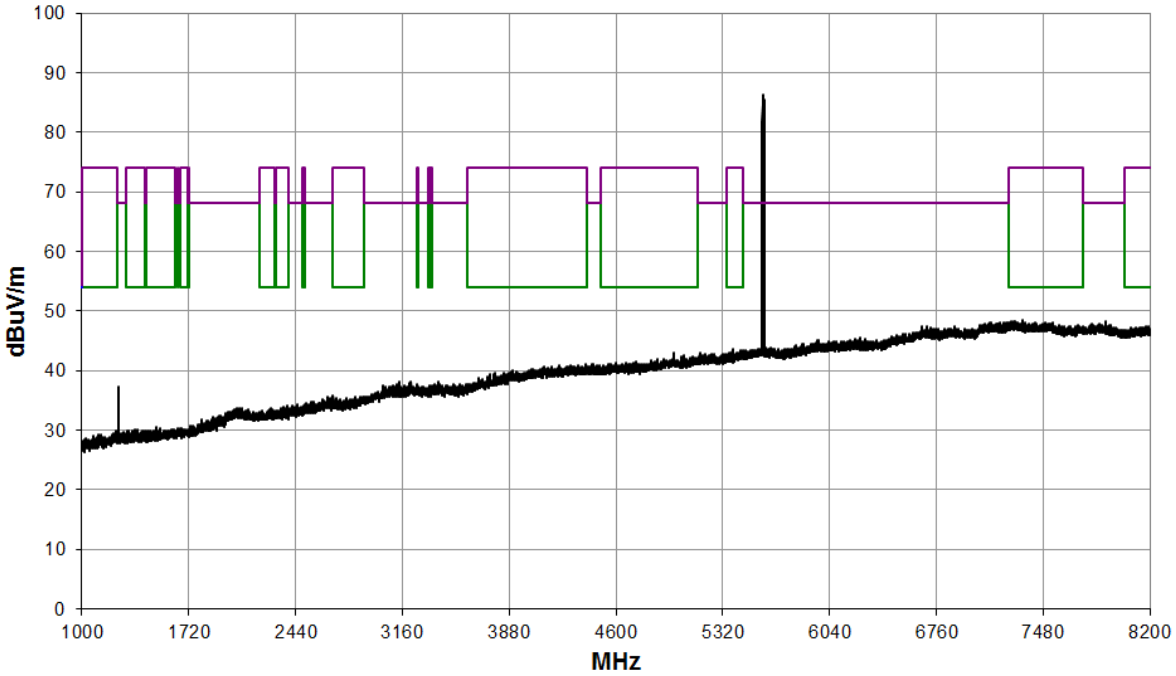
Channel: 11; Frequency: 5592.5 MHz										
Detector	***Freq. (MHz)***	***Meas'd Emission (dBµV)***	***Cable Loss (dB)***	***Antenna Factor (dB/m)***	***Pre-amp Gain (dB)***	***Duty Cycle Corr'n (dB)***	***Field Strength (dBµV/m)***	***Distance Extrap'n Factor (dB)***	***Field Strength (µV/m)***	***Limit (µV/m)***
QP	31.1	1.1	0.7	24.6	0.0	0.0	26.4	0.0	20.9	40.0
QP	40.5	-0.2	0.7	19.7	0.0	0.0	20.4	0.0	10.5	40.0
QP	58.2	7.6	0.9	12.5	0.0	0.0	21.0	0.0	11.2	40.0
QP	375.0	5.9	2.7	20.4	0.0	0.0	29.0	0.0	28.2	46.0

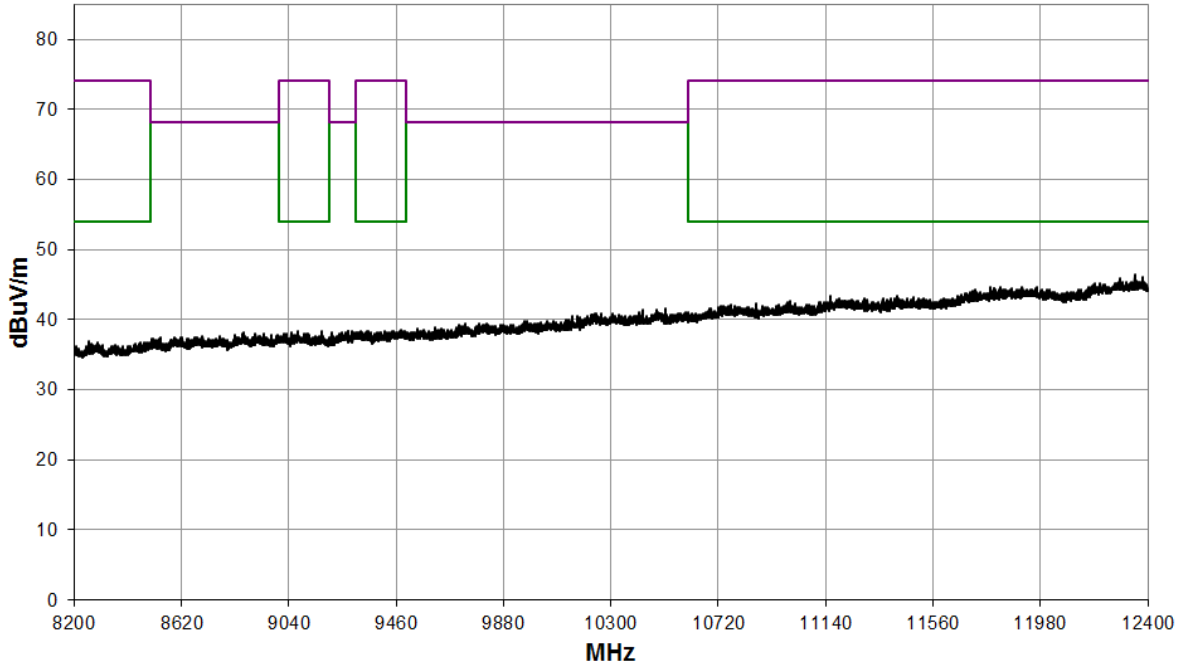
30 MHz to 1 GHz



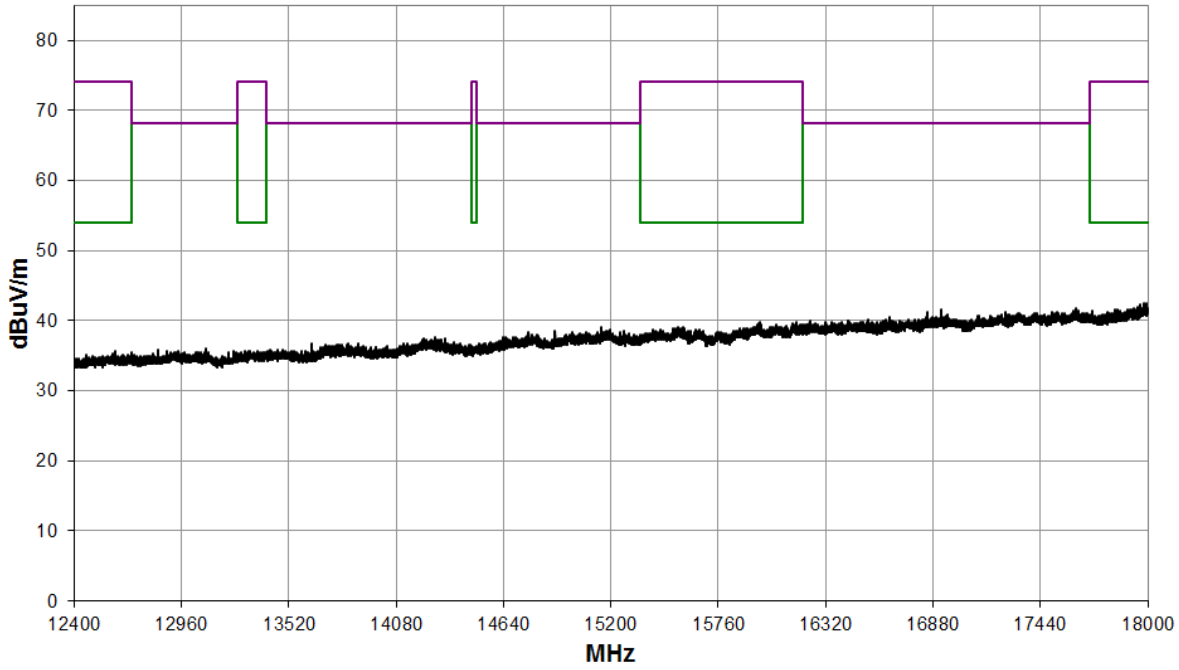
1 GHz to 8.2 GHz



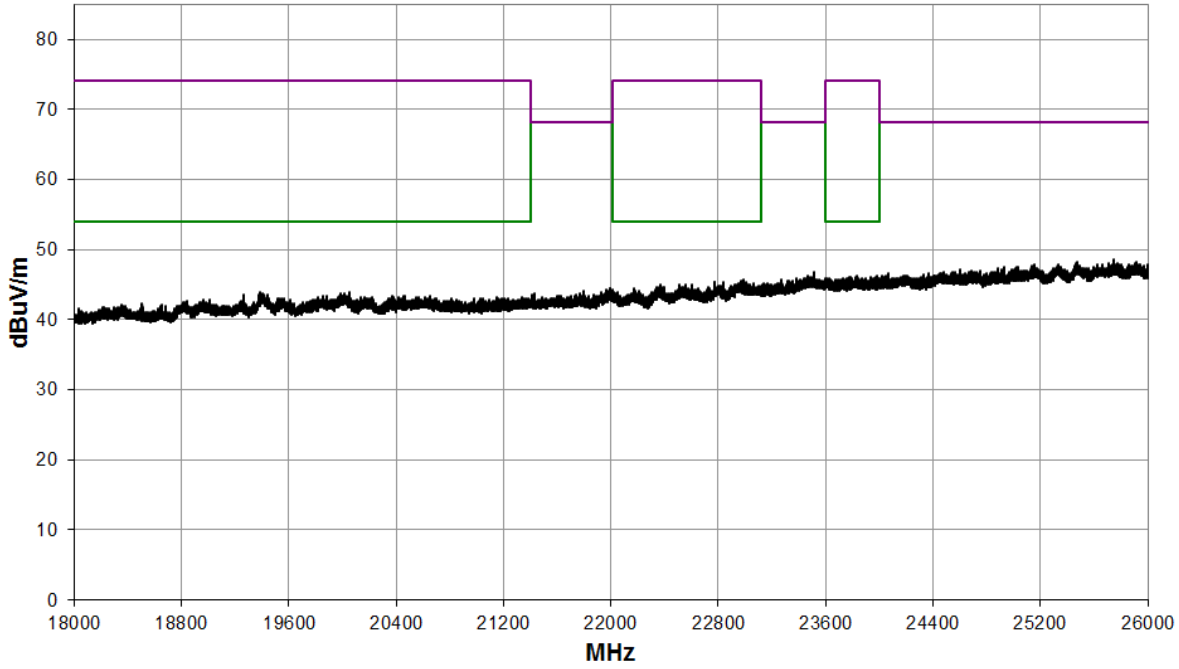
8.2 GHz to 12.4 GHz



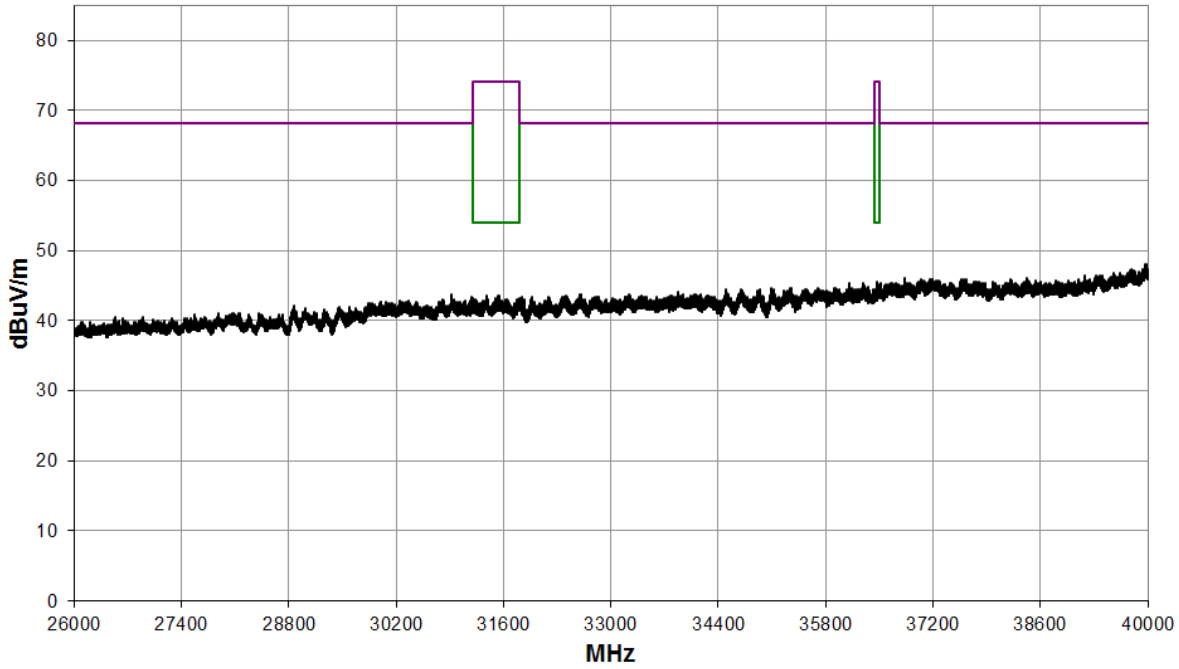
12.4 GHz to 18 GHz



18 GHz to 26 GHz

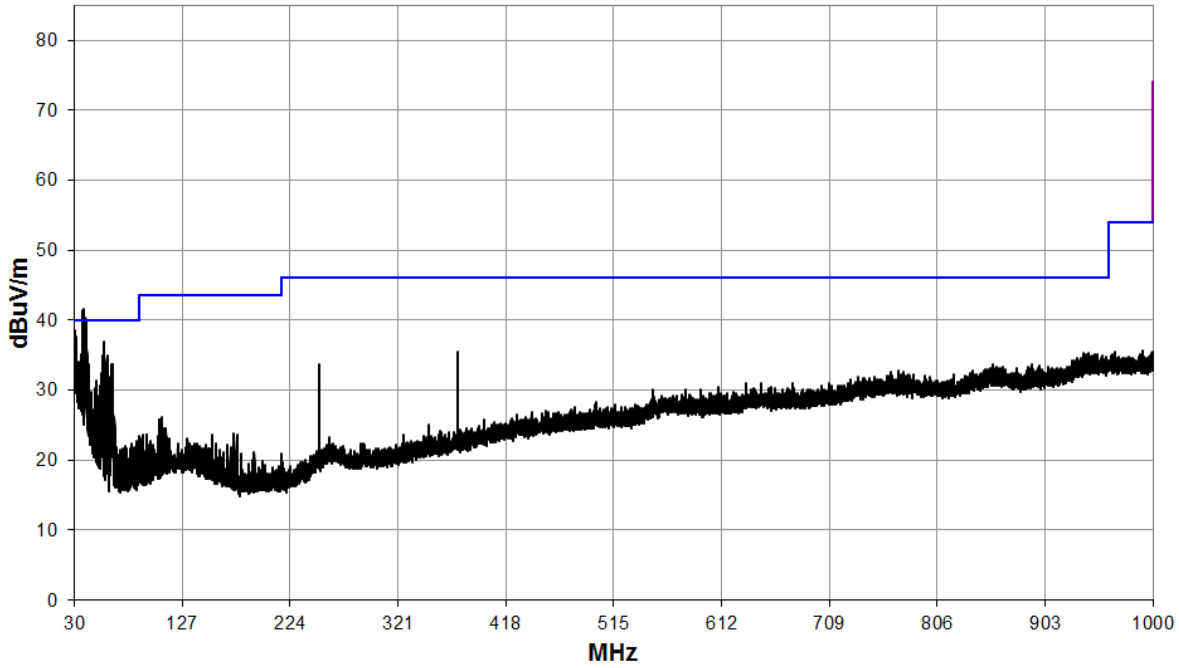


26 GHz to 40 GHz

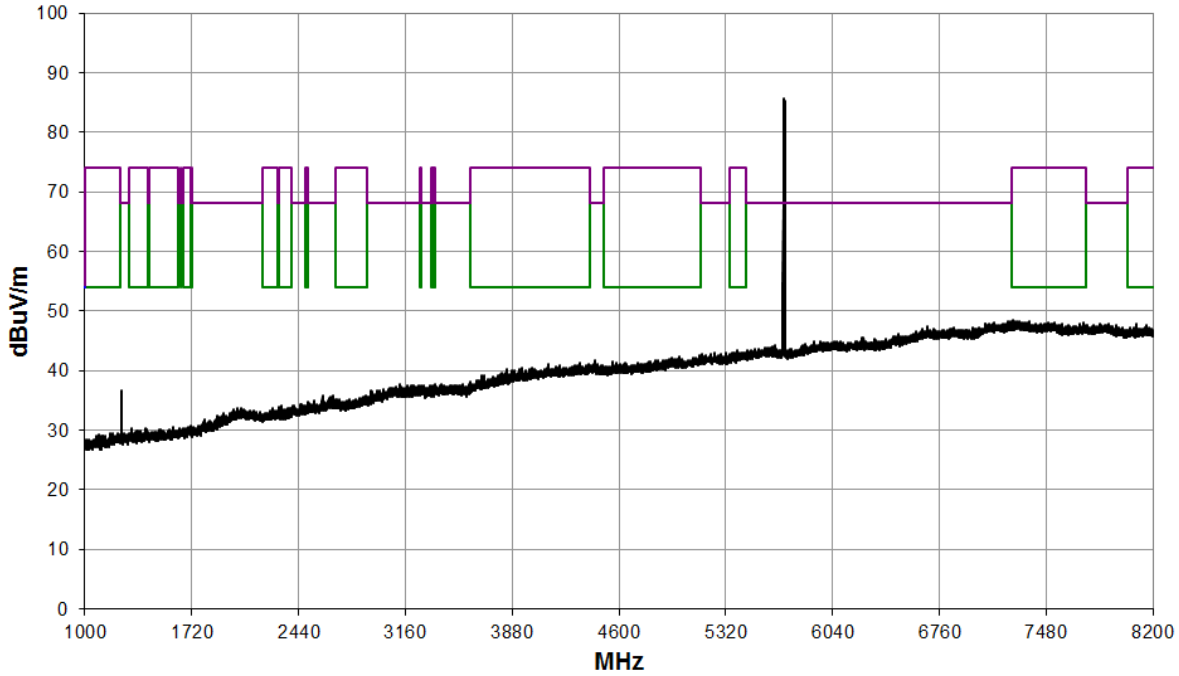


Channel: 23; Frequency: 5712.5 MHz										
Detector	***Freq. (MHz)***	***Meas'd Emission (dBµV)***	***Cable Loss (dB)***	***Antenna Factor (dB/m)***	***Pre-amp Gain (dB)***	***Duty Cycle Corr'n (dB)***	***Field Strength (dBµV/m)***	***Distance Extrap'n Factor (dB)***	***Field Strength (µV/m)***	***Limit (µV/m)***
QP	31.1	1.1	0.7	24.6	0.0	0.0	26.4	0.0	20.9	40.0
QP	40.5	-0.2	0.7	19.7	0.0	0.0	20.4	0.0	10.5	40.0
QP	58.2	7.6	0.9	12.5	0.0	0.0	21.0	0.0	11.2	40.0
QP	375.0	5.9	2.7	20.4	0.0	0.0	29.0	0.0	28.2	46.0

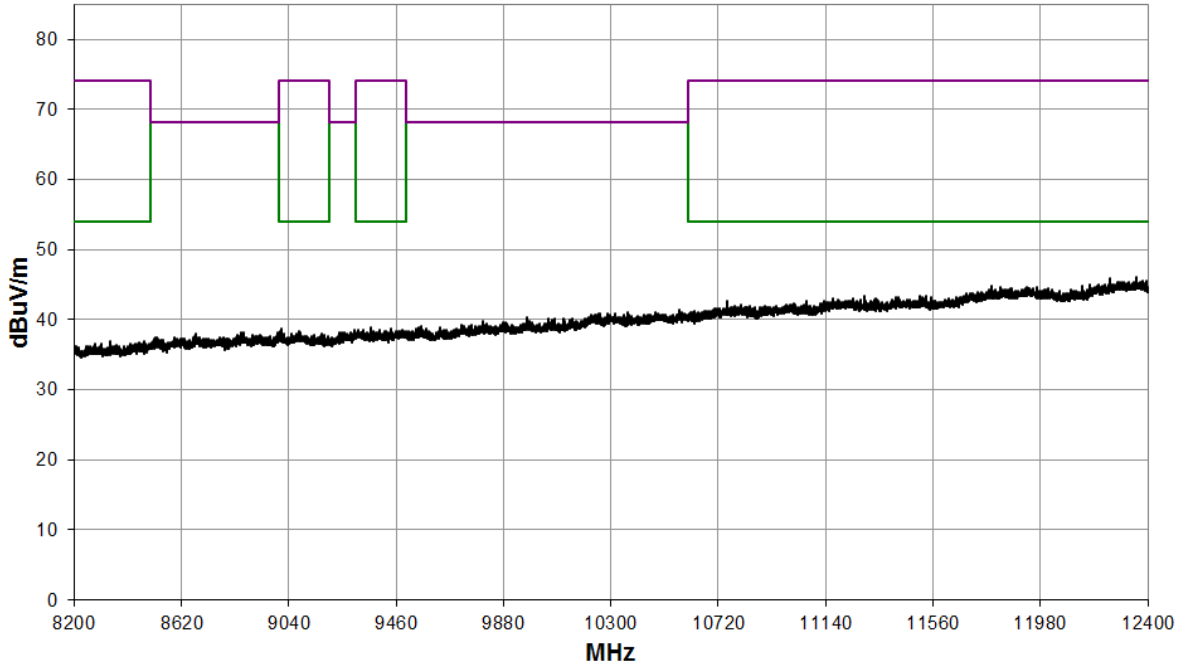
30 MHz to 1 GHz



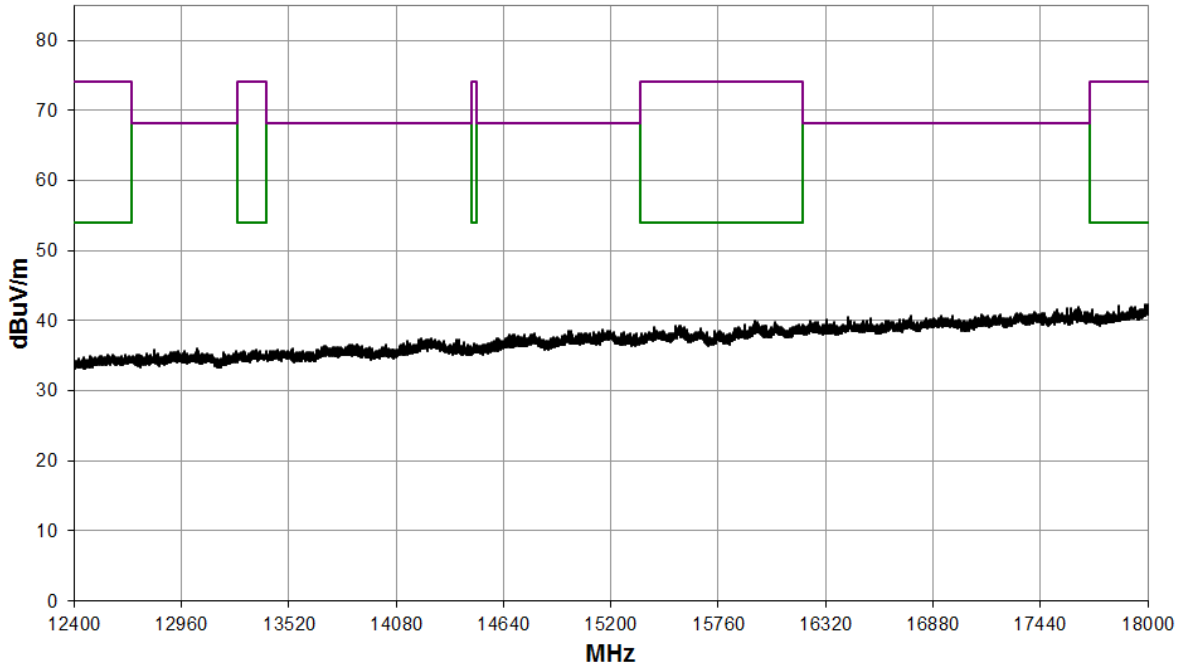
1 GHz to 8.2 GHz



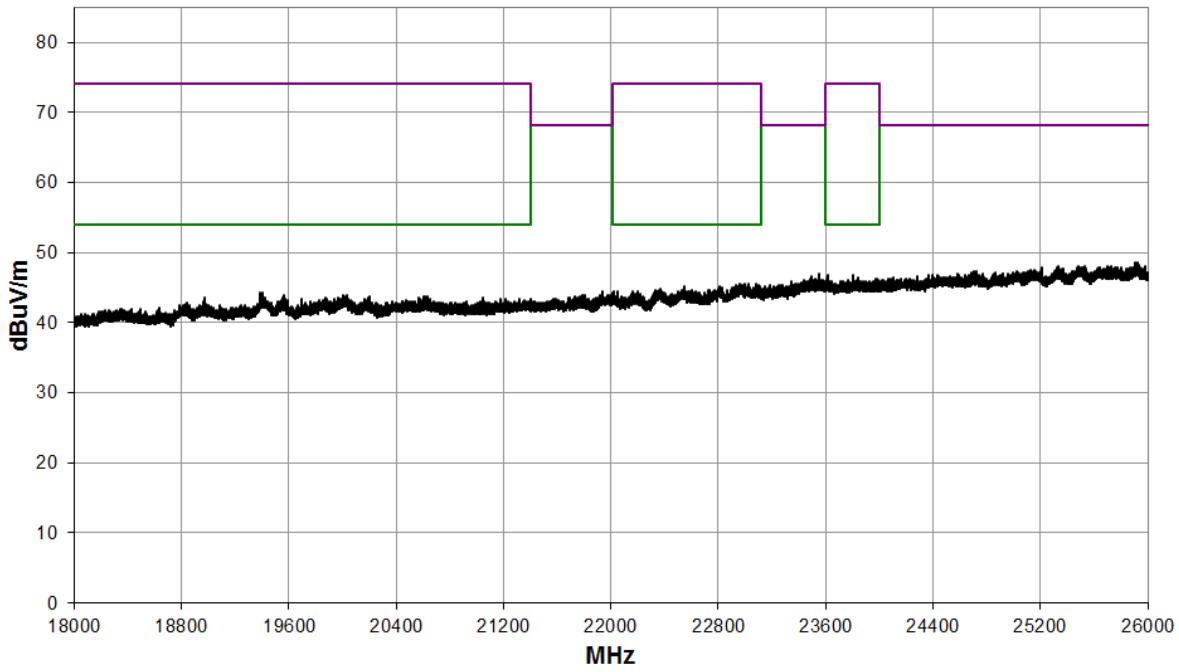
8.2 GHz to 12.4 GHz



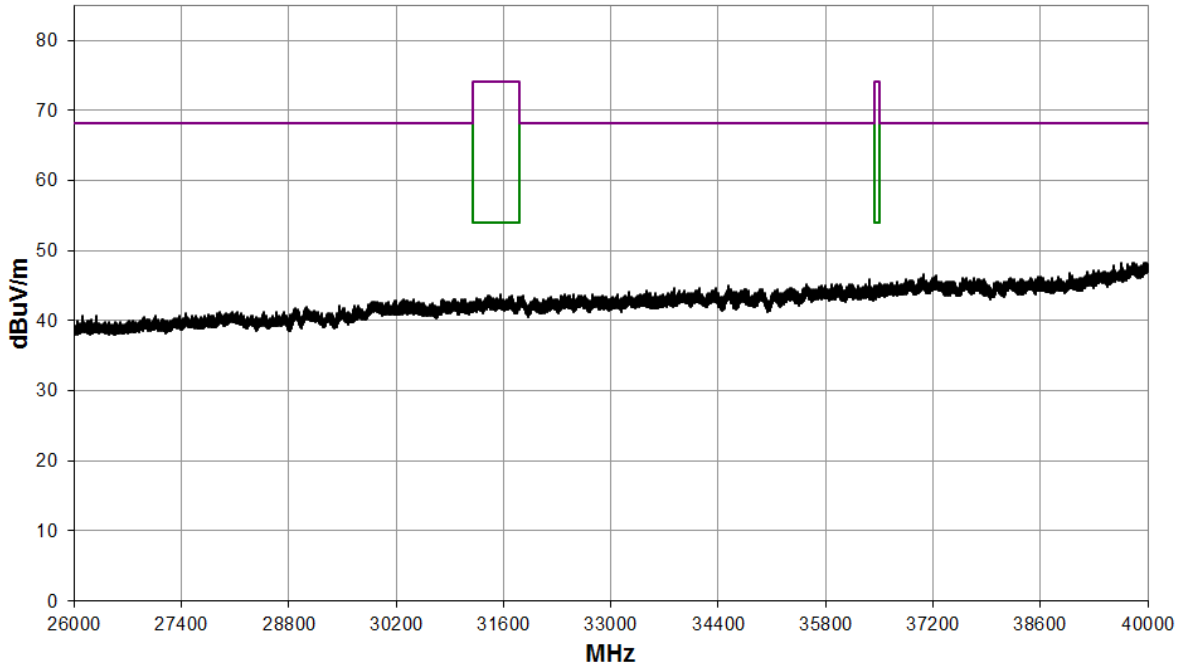
12.4 GHz to 18 GHz



18 GHz to 26 GHz

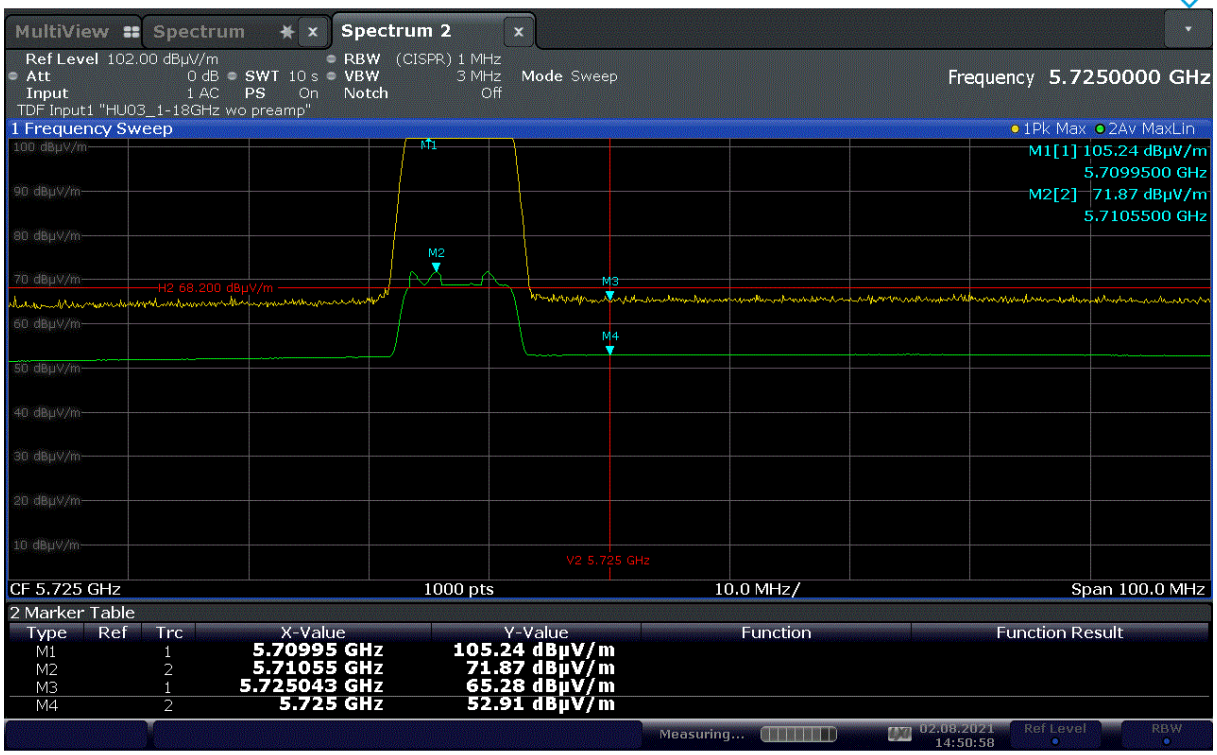


26 GHz to 40 GHz



Band Edge

Element



14:50:59 02.08.2021

12 Occupied Bandwidth

12.1 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.

12.2 Test Parameters

Test Location:	Element Hull
Test Chamber:	Wireless Laboratory 1
Test Standard and Clause:	ANSI C63.10-2013, Clause 6.9
EUT Channels / Frequencies Measured:	5482.5 MHz / 5592.5 MHz / 5712.5 MHz
EUT Channel Bandwidths:	10 MHz
EUT Test Modulations:	OFDM
Deviations From Standard:	None
Measurement BW: (FCC requirement: 100 kHz)	100 kHz
Spectrum Analyzer Video BW: (requirement at least 3x RBW)	300 kHz
Measurement Span: (requirement 2 to 5 times OBW)	20 MHz
Measurement Detector:	Peak

Environmental Conditions (Normal Environment)

Temperature: 23 °C	+15 ºC to +35 ºC (as declared)
Humidity: 45 %RH	20%RH to 75%RH (as declared)
Supply: 24 Vdc	(as declared)

Test Limits

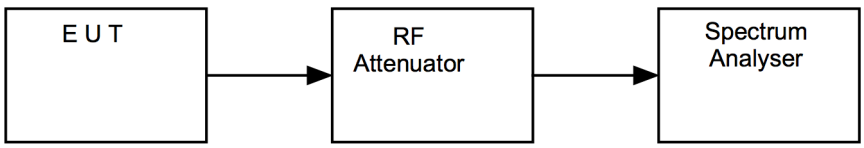
Within the 5.725–5.85 GHz band, the minimum 6 dB bandwidth of U–NII devices shall be at least 500 kHz.

There are no requirements outside of this band, the results were taken for the calculation of the power limits.

12.3 Test Method

With the EUT setup as per section 9 of this report and connected as per Figure iii, the bandwidth of the EUT was measured on a spectrum analyser.
The measurements were performed with EUT set at its maximum duty. All modulation schemes, data rates and power settings were used to observe the worst-case configuration in each bandwidth.

Figure iii Test Setup



12.4 Test Equipment

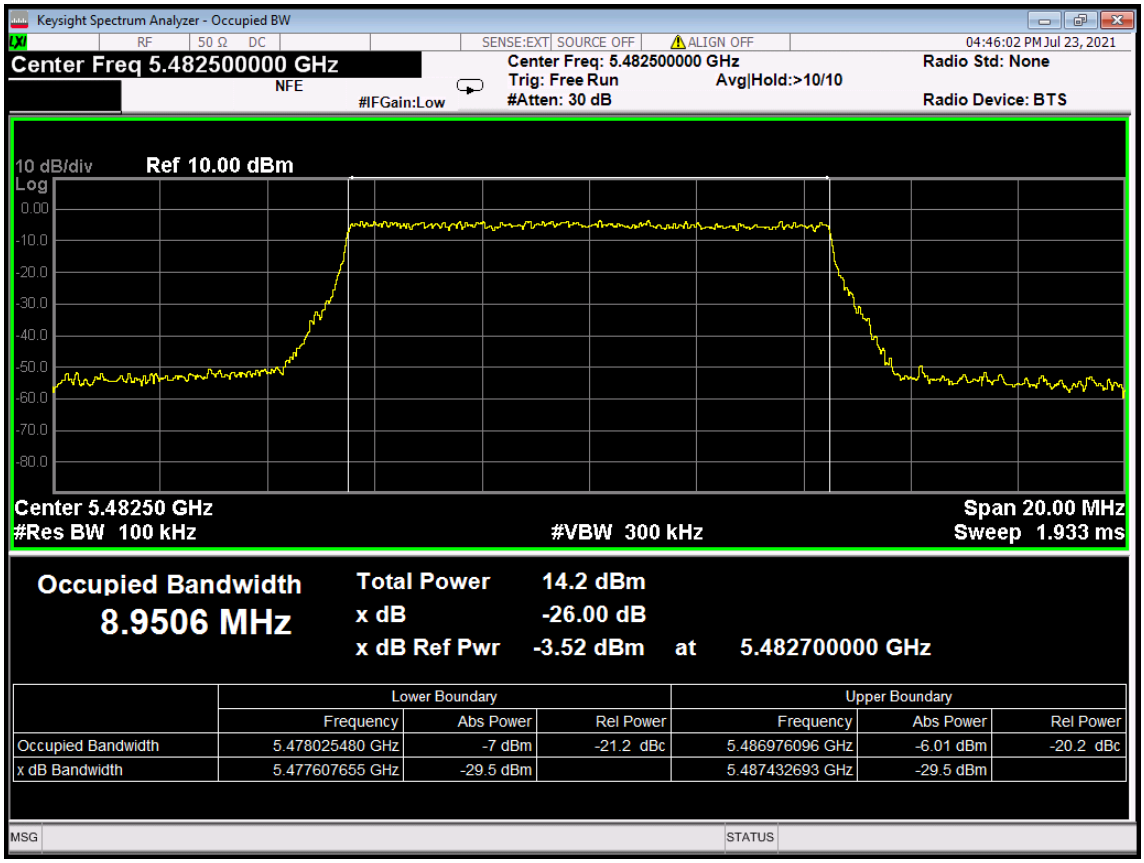
Equipment Description	*Manufacturer*	*Equipment Type*	*Element No*	*Last Cal Calibration*	*Calibration Period*	*Due For Calibration*
Spectrum Analyser	Agilent	N9030A	REF2167	2020-08-19	12	2021-08-19

12.5 Test Results

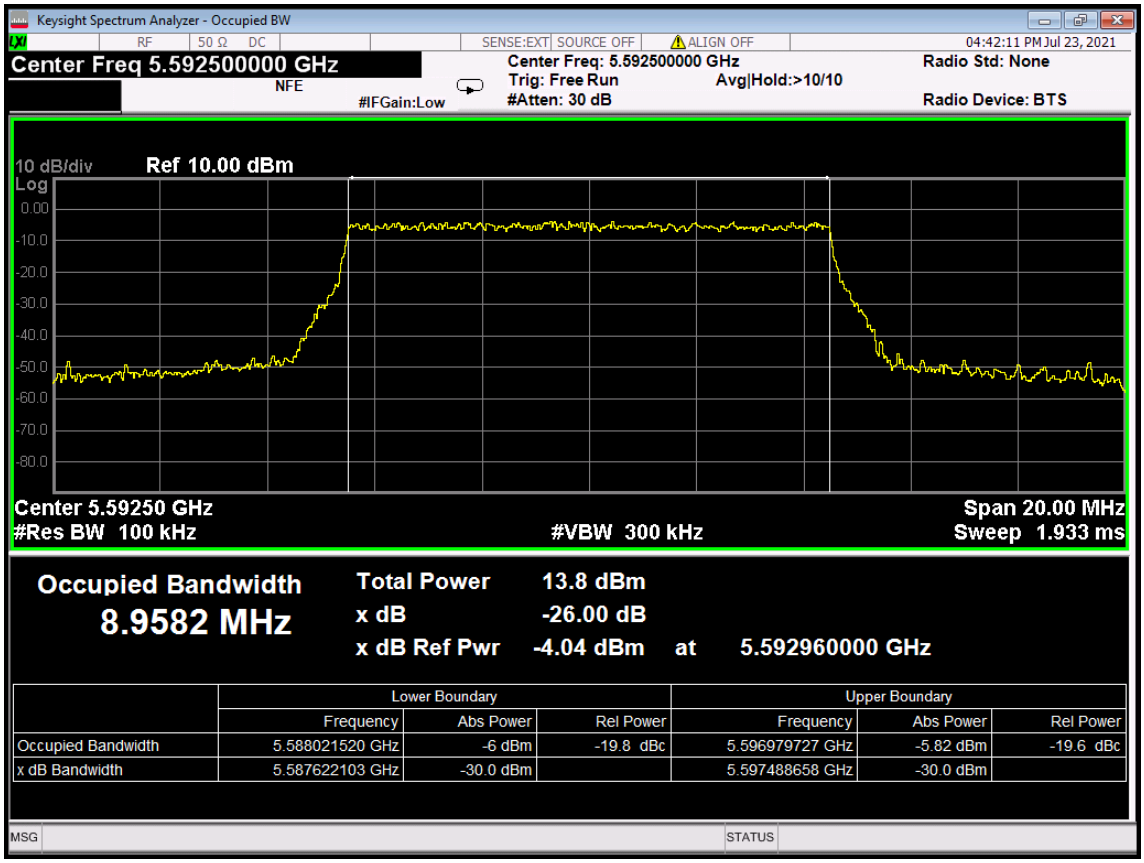
Modulation: OFDM; Power setting: Full				
Channel Frequency (MHz)	F_L (MHz)	F_H (MHz)	26dB Bandwidth (MHz)	Result
5482.5	5477.607655	5487.432693	9.825038	PASS
5592.5	5587.622103	5597.488658	9.866555	PASS
5712.5	5707.497090	5717.483953	9.986863	PASS

Modulation: OFDM; Power setting: Full			
Channel Frequency (MHz)	26dB bandwidth (MHz)	99% bandwidth (MHz)	Result
5482.5	9.825038	8.9506	N/A
5592.5	9.866555	8.9582	N/A
5712.5	9.986863	8.9550	N/A

Channel 0 : 5482.5 MHz

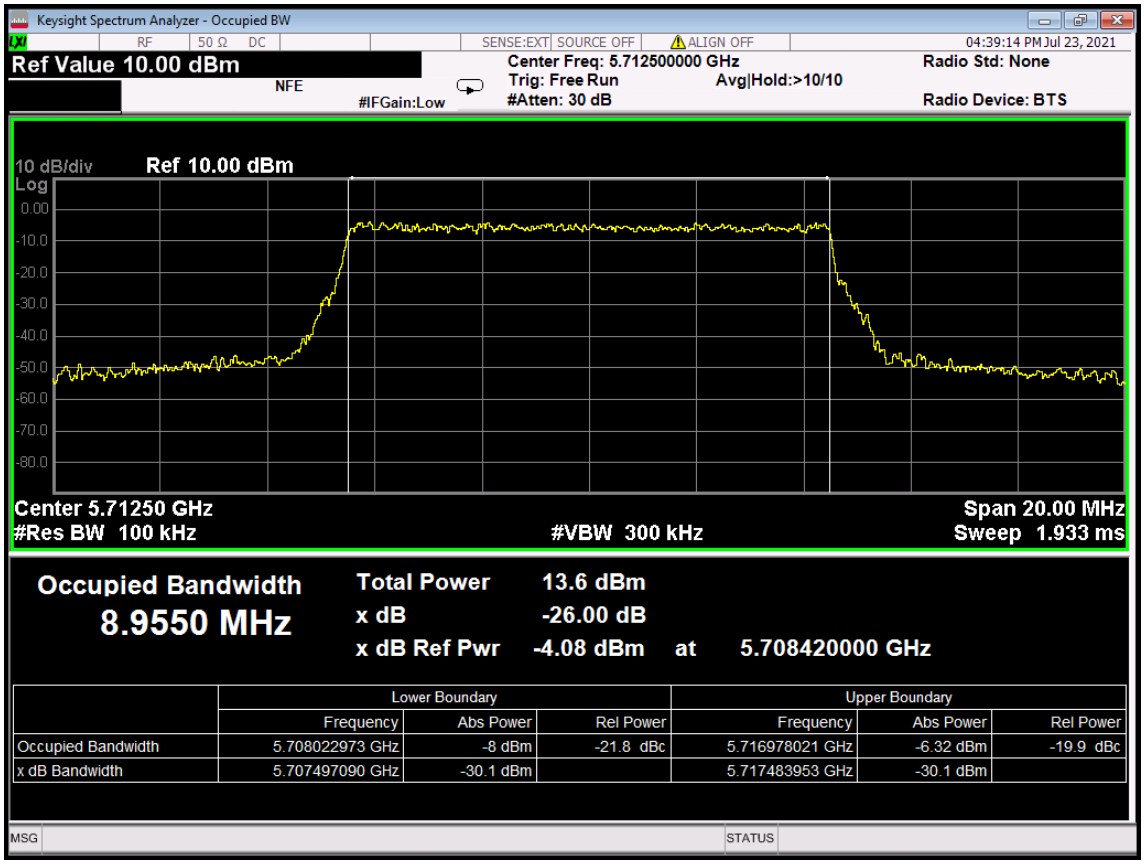


Channel 11 : 5592.5 MHz



	Lower Boundary			Upper Boundary		
	Frequency	Abs Power	Rel Power	Frequency	Abs Power	Rel Power
Occupied Bandwidth	5.588021520 GHz	-6 dBm	-19.8 dBc	5.596979727 GHz	-5.82 dBm	-19.6 dBc
x dB Bandwidth	5.587622103 GHz	-30.0 dBm		5.597488658 GHz	-30.0 dBm	

Channel 23 : 5712.5 MHz



	Lower Boundary			Upper Boundary		
	Frequency	Abs Power	Rel Power	Frequency	Abs Power	Rel Power
Occupied Bandwidth	5.708022973 GHz	-8 dBm	-21.8 dBc	5.716978021 GHz	-6.32 dBm	-19.9 dBc
x dB Bandwidth	5.707497090 GHz	-30.1 dBm		5.717483953 GHz	-30.1 dBm	

13 Maximum conducted output power

13.1 Definition

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.

13.2 Test Parameters

Test Location:	Element Hull
Test Chamber:	Wireless Laboratory 1
Test Standard and Clause:	ANSI C63.10-2013, Clause 12.3
EUT Channels / Frequencies Measured:	5482.5 MHz / 5592.5 MHz / 5712.5 MHz
EUT Occupied Bandwidths:	9.825038 MHz
EUT Duty Cycle:	47.5%
EUT Antenna Gain:	14.5 dBi
Deviations From Standard:	None
Measurement BW:	Wideband Power Meter used
Measurement Span:	Wideband Power Meter used
Measurement Points:	Wideband Power Meter used
Measurement Detector:	RMS

Environmental Conditions (Normal Environment)

Temperature: 22 °C	+15 ºC to +35 ºC (as declared)
Humidity: 57 %RH	20%RH to 75%RH (as declared)

Test Limits

For an access point operating in the band 5.15–5.25 GHz, the maximum conducted output power over the frequency band of operation shall not exceed 1 W.
For mobile and portable client devices in the 5.15–5.25 GHz band, the maximum conducted output power over the frequency band of operation shall not exceed 250 mW.
For the 5.25–5.35 GHz and 5.47–5.725 GHz bands, the maximum conducted output power over the frequency bands of operation shall not exceed the lesser of 250 mW or 11 dBm + 10 log B, where B is the 26 dB emission bandwidth in megahertz.
For the band 5.725–5.85 GHz, the maximum conducted output power over the frequency band of operation shall not exceed 1 W.

If transmitting antennas of directional gain greater than 6 dBi are used, both the maximum conducted output power and the maximum power spectral density shall be reduced by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

Fixed point-to-point U–NII devices operating in the band 5.725-5.85 GHz may employ antennas with directional gain greater than 6 dBi without any corresponding reduction in transmitter conducted power.
Fixed point-to-point U-NII devices operating in other bands may employ antennas with directional gain up to 23dBi without any corresponding reduction in the maximum conducted output power or maximum power spectral density. For fixed point-to-point transmitters that employ a directional antenna gain greater than 23 dBi, a 1 dB reduction in maximum conducted output power and maximum power spectral density is required for each 1 dB of antenna gain in excess of 23 dBi.
The EUT had a minimum 26 dB emission bandwidth of 9.825038 MHz giving a calculated limit of 11 + 10 log 9.825038 dBm = 20.92 dBm (or 123.6 mW).

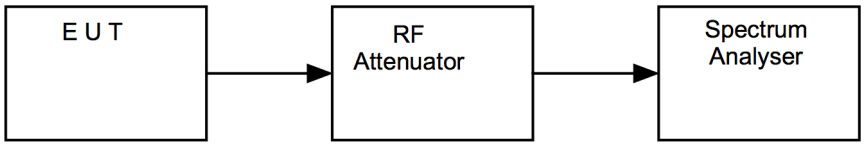
The antenna gain for the EUT was 14.5 dBi which exceeds 6 dBi by 8.5 dB, therefore the limit needs to be reduced by 8.5 dB.

The final calculated limit for the band 5.47 GHz to 5.725 GHz band is : 12.42 dBm (or 17.46 mW).

13.3 Test Method

The EUT was setup as per section 9 of this report and, as per Figure iv, the analyser was used to measure each antenna output in turn, having taken account of all path losses. The resolution bandwidth of the spectrum analyser was set between 1 and 5 % of the EUT occupied bandwidth and the analyser band power function used to calculate the average power. The results were summed as in the tables below.
The measurements were performed with EUT set at its maximum duty. All modulation schemes, data rates and power settings were used to observe the worst case configuration in each bandwidth.

Figure iv Test Setup



13.4 Test Equipment

Equipment Description	*Manufacturer*	*Equipment Type*	*Element No*	*Last Cal Calibration*	*Calibration Period*	*Due For Calibration*
Power Meter	ETS Lindgren	7002-006	REF2324	2021-01-29	12	2022-01-29

13.5 Test Results

Channel: 5482.5 MHz; Power setting: Full			
Antenna Chain	*Analyzer Level (dBm)*	*Cable loss (dB)*	*Power (mW)*
A	-13.2	20.7	5.62
Result:			PASS

Channel: 5592.5 MHz; Power setting: Full			
Antenna Chain	*Analyzer Level (dBm)*	*Cable loss (dB)*	*Power (mW)*
A	-12.3	20.7	6.92
Result:			PASS

Channel: 5712.5 MHz; Power setting: Full			
Antenna Chain	*Analyzer Level (dBm)*	*Cable loss (dB)*	*Power (mW)*
A	-13.3	20.7	5.50
Result:			PASS

14 Power spectral density

14.1 Definition

The power spectral density is the total energy output per unit bandwidth from a pulse or sequence of pulses for which the transmit power is at its maximum level, divided by the total duration of the pulses.

14.2 Test Parameters

Test Location:	Element Hull
Test Chamber:	Wireless Laboratory 1
Test Standard and Clause:	ANSI C63.10-2013, Clause 12.5
EUT Frequencies Measured:	5482.5 MHz / 5592.5 MHz / 5712.5 MHz
EUT Channel Bandwidths:	10 MHz
Deviations From Standard:	None
Measurement BW:	1 MHz
Spectrum Analyzer Video BW: (requirement at least 3x RBW)	3 MHz
Measurement Span: (requirement 1.5 times Channel BW)	15 MHz
Measurement Detector:	RMS

Environmental Conditions (Normal Environment)

Temperature: 23 °C	+15 ºC to +35 ºC (as declared)
Humidity: 45 %RH	20%RH to 75%RH (as declared)
Supply: 24 Vdc	(as declared)

Test Limits

For an access point operating in the band 5.15–5.25 GHz the maximum power spectral density shall not exceed 17 dBm in any 1 megahertz band.
For mobile and portable client devices in the 5.15–5.25 GHz band, the maximum power spectral density shall not exceed 11 dBm in any 1 megahertz band.
For the 5.25-5.35 GHz and 5.47-5.725 GHz bands, the maximum power spectral density shall not exceed 11 dBm in any 1 megahertz band.
For the band 5.725–5.85 GHz, the maximum power spectral density shall not exceed 30 dBm in any 500-kHz band.

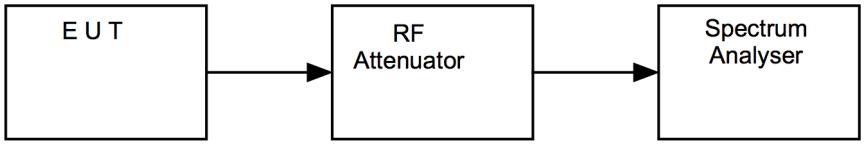
If transmitting antennas of directional gain greater than 6 dBi are used, both the maximum conducted output power and the maximum power spectral density shall be reduced by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

Fixed point- to-point U–NII devices may employ antennas with directional gain up to 23dBi without any corresponding reduction in the maximum conducted output power or maximum power spectral density. For fixed point-to-point transmitters that employ a directional antenna gain greater than 23 dBi, a 1 dB reduction in maximum conducted output power and maximum power spectral density is required for each 1 dB of antenna gain in excess of 23 dBi.

14.3 Test Method

With the EUT setup as per section 9 of this report and connected as per Figure v, 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 v Test Setup



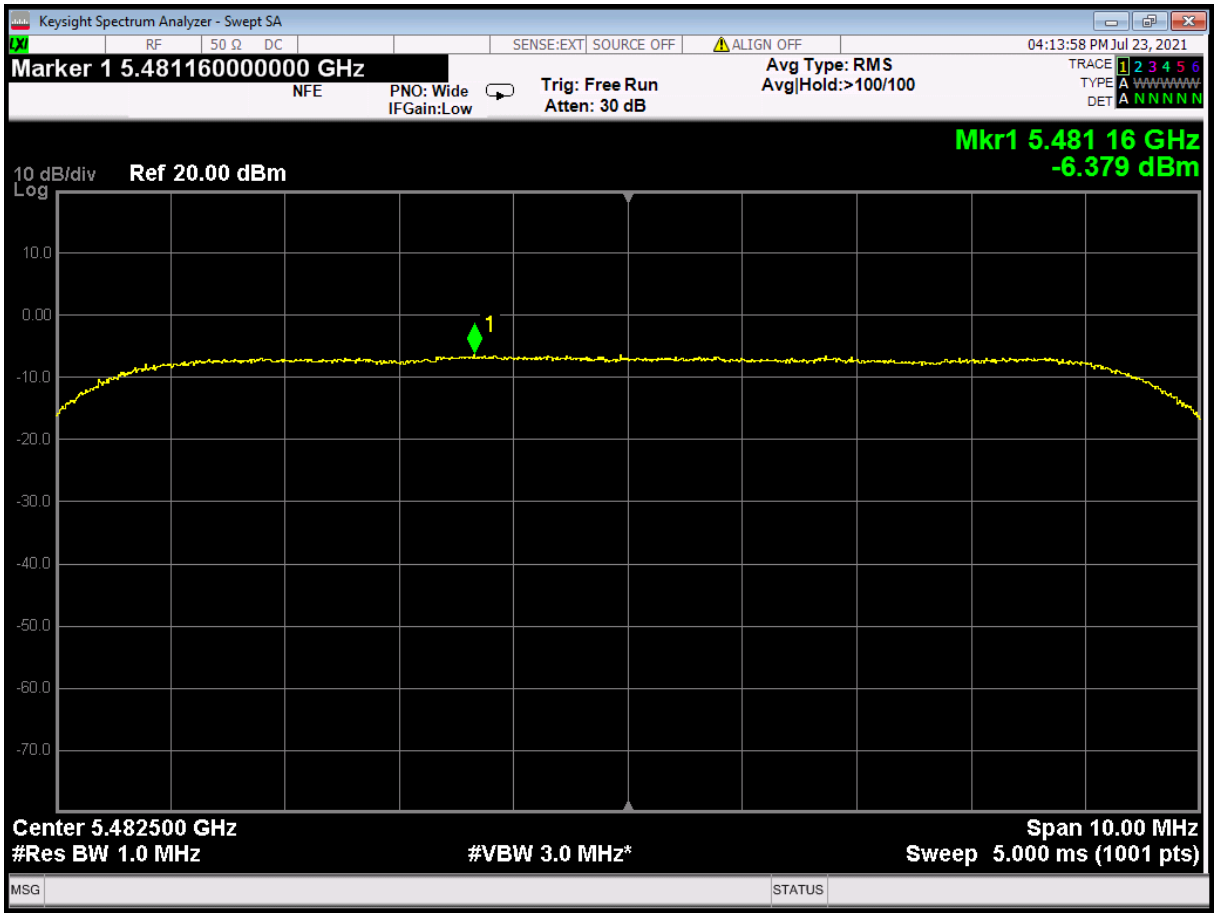
14.4 Test Equipment

Equipment Description	*Manufacturer*	*Equipment Type*	*Element No*	*Last Cal Calibration*	*Calibration Period*	*Due For Calibration*
Spectrum Analyser	Agilent	N9030A	REF2167	2020-08-19	12	2021-08-19

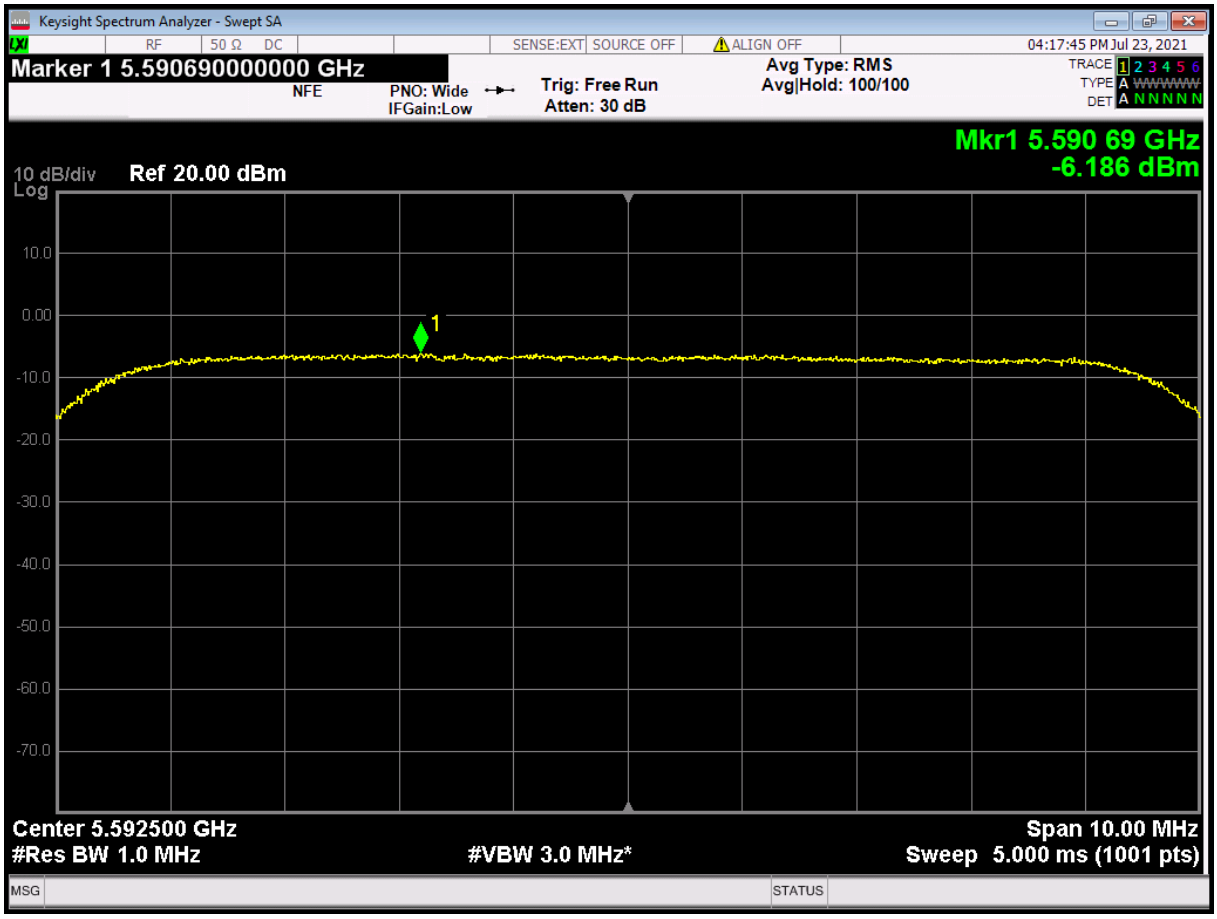
14.5 Test Results

Modulation: OFDM; Power setting: Full						
Measurement Bandwidth (MHz)	*Channel Frequency (MHz)*	*Analyzer Level (dBm)*	*Cable loss (dB)*	*Duty Cycle Correction (dB)*	*Power (dBm)*	*Result*
1.0	5482.5	-6.4	0.9	4.3	-1.2	PASS
1.0	5592.5	-6.2	0.9	4.3	-1.0	PASS
1.0	5712.5	-6.4	0.9	4.3	-1.2	PASS

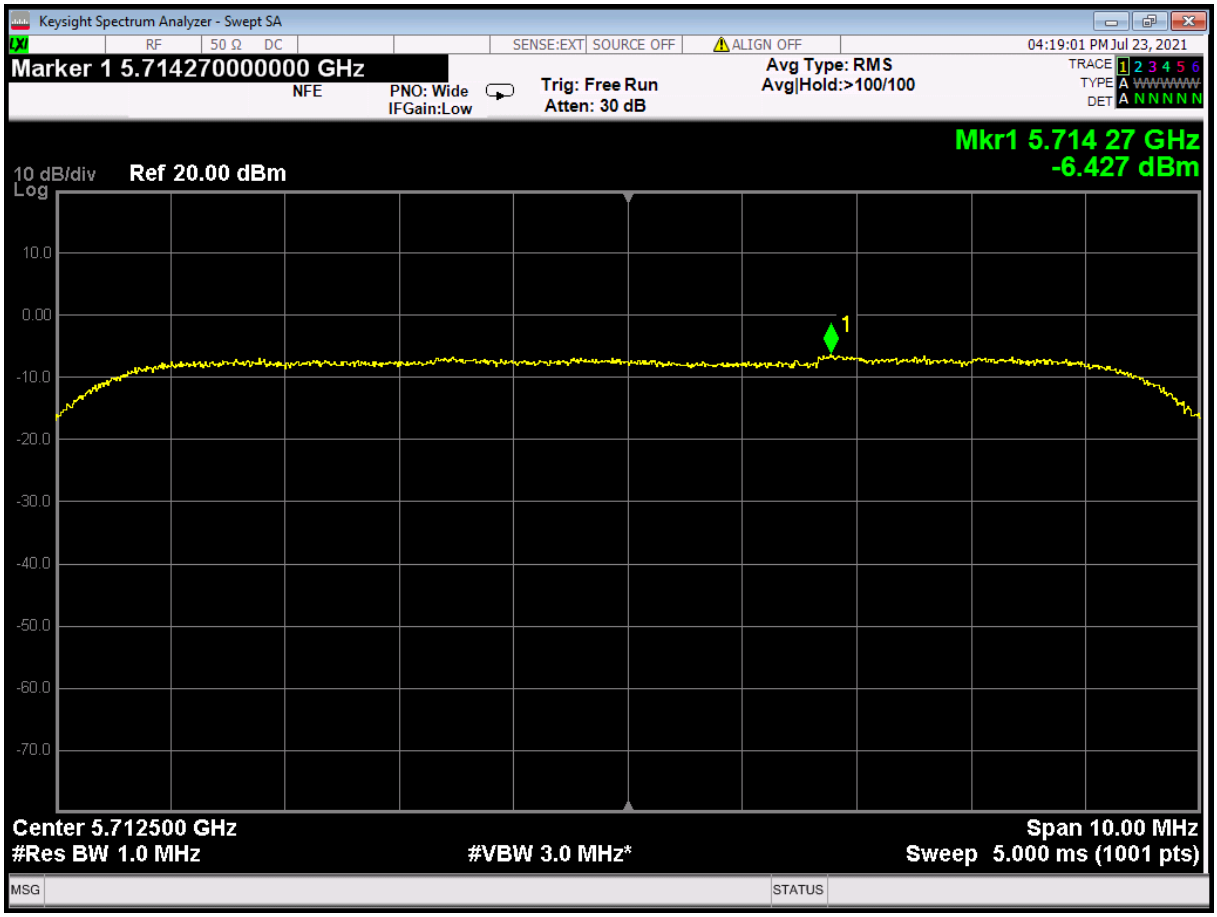
5482.5 MHz



5592.5 MHz



5714.5 MHz



15 Out-of-band spurious emissions

15.1 Definition

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

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

15.2 Test Parameters

Test Location:	Element Hull
Test Chamber:	Wireless Laboratory 1
Test Standard and Clause:	ANSI C63.10-2013, Clause 12.7.3
EUT Frequencies Measured: (requirement as close to upper and lower frequency band edges as the design of the equipment permits).	5482.5 MHz / 5592.5 MHz / 5712.5 MHz
EUT Channel Bandwidths:	10 MHz
Deviations From Standard:	None
Measurement BW:	1 MHz
Spectrum Analyzer Video BW: (requirement at least 3x RBW)	3 MHz
Measurement Detector:	Peak
Measurement Range:	1 GHz to 40 GHz
Antenna Gain: (required if conducted measurement made)	14.5 dBi

Environmental Conditions (Normal Environment)

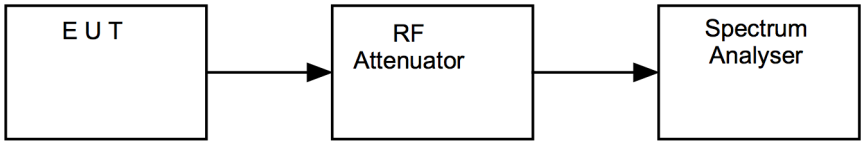
Temperature: 23 °C	+15 ºC to +35 ºC (as declared)
Humidity: 50 %RH	20%RH to 75%RH (as declared)
Supply: 24 Vdc	(as declared)

Test Limits
15.407(b):
(1) For transmitters operating in the 5.15–5.25 GHz band: All emissions outside of the 5.15–5.35 GHz band shall not exceed an e.i.r.p. of -27 dBm/MHz.
(2) For transmitters operating in the 5.25–5.35 GHz band: All emissions outside of the 5.15–5.35 GHz band shall not exceed an e.i.r.p. of -27 dBm/MHz.
(3) For transmitters operating in the 5.47–5.725 GHz band: All emissions outside of the 5.47–5.725 GHz band shall not exceed an e.i.r.p. of -27 dBm/MHz.
(4) For transmitters operating in the 5.725–5.85 GHz band: All emissions within the frequency range from the band edge to 10 MHz above or below the band edge shall not exceed an e.i.r.p. of -17 dBm/MHz; for frequencies 10 MHz or greater above or below the band edge, emissions shall not exceed an e.i.r.p. of -27 dBm/MHz.

15.3 Test Method

With the EUT setup as per section 9 of this report and connected as per Figure vii, 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.

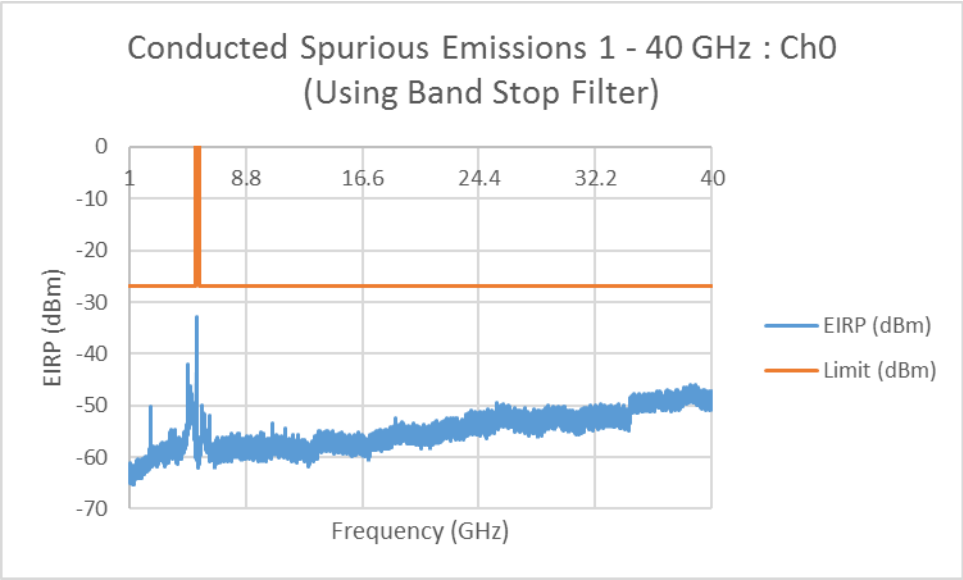
Figure vii Test Setup

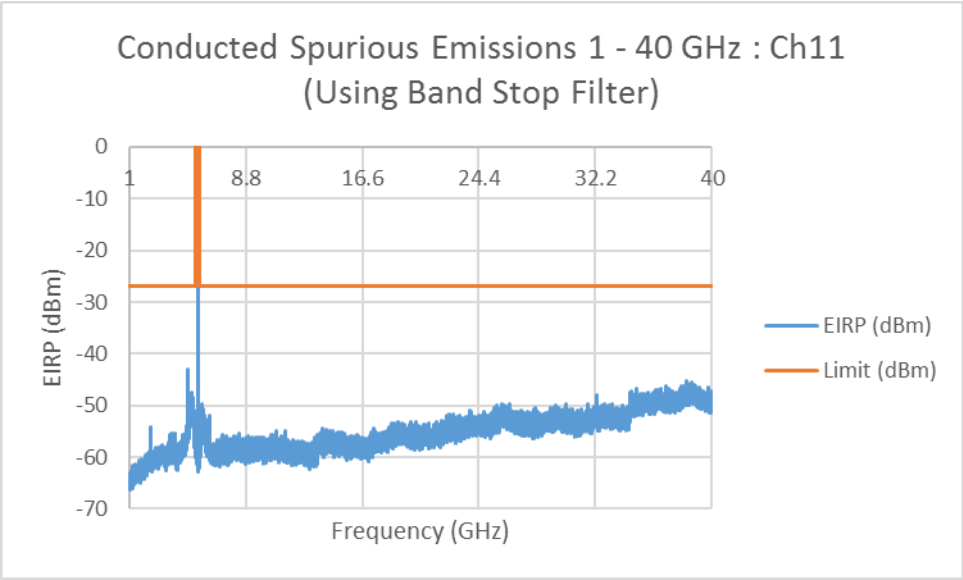


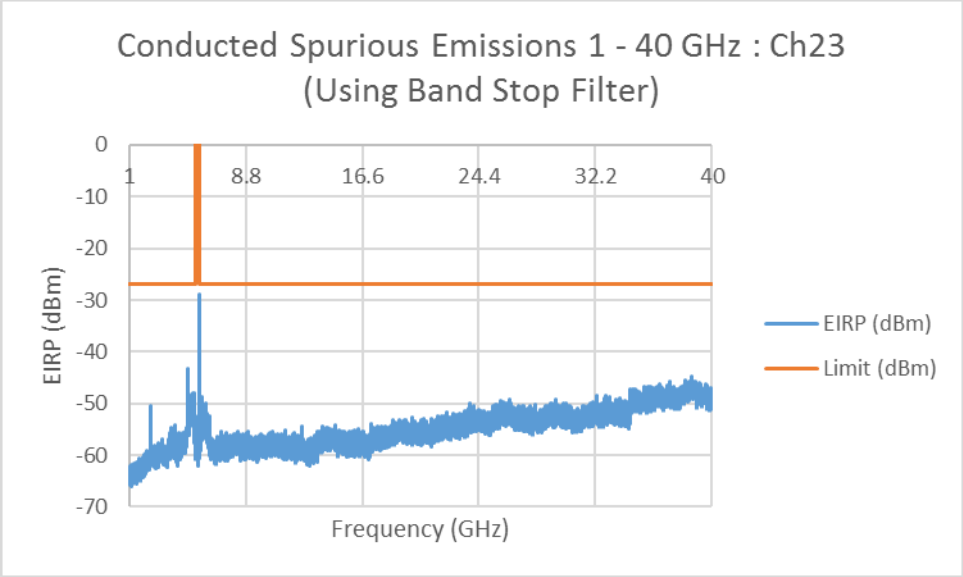
15.4 Test Equipment

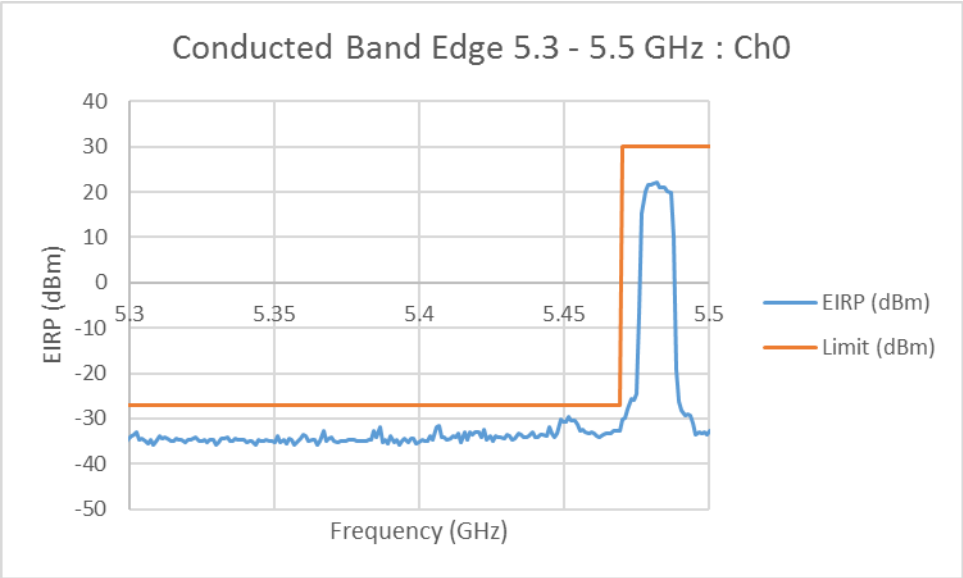
Equipment Description	*Manufacturer*	*Equipment Type*	*Element No*	*Last Cal Calibration*	*Calibration Period*	*Due For Calibration*
Spectrum Analyser	Agilent	N9030A	REF2167	2020-08-19	12	2021-08-19

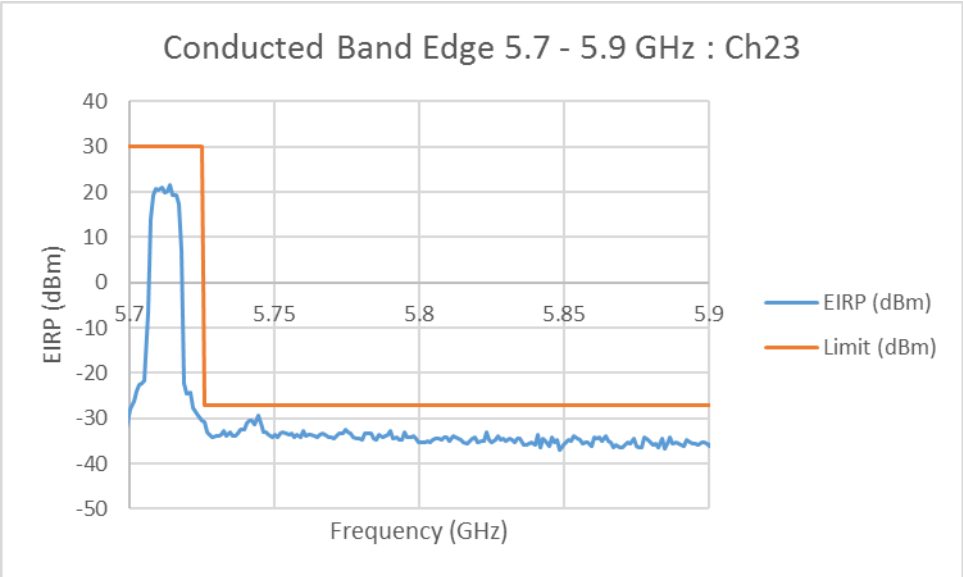
15.5 Test Results











As the limit is stated as an eirp, the maximum antenna gain of 14.5 dBi is added to the conducted power results for out-of-band emissions. This gain adjustment is factored into the levels shown in the above plots.

16 Duty Cycle

16.1 Definition

Duty cycle (x), as used in this clause, refers to the fraction of time over which the transmitter is on and is transmitting at its maximum power control level.

16.2 Test Parameters

Test Location:	Element Hull
Test Chamber:	Wireless Laboratory 1
Test Standard and Clause:	ANSI C63.10-2013, Clause 12.2
EUT Frequencies Measured:	5482.5 MHz / 5592.5 MHz / 5712.5 MHz
EUT Channel loading and modulation:	Full, OFDM
Deviations From Standard:	None
Temperature Extreme Environment Test Range:	N/A
Voltage Extreme Environment Test Range:	N/A

Environmental Conditions (Normal Environment)

Temperature: 23 °C	+15 ºC to +35 ºC (as declared)
Humidity: 45 %RH	20%RH to 75%RH (as declared)
Supply: 24 Vdc	(as declared)

Test Limits
N/A.

16.3 Test Method

With the EUT setup as per section 9 of this report and connected as per Figure viii, the duty of the EUT was calculated from the sum of total on and off times over the observation period.
The measurements were performed with EUT set at its maximum duty. All modulation schemes, bandwidths, data rates and power settings were used to completely characterise the system.

[1] Single antenna output devices

Duty was measured at the antenna port / at a distance of 3m.

[2] Multiple antenna output devices

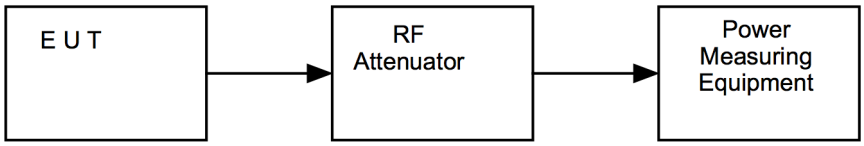
Duty was measured as the combination of all ports simultaneously / at a distance of 3m.

The duty cycle correction factor, DC, is used to adjust emissions measured with an average detector to give an equivalent value as would be measured during the on time only:

$$DC = 10 \log (\text{duty ratio})$$

Where, duty ratio is total on-time divided by total off-time.

Figure viii Test Setup



16.4 Test Equipment

Equipment Description	Manufacturer	Equipment Type	Element No	Last Cal Calibration	Calibration Period	Due For Calibration
Spectrum Analyser	Agilent	N9030A	REF2167	2020-08-19	12	2021-08-19

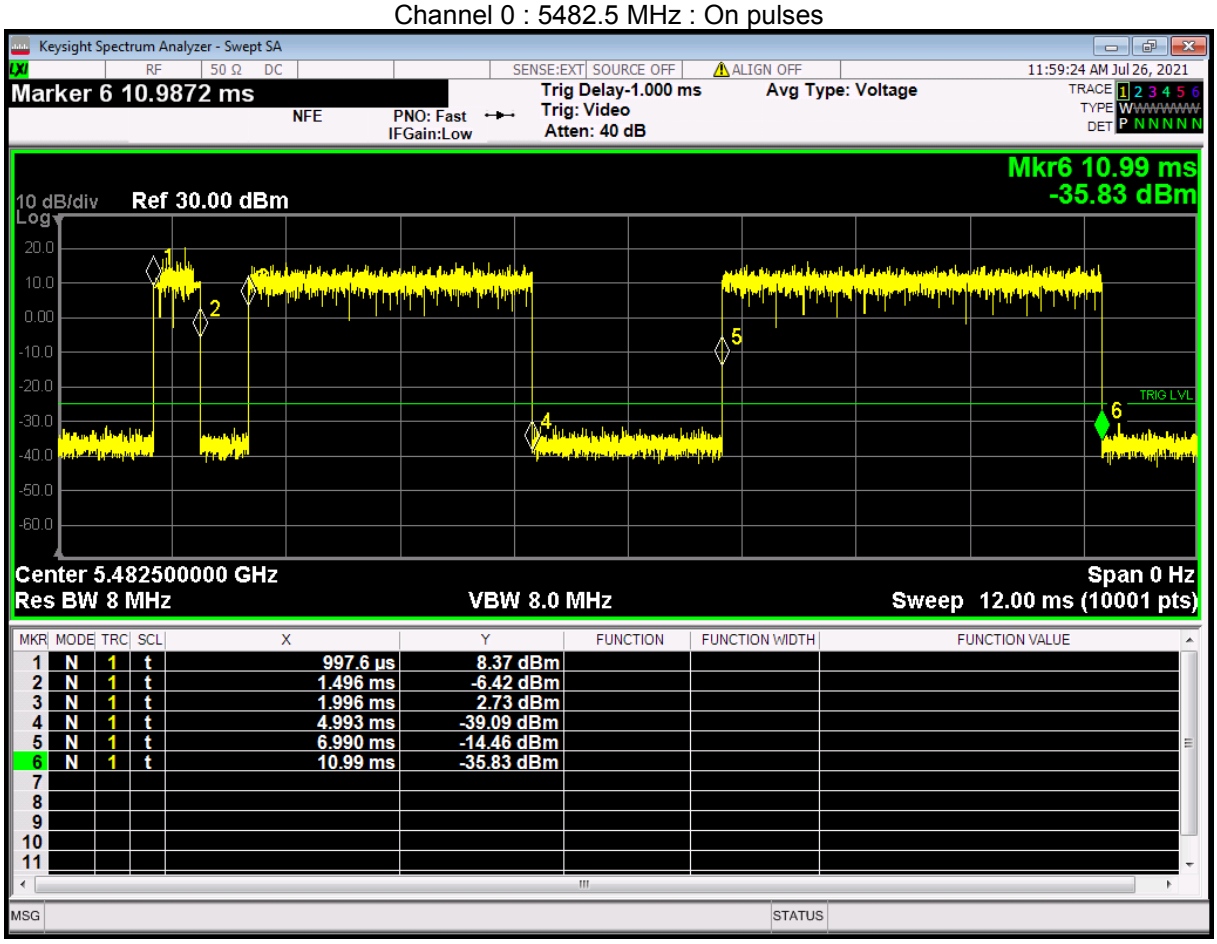
16.5 Test Results

Frequency: 5482.5 MHz						
Test Environment		Single Channel TxOn time (ms)	Total TxOn time (ms)	Observation period (ms)	Duty (%)	Calculated Factor
$V_{nominal}$	$T_{nominal}$	7.4954	7.4954	20	37.5	4.3

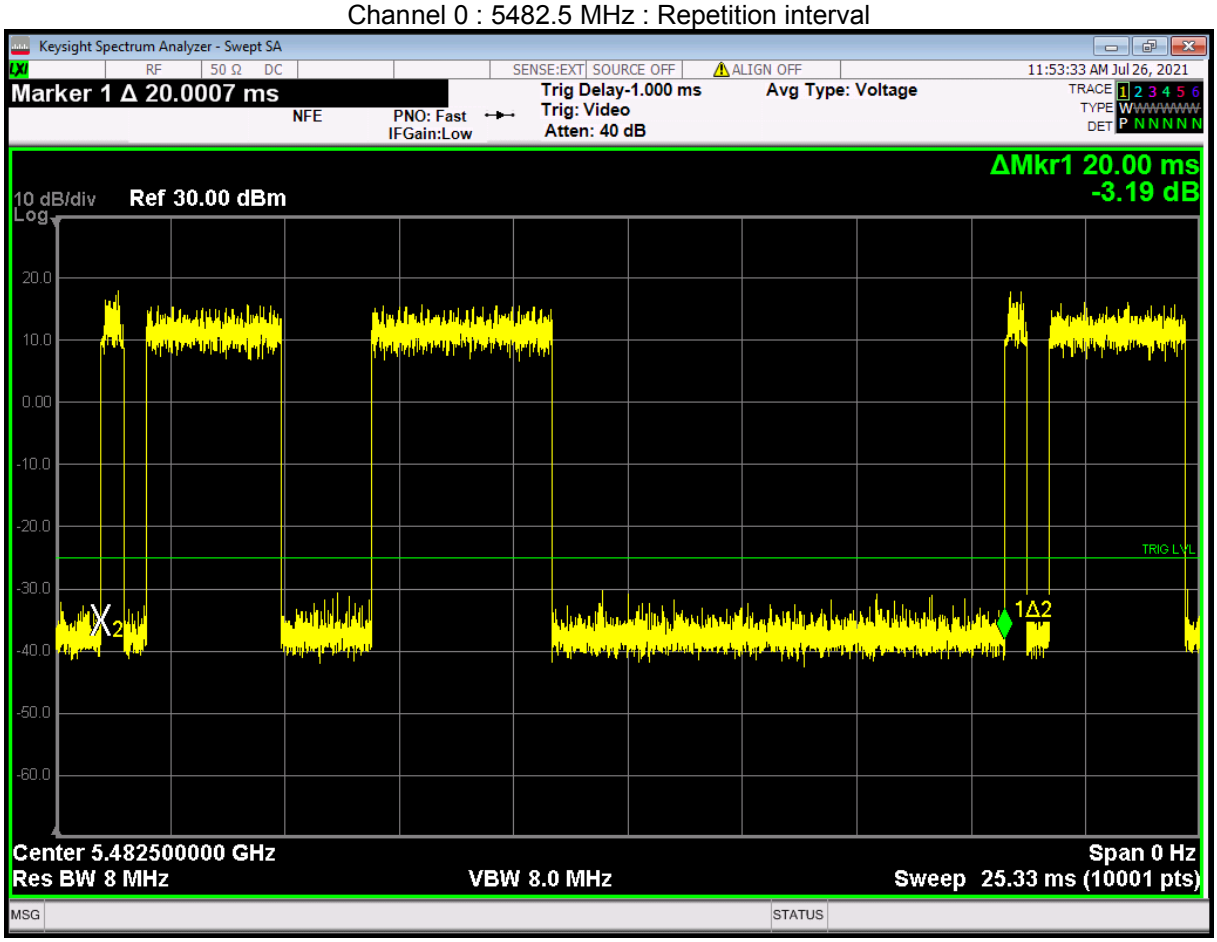
Frequency: 5592.5 MHz						
Test Environment		Single Channel TxOn time (ms)	Total TxOn time (ms)	Observation period (ms)	Duty (%)	Calculated Factor
$V_{nominal}$	$T_{nominal}$	7.4942	7.4942	20	37.5	4.3

Frequency: 5712.5 MHz						
Test Environment		Single Channel TxOn time (ms)	Total TxOn time (ms)	Observation period (ms)	Duty (%)	Calculated Factor
$V_{nominal}$	$T_{nominal}$	7.4964	7.4964	20	37.5	4.3

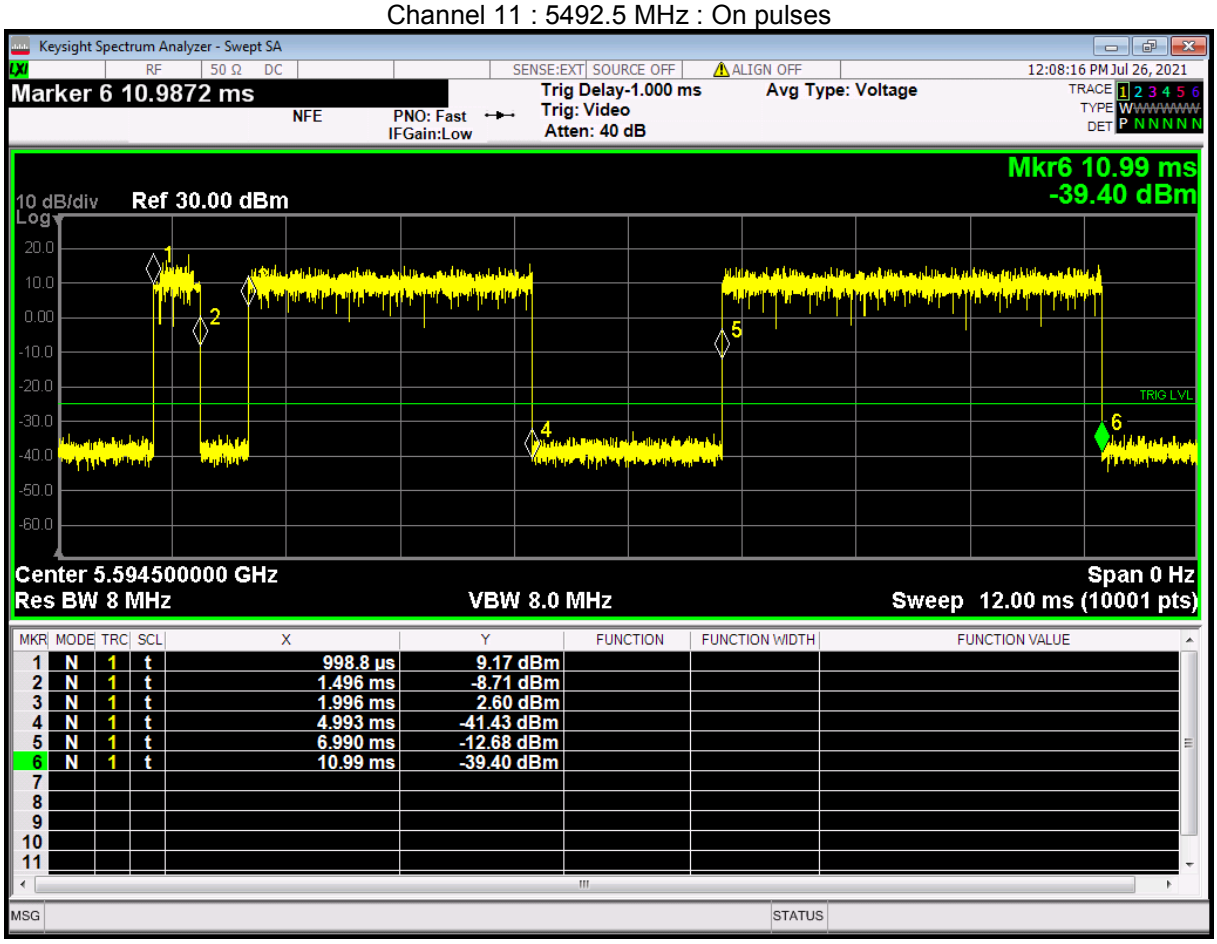
Channel 0 : 5482.5 MHz : On pulses



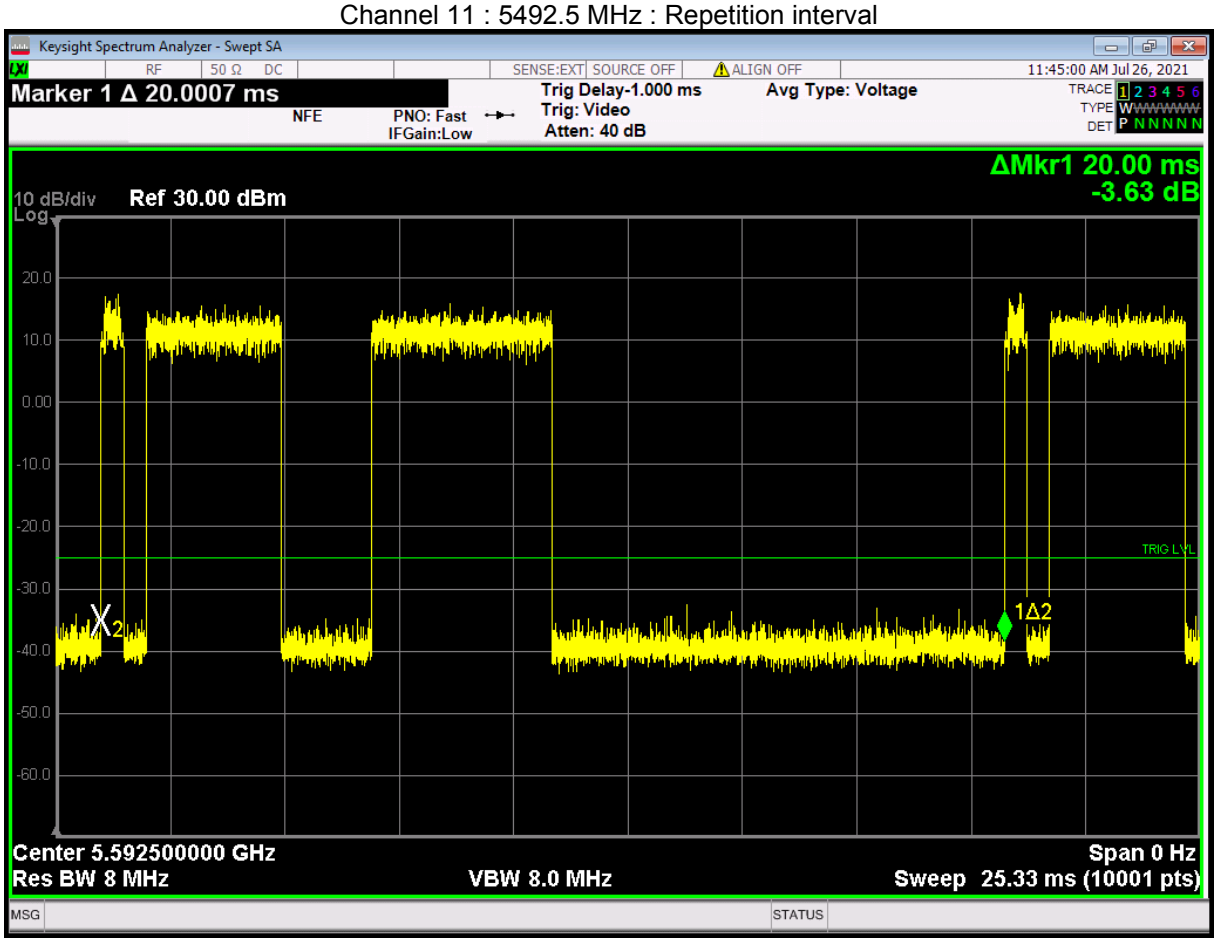
Channel 0 : 5482.5 MHz : Repetition interval



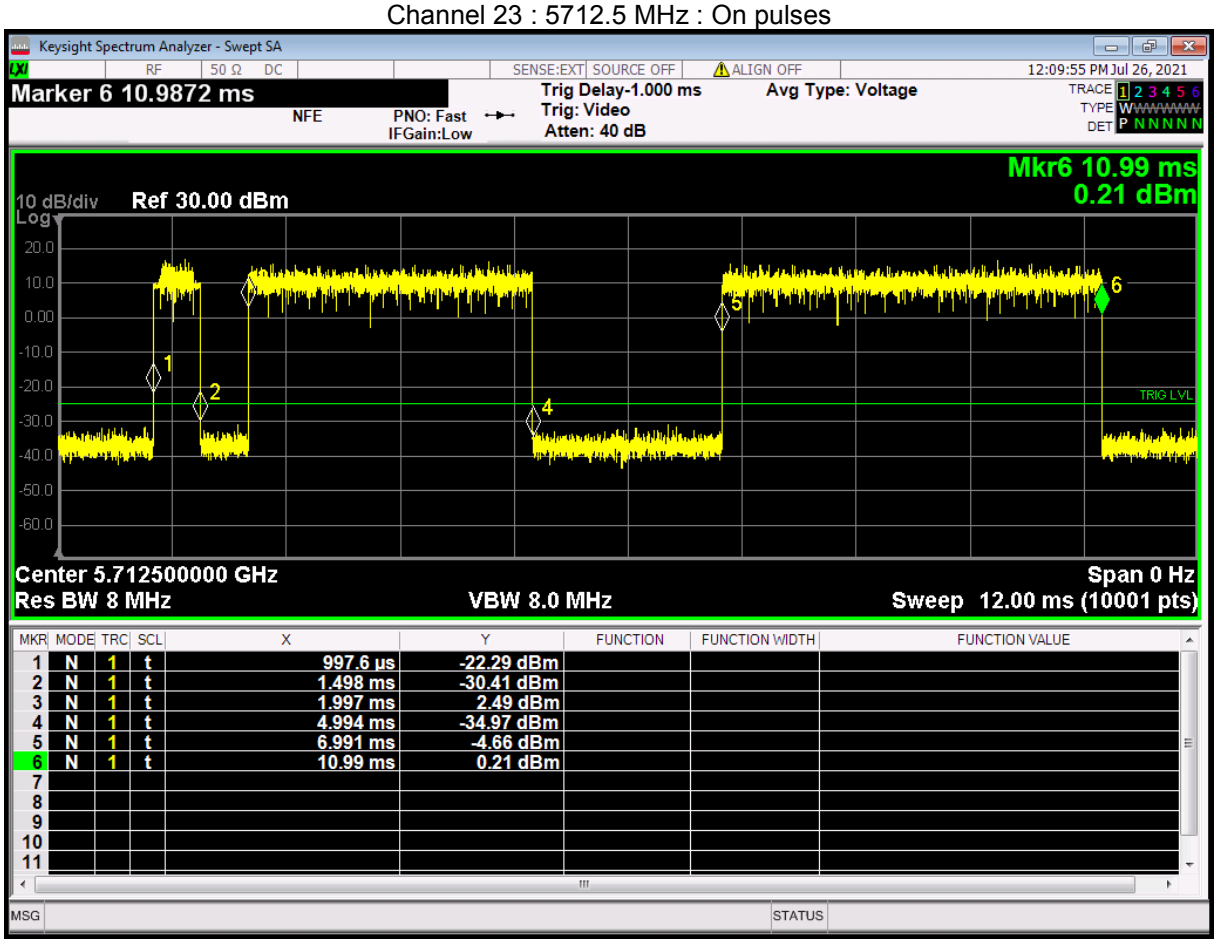
Channel 11 : 5492.5 MHz : On pulses



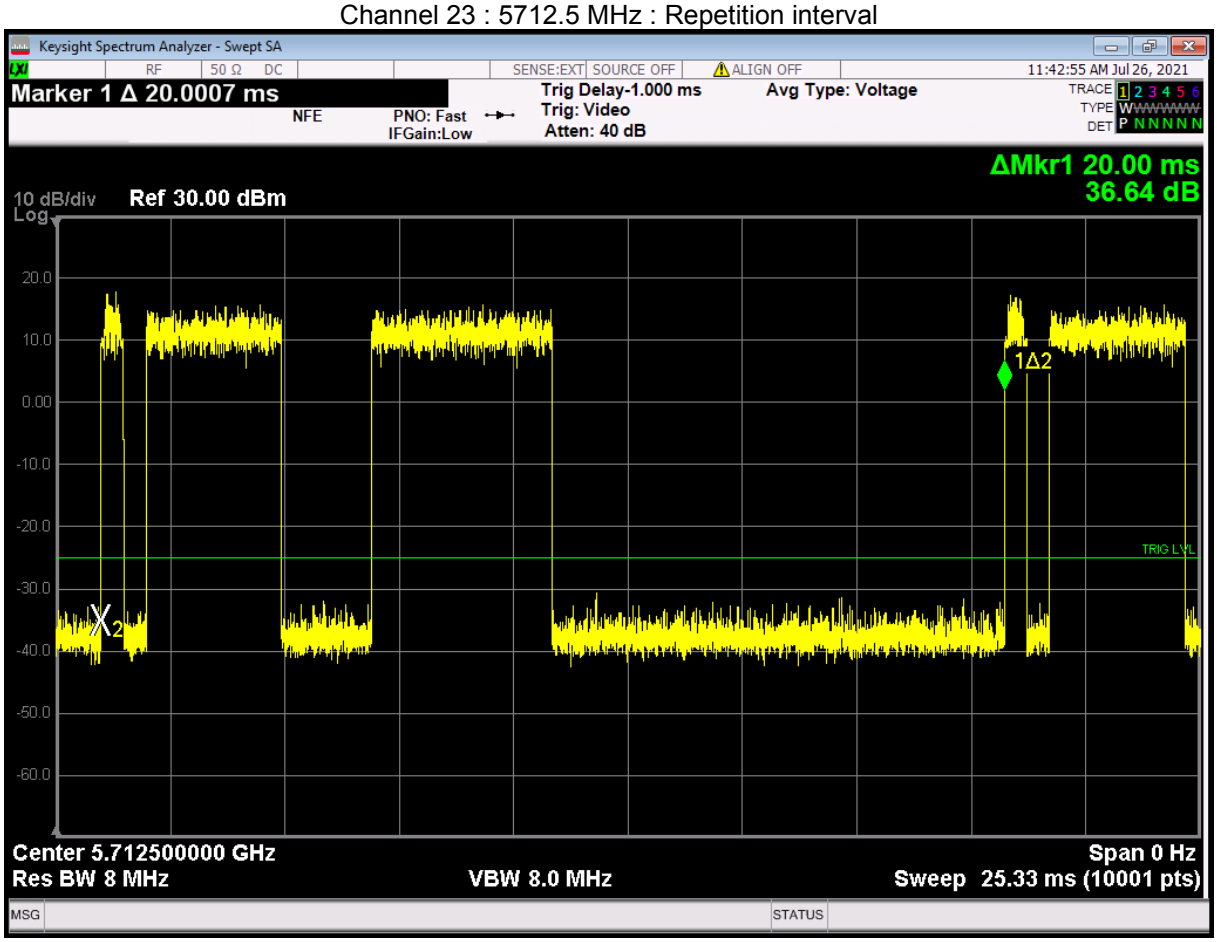
Channel 11 : 5492.5 MHz : Repetition interval



Channel 23 : 5712.5 MHz : On pulses



Channel 23 : 5712.5 MHz : Repetition interval



17 Measurement Uncertainty

Radio Testing – General Uncertainty Schedule

All statements of uncertainty are expanded standard uncertainty using a coverage factor of 1.96 to give a 95 % confidence where no required test level exists.

Reference No.	Parameter	Description	Value	Unit
1	Adjacent Channel Power	Uncertainty in test result	***1.86***	dB
2	Carrier Power	Uncertainty in test result (Power Meter) Uncertainty in test result (Spectrum Analyser)	**0.070** ***3.11***	dB
3	Effective Radiated Power	Uncertainty in test result	***4.71***	dB
4	Radiated Spurious Emissions	Uncertainty in test result 30 MHz to 1 GHz 1 GHz to 18 GHz	***4.75*** ***4.46***	dB
5	Maximum Frequency Error	Uncertainty in test result (CMTA)	**113.441**	Hz
6	Radiated Emissions, Field Strength OATS 9 kHz – 110 GHz Electric Field	Uncertainty in test result (9 kHz – 30 MHz) Uncertainty in test result (30 MHz – 1 GHz) Uncertainty in test result (1 GHz – 18 GHz) Uncertainty in test result (18 GHz – 26 GHz) Uncertainty in test result (26 GHz – 40 GHz) Uncertainty in test result (40 GHz – 50 GHz) Uncertainty in test result (50 GHz – 75 GHz) Uncertainty in test result (75 GHz – 110 GHz)	**2.3** ***4.75*** ***4.46*** **3.2** **3.3** **3.5** **3.6** **3.6**	dB
7	Frequency Deviation	Uncertainty in test result	**3.7**	%
8	Magnetic Field Emissions	Uncertainty in test result	**2.3**	dB
9	Conducted Spurious	Uncertainty in test result Up to 26 GHz	**0.921**	dB
10	Channel Bandwidth	Uncertainty in test result	***15.71***	%

Reference No.	Parameter	Description	Value	Unit
11	Spectrum Mask Measurements	Uncertainty in test result (frequency) Uncertainty in test result (amplitude)	***2.59*** ***1.32***	% dB
12	Adjacent Sub Band Selectivity	Uncertainty in test result	***1.24***	dB
13	Receiver Blocking – Listen Mode, Radiated	Uncertainty in test result	***3.23***	dB
14	Receiver Blocking – Talk Mode, Radiated	Uncertainty in test result	***3.36***	dB
15	Receiver Blocking – Talk Mode, Conducted	Uncertainty in test result	***1.24***	dB
16	Receiver Threshold	Uncertainty in test result	***3.42***	dB
17	Transmission Time Measurement	Uncertainty in test result	***4.40***	%

18 RF Exposure

U-NII devices are subject to the radio frequency radiation exposure requirements specified in §1.1307(b), §2.1091 and §2.1093 of chapter 47 of the CFR, as appropriate. All equipment shall be considered to operate in a ‘‘general population/uncontrolled’’ environment. Applications for equipment authorization of devices operating under this section must contain a statement confirming compliance with these requirements for both fundamental emissions and unwanted emissions. Technical information showing the basis for this statement must be submitted to the Commission upon request.

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

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

Where:

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

Result

Channel Frequency (MHz)	*EIRP (mW)*	*Power density limit (S) (mW/cm²)*	*Distance (R) cm required to be less than the power density limit*
5592.5	195.0	1.0	3.9