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Emissions
Test Report

EUT Name: Echo Frames

Model No.: Z4NEU3

CFR 47 Part 15.247:2020

Prepared for:

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Prepared by:

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Revisions

Revision No.	Date MM/DD/YYYY	Reason for Change	Author
0	06/30/2020	Original Document	JB
1	07/13/2020	Reviewer corrections	JB
2	08/04/2020	Customer Review	JB

Note: Latest revision report will replace all previous reports.

Statement of Compliance

Applicant:	Eleven Forty Three A.M. LLC 1661 International Drive, Suite 400 Memphis, TN 38120 USA
Requester / Applicant:	Eleven Forty Three A.M. LLC
Name of Equipment:	Echo Frames
Model No.	Z4NEU3
Type of Equipment:	Intentional Radiator
Application of Regulations:	CFR 47 Part 15.247:2020
Test Dates:	June 22nd, 2020 to June 30th, 2020

Guidance Documents:

Emissions: ANSI C63.10-2013, KDB 558074 D01 15.247 Measurement Guidance v05

Test Methods:

Emissions: ANSI C63.10-2013, KDB 558074 D01 15.247 Measurement Guidance v05

The electromagnetic compatibility test and documented data described in this report has been performed and recorded by TUV Rheinland, in accordance with the standards and procedures listed herein. As the responsible authorized agent of the EMC laboratory, I hereby declare that the equipment described above has been shown to be compliant with the EMC requirements of the stated regulations and standards based on these results. If any special accessories and/or modifications were required for compliance, they are listed in the Executive Summary of this report.

This report must not be used to claim product endorsement by A2LA or any agency of the U.S. Government. This report contains data that are not covered by A2LA accreditation. This report shall not be reproduced except in full, without the written authorization of TUV Rheinland of North America.

James Borrott	8/5/2020	Osvaldo Casorla	8/5/2020
Test Engineer	Date	Laboratory Signature	Date

Testing Cert #3331.02 **US1131** **US0185**

1 Executive Summary

1.1 Scope

This report is intended to document the status of conformance with the requirements of the CFR 47 Part 15.247:2020 based on the results of testing performed on June 22nd, 2020 to June 30th, 2020 on the Echo Frames manufactured by Eleven Forty Three A.M. LLC This report only applies to the specific samples tested under the stated test conditions. It is the responsibility of the manufacturer to assure that additional production units of this model are manufactured with identical or EMI equivalent electrical and mechanical components. This report is further intended to document changes and modifications to the EUT throughout its life cycle. All documentation will be included as a supplement.

1.2 Purpose

Testing were performed to evaluate the EMC performance of the EUT in accordance with the applicable requirements, procedures, and criteria defined in the application of regulations and application of standards listed in this report.

The report documents the 2.4 GHz Bluetooth BR/EDR radio characteristics for the Z4NEU3.

1.3 Summary of Test Results

Table 1: Summary of Test Results

Test	Test Method ANSI C63.10:2013	Test Parameters	Measured Value (Worse Case)	Result
2400 MHz to 2483.5 MHz Band				
Spurious Emission in Transmitted Mode	CFR47 15.209, CFR47 15.247 (d)	Class B	-7.08dB (Margin)	**Complied**
Restricted Bands of Operation	CFR47 15.205	Class B		**Complied**
AC Power Conducted Emission	CFR47 15.207	Class B	-10.71 dB (Margin)	**Complied**
Occupied Bandwidth	CFR47 15.247 (a1)	N/A	20dB BW = 1.263 MHz	**Complied**
Channel Separation	CFR47 15.247 (a1)	> Two-Third 20dB BW	985.557 kHz	**Complied**
Number of Hopping Channels	CFR47 15.247 (a1)(iii)	>15	79 Channels	**Complied**
Average time occupancy of Channel	CFR47 15.247 (a1), RSS 247 Sect. 5.1(d)	< 0.4 sec	319.42306 ms	**Complied**
Maximum Transmitted Power	CFR47 15.247 (a1), RSS 247 Sect. 5.1 (b)	<125 mWatts	13.77 mW	**Complied**
Out of Band Emission	CFR47 15.247 (d), RSS 247 Sect. 5.5	< -20 dBr	-42.06 dBc @ 2400MHz, 3DH5, Low	**Complied**

Note: 1. Meet restricted band emission requirements.
2. This report is only documented for 2402 – 2480MHz.

1.4 Special Accessories

No special accessories were necessary in order to achieve compliance.

1.5 Equipment Modifications

None

2 Laboratory Information

2.1 Accreditations & Endorsements

2.1.1 US Federal Communications Commission

TUV Rheinland of North America at 1279 Quarry Ln, Pleasanton, CA 94566, and 5015 Brandin Ct, Fremont, CA 94538 is recognized by the commission for performing testing services for the general public on a fee basis. These laboratory test facilities have been fully described in reports submitted to and accepted by the FCC (US1131). The laboratory scope of accreditation includes: Title 47 CFR Parts 15, 18, and 90. The accreditation is updated every 3 years.

2.1.2 NIST / A2LA

TUV Rheinland of North America is accredited by the National Voluntary Laboratory Accreditation Program, which is administered under the auspices of the National Institute of Standards and Technology. The laboratory has been assessed and accredited in accordance with ISO Guide 17025:2017. The scope of laboratory accreditation includes emission and immunity testing. The accreditation is updated annually.

2.1.3 ISED

The Pleasanton 5-meter Semi-Anechoic Chamber, has been accepted by ISED to perform testing to 3 and 5 meters based on the test procedures described in ANSI C63.4-2014. The Fremont 10-meter Semi-Anechoic Chamber, has been accepted by ISED to perform testing to 3 and 10 meters based on the test procedures described in ANSI C63.4-2014. Under 2932D

2.1.4 Japan – VCCI

The Voluntary Control Council for Interference by Information Technology Equipment (VCCI) is a group that consists of Information Technology Equipment (ITE) manufacturers and EMC test laboratories. The purpose of the Council is to take voluntary control measures against electromagnetic interference from Information Technology Equipment, and thereby contribute to the development of a socially beneficial and responsible state of affairs in the realm of Information Technology Equipment in Japan. TUV Rheinland of North America at 1279 Quarry Ln, Pleasanton, CA 94566 and 5015 Brandin Ct, Fremont, CA 94538 has been assessed and approved in accordance with the Regulations for Voluntary Control Measures.

VCCI Registration No. for Pleasanton: A-0326

VCCI Registration No. for Fremont: A-0327

2.1.5 Acceptance by Mutual Recognition Arrangement

The United States has an established agreement with specific countries under the Asia Pacific Laboratory Accreditation Corporation (APLAC) Mutual Recognition Arrangement. Under this agreement, all TUV Rheinland at 1279 Quarry Ln, Pleasanton, CA 94566 and 5015 Brandin Ct, Fremont, CA 94538 test results and test reports within the scope of the laboratory NIST / A2LA accreditation will be accepted by each member country.

2.2 Test Facilities

All of the test facilities are located at 1279 Quarry Lane, Pleasanton, California 94566, USA and 5015 Brandin Ct, Fremont, CA 94538 USA.

2.2.1 Emission Test Facility

The Semi-Anechoic chamber and AC Line Conducted measurement facility used to collect the radiated and conducted data has been constructed in accordance with ANSI C63.7:1992. The site has been measured in accordance with and verified to comply with the theoretical normalized site attenuation requirements of ANSI C63.4-2014, at a test distance of 3 and 5 meters. The site is listed with the FCC and accredited by A2LA (Lab Code 3331.02). The 3/5-meter semi-anechoic chamber used to collect the radiated data has been verified to comply with the theoretical normalized site attenuation requirements of ANSI C63.4-2014, at a test distance of 3 meter and 5 meters. A report detailing this site can be obtained from TUV Rheinland of North America.

2.3 Measurement Uncertainty

Two types of measurement uncertainty are expressed in this report, per *ISO Guide To The Expression Of Uncertainty In Measurement*, 1st Edition, 1995.

The Combined Standard Uncertainty is the standard uncertainty of the result of a measurement when that result is obtained from the values of a number of other quantities; it is equal to the positive square root of the sum of the variances or co-variances of these other quantities, weighted according to how the measurement result varies with changes in these quantities. The term *standard uncertainty* is the result of a measurement expressed as a standard deviation.

2.3.1 Sample Calculation – radiated & conducted emissions

The field strength is calculated by subtracting the Amplifier Gain and adding the Cable Loss and Antenna Correction Factor to the measured reading. The basic equation is as follows:

Field Strength (dBμV/m) = RAW - AMP + CBL + ACF

Where: RAW = Measured level before correction (dBμV)

AMP = Amplifier Gain (dB)

CBL = Cable Loss (dB)

ACF = Antenna Correction Factor (dB/m)

$$\mu V/m = 10^{\frac{dB\mu V/m}{20}}$$

Sample radiated emissions calculation @ 30 MHz

Measurement +Antenna Factor–Amplifier Gain+Cable loss=Radiated Emissions (dBuV/m)

25 dBuV/m + 17.5 dB – 20 dB + 1.0 dB = 23.5 dBuV/m

2.3.2 Measurement Uncertainty Emissions

Per CISPR 16-4-2	**U_{lab}**	**U_{cispr}**
Radiated Disturbance @ 10 meters		
30 – 1,000 MHz	2.25 dB	4.51 dB
Radiated Disturbance @ 3 meters		
30 – 1,000 MHz	2.26 dB	4.52 dB
1 – 6 GHz	2.12 dB	4.25 dB
6 – 18 GHz	2.47 dB	4.93 dB
Conducted Disturbance @ Mains Terminals		
150 kHz – 30 MHz	1.09 dB	2.18 dB
Disturbance Power		
30 MHz – 300 MHz	3.92 dB	4.3 dB

Voltech PM6000A

The estimated combined standard uncertainty for harmonic current and flicker measurements is ± 5.0%.	Per CISPR 16-4-2 Methods

2.3.3 Measurement Uncertainty Immunity

The estimated combined standard uncertainty for ESD immunity measurements is ± 8.2%.	Per IEC 61000-4-2
The estimated combined standard uncertainty for radiated immunity measurements is ± 4.10 dB.	Per IEC 61000-4-3
The estimated combined standard uncertainty for conducted immunity measurements with CDN is ± 3.66 dB	Per IEC 61000-4-6
The estimated combined standard uncertainty for power frequency magnetic field immunity is ± 2.9%.	Per IEC 61000-4-8

Thermo KeyTek EMC Pro

The estimated combined standard uncertainty for EFT fast transient immunity measurements is ± 2.6%.
The estimated combined standard uncertainty for surge immunity measurements is ± 2.6%.
The estimated combined standard uncertainty for voltage variation and interruption measurements is ± 1.74%.

The expanded uncertainty at a level of 95% confidence is obtained by multiplying the combined standard uncertainty by a coverage factor of 2. Compliance criteria are not based on measurement uncertainty.

2.4 Calibration Traceability

All measurement instrumentation is traceable to the National Institute of Standards and Technology (NIST). Measurement method complies with ANSI/NCSL Z540-1-1994 and ISO Standard 17025:2017.

3 Product Information

3.1 Product Description

The Model Z4NEU3 has wireless capability, Bluetooth BR and EDR, operating in the 2400-2483.5 MHz Band.

3.2 Equipment Configuration

A description of the equipment configuration is given in the Test Plan Section. The EUT was tested as called for in the test standard and was configured and operated in a manner consistent with its intended use. The EUT was connected to rated power and allowed to reach intended operating conditions. The placement of the EUT system components was guided by the test standard and selected to represent typical installation conditions.

In the case of a EUT that can operate in more than one configuration, preliminary testing was performed to determine the configuration that produced maximum radiation.

The final configuration was selected to produce the worst case radiation for emissions testing and to place the EUT in the most susceptible state for immunity testing.

3.3 Operating Mode

A description of the operation mode is given in the Test Plan Section. In the case of a EUT that can operate in more than one state, preliminary testing was performed to determine the operating mode that produced maximum radiation.

The final operating mode was selected to produce the worst case radiation for emissions testing.

3.4 Unique Antenna Connector

An intentional radiator shall be designed to ensure that no antenna other than that furnished by the responsible party shall be used with the device. The use of a permanently attached antenna or of an antenna that uses a unique coupling to the intentional radiator shall be considered sufficient to comply with the provisions of this Section. The manufacturer may design the unit so that a broken antenna can be replaced by the user, but the use of a standard antenna jack or electrical connector is prohibited. This requirement does not apply to carrier current devices or to devices operated under the provisions of CFR47 Parts 15.211, 15.213, 15.217, 15.219, or 15.221.

3.4.1 Results

The Echo Frames has 1 dedicated PIFA Bluetooth antenna that has maximum gain of 2.1 dBi. It is integrated into the EUT PCB and is not easily accessible to the end user.

4 Emission

Testing was performed in accordance with CFR 47 Part 15.247:2020. These test methods are listed under the laboratory's A2LA Scope of Accreditation. This test measures the levels emanating from the EUT, thus evaluating the potential for the EUT to cause radio frequency interference to other electronic devices. Procedures described in Section 8 of the standard were used.

4.1 Output Power Requirements

The maximum output power requirement is the maximum equivalent isotropic radiated power delivering at the transmitting antenna under specified conditions of measurements in the presence of modulation.

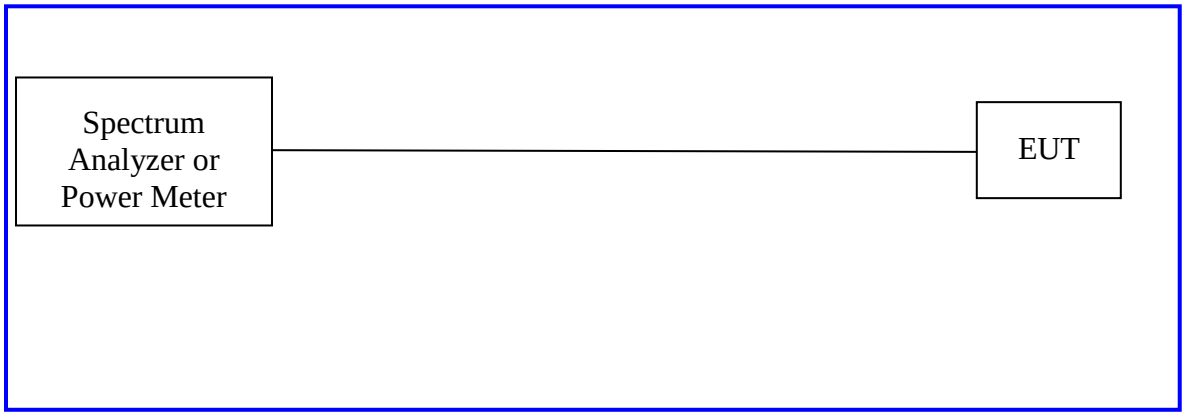
The maximum output power and harmonics shall not exceed CFR47 Part 15.247 (a)(1) and RSS 247 Sect. 5.1(b)

Frequency hopping systems in the 2400-2483.5 MHz band: 125 mW.

4.1.1 Test Method

The conducted method was used to measure the channel power output according to ANSI C63.10:2013 Section 11.9.1.1. The measurement was performed with modulation per CFR47 Part 15.247 (a)(1) and RSS-247 Sect. 5.1. This test was conducted on 3 channels. The worst mode result indicated below.

Test Setup:

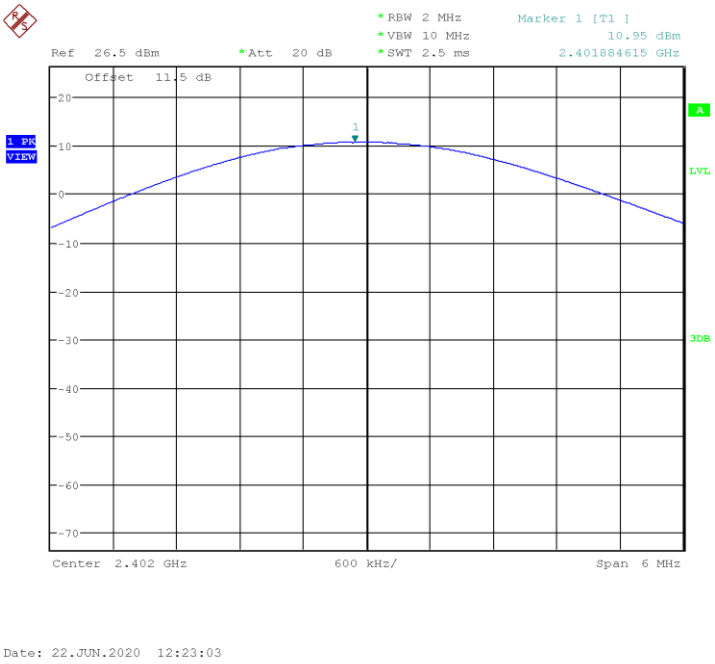


4.1.2 Results

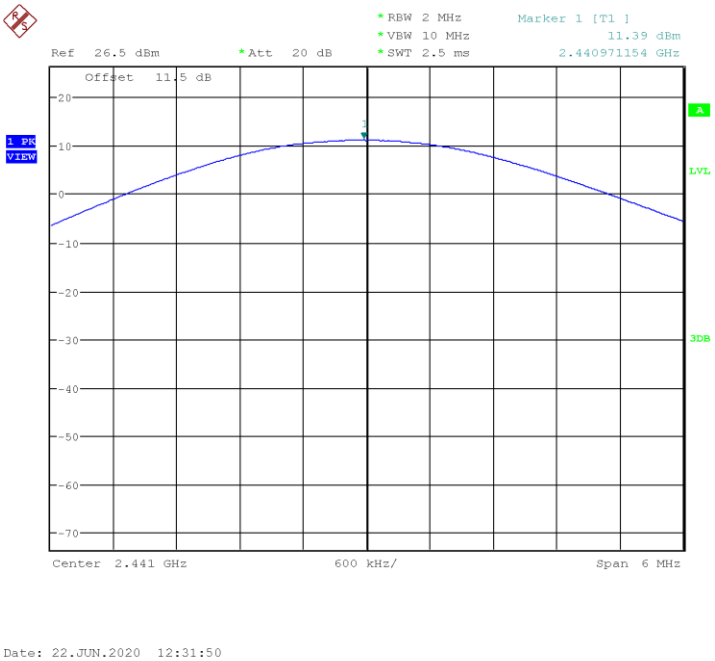
As originally tested, the EUT was found to be compliant to the requirements of the test standard(s).

Table 2: RF Output Power at the Antenna Port – Test Results

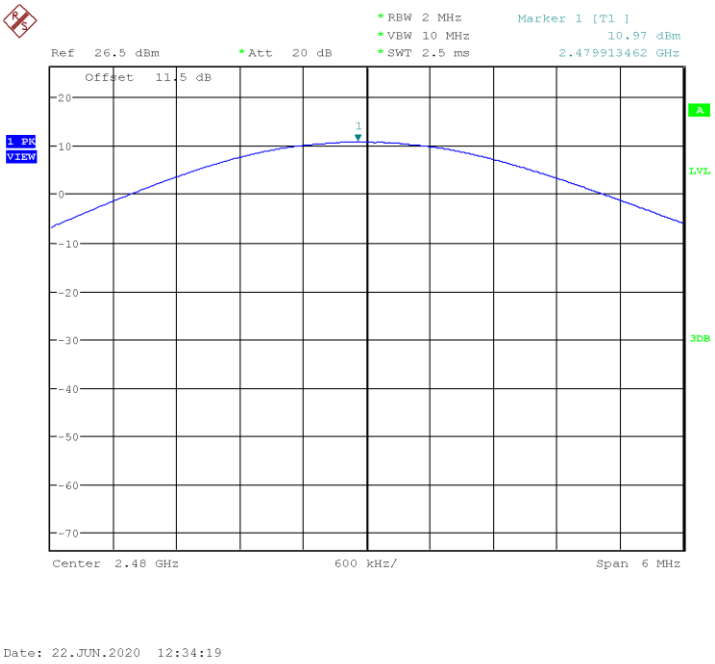
Conducted Output Power – EDR, BR				
Packet	**Operating Channel**	**Limit [dBm]**	**Power [dBm]**	**Margin [dB]**
DH5	2402 MHz	+21.00	10.95	-10.05
	2441 MHz	+21.00	11.39	-9.61
	2480 MHz	+21.00	10.97	-10.03
2-DH5	2402 MHz	+21.00	10.33	-10.67
	2441 MHz	+21.00	10.74	-10.36
	2480 MHz	+21.00	10.39	-10.61
3-DH5	2402 MHz	+21.00	10.74	-10.36
	2441 MHz	+21.00	11.16	-9.84
	2480 MHz	+21.00	10.84	-10.16
Note: The EUT is capable to transmit at both BDR and EDR. The worst case modes at low, middle, and high frequencies were investigated.				



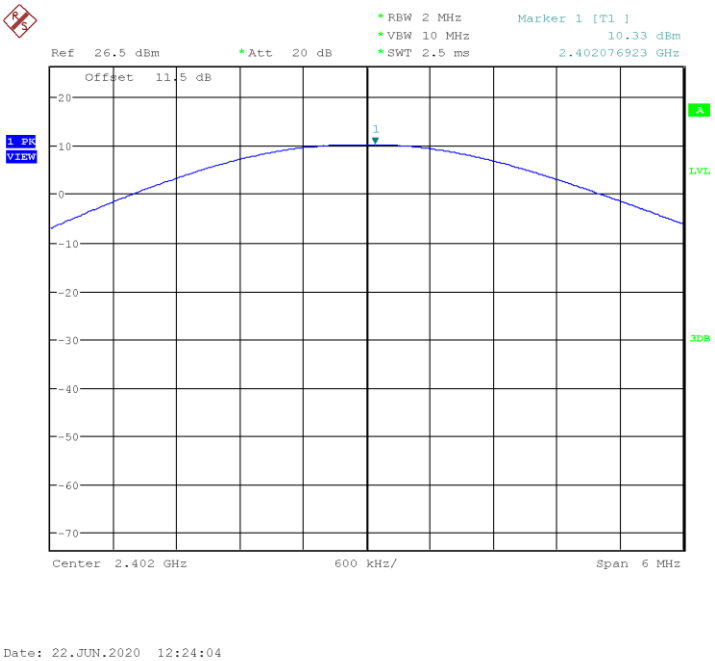
Plot 1. DH5, 2402MHz Power



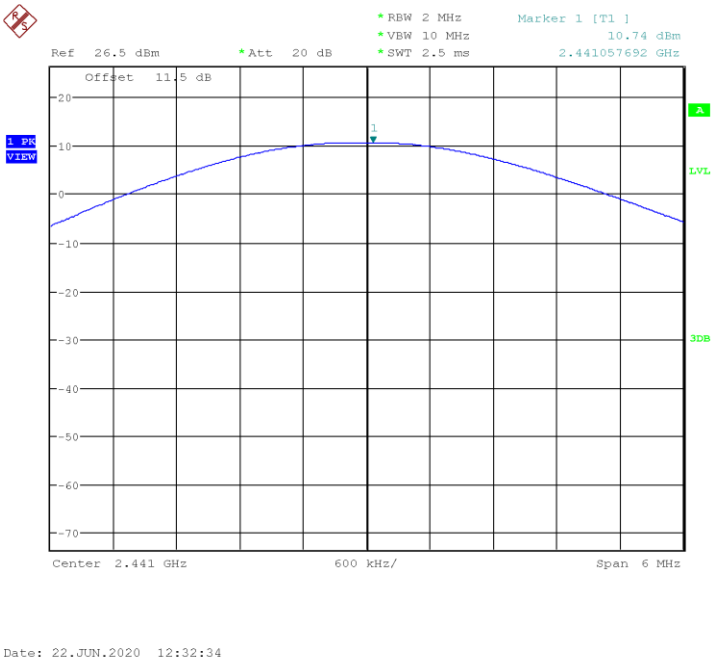
Plot 2. DH5, 2441MHz Power



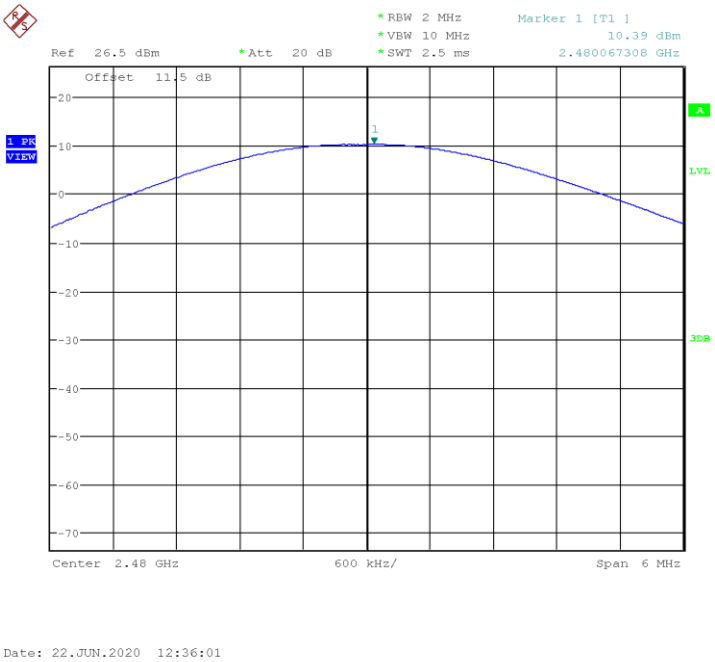
Plot 3. DH5, 2480MHz Power



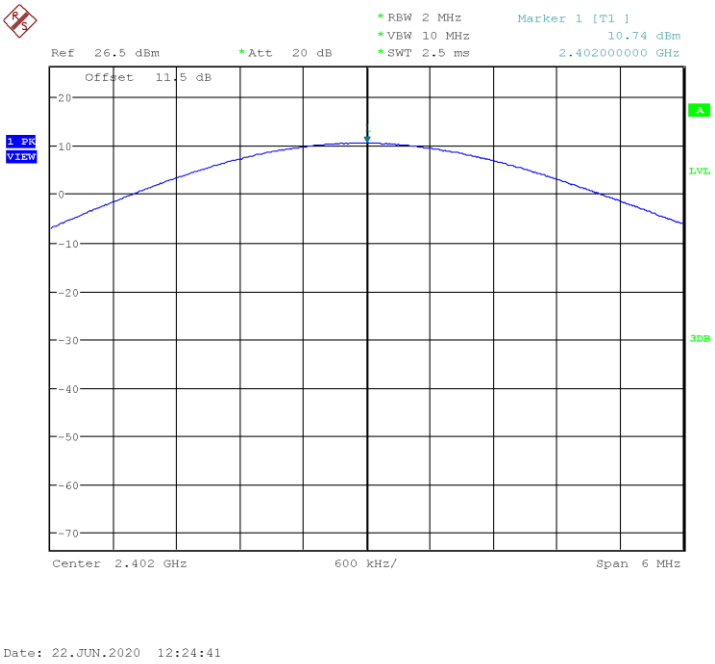
Plot 4. 2DH5, 2402MHz Power



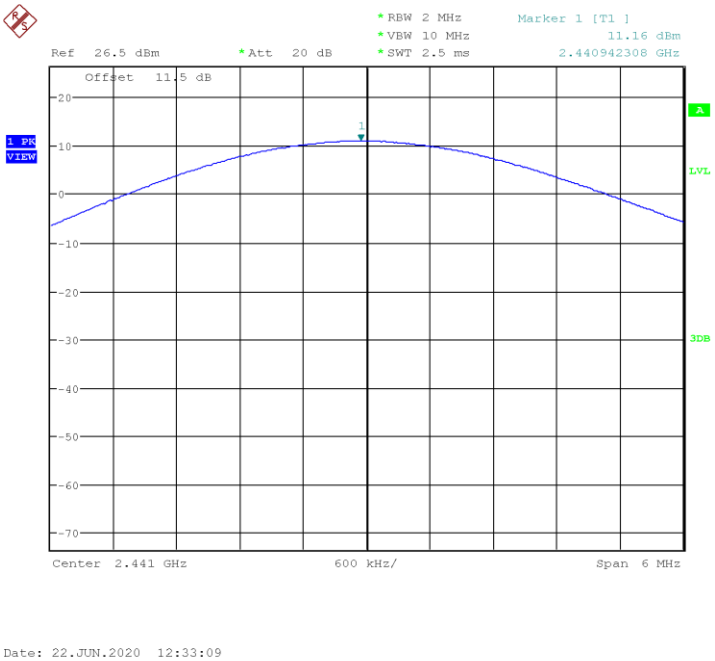
Plot 5. 2DH5, 2441MHz Power



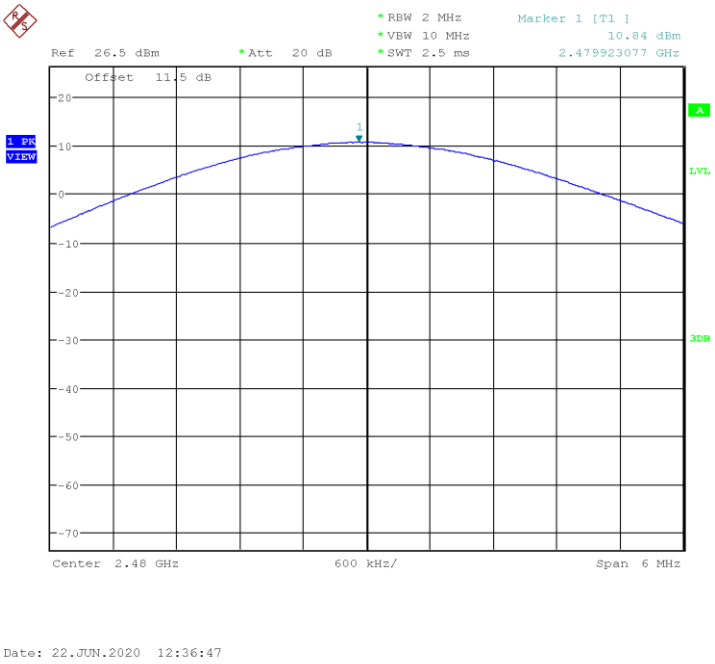
Plot 6. 2DH5, 2480MHz Power



Plot 7. 3DH5, 2402MHz Power



Plot 8. 3DH5, 2441MHz Power



Plot 9. 3DH5, 2480MHz Power

4.2 Occupied Bandwidth

The occupied bandwidth is measured at an amplitude level reduced from the reference level by a specified ratio. The reference level is the *level of the highest amplitude signal observed from the transmitter at the fundamental frequency.*

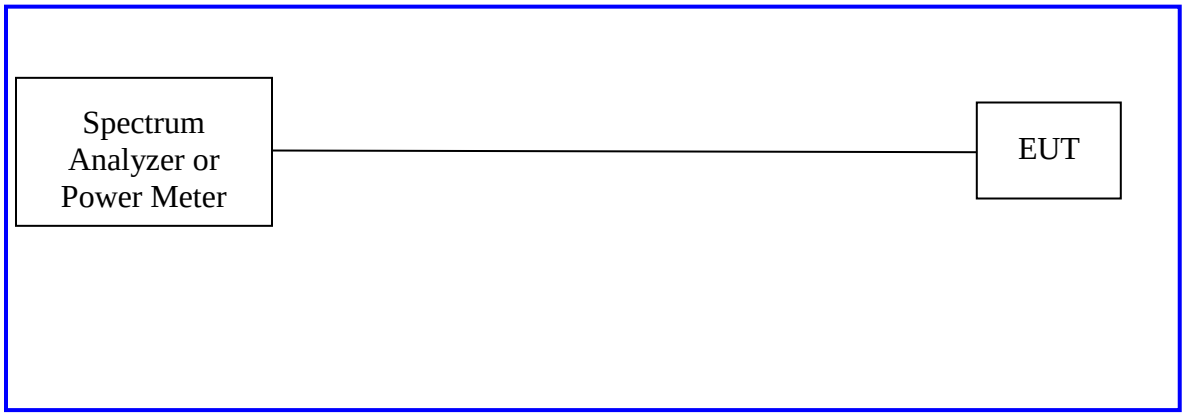
The 99% bandwidth is the bandwidth in which 99% of the transmitted power occupied.

20 dB bandwidth was performed by coupling the output of the EUT to the input of a spectrum analyzer.

4.2.1 Test Method

The conducted method was used to measure the occupied bandwidth. The measurement was performed with modulation per CFR47 15.247 (a)(1) and RSS GEN Sect. 6.7. This test was conducted on 3 channels. The worst sample result indicated below.

Test Setup:

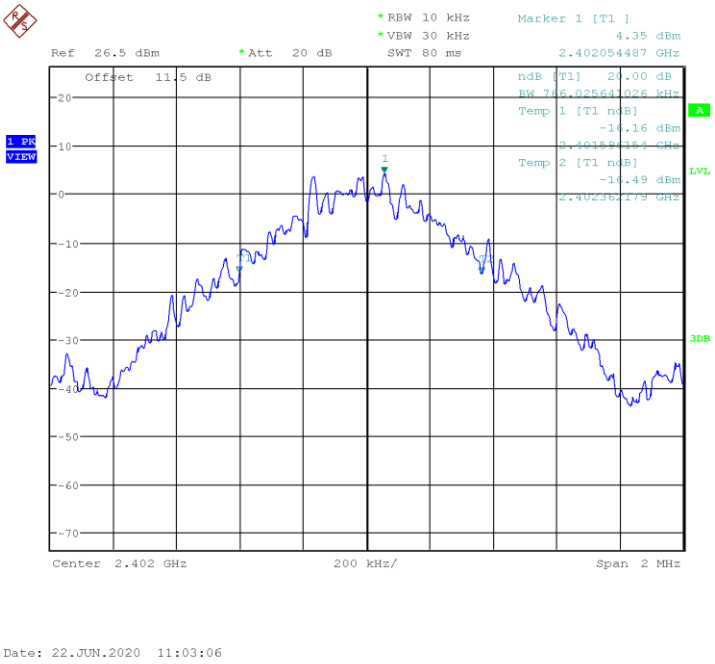


4.2.2 Results

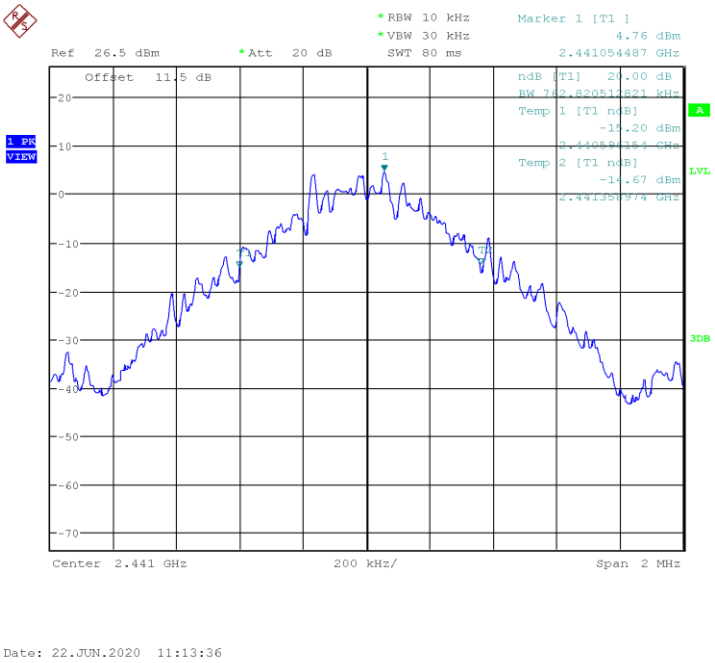
These measurements were used for information only

Table 3: Occupied Bandwidth – Test Results

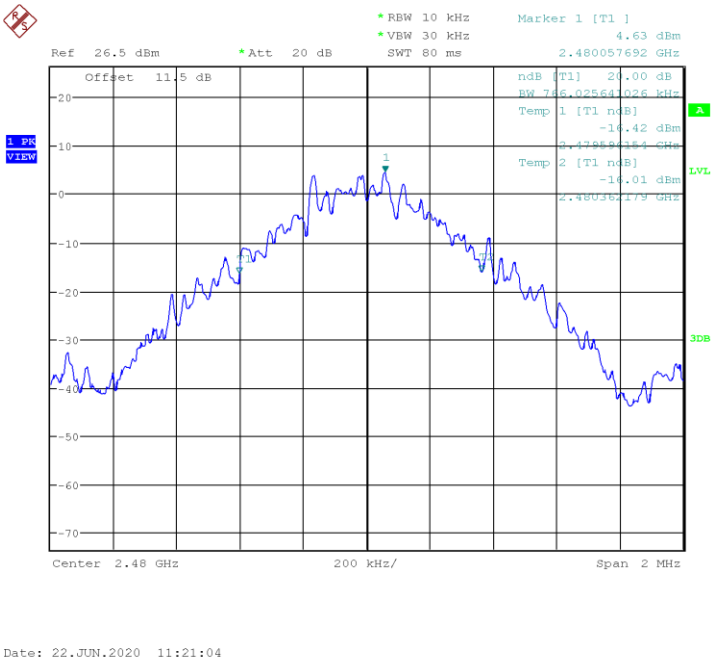
Bandwidth (MHz)			
Packet	**Freq. (MHz)**	**20dB Bandwidth MHz**	**99% Bandwidth MHz**
DH5	2402	0.766	0.872
	2441	0.763	0.872
	2480	0.766	0.872
2-DH5	2402	1.234	1.170
	2441	1.234	1.173
	2480	1.234	1.173
3-DH5	2402	1.263	1.179
	2441	1.263	1.183
	2480	1.263	1.179
Note: The EUT is capable to transmit at both BDR and EDR. The worst case modes at low, middle, and high frequencies were investigated.			



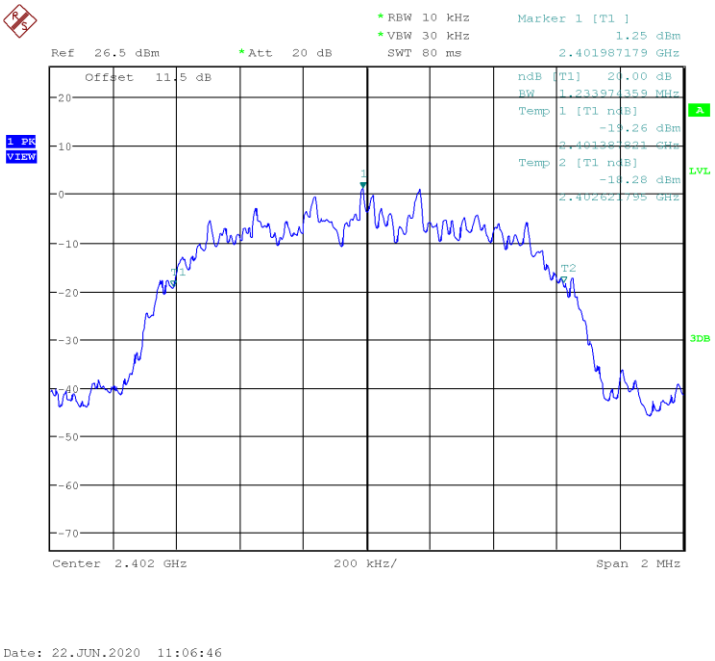
Plot 10. DH5 2402MHz 20dB Bandwidth



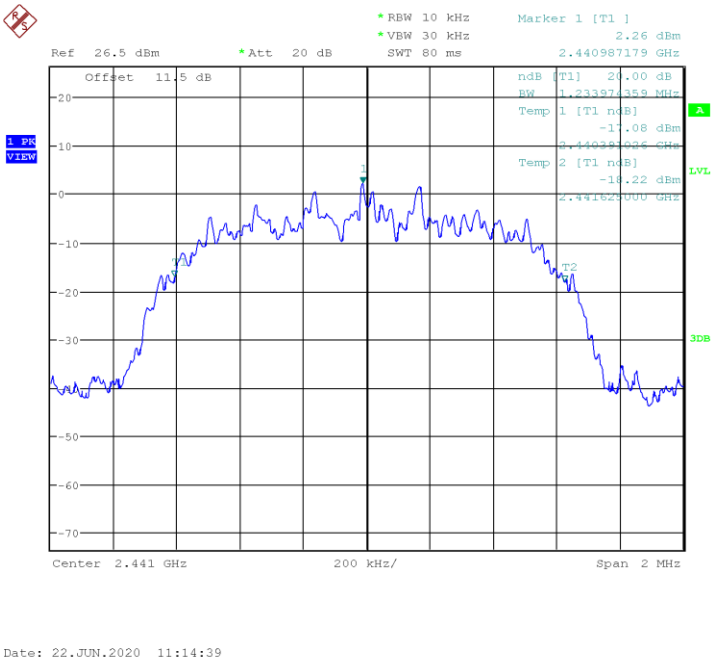
Plot 11. DH5 2441MHz 20dB Bandwidth



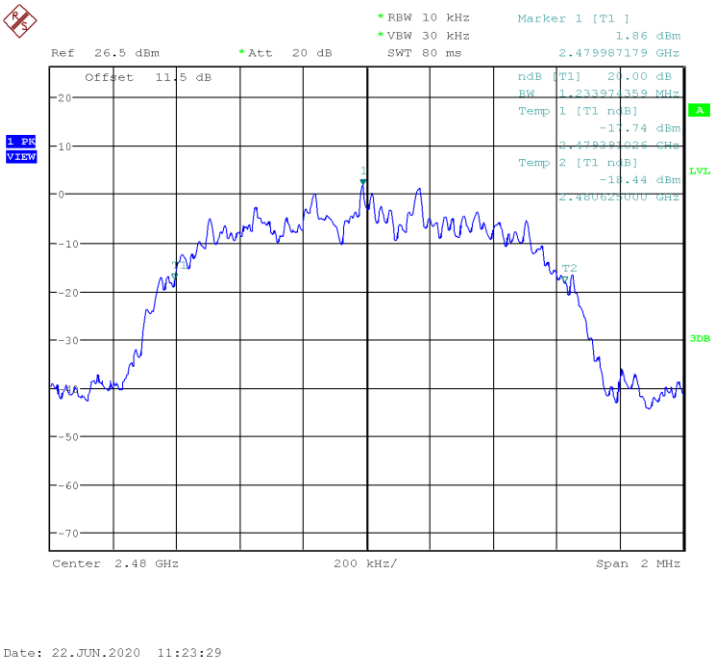
Plot 12. DH5 2480MHz 20dB Bandwidth



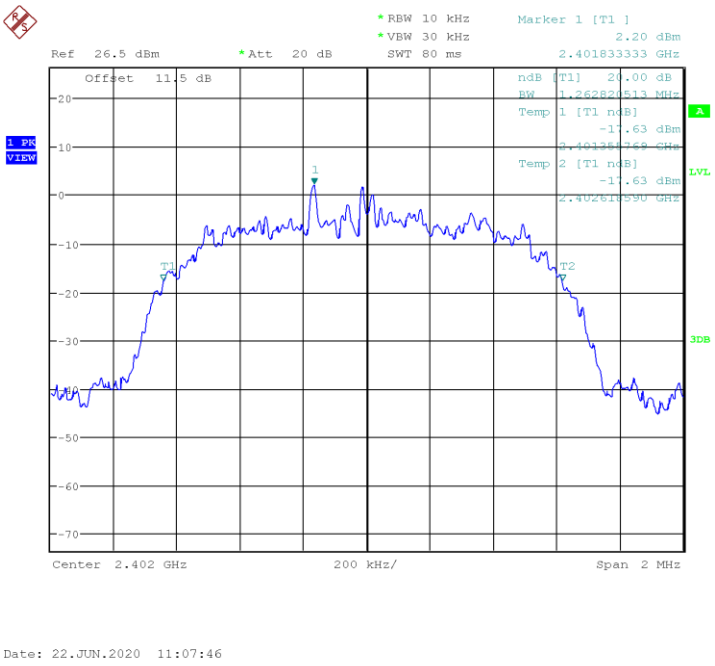
Plot 13. 2DH5 2402MHz 20dB Bandwidth



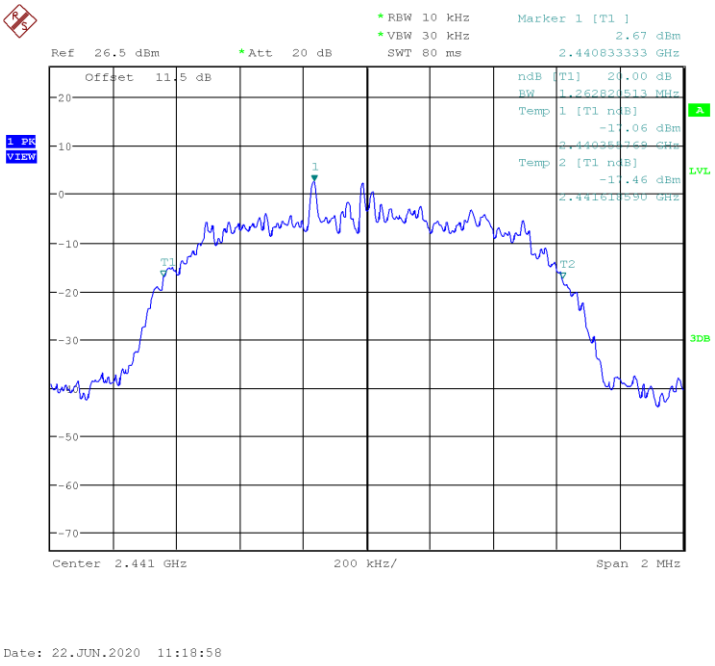
Plot 14. 2DH5 2441MHz 20dB Bandwidth



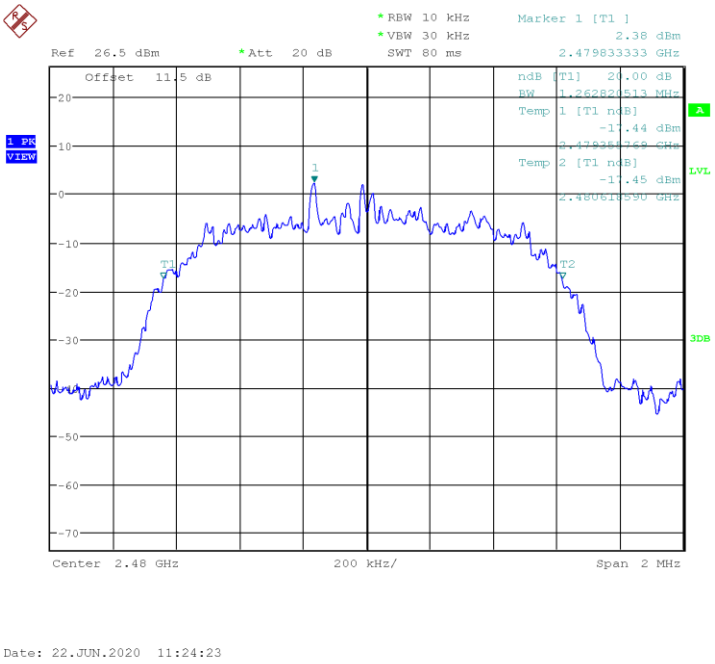
Plot 15. 2DH5 2480MHz 20dB Bandwidth



Plot 16. 3DH5 2402MHz 20dB Bandwidth



Plot 17. 3DH5 2441MHz 20dB Bandwidth



Plot 18. 3DH5 2480MHz 20dB Bandwidth

4.3 Hopping Frequency Requirements

The Frequency Hopping Requirements are applicable to the equipment using Frequency Hopping Spread Spectrum (FHSS) modulation.

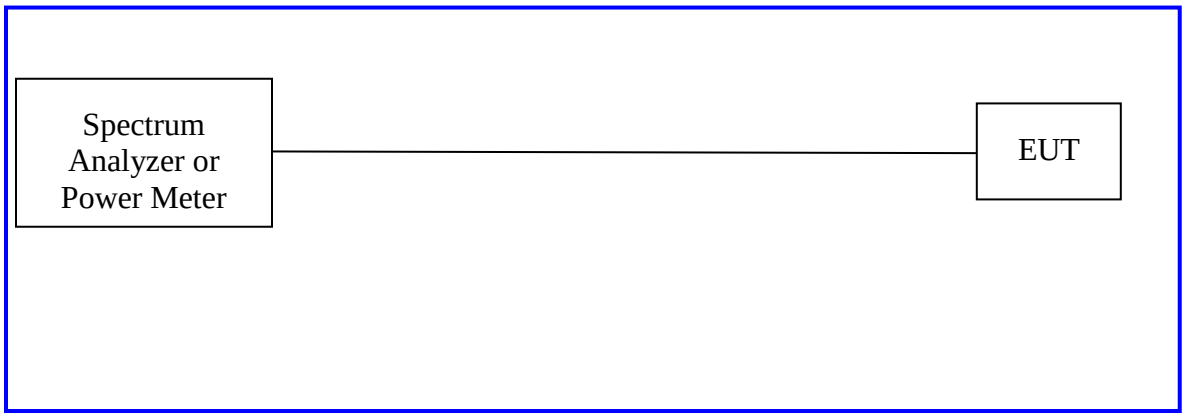
Per CFR47 15.247 (a)(1)(iii), RSS 247 Sect.5.1(b) and 5.1(d), frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the 20 dB bandwidth of the hopping channel, whichever is greater. Alternatively, frequency hopping systems operating in the 2400-2483.5 MHz band 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 the systems operate with an output power no greater than 125 mW.

Frequency hopping systems in the 2400–2483.5 MHz band shall use at least 15 channels. 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.

4.3.1 Test Method

The conducted method were used to measure the carrier frequency separation according to ANSI C63.10:2013 Section 7.8.2, frequency hopping system in Sect. 7.8.3, and time of occupancy in Sect. 7.8.4. The measurement was performed with the EUT set to hop to channel frequencies. Results indicated below.

Test Setup:



4.3.2 Results

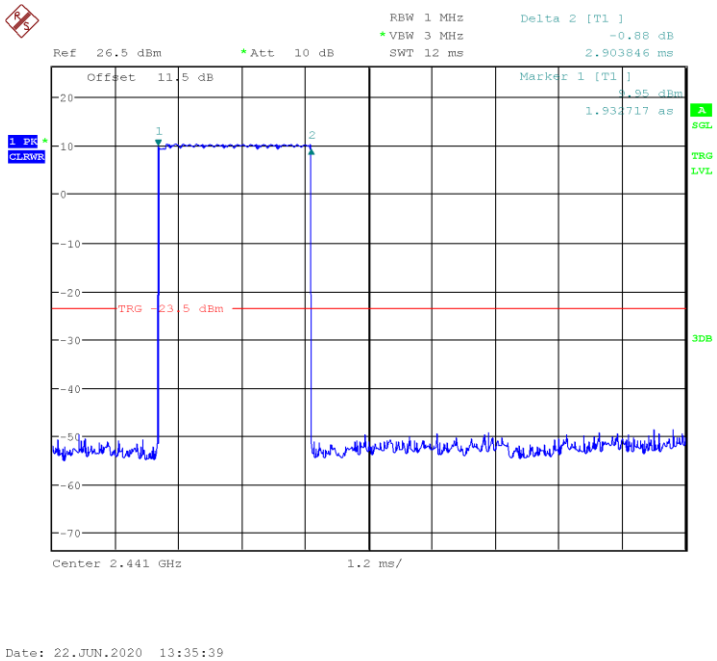
As originally tested, the EUT was found to be compliant to the requirements of the test standard(s).

Table 4: Frequency Hopping Requirements

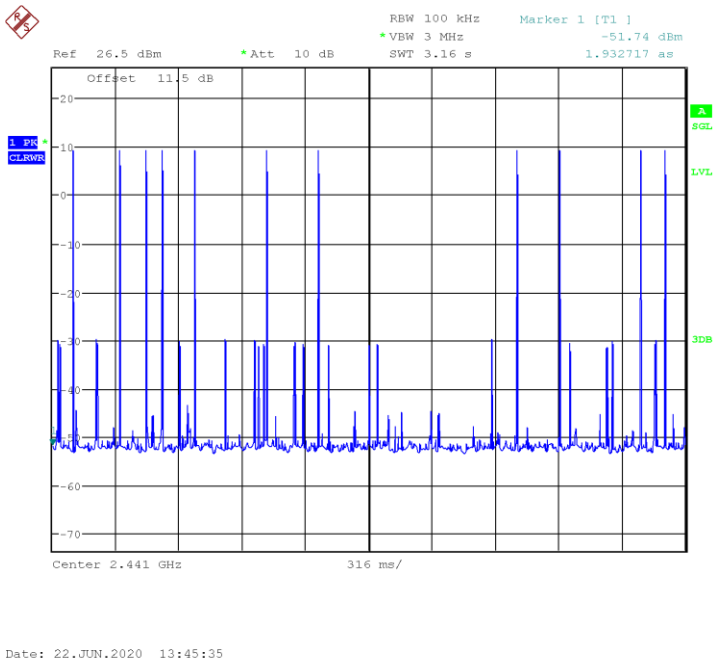
Average Occupancy Time					
Packet	**Pulse Width (ms)**	**# of Pulses (3.16s)**	**Ave. Time (ms)**	**Limit (ms)**	**Result**
DH5	2.884615	10	288.4615	<400	Pass
2-DH5	2.884615	9	259.61535	<400	Pass
3-DH5	2.903846	11	319.42306	<400	Pass
Note: The dwell time in each channel must be less than 0.4 seconds. The total time for 79 hopping channels is 31.6 seconds. To determine the average dwell time, the frequency 2441MHz was sample in 3.16 second, an 1/10th of the total 79 hopping channels dwell time.					

Minimum Channel Separation				
Package	**Hopping Separation (kHz)**	**20dB Bandwidth (MHz)**	**Two-Third of 20dB Bandwidth Limit (kHz)**	**Result**
DH5	1019.23	0.763	>508.55	Pass
2-DH5	985.577	1.234	>822.65	Pass
3-DH5	1019.231	1.263	>841.88	Pass
Note 1: The EUT was hopping randomly all 79 operating channels. The channel separation was measured at the middle channel, 2441 MHz. Two-Third of the highest 20dB bandwidth was used. **Note 2:** For 20 dB Occupied Bandwidth plot, refer to Section 5.2 of this test report.				

Minimum Number of Channels		
Range (2402MHz -2480MHz)	**Min. Channel Limit**	**Result**
79	15	Pass
Note: Both BDR and EDR used the same number of hopping channels. All packet types were tested		

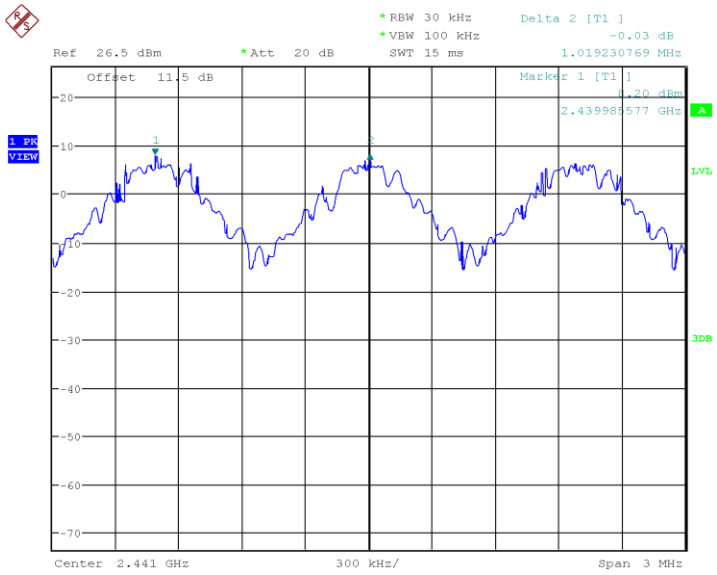


Plot 19. Pulse Width for 3DH5

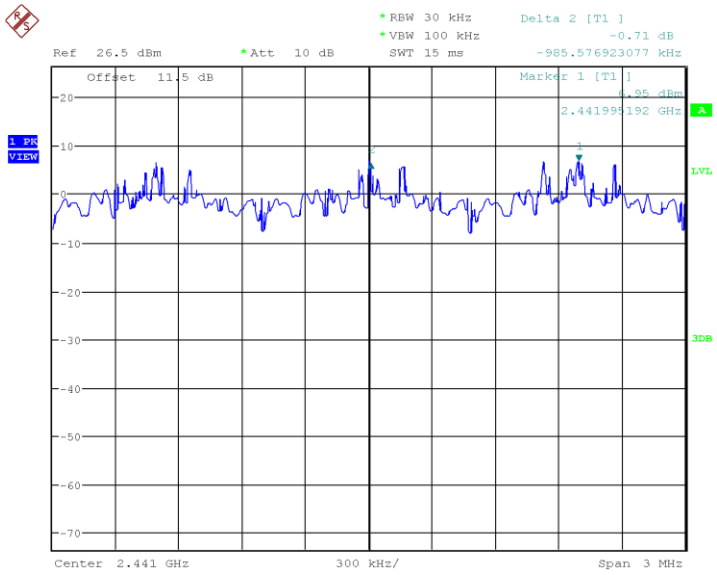


Plot 20. Number of Pulses in 3.16 sec for 3DH5

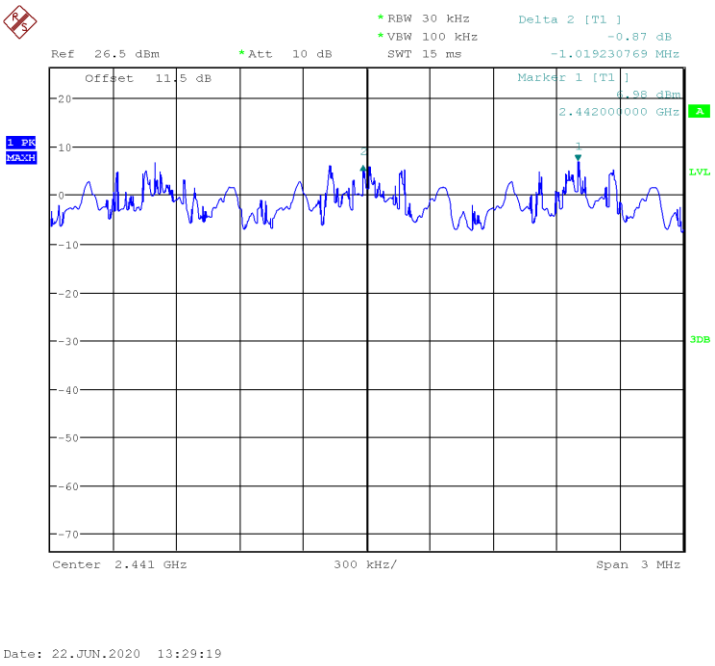
Note: There are 11 pulses in 3.16 seconds.



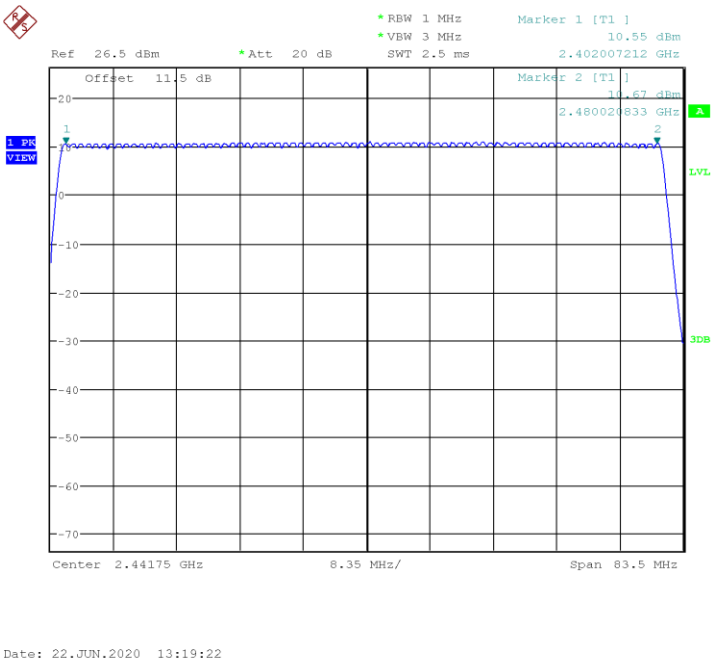
Plot 21. Hopping Separation for DH5



Plot 22. Hopping Separation for 2DH5



Plot 23. Hopping Separation for 3DH5



Plot 24. Number of Operating Channels (79)

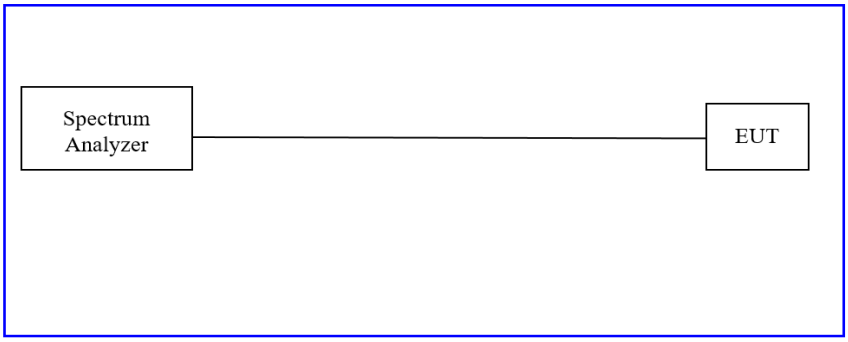
4.4 Out of Band Emissions: Non-Restricted Bands

Any frequency outside the band of 2400 MHz to 2483.5 MHz, the radio frequency power that is produced by the intentional radiator 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. If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under the regulation, the attenuation required under this paragraph shall be 30 dB instead of 20 dB. ; CFR 47 Part 15.247(d) and RSS 247 Sect. 5.5.

4.4.1 Test Method

Conducted measurements per ANSI C63.10-2013 Sections 6.10, 11.11, 14.3.3 were used to measure the undesirable emission requirement in non-restricted bands. The measurement was performed with modulation. The measurement was conducted from 30MHz to 26.5GHz on 3 channels in each mode on the EUT. Reference level was established on the channel with highest measured PSD (2480MHz/1Mbps and 2402MHz/2Mbps) as stated in ANSI C63.10-2013 Section 11.11.2. Band edge tests were conducted on the low and high channel of each mode. The worst case measurement of each mode is recorded in this report.

Test setup:

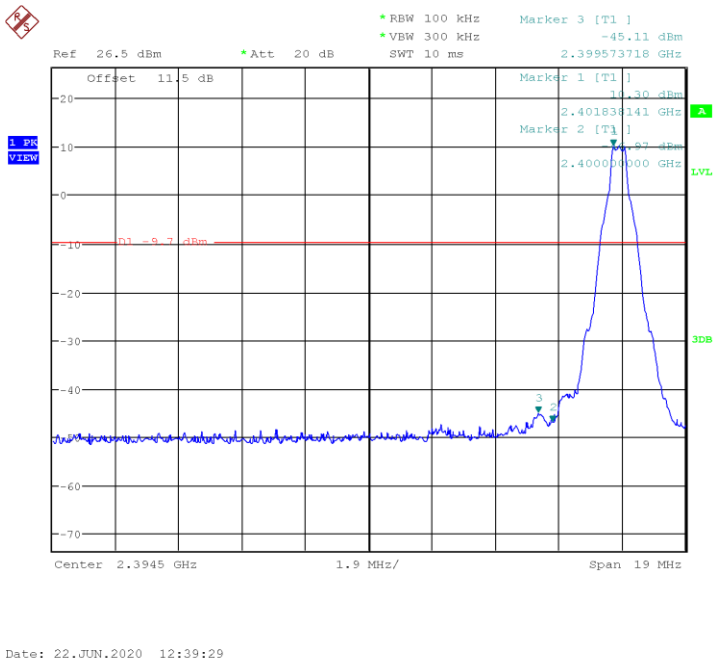


4.4.2 Results

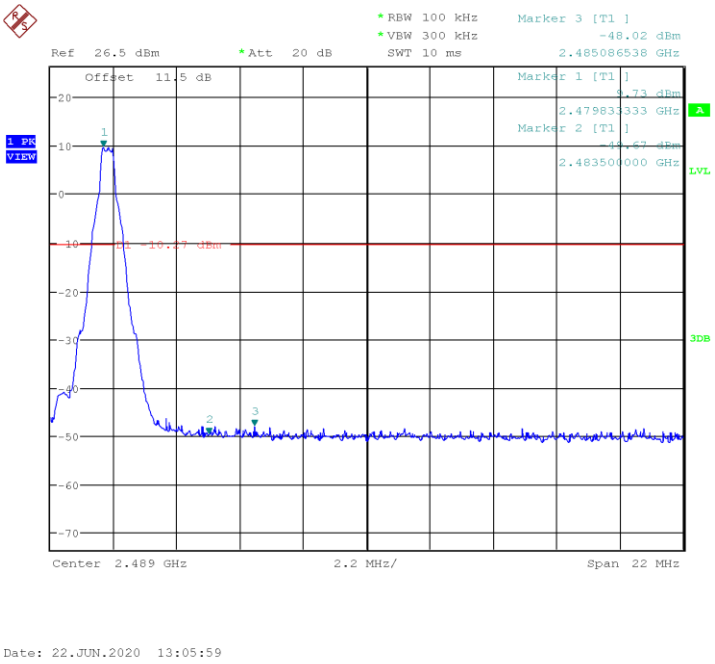
As originally tested, the EUT was found to be compliant to the requirements of the test standard(s).

Table 5: Band Edge Requirements – Test Results

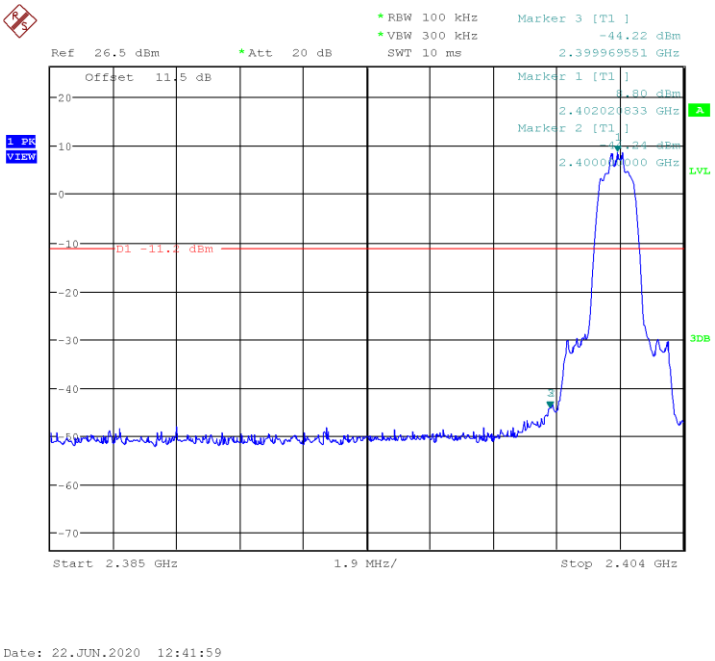
Non-Restricted Frequency Band Edge Emissions						
Package/ Power	**Band Edge**	**Operating Freq. (MHz)**	**Measured (dBc)**	**Limit (dBc)**	**Frequency (MHz)**	**Result**
DH5	Low	2402	45.11	>20	2399.57	Pass
	High	2480	48.02	>20	2485.09	Pass
2DH5	Low	2402	44.22	>20	2399.97	Pass
	High	2480	47.97	>20	2488.89	Pass
3DH5	Low	2402	42.06	>20	2400.00	Pass
	High	2480	48.18	>20	2490.41	Pass
Note 1: The stated limits for 20 dBc are relative to each individual output per KDB 662911 Method. The worst case of each data rate is recorded. **Note 2:** Worse case package was tested for each data rate						



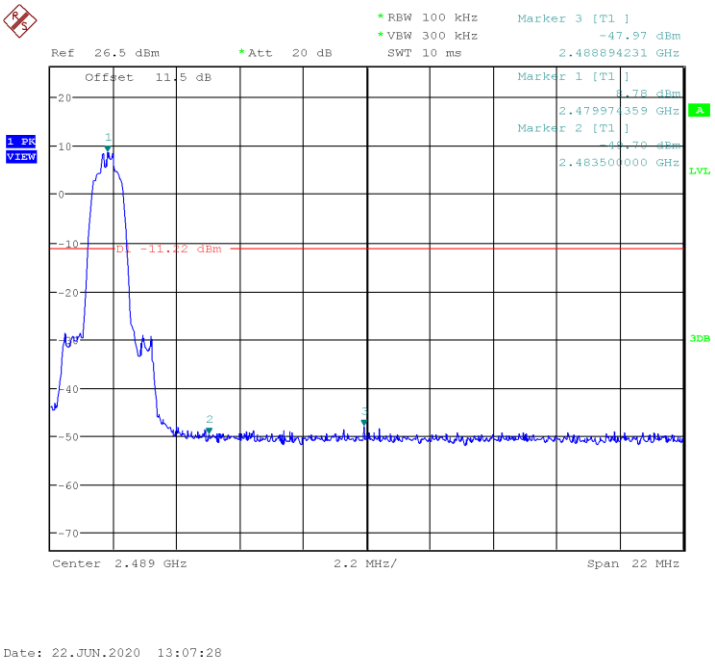
Plot 25. DH5 2402MHz Lower Band edge



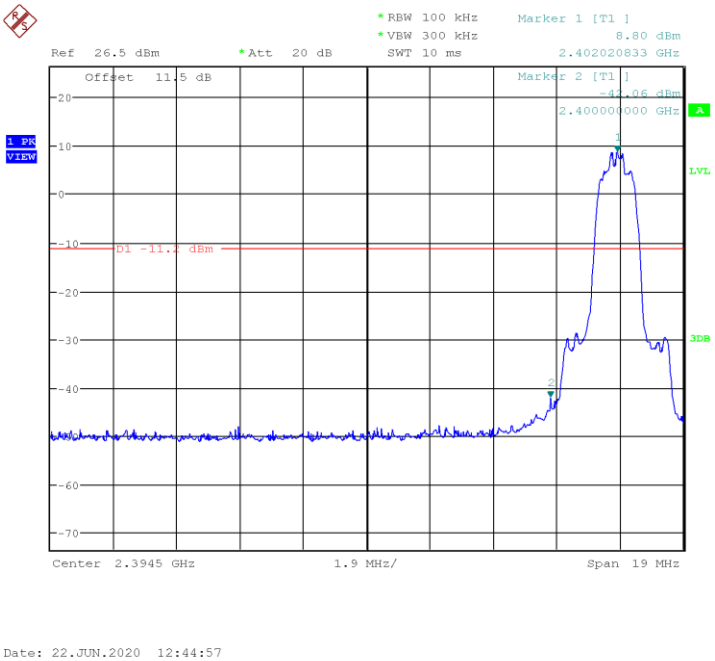
Plot 26. DH5 2480MHz Upper Band Edge



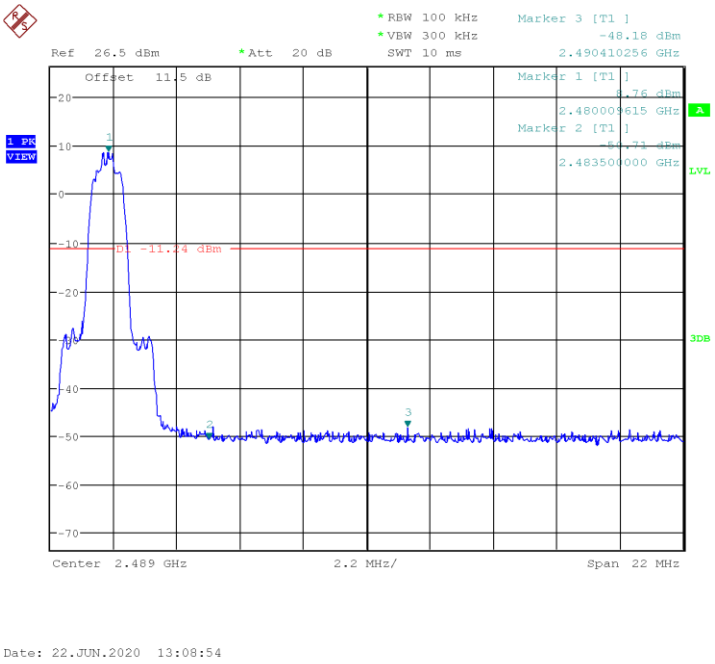
Plot 27. 2DH5 2402MHz Lower Band Edge



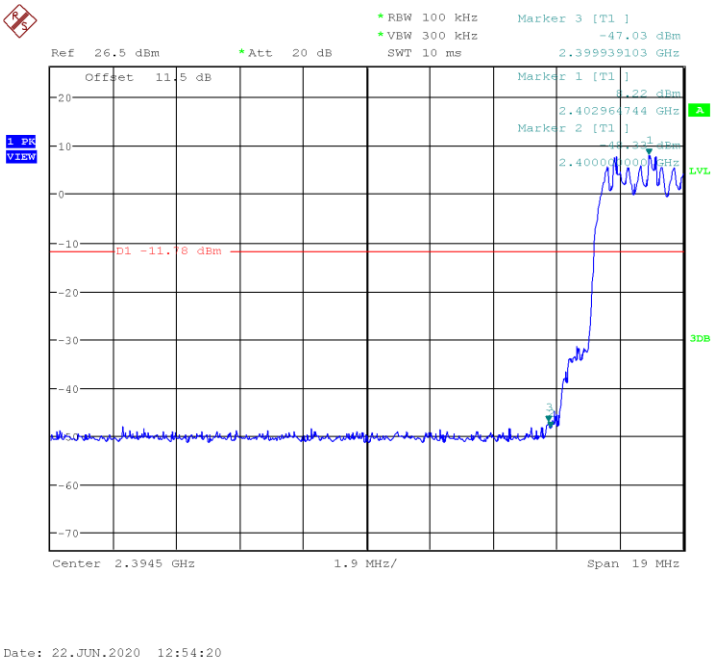
Plot 28. 2DH5 2480MHz Upper Band Edge



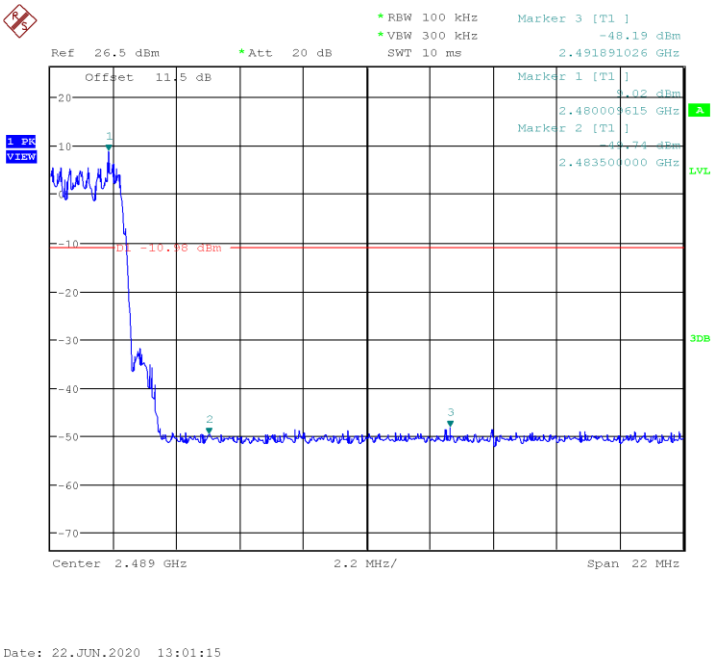
Plot 29. 3DH5 2402MHz Lower band Edge



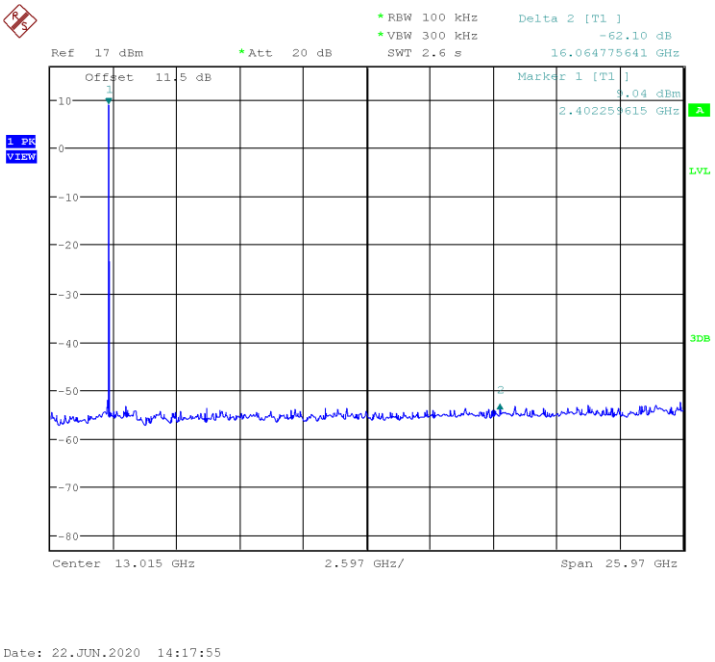
Plot 30. 3DH5 2480MHz Upper Band Edge



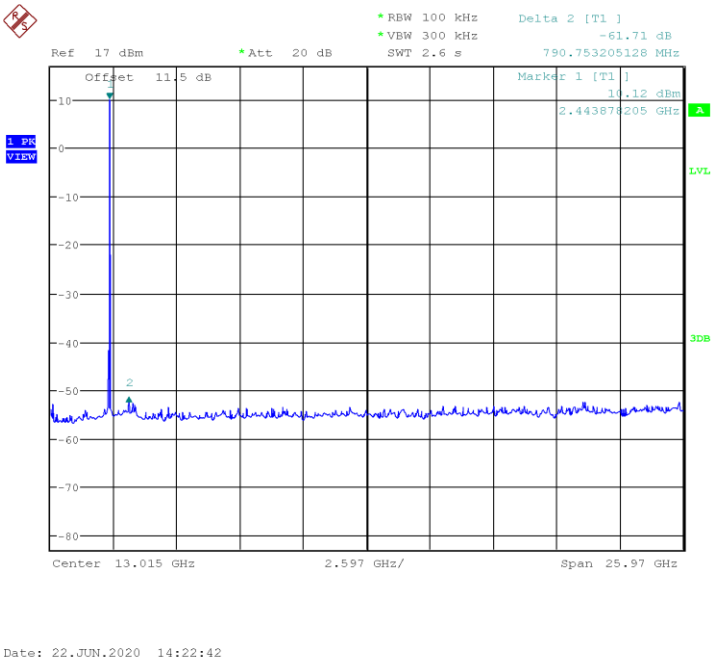
Plot 31. 3DH5 Hopping Lower Band Edge



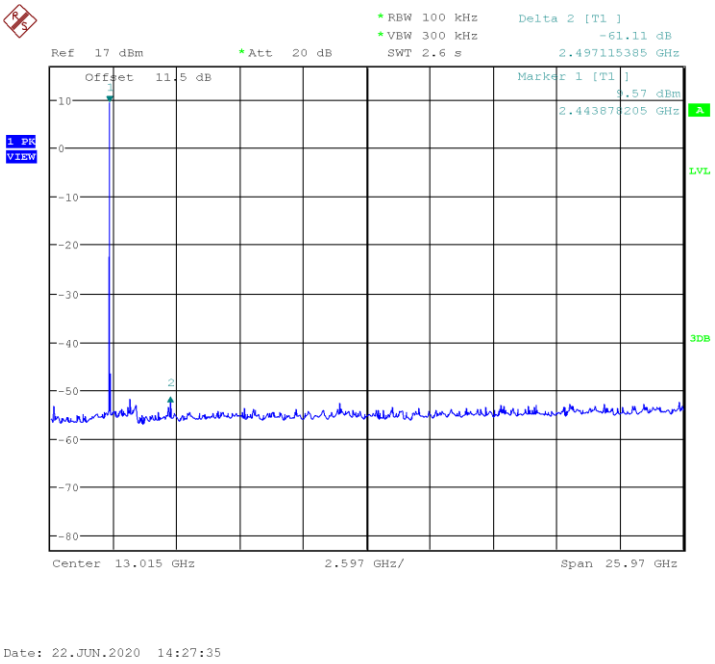
Plot 32. 3DH5 Hopping Upper Band Edge



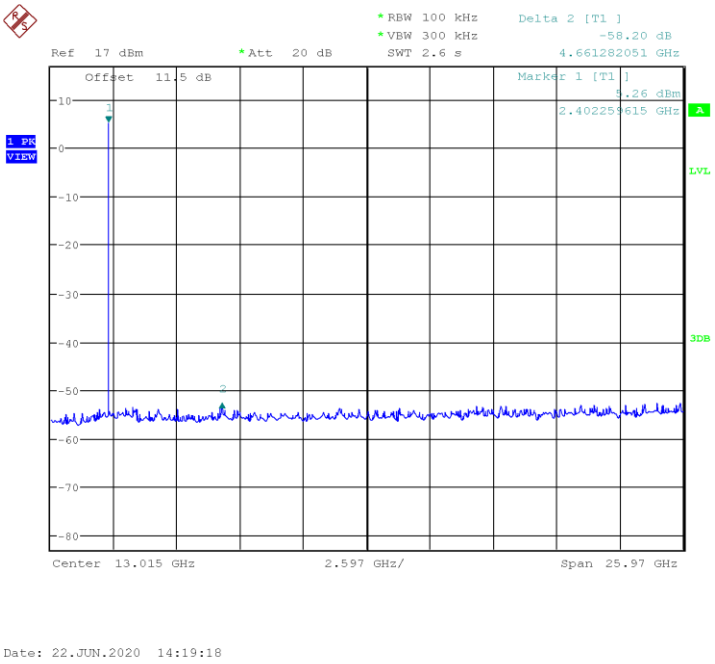
Plot 33. DH5 2402MHz, 30MHz-26.5GHz Spurious



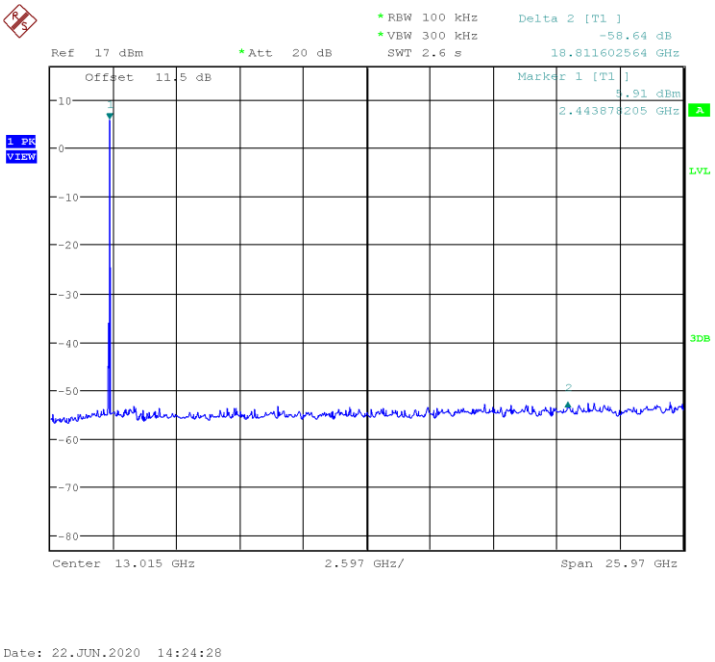
Plot 34. DH5 2441MHz, 30MHz-26.5GHz Spurious



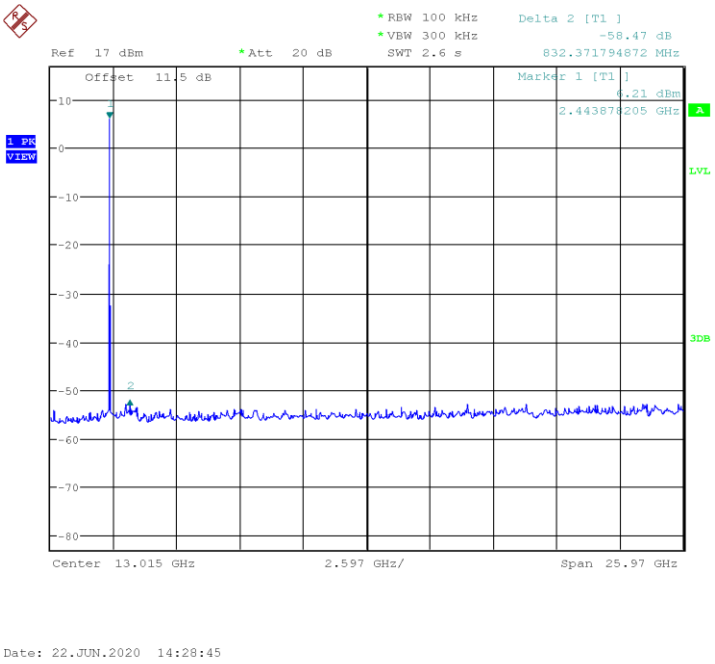
Plot 35. DH5 2480MHz, 30MHz-26.5GHz Spurious



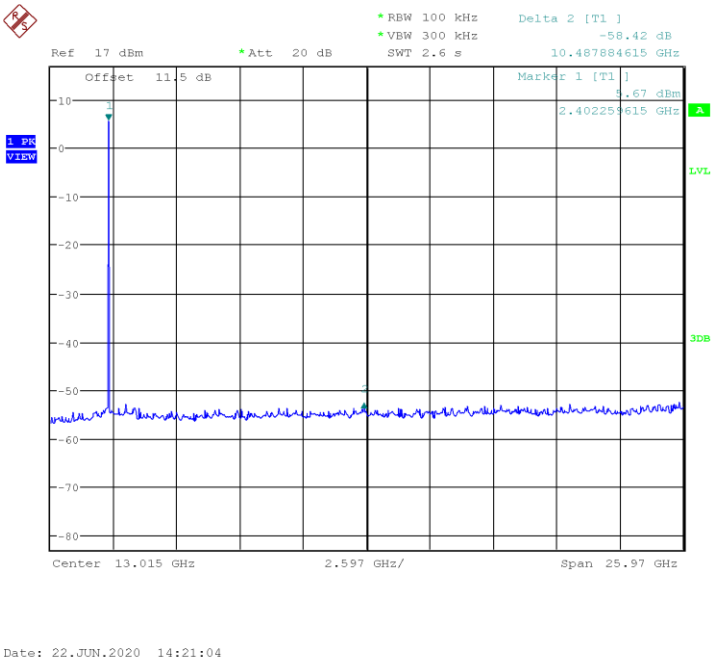
Plot 36. 2DH5 2402MHz, 30MHz-26.5GHz Spurious



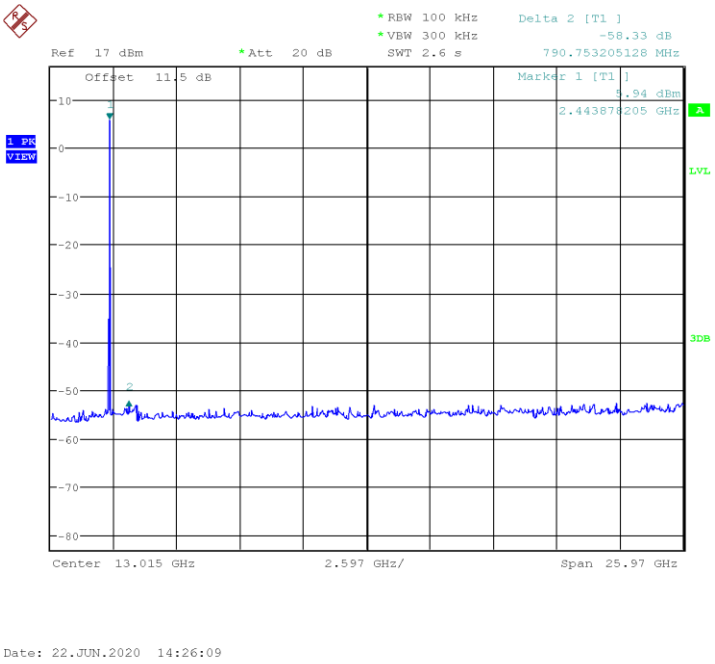
Plot 37. 2DH5 2441MHz, 30MHz-26.5GHz Spurious



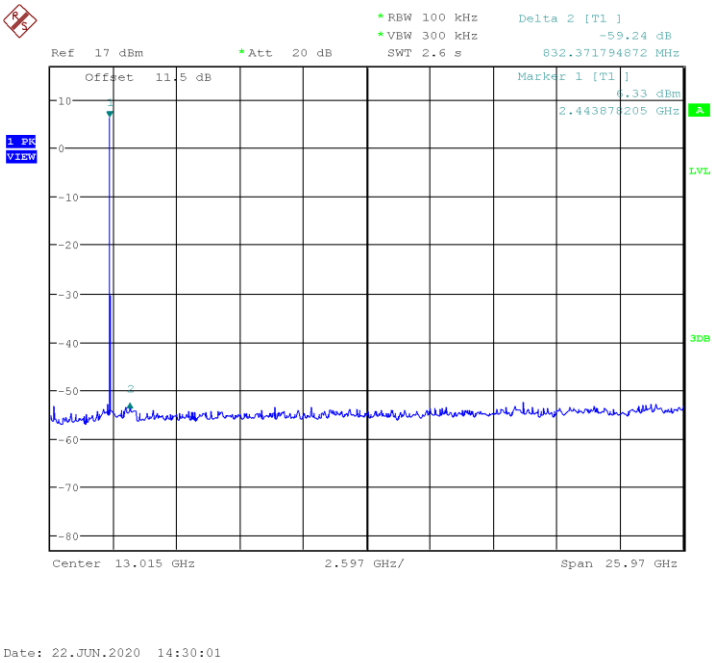
Plot 38. 2DH5 2480MHz, 30MHz-26.5GHz Spurious



Plot 39. 3DH5 2402MHz, 30MHz-26.5GHz Spurious



Plot 40. 3DH5 2441MHz, 30MHz-26.5GHz Spurious



Plot 41. 3DH5 2480MHz, 30MHz-26.5GHz Spurious

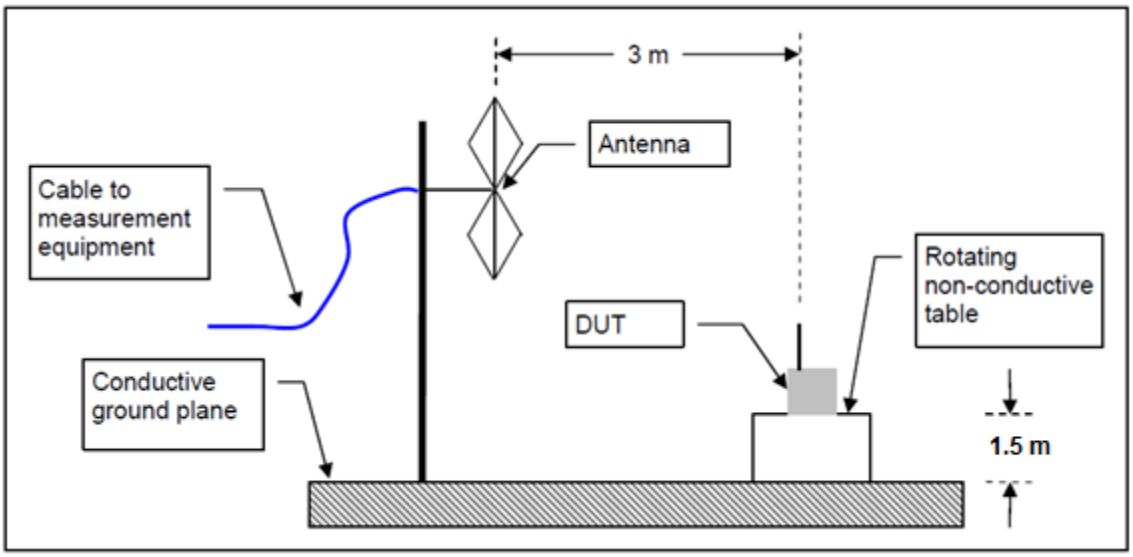
4.5 Out of Band Emissions: Restricted Band Edge

Transmitter spurious emissions are emissions outside the frequency range of the equipment when the equipment is in transmitting mode; per requirement of CFR47 15.205, 15.209, 15.247(d), RSS-247 Sect. 5.5, RSS-GEN Sect. 8.9 and 8.10.

4.5.1 Test Method

Radiated measurements per ANSI C63.10-2013 Section 6.10.5 were used to measure the undesirable emission requirement in restricted bands. Peak points were found and RMS Average was taken for each point found. An RBW of 1MHz and VBW of 3MHz was used. The measurement was performed with modulation. This test was conducted on the upper and lower most channels in each worse case mode on the EUT. The worst case measurement of each channel is recorded in this report. All channels were tested at highest power settings.

Test Setup



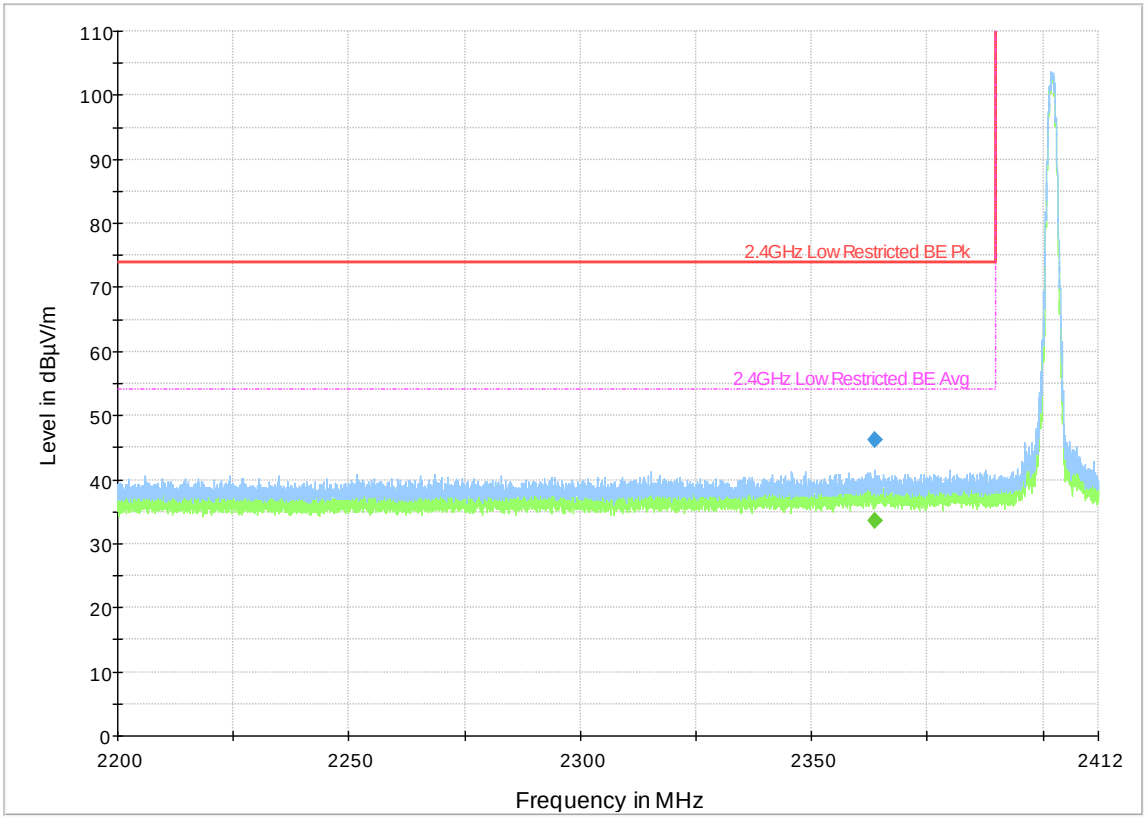
The DUT was stimulated by manufacturer provided test software that is not available to the end user.

4.5.2 Test Results

Table 6: Transmit Spurious Emission at Restricted Band Edge Requirements

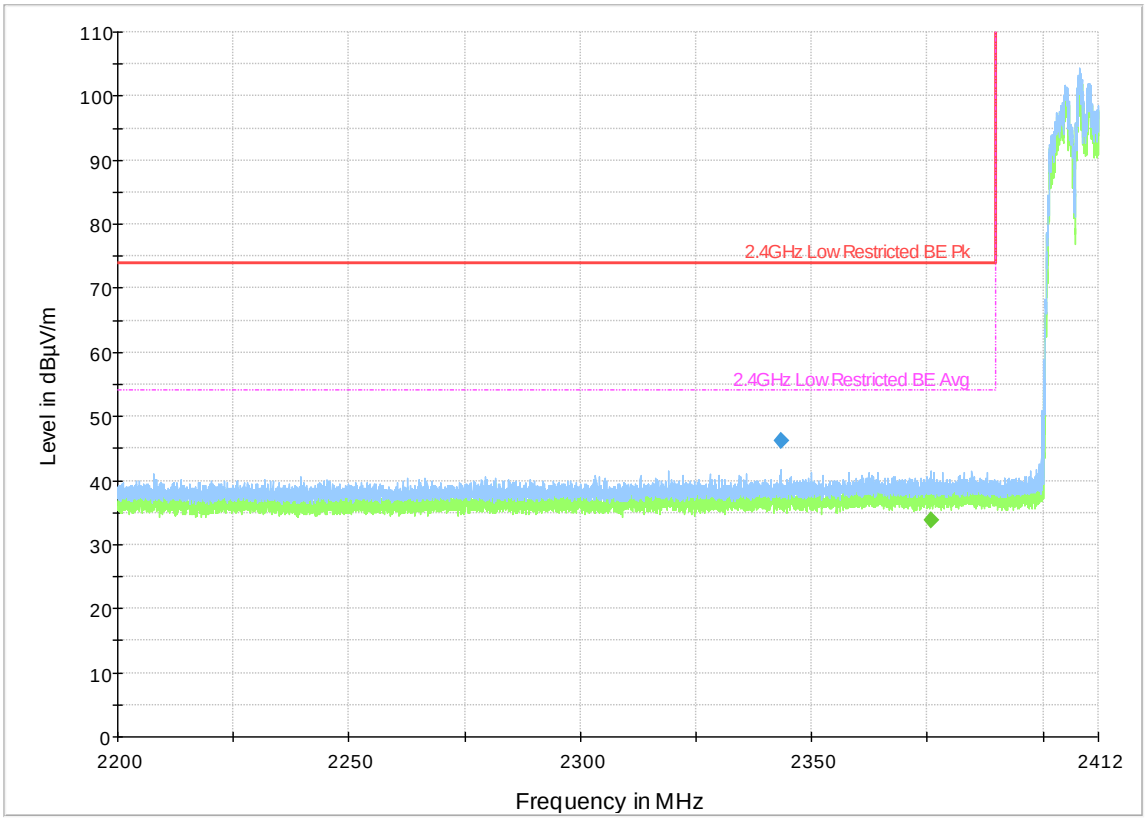
Test Conditions: Radiated Measurement, Normal Temperature and Voltage							
Lower Restricted Band Edge							
Freq. (MHz)	**Mode**	**Center Freq (MHz)**	**Detector (Average/ Peak)**	**Measured (dBuV/m)**	**Limit (dBuV/m)**	**Margin**	**Results**
2363.7912	3DH5	2402	Average	33.59	54	20.41	Pass
2363.7912	3DH5	2402	Peak	46.22	74	27.78	Pass
2375.8328	3DH5 Hopping	2402	Average	33.76	54	20.24	Pass
2343.3332	3DH5 Hopping	2402	Peak	46.3	74	27.70	Pass
Upper Restricted Band Edge							
Freq. (MHz)	**Mode**	**Center Freq (MHz)**	**Detector (Average/ Peak)**	**Measured (dBuV/m)**	**Limit (dBuV/m)**	**Margin**	**Results**
2484.2624	3DH5	2480	Average	35.42	54	18.58	Pass
2483.6576	3DH5	2480	Peak	50.48	74	23.52	Pass
2579.0432	3DH5 Hopping	2480	Average	34.54	54	19.46	Pass
2645.888	3DH5 Hopping	2480	Peak	47.28	74	26.72	Pass
Note: All restricted band edge tests were performed at full power. Worse case (3DH5) reported							

Frequency (MHz)	MaxPeak (dBµV/m)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)
2363.791200	---	33.59	54.00	20.41	1000.000	297.0	H	45.0
2363.791200	46.22	---	74.00	27.78	1000.000	203.0	H	45.0



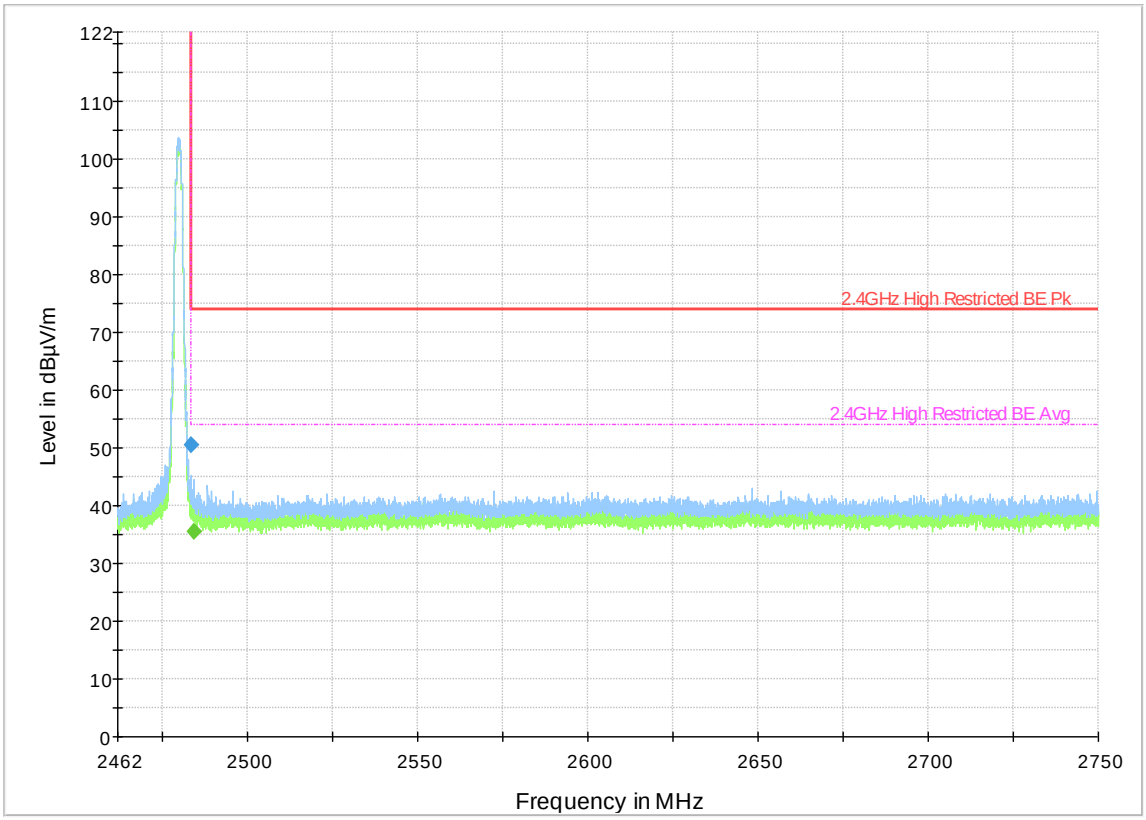
Plot 42. Lower Restricted Band Edge, 2402MHz, 3DH5

Frequency (MHz)	MaxPeak (dBµV/m)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)
2343.333200	46.30	---	74.00	27.70	1000.000	297.0	H	166.0
2375.832800	---	33.76	54.00	20.24	1000.000	204.0	V	34.0



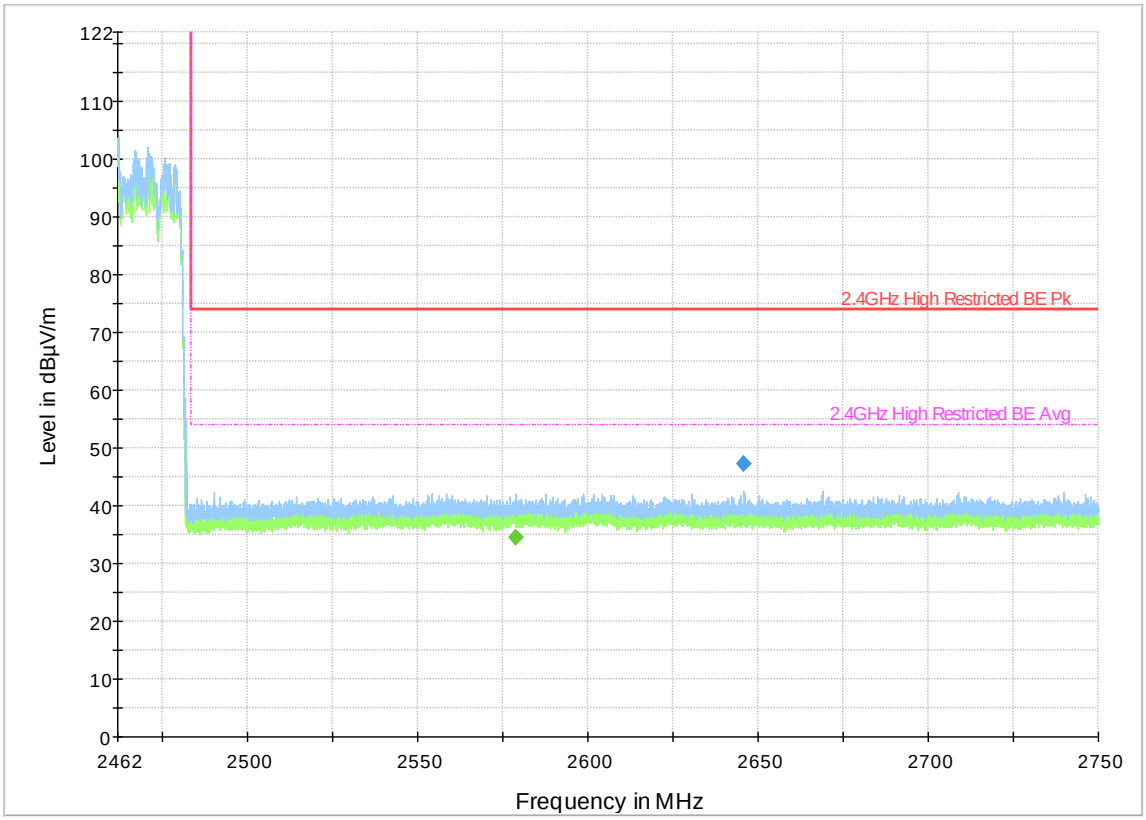
Plot 43. Lower Restricted Band Edge, 2402MHz, 3DH5, Hopping

Frequency (MHz)	MaxPeak (dBµV/m)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)
2483.657600	50.48	---	74.00	23.52	1000.000	203.0	H	-42.0
2484.262400	---	35.42	54.00	18.58	1000.000	154.0	H	152.0



Plot 44. Upper Restricted Band Edge, 2480MHz, 3DH5

Frequency (MHz)	MaxPeak (dBµV/m)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)
2579.043200	---	34.54	54.00	19.46	1000.000	154.0	H	128.0
2645.888000	47.28	---	74.00	26.72	1000.000	247.0	V	-25.0



Plot 45. Upper Restricted Band Edge, 2480MHz, 3DH5, Hopping

4.6 Transmitter Spurious Emissions

Transmitter spurious emissions are emissions outside the frequency range of the equipment when the equipment is in transmitting mode; per requirement of CFR47 15.205, 15.209, 15.247(d), RSS GEN Sect. 8.9 and 8.10.

4.6.1 Test Methodology

4.6.1.1 *Preliminary Test*

A test program that controls instrumentation and data logging was used to automate the preliminary RF emission test procedure. The frequency range of interest was divided into sub-ranges to yield a frequency resolution of approximately 120 kHz and provide a reading at each frequency for no more than 12° of turntable rotation. For each frequency sub-range the turntable was rotated 360° while peak emission data was recorded and plotted over the frequency range of interest in horizontal and vertical antenna polarization's.

Preliminary emission profile testing was performed inside the anechoic chamber. The EUT was placed on a 1.0m x 1.5m non-conductive table 80cm (<1 GHz) and 150cm (>1 GHz) above the floor. The EUT was positioned as shown in the setup photographs. The receiving antenna was placed at a distance of 3m at a height of 1 – 4m. Measurement equipment was located outside of the chamber < 1GHz frequency range. RBW was set at 120kHz for measurements form 30MHz – 1000MHz and 1MHz for measurements above 1GHz. VBW was set to ~3x the RBW.

4.6.1.2 *Final Test*

For each frequency measured, the peak emission was maximized by manipulating the receiving antenna from 1 to 4 meters above the ground plane and placing it at the position that produced the maximum signal strength reading. The turntable was then rotated through 360° while observing the peak signal and placing the EUT at the position that produced maximum radiation. The six highest emissions relative to the limit were measured unless such emissions were more than 20 dB below the limit. If less than six emissions are within 20 dB of the limit, than the noise level of the receiver is measured at frequencies where emissions are expected. Multiples of all oscillator and microprocessor frequencies were also checked. RBW was set at 120kHz for measurements form 30MHz – 1000MHz and 1MHz for measurements above 1GHz. VBW was set to ~3x the RBW.

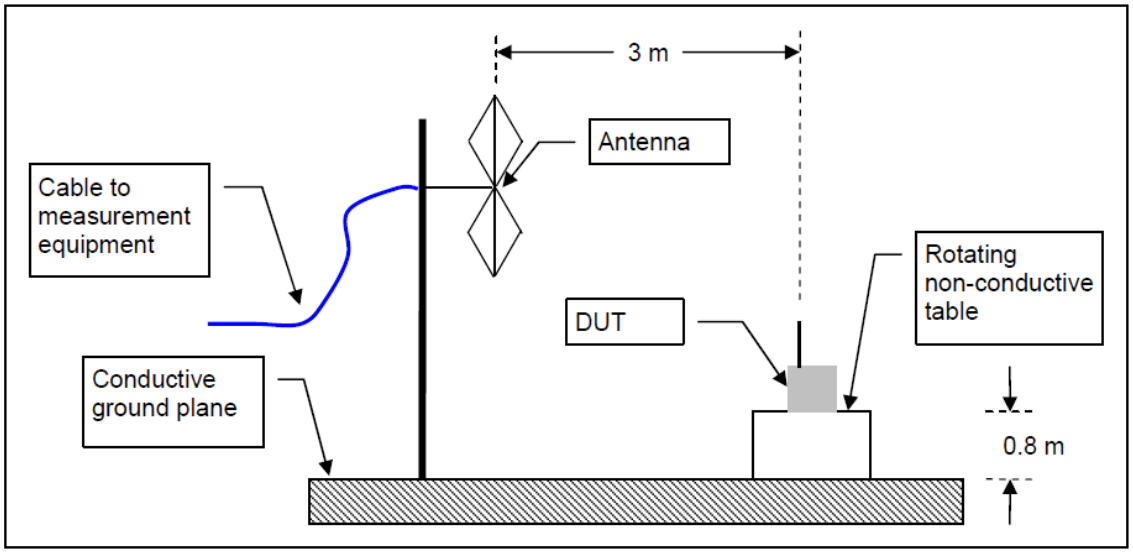
Final testing was performed on an NSA compliant test site. The EUT was placed on a 1.0m x 1.5m non-conductive table 80cm (<1 GHz) and 150cm (>1 GHz) above the ground plane. The placement of EUT and cables were the same as for preliminary testing and is shown in the setup photographs.

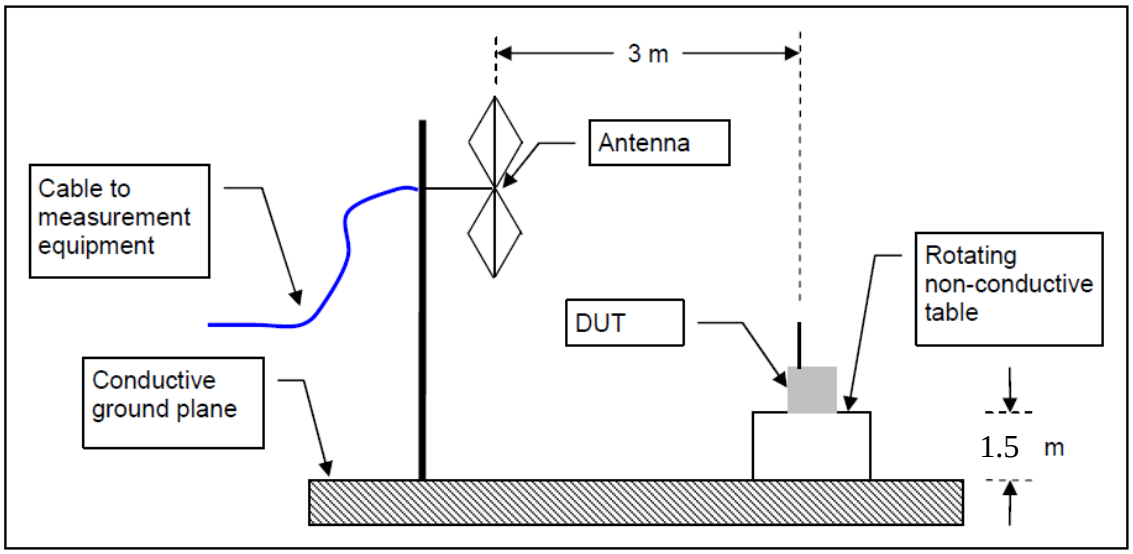
The final scans performed on the highest power measured, for three operating channels: 2402 MHz, 2441 MHz, and 2480 MHz. Worse case operating mode reported.

4.6.1.3 *Deviations*

None.

Test Setup:


3 m
Antenna
Cable to measurement equipment
Rotating non-conductive table
DUT
Conductive ground plane
0.8 m


3 m
Antenna
Cable to measurement equipment
Rotating non-conductive table
DUT
Conductive ground plane
1.5 m

4.6.2 Transmitter Spurious Emission Limit

The spurious emissions of the transmitter shall not exceed the values in CFR47 Part 15.205, 15.209: 2018 and RSS Gen Sect. 8.9, 8.10: 2018.

Frequency (MHz)	Field strength (microvolts/meter)	Measurement distance (meters)
0.009-0.490	2400/F(kHz)	300
0.490-1.705	24000/F (kHz)	30
1.705-30.0	30	30
30-88	100 **	3
88-216	150 **	3
216-960	200 **	3
Above 960	500	3

All harmonics and spurious emission which are outside of the restricted band shall be 20 dB below the in-band emission.
Sample Calculation

The field strength is calculated by subtracting the Amplifier Gain and adding the Cable Loss and Antenna Correction Factor to the measured reading. The basic equation is as follows:

Field Strength (dBμV/m) = FIM - AMP + CBL + ACF

Where:
FIM = Field Intensity Meter (dBμV)
AMP = Amplifier Gain (dB)
CBL = Cable Loss (dB)
ACF = Antenna Correction Factor (dB/m)

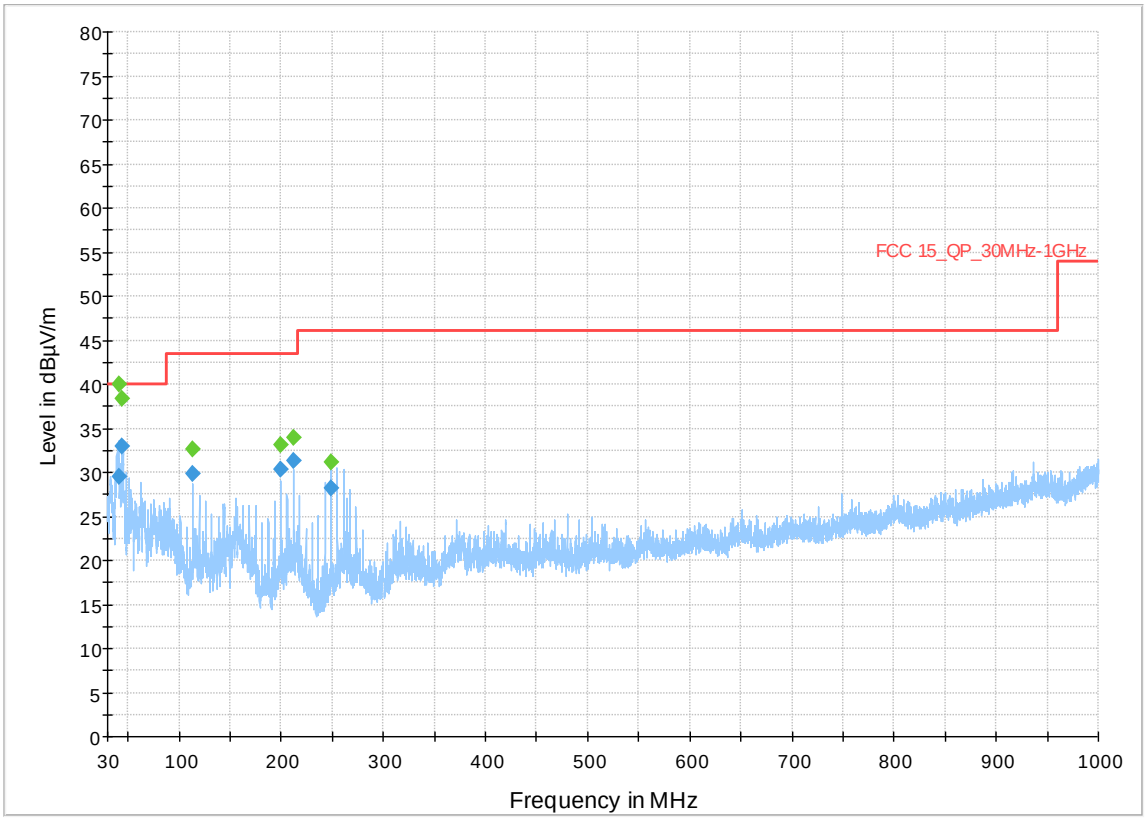
$$\mu V/m = 10^{\frac{dB\mu V/m}{20}}$$

4.6.3 Test Results

The final measurement data was taken under the worst case operating modes, configurations, and/or cable positions. It also reflects the results including any modifications and/or special accessories listed in Sections 1.4 and Test Plan.

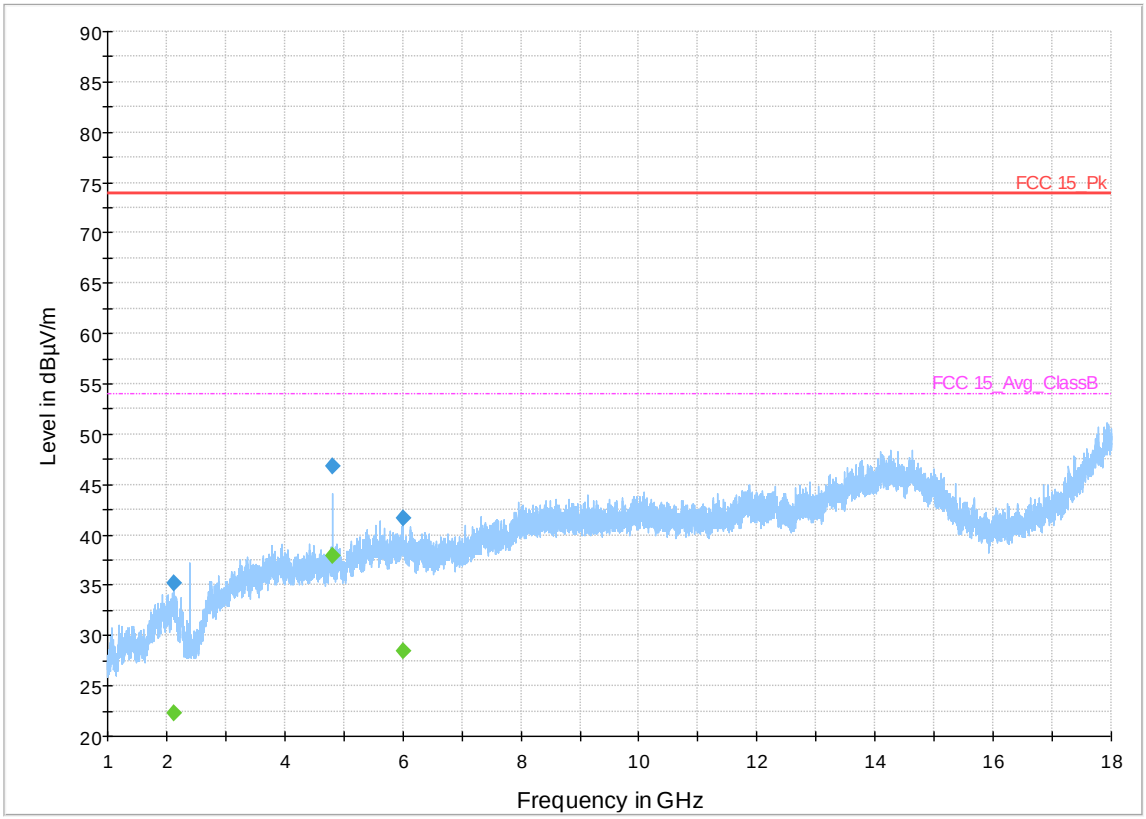
As originally tested, the EUT was found to be compliant to the requirements of the test standard(s). Worse case modes are provided below

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)
41.258360	29.47	40.00	10.53	120.000	103.0	V	180.0
44.157320	32.92	40.00	7.08	120.000	103.0	V	161.0
113.679280	29.81	43.52	13.71	120.000	103.0	V	-180.0
199.679760	30.27	43.52	13.25	120.000	103.0	V	-106.0
211.974520	31.30	43.52	12.22	120.000	103.0	V	60.0
248.829840	28.22	46.00	17.78	120.000	103.0	V	158.0



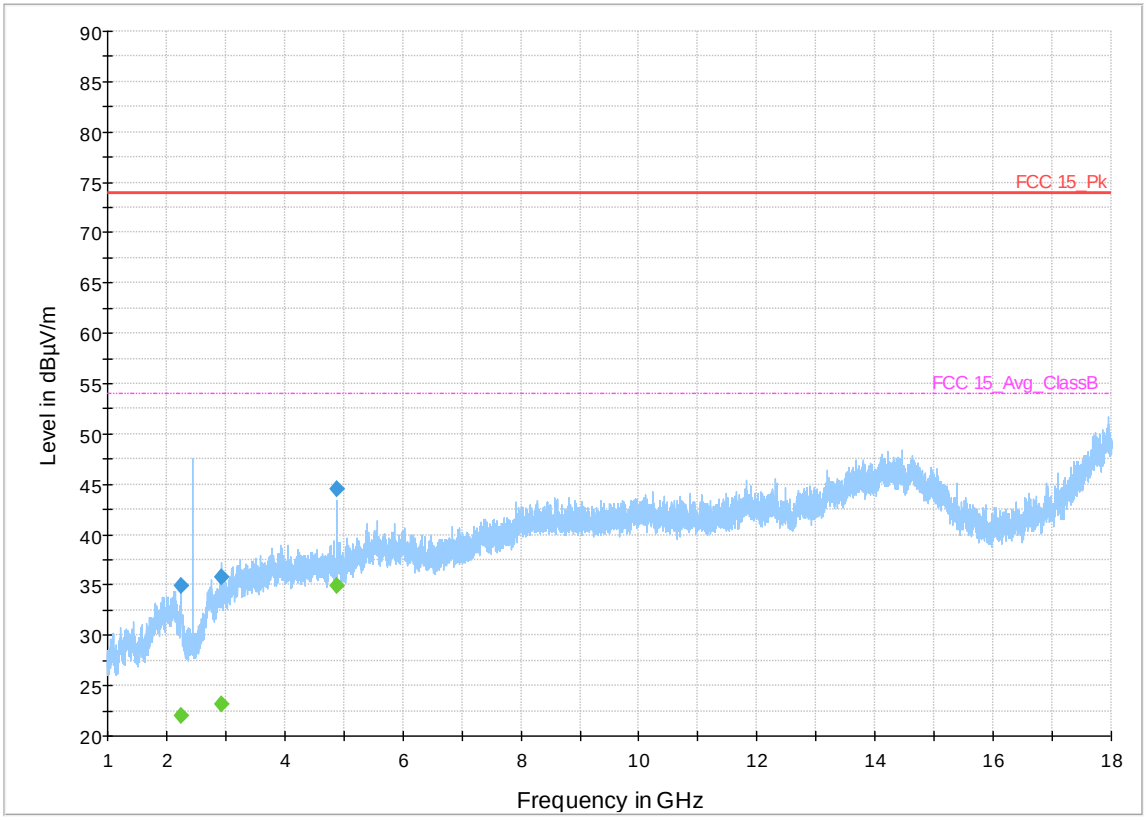
Plot 46. 30-1000MHz, 2480 MHz, DH5

Frequency (MHz)	MaxPeak (dBµV/m)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)
2125.822500	---	22.28	54.00	31.72	1000.000	105.0	V	180.0
2125.822500	35.23	---	74.00	38.77	1000.000	105.0	V	180.0
4803.661500	46.78	---	74.00	27.22	1000.000	104.0	H	77.0
4803.661500	---	37.86	54.00	16.14	1000.000	104.0	H	77.0
6012.829000	41.68	---	74.00	32.32	1000.000	104.0	V	12.0
6012.829000	---	28.52	54.00	25.48	1000.000	104.0	V	12.0



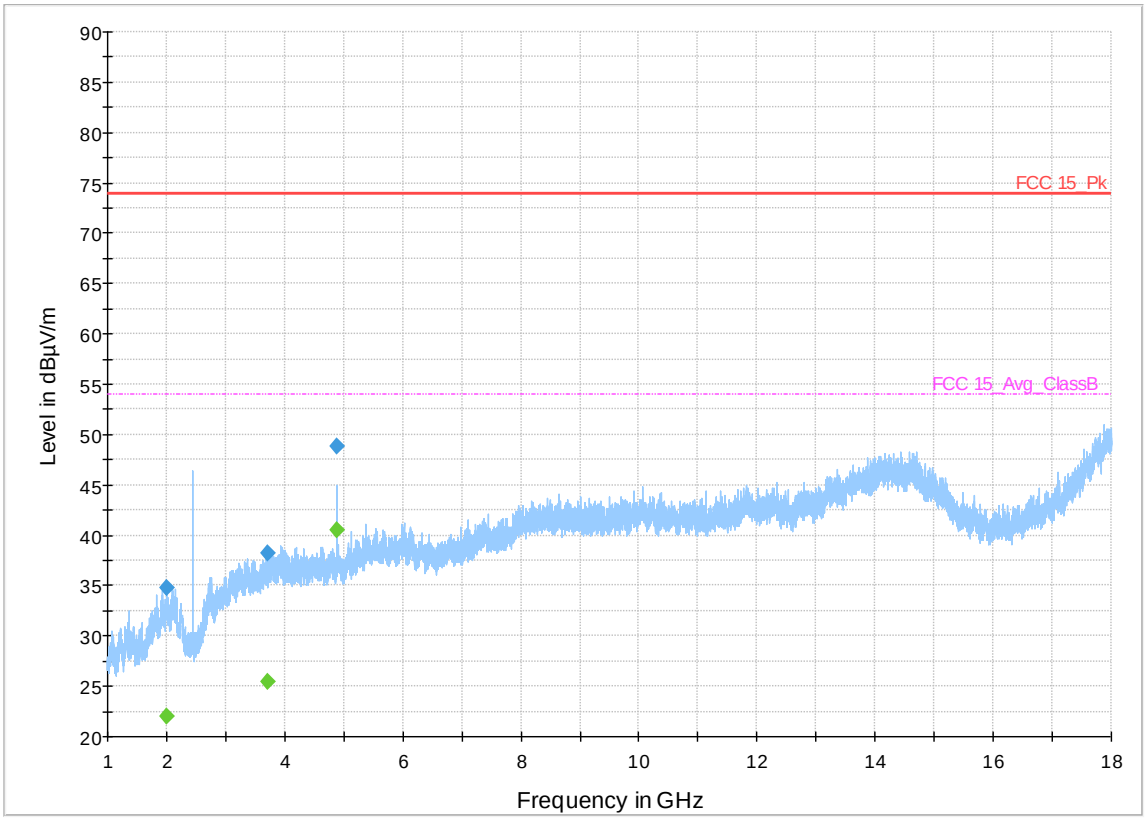
Plot 47. 1-18GHz, 2402MHz, DH5

Frequency (MHz)	MaxPeak (dBµV/m)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)
2240.642000	34.92	---	74.00	39.08	1000.000	106.0	V	180.0
2240.642000	---	22.01	54.00	31.99	1000.000	106.0	V	180.0
2927.873000	---	23.09	54.00	30.91	1000.000	106.0	H	180.0
2927.873000	35.76	---	74.00	38.24	1000.000	106.0	H	180.0
4881.668500	44.48	---	74.00	29.52	1000.000	106.0	H	121.0
4881.668500	---	34.85	54.00	19.15	1000.000	106.0	H	121.0



Plot 48. 1-18GHz, 2441MHz, DH5

Frequency (MHz)	MaxPeak (dBµV/m)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)
2012.277000	34.79	---	74.00	39.21	1000.000	103.0	V	-129.0
2012.277000	---	22.04	54.00	31.96	1000.000	103.0	V	-129.0
3717.364000	38.22	---	74.00	35.78	1000.000	104.0	V	180.0
3717.364000	---	25.46	54.00	28.55	1000.000	104.0	V	180.0
4882.288000	---	40.54	54.00	13.46	1000.000	107.0	H	147.0
4882.288000	48.78	---	74.00	25.22	1000.000	107.0	H	147.0



Plot 49. 1-18GHz, 2480MHz, DH5

4.7 AC Conducted Emissions

Testing was performed in accordance with ANSI C63.4: 2014. These test methods are listed under the laboratory's A2LA Scope of Accreditation.

This test measures the levels emanating from the EUT's AC input port, thus evaluating the potential for the EUT to cause radio frequency interference to other electronic devices.

The AC conducted emissions of equipment under test shall not exceed the values in CFR47 Part 15.207: 2018 and RSS- GEN Sect. 8.8: 2018.

4.7.1 Test Methodology

A test program that controls instrumentation and data logging was used to automate the AC Power Line Conducted emission test procedure. The frequency range of interest was divided into sub-ranges such as to yield a frequency resolution of 9 kHz. Each phase and neutral of the AC power line were measured with respect to ground. Measurements were performed using a set of 50μH / 50Ω LISNs.

Testing is performed in Lab 2. The setup photographs clearly identify which site was used. The vertical ground plane used in the semi-anechoic chamber is a 2m x 2m solid aluminum frame and panel, and it is bonded to the horizontal ground plane.

In the case of tabletop equipment, the EUT is placed on a 1.0m x 1.5m non-conductive table 80cm above the ground plane and 40cm from a vertical ground reference plane. The rear of the EUT was positioned flush with the backside of the table and directly over the LISNs. The power and I/O cables were routed over the edge of the table and bundled approximately 40cm from the ground plane. Support equipment was powered from a separate LISN.

4.7.1.1 *Deviations*

There were no deviations from this test methodology.

4.7.2 Test Results

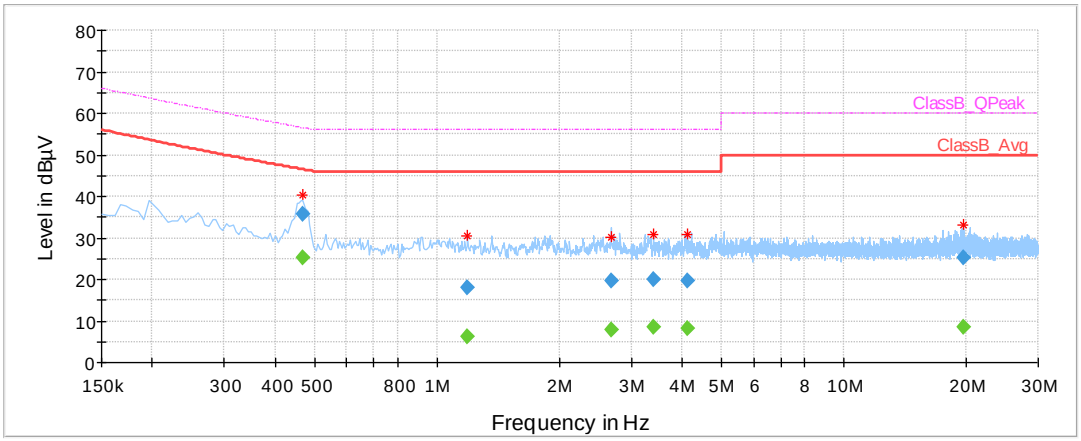
As originally tested, the EUT was found to be compliant to the requirements of the test standard(s).

Table 7: AC Conducted Emissions – Test Results

Test Conditions: Conducted Measurement at Normal Conditions only		
AC Power: 120 Vac/60 Hz	**Configuration:** Tabletop	
Configuration	**Frequency Range**	**Test Result**
Line 1 (Hot)	0.15 to 30 MHz	Pass
Line 2 (Neutral)	0.15 to 30 MHz	Pass

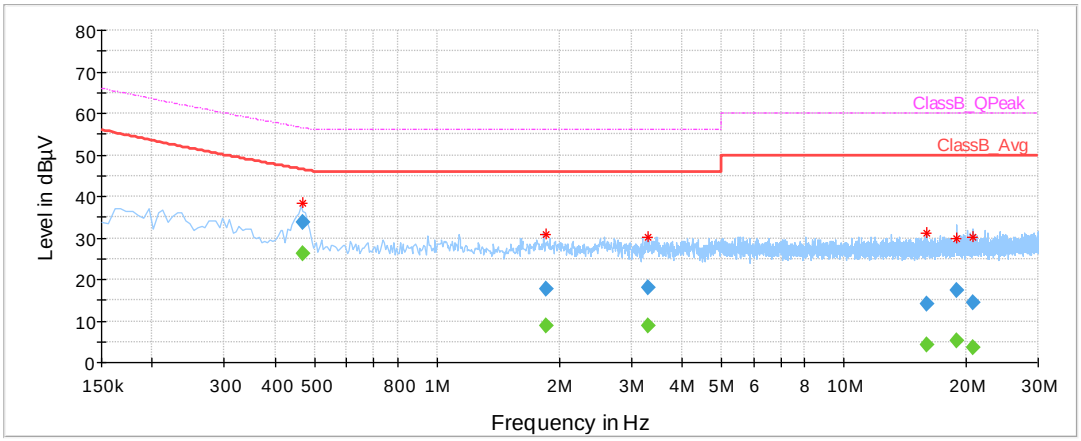
Live Line

Frequency (MHz)	QuasiPeak (dBµV)	Average (dBµV)	Limit (dBµV)	Margin (dB)	Bandwidth (kHz)	Line
0.466403	---	25.10	56.53	31.44	10.000	L1
0.466403	35.81	---	46.53	10.71	10.000	L1
1.184676	---	6.28	56.00	49.72	10.000	L1
1.184676	17.94	---	46.00	28.06	10.000	L1
2.688190	---	7.78	56.00	48.22	10.000	L1
2.688190	19.53	---	46.00	26.47	10.000	L1
3.407486	---	8.41	56.00	47.59	10.000	L1
3.407486	20.02	---	46.00	25.98	10.000	L1
4.112786	---	8.16	56.00	47.84	10.000	L1
4.112786	19.56	---	46.00	26.44	10.000	L1
19.600919	---	8.42	60.00	51.58	10.000	L1
19.600919	25.25	---	50.00	24.75	10.000	L1



Neutral Line

Frequency (MHz)	QuasiPeak (dBµV)	Average (dBµV)	Limit (dBµV)	Margin (dB)	Bandwidth (kHz)	Line
0.467485	---	26.08	56.52	30.43	10.000	N
0.467485	33.78	---	46.51	12.72	10.000	N
1.848046	---	8.88	56.00	47.12	10.000	N
1.848046	17.57	---	46.00	28.43	10.000	N
3.308667	---	8.87	56.00	47.13	10.000	N
3.308667	17.91	---	46.00	28.09	10.000	N
15.979910	---	4.13	60.00	55.87	10.000	N
15.979910	14.10	---	50.00	35.90	10.000	N
18.854459	---	5.34	60.00	54.66	10.000	N
18.854459	17.30	---	50.00	32.70	10.000	N
20.774198	---	3.57	60.00	56.43	10.000	N
20.774198	14.57	---	50.00	35.43	10.000	N



5 Test Equipment Use List

5.1 Equipment List

Equipment	Manufacturer	Model #	Serial/Inst #	Last Cal mm/dd/yyyy	Next Cal mm/dd/yyyy
Spectrum Analyzer	Rohde & Schwarz	FSU26.5	1166.1660.26	02/23/2020	02/23/2021
EMI Receiver	Rohde & Schwarz	ESW44	101663-dv	07/18/2019	07/18/2021
L.I.S.N.	Com-Power	LI-215	192000	01/16/2019	01/16/2021
Transient Limiter	Com-Power	LIT-930	531582	01/16/2019	01/16/2021
Preamplifier, 9 kHz – 1 GHz	Sonoma	310N	213221	01/16/2019	01/16/2021
Bilog Antenna	Sunol Sciences	JB3	A061907	12/19/2018	12/19/2020
Amplifier	Miteq	TTA1800-30-HG	1842452	01/15/2019	01/15/2021
Horn Antenna	Sunol Sciences	DRH-118	A040806	03/05/2019	03/05/2021
Amplifier	HP	8449B	3008A01013	06/08/2020	06/08/2022
1.6 GHz Low Pass Filter	K&L Microwave	8L120-X1600-0/09135-0249	UA691-35	N/A (See Note)	
2.4GHZ Band Pass Filter	Microtronics	BRM50702	009	N/A (See Note)	

Note: Equipment is characterized before use.

6 EMC Test Plan

6.1 Introduction

This section provides a description of the Equipment Under Test (EUT), configurations, operating conditions, and performance acceptance criteria. It is an overview of information provided by the manufacturer so that the test laboratory may perform the requested testing.

6.2 Customer

Table 8: Customer Information

Company Name	Eleven Forty Three A.M. LLC
Address	1661 International Drive, Suite 400
City, State, Zip	Memphis, TN 38120
Country	U.S.A.

Table 9: Technical Contact Information

Name	Pamela A. Jasinski
E-mail	1143amllc@gmail.com

6.3 Equipment Under Test (EUT)

Table 10: EUT Specifications

EUT Specifications	
AC Input	120 VAC, 60Hz
Environment	Indoor/Outdoor
Operating Temperature Range:	0 to 35 degrees C
Multiple Feeds:	☐ Yes and how many ☒ No
Product Marketing Name (PMN)	Echo Frames
Hardware Version Identification Number (HVIN)	Ver1
Firmware Version Identification Number (FVIN)	1125306
Bluetooth Radio	
Operating Mode	BDR and EDR
Transmitter Frequency Band	2402 MHz to 2480 MHz
Operating Bandwidth	1 MHz
Max. Power Output	11.35 dBm Conducted
Antenna Type	PIFA
Antenna Gain	2.1 dBi
Modulation Type	GFSK, π/4-DQPSK and 8DPSK
Data Rate	1 Mbps, 2Mbps, and 3Mbps
Note: 1. This report only documents the radio characteristics for 2402 - 2480 MHz bands.	

Table 11: Interface Specifications

Interface Type	Cabled with what type of cable?	Is the cable shielded?	Maximum potential length of the cable?	Metallic (M), Coax (C), Fiber (F), or Not Applicable?
USB (used for data communication)	USB	☒ No	☒ Metric: 3 m	☒ M
Note: These USB cables were use for test purposes only.				

Table 12: Supported Equipment

Equipment	Manufacturer	Model	Serial	Used for
Note:				

Table 13: Description of Sample used for Testing

Device	Serial	RF Connection	CFR47 Part 15.247
Echo Frames	N/A	Integrated Antenna	Radiated Emissions Conducted Emissions
		Direct via SMA Connection	Transmit Power, Occupied Bandwidth, Out of Band Emission, Hopping Requirement

Table 14: Description of Test Configuration used for Radiated Measurement.

Device	Antenna	Mode	Setup Photo (X-Axis)	Setup Photo (Y-Axis)	Setup Photo (Z-Axis)
Echo Frames	PIFA	Transmit	EUT Upright	N/A	N/A
Note: EUT was tested on its X –Axis, which was its worse case.					

6.4 Test Specifications

Testing requirements

Table 15: Test Specifications

Emissions and Immunity	
Standard	Requirement
CFR 47 Part 15.247: 2020	All

END OF REPORT