Project 22480-15

Hetronic
CSM2400FH Radio Module

Wireless Certification Report

Prepared for:

Hetronic
3905 NW 36th St.
Oklahoma City, OK 73112

By

Professional Testing (EMI), Inc.
1601 North A.W. Grimes Blvd., Suite B
Round Rock, Texas 78665

11 November 2021

Written by

Larry Finn
Chief Technical Officer

Revision History

Revision Number	Description	Date
Draft01	Draft release for review	25 Oct 2021
Final01	Initial release to agency	01 Nov 2021
Final02	Added power info for module	11 Nov 2021

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Compliance Certificate

FCC MRA Designation Number: US5270 NVLAP Accreditation Number: 200062-0

Applicant	Device & Test Identification	
Hetronic	FCC ID:	LW9-CSM2400FH
3905 NW 36th St.	Industry Canada ID:	2119B-CSM2400FH
Oklahoma City, OK 73112 USA	Model(s):	CSM2400FH
Certificate Date: 11 Nov 2021	Laboratory Project ID:	22480-15

The device named above was tested utilizing the following standards and found to be in compliance with the required criteria:

Requirement	Reference	Detail
FCC 47 CFR Part 15 C	15.247	Operation within the bands 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz.
FCC 47 CFR Part 15 C	15.209	Radiated emission limits; general requirements.
FCC 47 CFR Part 15 C	15.205	Restricted Bands of Operation
KDB 558074 D01	DR01	DTS Measurement Guidance v03r02
KDB 412172	D01	Guidelines for Determining the ERP and EIRP of an RF Transmitting System
OET Bulletin 65*	Edition 97-01, and Supplement C, Ed. 01-01	Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields
RSS-247	Issue 2	Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and Licence-Exempt Local Area Network (LE-LAN) Devices
RSS-Gen	Issue 5 Amd 1	General Requirements and Information for the Certification of Radio Apparatus
RSS-102	Issue 5	Radio Frequency (RF) Exposure Compliance of Radiocommunication Apparatus (All Frequency Bands)

*MPE is reported separately from this document. **Corresponding RSS references are listed in the body of the report.

I, Larry Finn, for Professional Testing (EMI), Inc., being familiar with the above requirements and test procedures have reviewed the test setup, measured data, and this report. I believe them to be true and accurate.

TESTING
NVLAP LAB CODE 200062-0

Larry Finn
Chief Technical Officer

This report has been reviewed and accepted by the Applicant**.** The undersigned is responsible for ensuring that this device will continue to comply with the requirements listed above.

_____
Representative of Applicant

1.0 Introduction

1.1 Scope

This report describes the extent to which the equipment under test (EUT) conformed to the intentional radiator requirements of the United States and Canada.

Professional Testing (EMI), Inc., (PTI) follows the guidelines of National Institute of Standards and Technology (NIST) for all uncertainty calculations, estimates, and expressions thereof for electromagnetic compatibility testing.

1.2 EUT Description

Table 1.2.1: Equipment Under Test		
Manufacturer / Model	**Serial #**	**Description**
Hetronic CSM2400FH Radio Module	none	Full duplex dual output frequency hopping radio module operating in the 2400-2483.5 MHz band

1.3 EUT Test Configuration

The EUT was exercised in a manner consistent with normal operations. The CSM2400 Radio Module is designed with two antenna ports which operate simultaneously. Both ports transmit the same signals for redundant backup operation. The CSM2400FH Radio Module will operate under battery power or receive power from a vehicle power system (no AC mains derived power will be used to power the device).

Figure 1.3: CSM2400FH Radio Module

1.4 Modifications to Equipment

The radio power level was adjusted to setting ‘13’.

1.5 Test Site

Measurements were made at the PTI semi-anechoic facility designated Site 45 (FCC 776781, IC 3036B-1) in Austin, Texas. The site is registered with the FCC under Section 2.948 and Industry Canada per RSS-GEN, and is subsequently confirmed by laboratory accreditation (NVLAP). The test site is located at 11400 Burnet Road, Austin, Texas 78758, while the main office is located at 1601 North A.W. Grimes Boulevard, Suite B, Round Rock, Texas, 78665. CAB Identifier: US 0123.

1.6 Radiated Measurements

Table 1.6 1 Measurement Corrections	
Parameter	**From Sums Of**
Radiated Field Strength	Raw Measured Level + Antenna Factor + Cable Losses – Amplifier Gain
Conducted Antenna Port	Raw Measured Level + Attenuator Factor + Cable Losses
Conducted Mains Port	Raw Measured Level + LISN Factor + Cable/Filter/Limiter Losses

Additionally, measurement distance extrapolation factors (such as 1/d above 30 MHz) are applied and documented where used.

1.7 Additional Documents Applied

Table 1.7.1: Additional Documents Applied	
Document	**Title**
ANSI C63.10:2013	American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices
FCC KDB 662911	Emissions Testing of Transmitters with Multiple Outputs in the Same Band

2.0 Frequency Hopping Parameters; Clause 15.247(a)(1); RSS-247 5.1

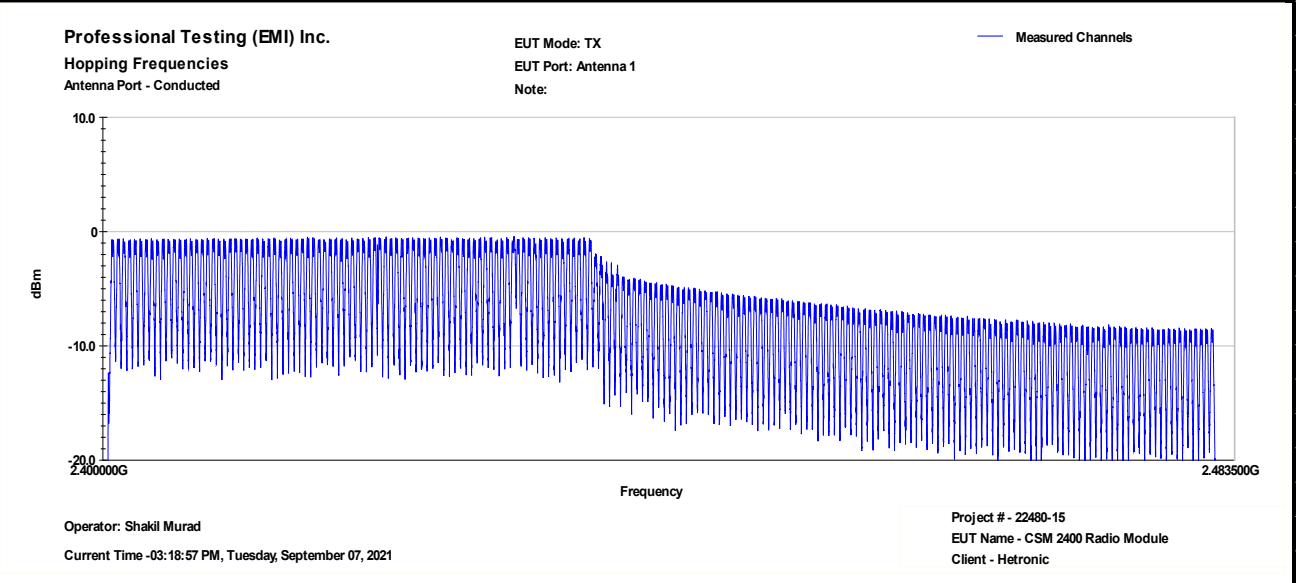
The CSM2400FH Radio Module utilizes 200 channels in a pseudo-random hopping sequence.

2.1 Test Procedure

The CSM2400FH module was connected through a 20dB attenuator to the spectrum analyzer. The radio was allowed to hop normally while the analyzer was in max hold mode. Both antenna ports yielded the same number of channels, as shown in Figure 2.1a below. The radio power setting was initially set to '20' for hopping channel parameter measurements. The power setting was reduced to '13' for all other measurements. Power setting '13' will be the final power setting for production.

The same setup was used for channel separation and channel occupancy time measurements. Hopping parameter measurements were made from 9/7/2021 – 9/15/2021.

Hopping Frequencies - Conducted Test Data																					
Environmental Conditions:	Temperature	20.5	°C	Humidity	55	RH	Barometric Pressure	29.98	in Hg												
Measurement Parameters:	RBW	100	kHz	VBW	300	kHz	Span	1	MHz	Detector	Peak										
Manufacturer Listed Hopping Channels				Measured Channels			Test Result														
200				200			Pass														

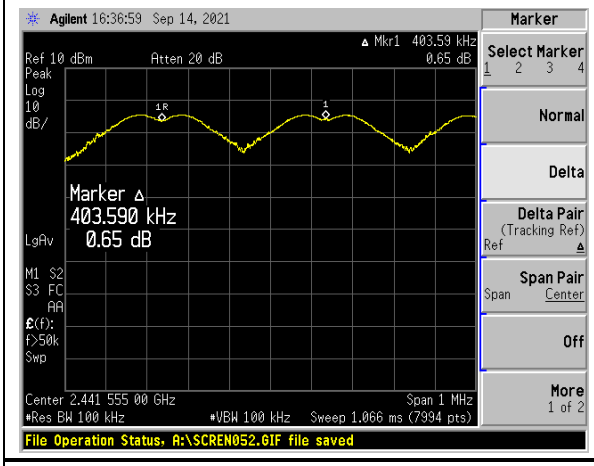


Hopping Channels																				
2400.7	2401.2	2401.5	2402.0	2402.3	2402.7	2403.1	2403.5	2403.9	2404.4	2404.7	2405.1	2405.6	2406.1	2406.4	2406.8	2407.2	2407.6	2408.1	2408.4
2408.8	2409.3	2409.6	2410.0	2410.4	2410.9	2411.2	2411.6	2412.0	2412.4	2412.8	2413.4	2413.7	2414.2	2414.6	2414.9	2415.3	2415.8	2416.1	2416.5
2417.0	2417.4	2417.7	2418.1	2418.5	2418.9	2419.3	2419.8	2420.1	2420.6	2421.0	2421.3	2421.8	2422.3	2422.6	2423.0	2423.4	2423.8	2424.2	2424.6
2425.0	2425.4	2425.8	2426.2	2426.7	2427.1	2427.6	2427.9	2428.4	2428.8	2429.1	2429.5	2430.0	2430.4	2430.7	2431.1	2431.5	2431.9	2432.3	2432.7
2433.1	2433.5	2434.0	2434.4	2434.8	2435.2	2435.6	2436.1	2436.4	2436.8	2437.2	2437.6	2438.1	2438.5	2438.9	2439.3	2439.6	2440.0	2440.5	2440.9
2441.2	2441.6	2442.1	2442.5	2442.8	2443.3	2443.7	2444.1	2444.6	2444.9	2445.3	2445.7	2446.1	2446.5	2446.9	2447.3	2447.7	2448.2	2448.5	2448.9
2449.3	2449.7	2450.2	2450.5	2450.9	2451.3	2451.9	2452.2	2452.7	2453.1	2453.4	2453.8	2454.3	2454.6	2455.0	2455.4	2455.9	2456.3	2456.6	2457.0
2457.5	2458.0	2458.3	2458.7	2459.1	2459.5	2459.9	2460.3	2460.7	2461.2	2461.6	2461.9	2462.3	2462.8	2463.1	2463.5	2463.9	2464.4	2464.7	2465.2
2465.6	2466.0	2466.4	2466.8	2467.2	2467.7	2468.0	2468.4	2468.9	2469.2	2469.6	2470.0	2470.4	2470.8	2471.2	2471.6	2472.1	2472.5	2472.9	2473.3
2473.7	2474.1	2474.5	2474.9	2475.3	2475.8	2476.1	2476.5	2476.9	2477.3	2478.1	2478.5	2478.9	2479.3	2479.8	2480.1	2480.5	2480.9	2481.4	2481.8

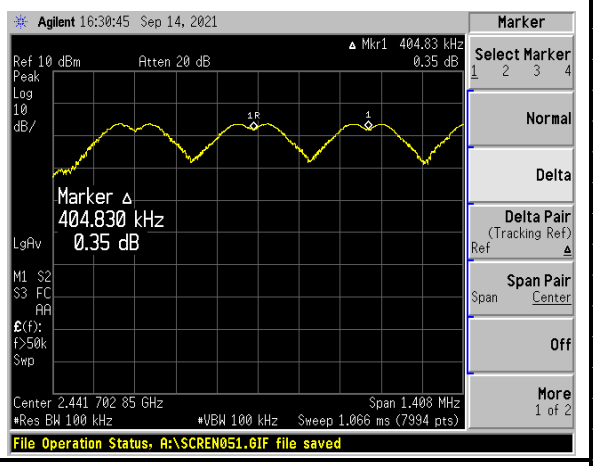
Figure 2.1a: Hopping Channel Listing

Hopping Frequency Separation

Carrier Frequency Separation - Conducted Test Data														
Environmental Conditions:	Temperature	20.5	°C	Humidity	55	RH	Barometric Pressure	29.98	in Hg					
Measurement Parameters:	RBW	100	kHz	VBW	100	kHz	Span	1	MHz	Detector	Peak			
Frequency	Minimum Frequency Separation Required (kHz)			Measured Frequency Separation (kHz)			Test Result							
Adjacent channels	25			404			Pass							



Antenna Port 1



Antenna Port 2

Figure 2.1b: Hopping Channel Separation

Transmitter Occupancy Time

Port A and B yielded the same transmitter ‘on’ time, shown in Figure 2.1c below.

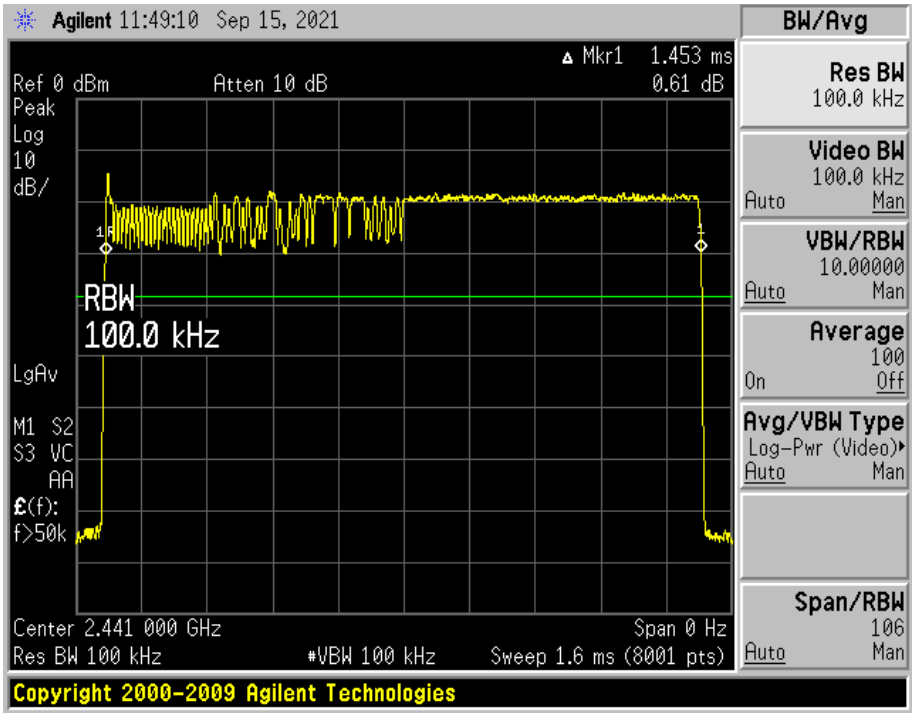


Figure 2.1c: Transmitter ‘On’ Time

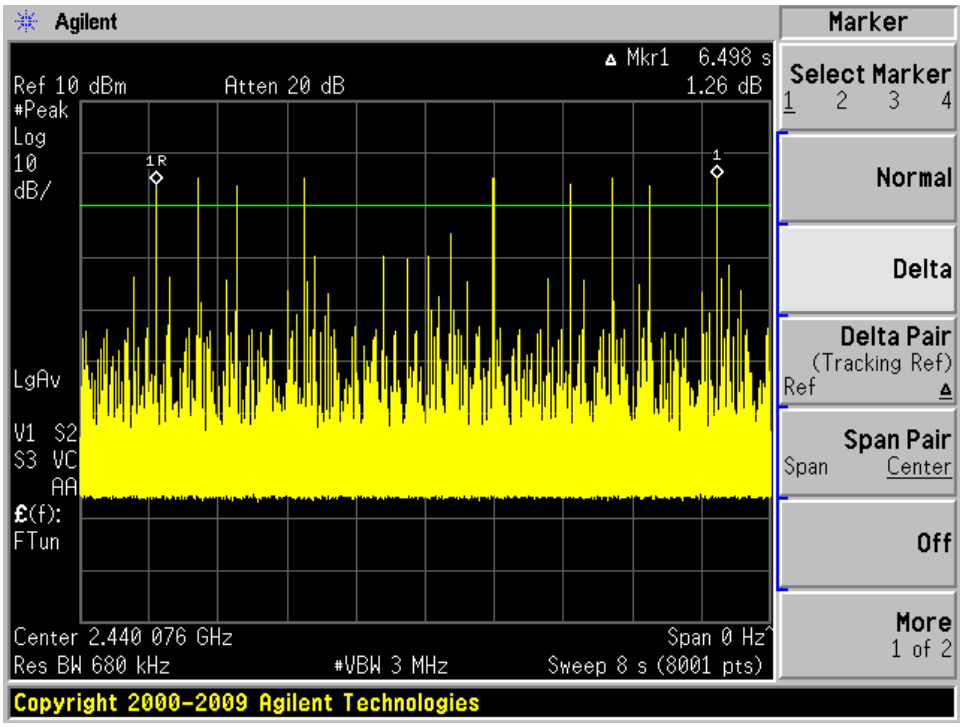


Figure 2.1d: Return to Channel Count

Hopping Channel Count -	Occupancy Period (0.4 x #Ch) (ms)	Transmitter 'On' Time (ms)	# of Transmissions (8 sec duration)	Total Occupancy Time (ms)	Occupancy Time Limit (ms)	Result -
200	80000	1.453	9	130.77	400	Pass

Occupancy time calculated as: [Transmitter on time per transmission] x [Number of transmissions over 8 sec] x [Occupancy Period / 8 sec] = 1.453ms x 9 x (80 / 8) = 130.77ms < 400ms.

Both antenna ports A and B exhibited the same occupancy time characteristics.

The EUT meets the requirements from 15.247(a)(1)(iii).

3.0 Fundamental Power; Clause 15.247(a)(3); RSS-247 5.2

3.1 Test Procedure

The CSM2400FH radio was connected through a 20dB attenuator to the spectrum analyzer for measurement. Antenna ports A and B were tested separately and summed for total output power as they transmit simultaneously during normal operation. Low, mid, and high channel output power was measured. Power measurements were made from 9/7/2021 – 9/15/2021.

3.2 Test Criteria

Conducted Power Limit
125 mW peak (20.97dBm)*

*125mW limit used per 15.247(a)(1). Maximum 20dB bandwidth was 563kHz. Minimum channel spacing was 404kHz. 2/3 of the 20dB bandwidth yields 375kHz. Since 563kHz > 404kHz > 375kHz, the maximum output power for this device was limited to 125mW.

3.3 Test Results, Peak Power (Ports A and B summed)

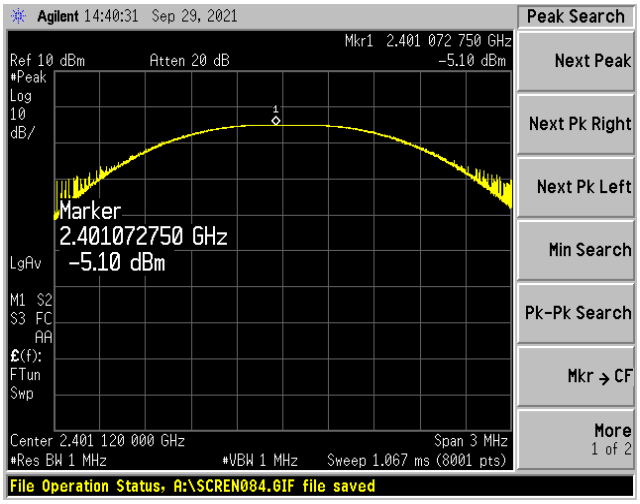
Per KDB 662911 E(1), the peak power measurements of antenna ports A and B were summed. Peak power measurements for each port were first converted into linear terms (Watts), then summed. The resulting summation was then converted back to dBm.

Channel	Frequency	Port A Peak Power		Port B Peak Power		Total Power		Limit	Result
-	(MHz)	(dBm)	(mW)	(dBm)	(mW)	(mW)	(dBm)	(dBm)	-
1	2401	15.01	31.70	15.29	33.81	65.50	18.2	20.97	Pass
100	2441	15.46	35.16	15.42	34.83	69.99	18.5	20.97	Pass
200	2481	14.96	31.33	14.55	28.51	59.84	17.8	20.97	Pass

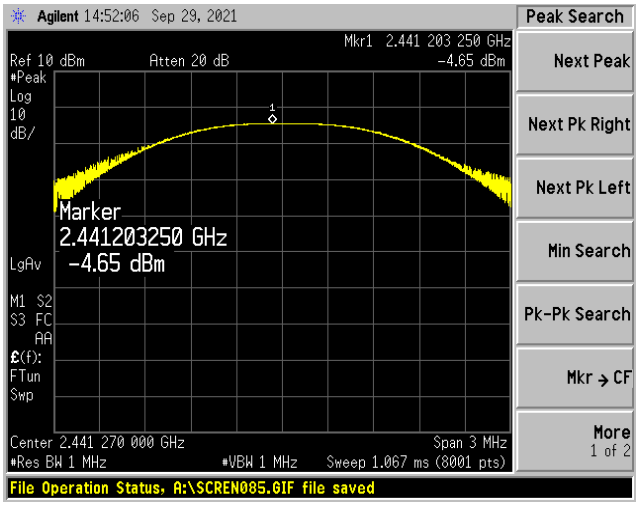
Peak output power, Port A

Peak Output Power - Conducted Test Data													
Environmental Conditions:	Temperature	20.4	°C	Humidity	53	RH	Barometric Pressure	29.98	in Hg				
EUT 20 dB Bandwidth:	0.56	MHz											
Measurement Parameters:	RBW	1	MHz	VBW	1	MHz	Span	3	MHz	Detector	Peak		

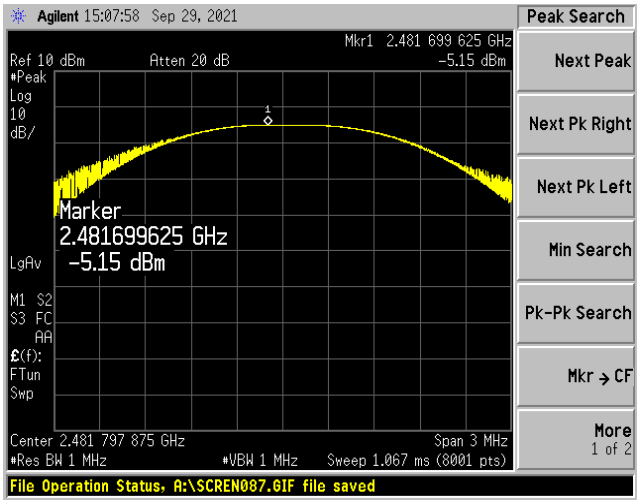
Channel	Frequency (MHz)	Measured Power (dBm)	Attenuator Factor (dB)	Corrected Power (dBm)	Limit (dBm)	Test Result
1	2401	-5.1	20.11	15.01	20.97	Pass
100	2441	-4.65	20.11	15.46	20.97	Pass
200	2481	-5.15	20.11	14.96	20.97	Pass



Low Channel



Mid Channel

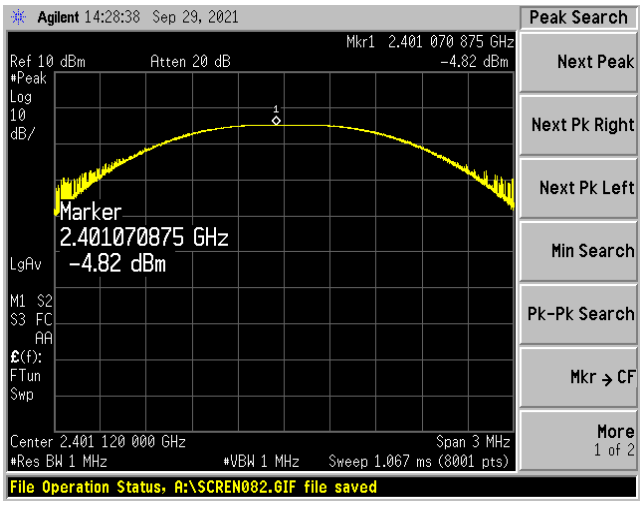


High Channel

Peak output power, Port B

Peak Output Power - Conducted Test Data													
Environmental Conditions:	Temperature	20.4	°C	Humidity	53	RH	Barometric Pressure	29.98	in Hg				
EUT 20 dB Bandwidth:	0.56	MHz											
Measurement Parameters:	RBW	1	MHz	VBW	1	MHz	Span	3	MHz	Detector	Peak		

Channel	Frequency (MHz)	Measured Power (dBm)	Attenuator Factor (dB)	Corrected Power (dBm)	Limit (dBm)	Test Result
1	2401	-4.82	20.11	15.29	20.97	Pass
100	2441	-4.69	20.11	15.42	20.97	Pass
200	2481	-5.56	20.11	14.55	20.97	Pass



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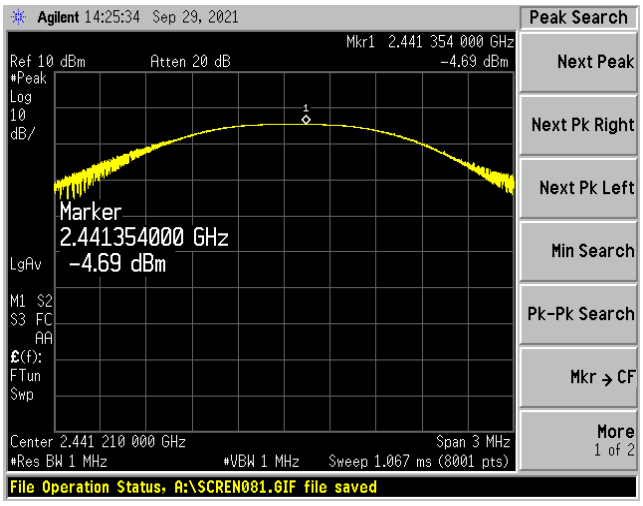
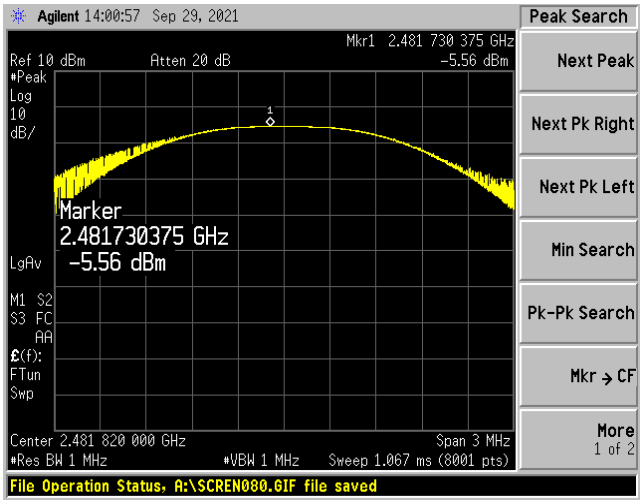


Mid Channel



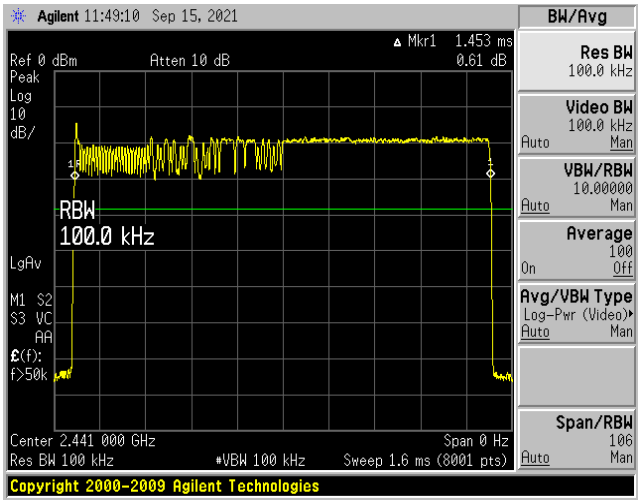
High Channel

4.0 Duty Cycle

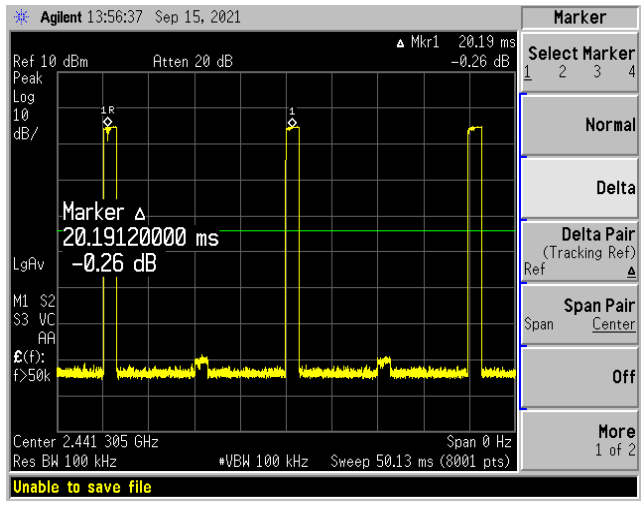
Measurement is based on intervals not to exceed 100 msec. Maximum transmitter on time is divided by the lesser of 100 msec or the actual measured minimum transmitter interval time. The result is converted to dB and applied as needed to peak measurements of transmitter artifacts to determine average power. This is not a pass/fail measurement.

Continuous packet transmission mode was used for the duty cycle measurement, which would represent a worst-case operating scenario. Duty Cycle measurement was performed on 15 Sep, 2021.

Duty Cycle - Conducted Test Data													
Environmental Conditions:	Temperature	22.2	°C	Humidity	55	RH	Barometric Pressure	29.84	in Hg				
Measurement Parameters:	RBW	100	kHz	VBW	100	kHz	Span	1	MHz	Detector	Peak		
Measured On Time (ms)	Maximum Interval (ms)			Measured Time Interval (ms)			Duty Cycle Factor (dB) (20 * Log(On time/Interval)			Duty Cycle Factor Allowed (dB)			
1.453	100			20.19			-22.9			-20.0			
RF Exposure Duty Cycle Reduction Factor (10 * Log(On Time/Period), (dB)										-11.4			



Transmitter On Time

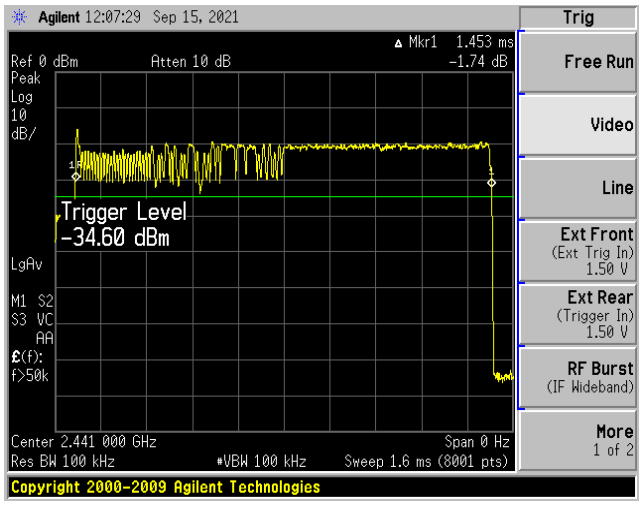


Transmitter Time Interval

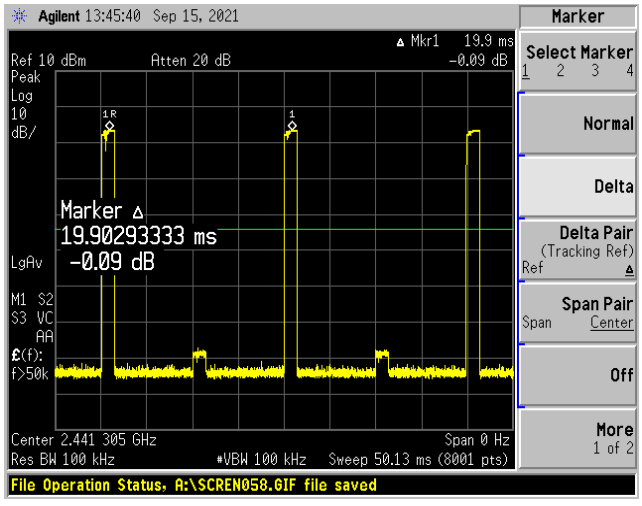
Duty Cycle, Antenna Port 'A'

Duty Cycle - Conducted Test Data													
Environmental Conditions:	**Temperature**		**22.2**	**°C**	**Humidity**		**55**	**RH**	**Barometric Pressure**			**29.84**	**in Hg**
Measurement Parameters:	**RBW**		**100**	**kHz**	**VBW**		**100**	**kHz**	**Span**		**1**	**MHz**	**Detector**	**Peak**

Measured On Time (ms)	Maximum Interval (ms)	Measured Time Interval (ms)	Duty Cycle Factor (dB) (20 * Log(On time/Interval)	Duty Cycle Factor Allowed (dB)
1.453	100	19.9	-22.7	-20.0
RF Exposure Duty Cycle Reduction Factor (10 * Log(On Time/Period), (dB)				-11.4



Transmitter On Time



Transmitter Time Interval

Duty Cycle, Antenna Port 'B'

5.0 Occupied Bandwidth; 15.247(a)(2), 2.1049; RSS-247, RSS-Gen 4.6

5.1 Test Procedure

Bandwidth is measured and recorded. The bandwidth measurement is used to verify DTS characteristics and/or for general reporting for agency application. Bandwidth measurements were made from 9/7/2021 – 9/15/2021.

5.2 Test Criteria

Bandwidth
6 dB 500 kHz minimum (non-hopping only) 20 dB (hopping only) 99% (all methods)

In cases where the software function fails to find/mark the correct edge of the modulated envelope, a manual measurement (marker-delta over display line) is taken with the same spectrum analyzer settings.

The radio was directly connected to the spectrum analyzer though a 20dB attenuator for OBW measurements. Both antenna ports A and B were measured.

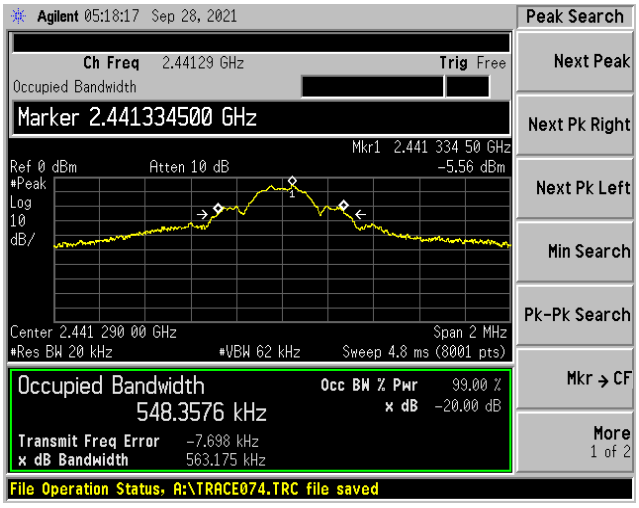
5.3 Test Results, Tabular

The requirements were satisfied. Bandwidth measurement used to determine maximum output power for device.

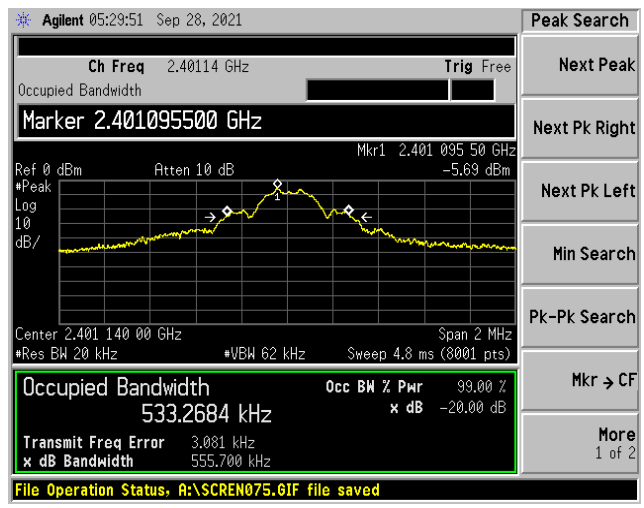
-20dB, 99% Bandwidth for Antenna Port 'A'

Occupied Bandwidth - Conducted Test Data													
Environmental Conditions:	Temperature	20.5	°C	Humidity	53	RH	Barometric Pressure	29.95	in Hg				
Measurement Parameters:	RBW	20	kHz	VBW	60	kHz	Span	2	MHz	Detector	Peak		
Measurement Bandwidth:		- 20	dB										

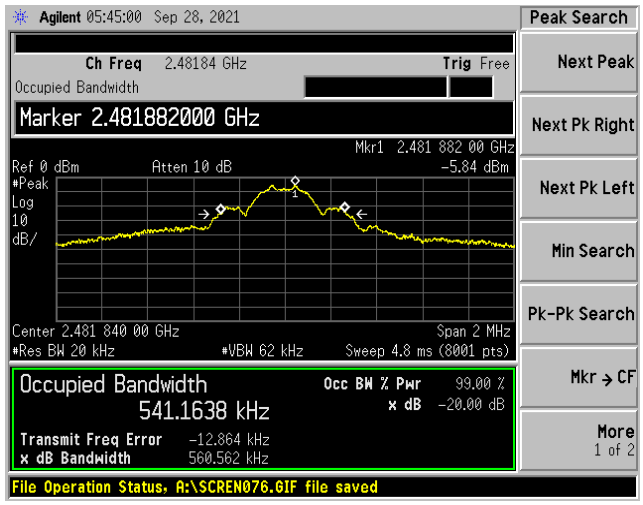
Channel	Frequency (MHz)	Measured Bandwidth (kHz)	Reported Maximum Bandwidth (kHz)
1	2401	563.175	563.175
100	2441	555.7	
200	2482	560.562	



Low Channel



Mid Channel

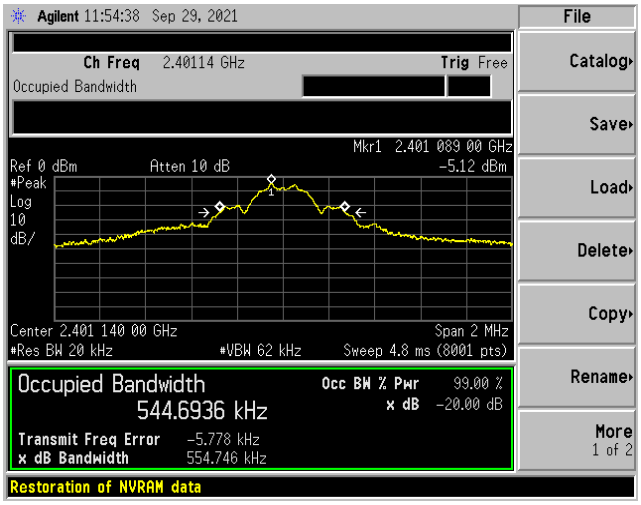


High Channel

-20dB, 99% Bandwidth for Antenna Port 'B'

Occupied Bandwidth - Conducted Test Data													
Environmental Conditions:	Temperature	20.5	°C	Humidity	53	RH	Barometric Pressure	29.95	in Hg				
Measurement Parameters:	RBW	20	kHz	VBW	60	kHz	Span	2	MHz	Detector	Peak		
Measurement Bandwidth:		- 20	dB										

Channel	Frequency (MHz)	Measured Bandwidth (kHz)	Reported Maximum Bandwidth (kHz)
1	2401	554.746	561.088
100	2441	552.368	
200	2482	561.088	



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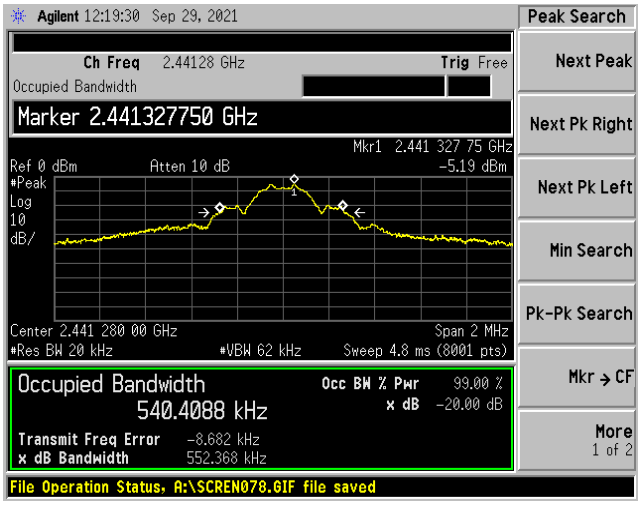
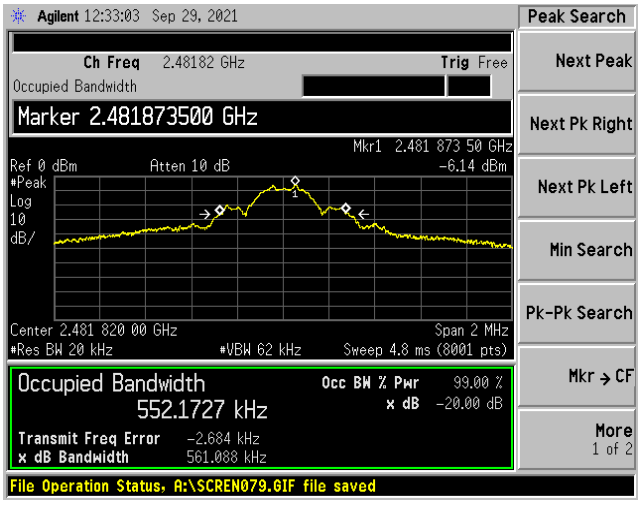


Mid Channel



High Channel

6.0 Band Edge; 15.247, 15.205; RSS-247 5.5; RSS-Gen 4.9

6.1 Test Procedure

EUT is placed into normal transmit operation on the nearest band edge channel. The spectrum analyzer is approximately centered on the band edge frequency with span sufficient to include the peak of the adjacent fundamental signal. Measurement includes at least two standard bandwidths from the respective band edge. If required, the band-edge marker-delta method is utilized. Band edge measurements were made from 9/7/2021 – 9/15/2021.

6.2 Test Criteria

Unwanted Emissions
Emissions Adjacent to Authorized Band

6.3 Test Results

Measurements included fundamental and more than 2 standard bandwidths (standard bandwidth 1 MHz) beyond the band edges to provide a clear view of the fundamental and the declining emission levels. Beyond this point, the general emission limits are applied in the radiated emission tests reported elsewhere in the report.

This is a conducted measurement with limits derived from the general emission field strength limits. The far field path loss equation is utilized to convert the field strength limits to EIRP limits in dBm as follows:

Given EIRP = $E_{dB\mu V/m} + 20Log_{10}(d) – 104.8$

EIRP = 54 dBµV/m + $20Log_{10}$(3 m) – 104.8 dB = -41.25 dBm (commonly -41 dBm is applied)

Emissions below band were measured with peak detection in 100 kHz RBW.

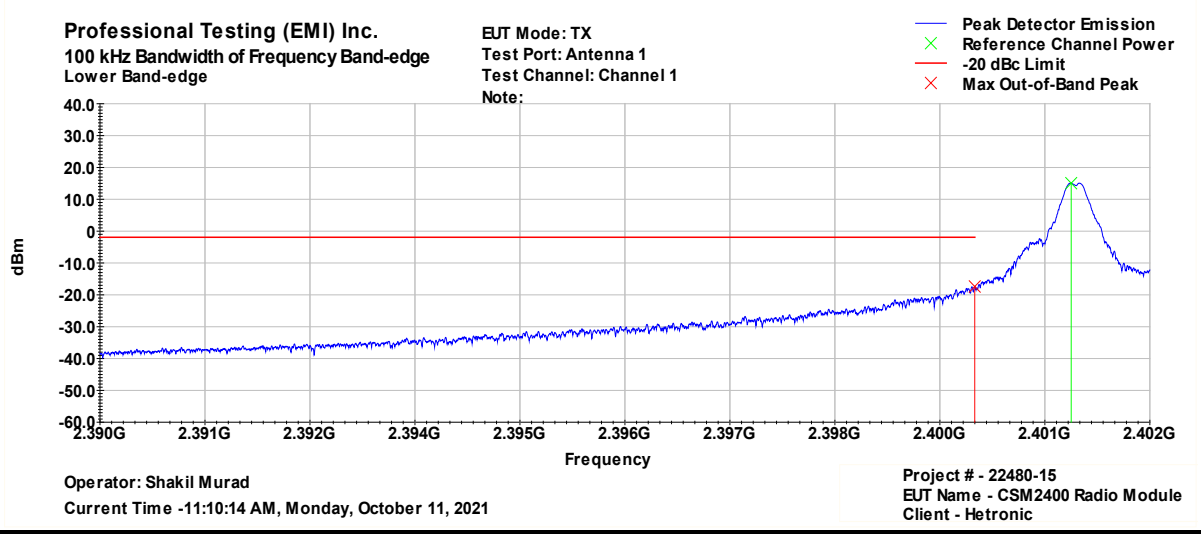
Emissions above band measured with peak detection and 1 Hz video average in 1 MHz RBW if the peak emission exceeds the average limit.

The requirement was satisfied. Plotted results appear on the following pages.

6.3.1 Antenna port A

Band-edge - Conducted Test Data													
Environmental Conditions:	Temperature	20.7	°C	Humidity	55	RH	Barometric Pressure	29.97	in Hg				
Test Port:	Antenna 1												
Measurement Parameters:	RBW	0.1	MHz	VBW	0.3	MHz	Measurement Detector	Peak					

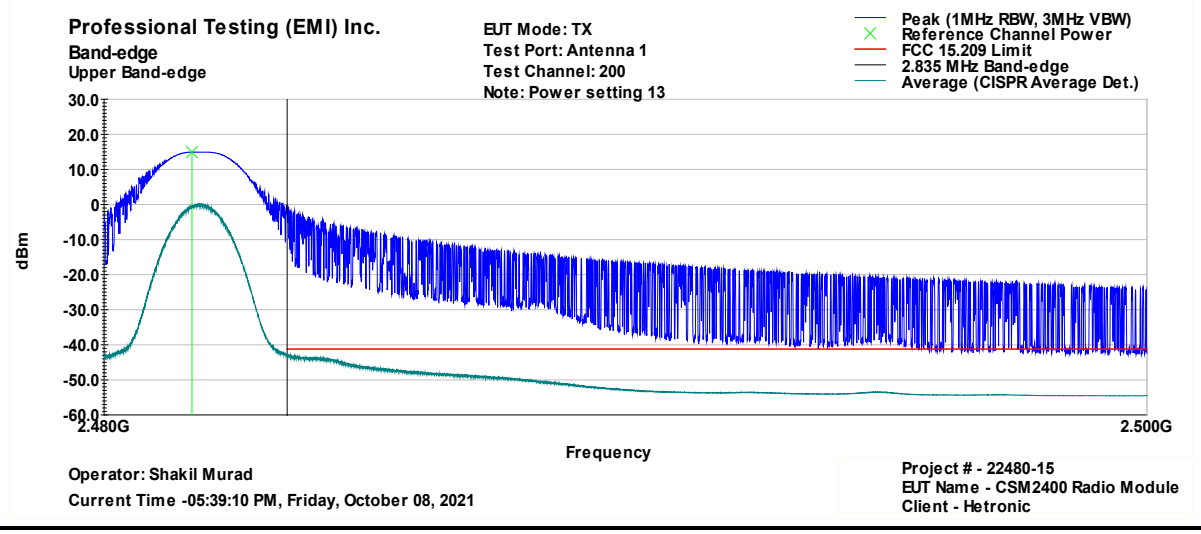
Channel	Frequency (MHz)	Max Peak Band Emission (dBm)	Max Out-of-Band Emission (dBm)	Limit (-20 dBc)	Delta (dB)	Result
Low	2401	15.044	-17.39	-4.956	12.43	Pass



Lower Band-edge

Measurement Parameters:	RBW	1	MHz	VBW	3	MHz	Measurement Detector	Average

Channel	Frequency (MHz)	Max Peak Band Emission (dBm)	Max Out-of-Band Emission (dBm)	Limit (dBm)	Delta (dB)	Result
High	2481	14.919	-42.798	-41.25	1.55	Pass

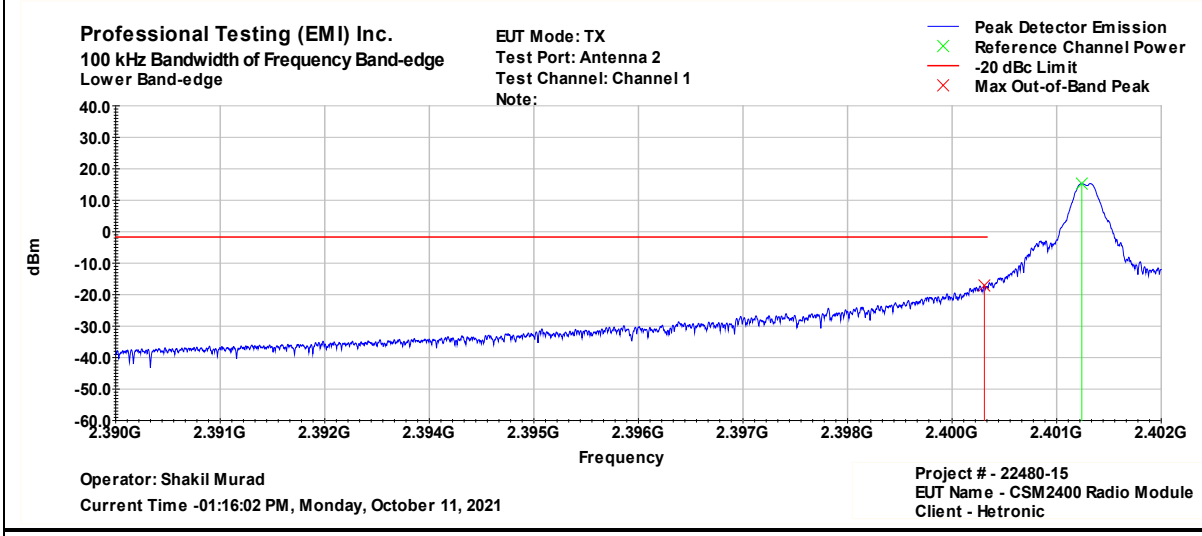


Upper Band-edge

6.3.2 Antenna port B

Band-edge - Conducted Test Data													
Environmental Conditions:	Temperature	20.7	°C	Humidity	55	RH	Barometric Pressure	29.97	in Hg				
Test Port:	Antenna 1												
Measurement Parameters:	RBW	0.1	MHz	VBW	0.3	MHz	Measurement Detector	Peak					

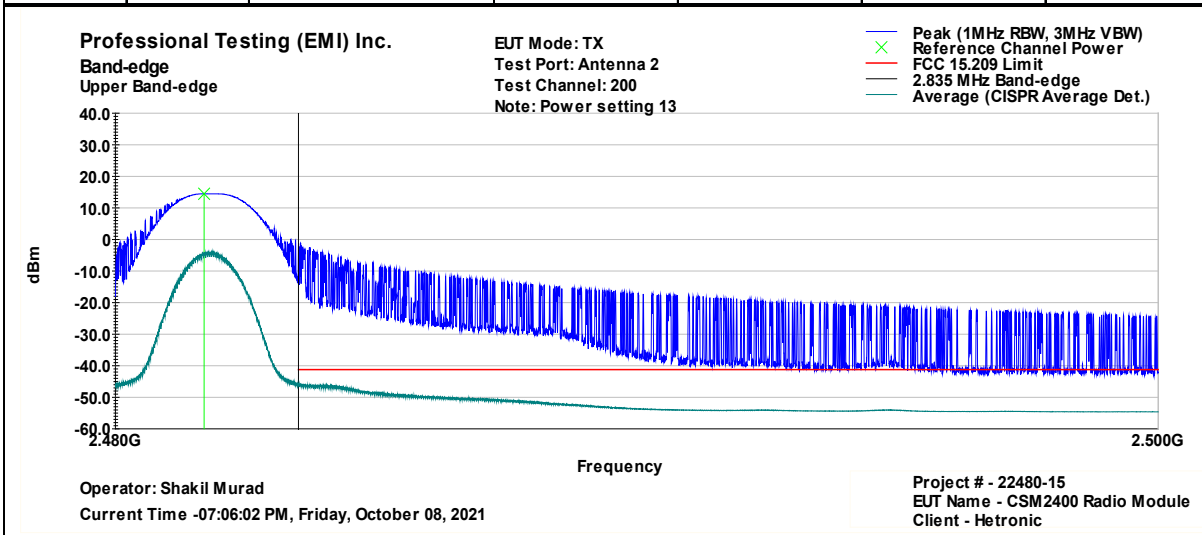
Channel	Frequency (MHz)	Max Peak Band Emission (dBm)	Max Out-of-Band Emission (dBm)	Limit (-20 dBc)	Delta (dB)	Result
Low	2401	15.282	-17.084	-4.718	12.37	Pass



Lower Band-edge

Measurement Parameters:	RBW	1	MHz	VBW	3	MHz	Measurement Detector	Average

Channel	Frequency (MHz)	Max Peak Band Emission (dBm)	Max Out-of-Band Emission (dBm)	Limit (dBm)	Delta (dB)	Result
High	2481	14.456	-45.818	-41.25	4.57	Pass



Upper Band-edge

7.0 Conducted Antenna Port Spurious Emissions, Transmit Mode; 15.247, 15.209; RSS-247 5.5, RSS-Gen 4.9 & 4.10

7.1 Test Procedure

Conducted antenna port emissions are measured with the EUT transmitting on the required frequencies. Conducted antenna port measurements were made from 10/4/2021 – 10/5/2021.

7.1.1 Test Parameters		
30 MHz to 1 GHz	**1 GHz to 18 GHz**	**18 GHz to 25 GHz**
120kHz RBW / 300kHz VBW	1MHz RBW / 3MHz VBW	1MHz RBW / 3MHz VBW
Quasi-peak	Peak & Average	Peak & Average

7.2 Test Criteria

Unwanted Emissions
Antenna Port Conducted Spurious/Harmonic Emissions Transmit Mode

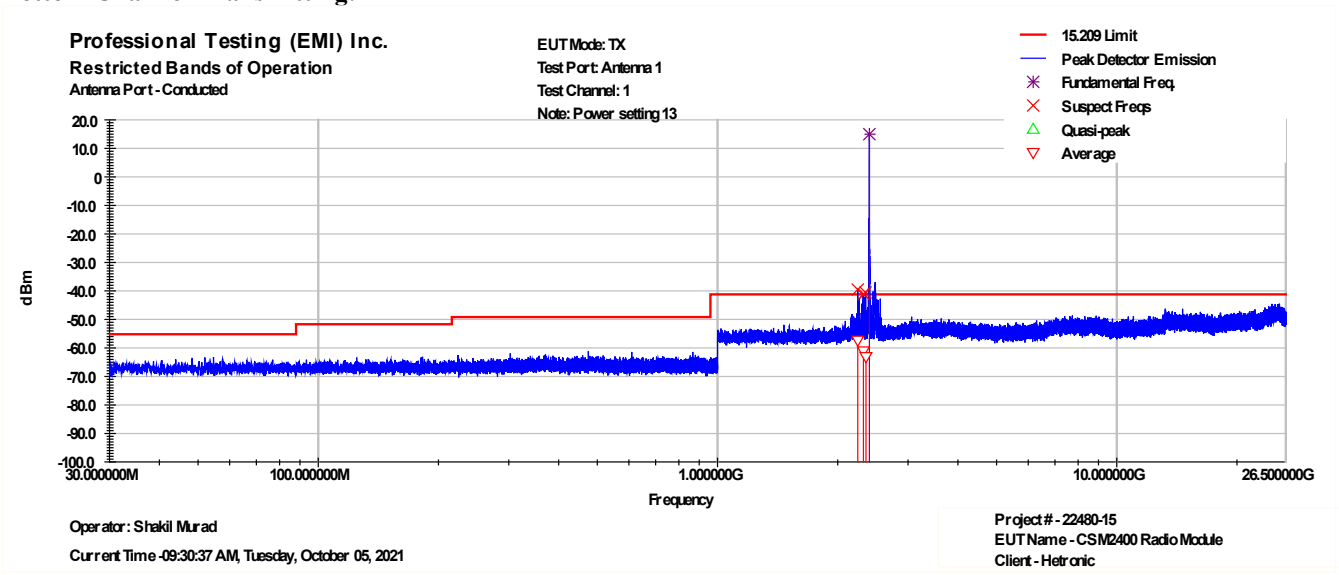
7.3 Test Results

Three channels were tested. EUT was transmitting continuously and unmodulated.

The top, middle and bottom channels were tested for each antenna port. 15.209 limits were applied to entire band for worst-case limits. The EUT satisfied the requirements.

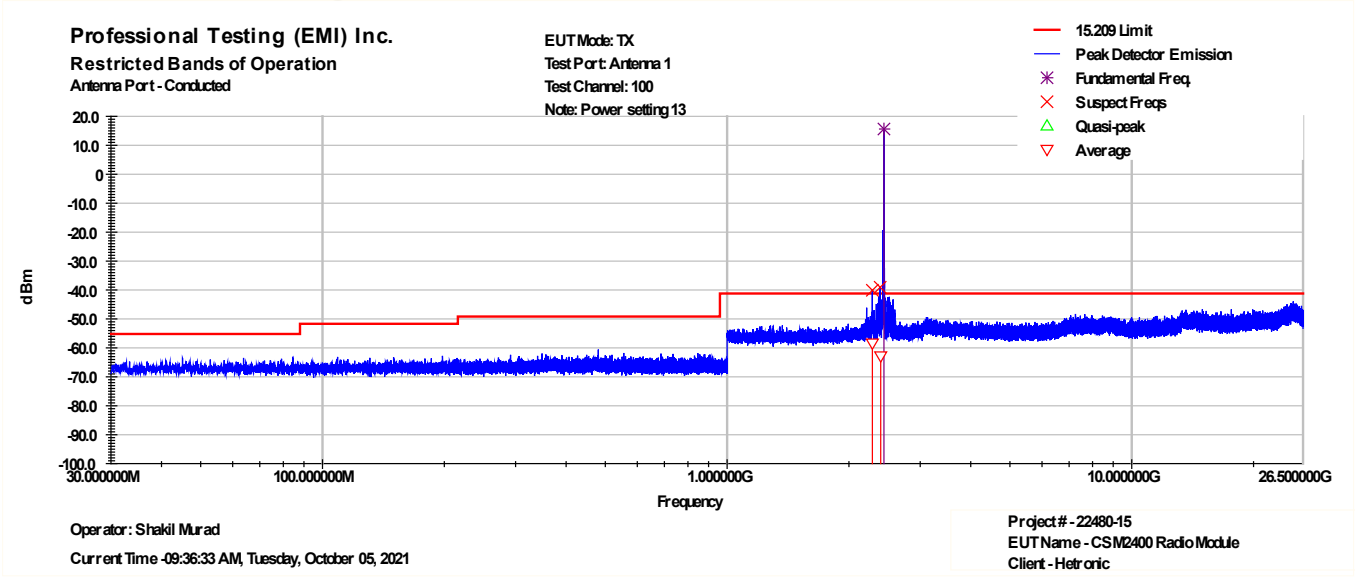
7.3.1 Antenna Port A

Bottom Channel Transmitting:



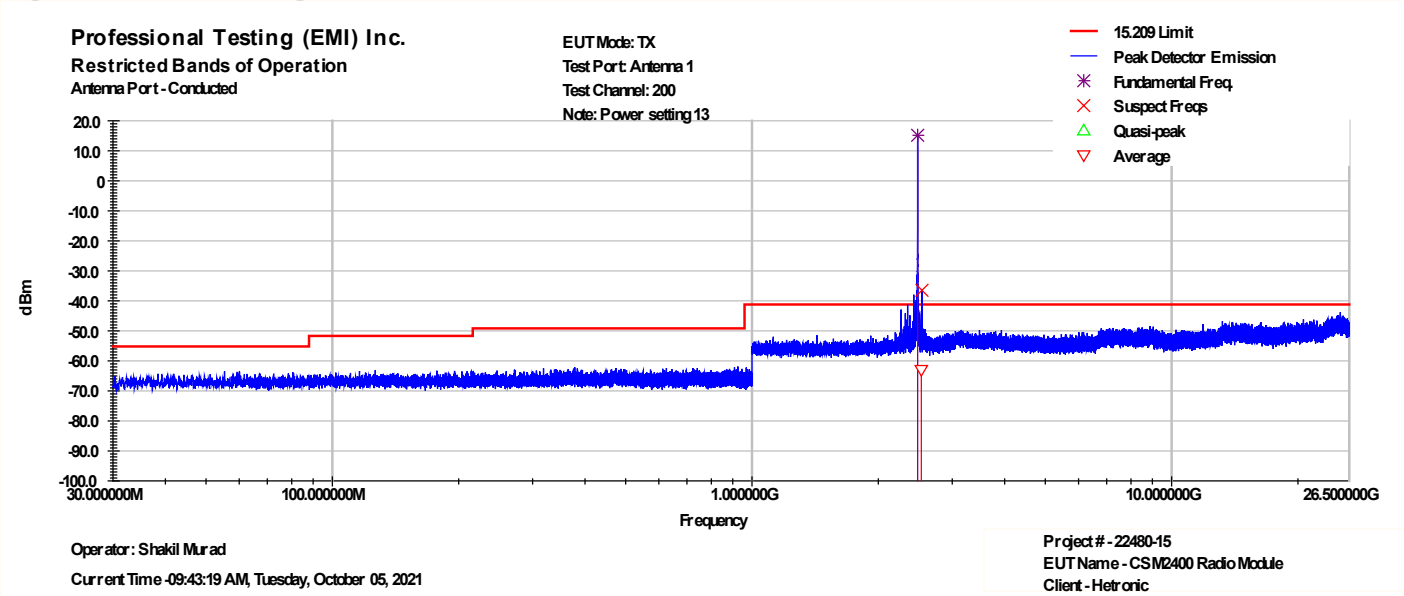
Frequency (MHz)	Corrected Level (dBm)	Limit (dBm)	Result -
2.245 GHz	-57.388	-41.25	PASS
2.320 GHz	-61.126	-41.25	PASS
2.355 GHz	-63.141	-41.25	PASS

Middle Channel Transmitting:



Frequency (MHz)	Corrected Level (dBm)	Limit (dBm)	Result -
2.285 GHz	-58.456	-41.25	PASS
2.397 GHz	-62.909	-41.25	PASS

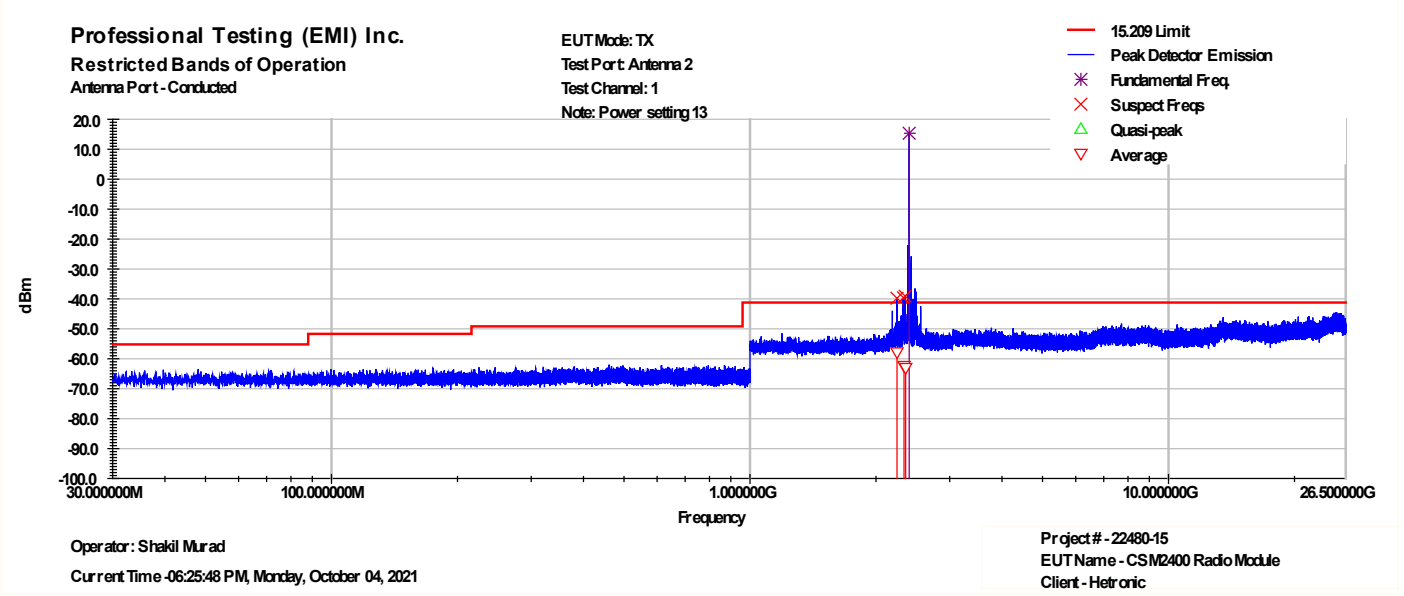
Top Channel Transmitting:



Frequency (MHz)	Corrected Level (dBm)	Limit (dBm)	Result -
2.532 GHz	-63.028	-41.25	PASS

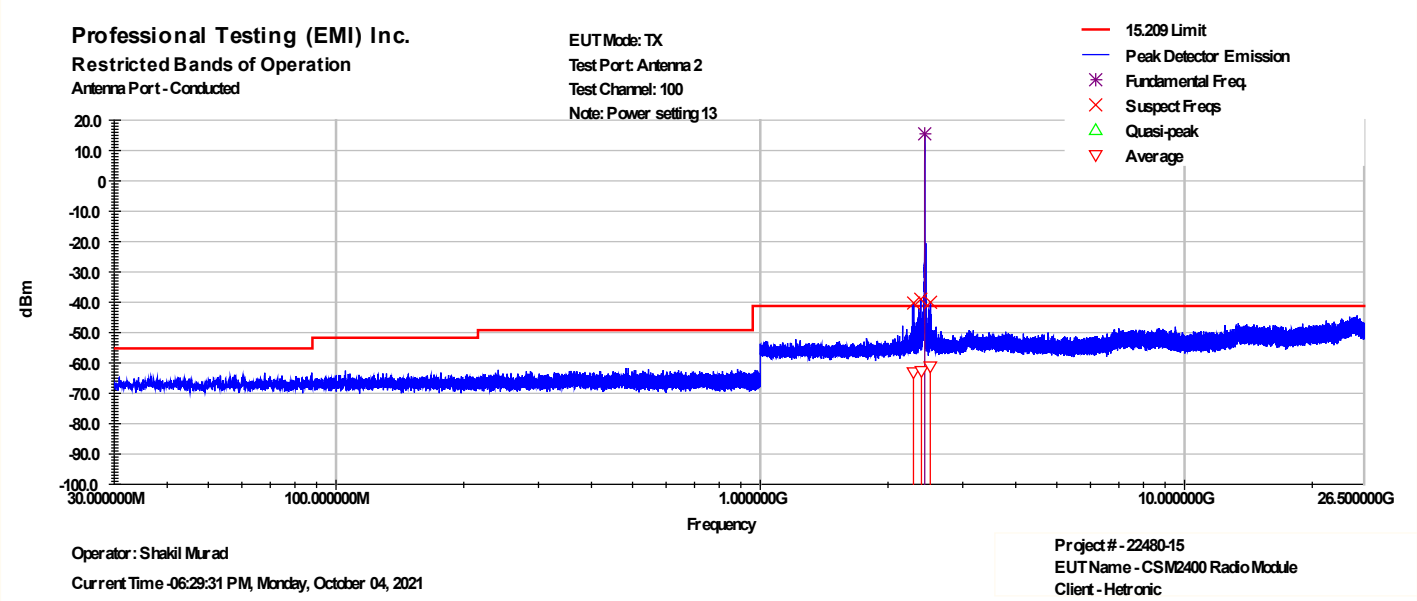
7.3.2 Antenna Port B

Bottom Channel Transmitting:



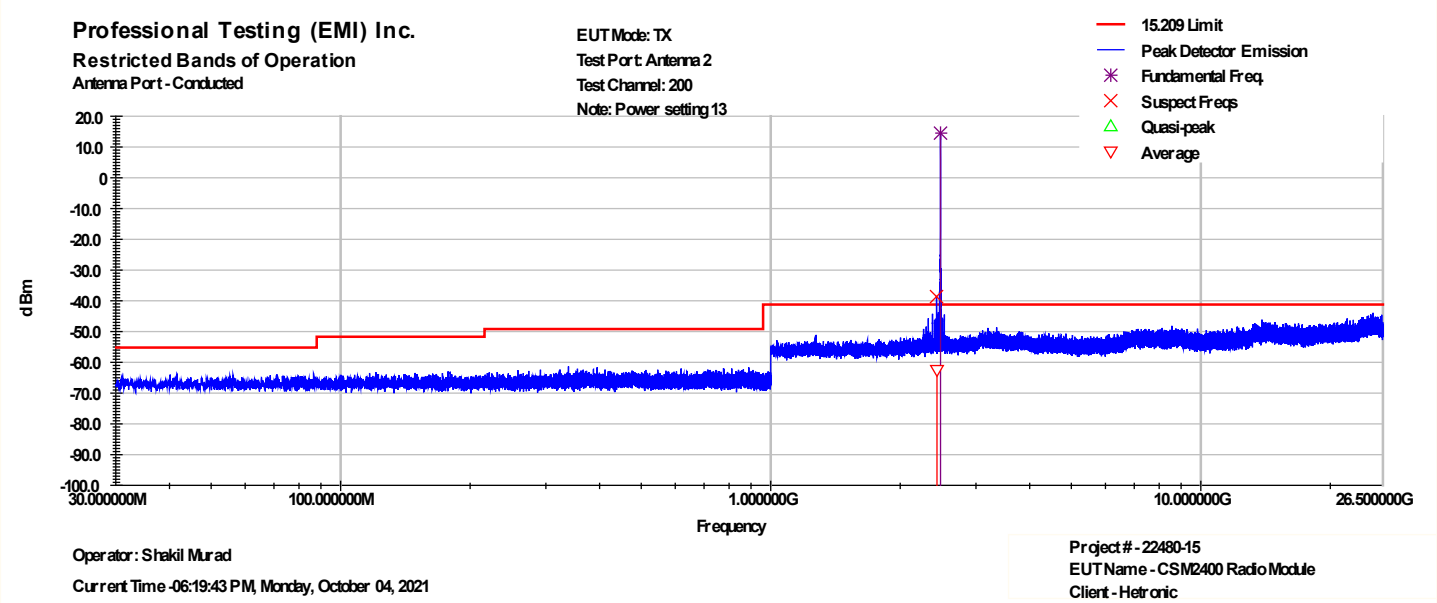
Frequency (MHz)	Corrected Level (dBm)	Limit (dBm)	Result -
2.245 GHz	-57.893	-41.25	PASS
2.334 GHz	-62.4	-41.25	PASS
2.354 GHz	-63.07	-41.25	PASS

Middle Channel Transmitting:



Frequency (MHz)	Corrected Level (dBm)	Limit (dBm)	Result -
2.297 GHz	-63.118	-41.25	PASS
2.399 GHz	-62.694	-41.25	PASS
2.517 GHz	-61.162	-41.25	PASS

Top Channel Transmitting:

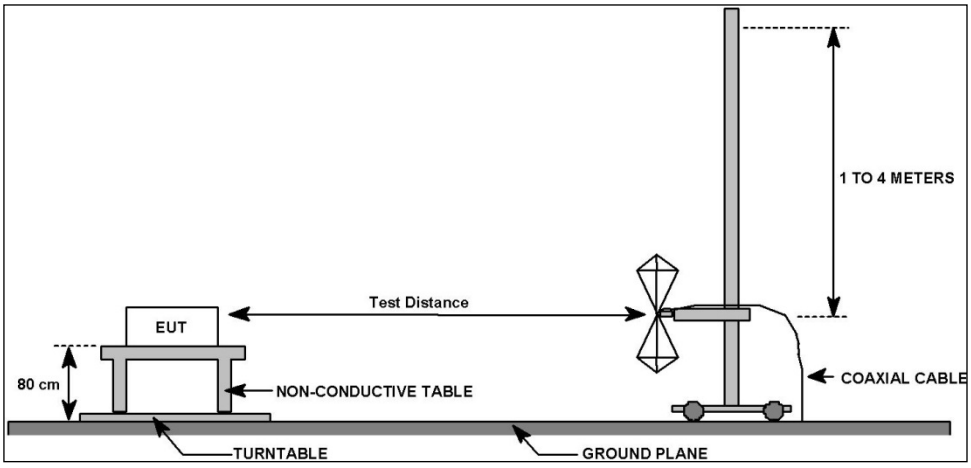


Frequency (MHz)	Corrected Level (dBm)	Limit (dBm)	Result -
2.435 GHz	-62.551	-41.25	PASS

8.0 Radiated Spurious Emissions, Transmit Mode; 15.247, 15.205; RSS-247 5.5; RSS-Gen 6.13 & 8.10

8.1 Test Procedure

Radiated emissions are measured with the EUT transmitting on the required frequencies.



6.1.1 Test Distance and Detection Method		
30 MHz to 1 GHz	**1 GHz to 18 GHz**	**18 GHz to 26.5 GHz**
10 m	3 m	1 m
Quasi-peak	Peak & Average	Peak & Average

8.2 Test Criteria

47 CFR (USA) // IC (Canada)		
Section Reference	Parameter	Date(s)
15.247(d), 15.205 // RSS-247 5.5, RSS-Gen 6.13 & 8.10	Field Strength of Radiated Spurious/Harmonic Emissions Transmit Mode	20, 22 Oct 2021

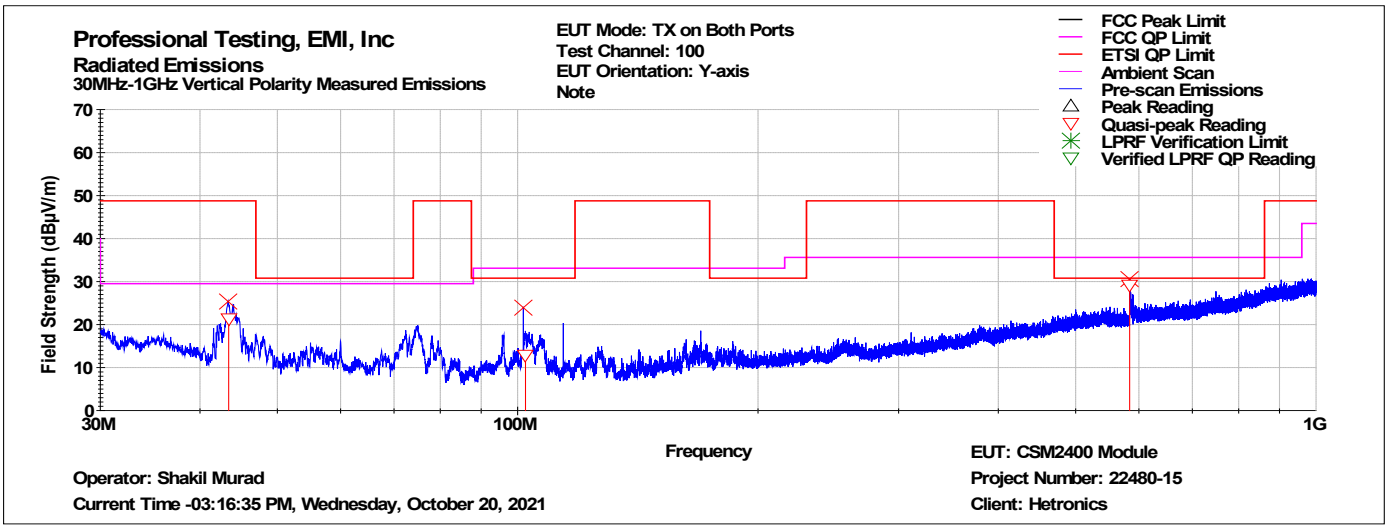
8.3 Test Results

Three channels were tested. EUT was transmitting continuously at power setting '13' on both antenna ports. Antenna ports were terminated with 50 Ohm resistive terminations. The worst-case orientation was selected for final measurements after initial prescan testing.

The EUT satisfied the requirement. Graphical and tabular data appears below.

8.3.1 Middle Channel, 30 MHz to 26.5 GHz

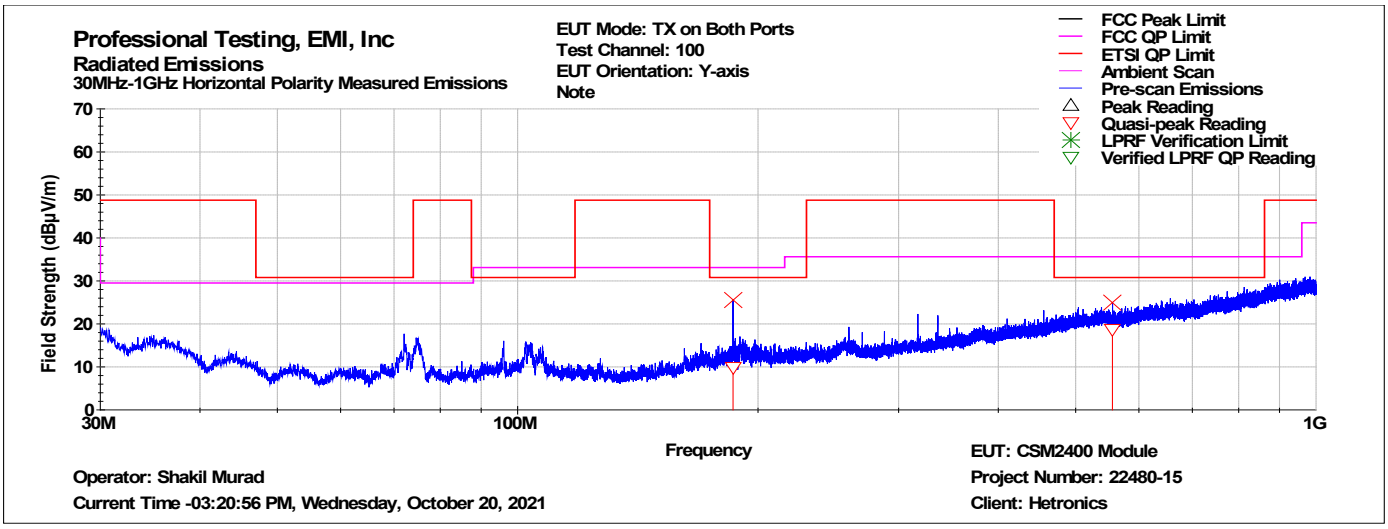
30MHz - 1GHz Vertical Polarity Measured Emissions Data



30MHz - 1GHz Vertical Polarity Measured Emissions Data - FCC

Frequency (MHz)	EUT Direction (Degrees)	Antenna Height (cm)	Quasi-peak Reading (dBµV)	Quasi-peak Limit (dBµV)	Quasi-peak Margin (dB)	Quasi-peak Results
43.450	296.000	128.000	21.214	29.500	-8.286	PASS
102.296	355.000	101.000	12.812	33.100	-20.288	PASS
584.305	20.000	412.000	29.122	35.600	-6.478	PASS

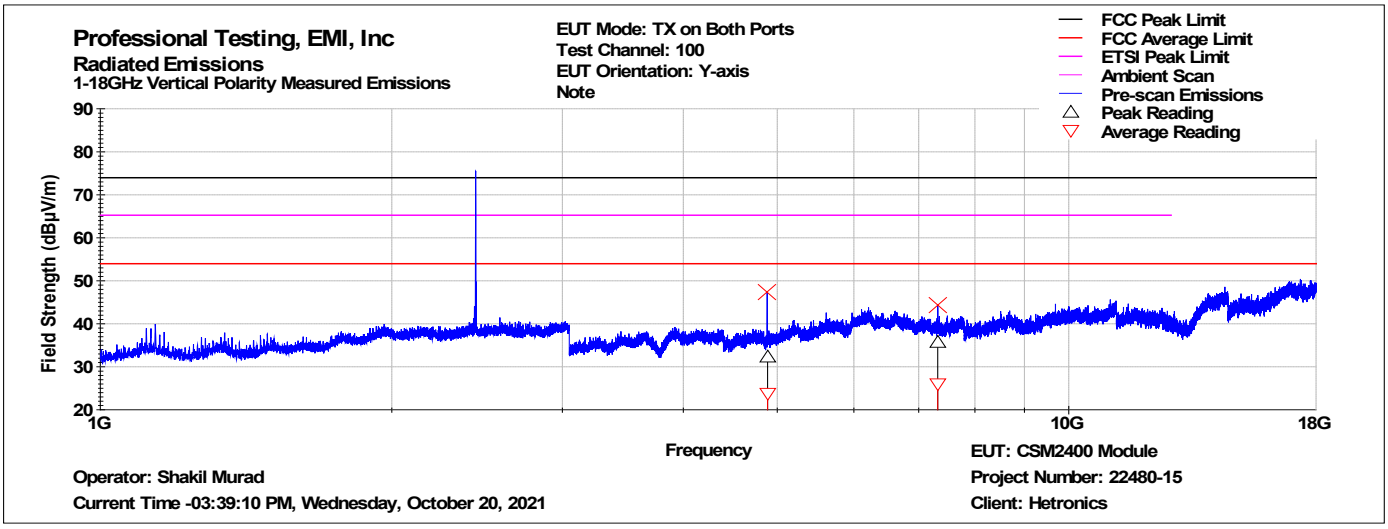
30MHz - 1GHz Horizontal Polarity Measured Emissions Data



30MHz - 1GHz Horizontal Polarity Measured Emissions Data - FCC

Frequency (MHz)	EUT Direction (Degrees)	Antenna Height (cm)	Quasi-peak Reading (dBµV)	Quasi-peak Limit (dBµV)	Quasi-peak Margin (dB)	Quasi-peak Results
186.087	300.000	348.000	9.800	33.100	-23.300	PASS
555.960	23.000	103.000	18.762	35.600	-16.838	PASS

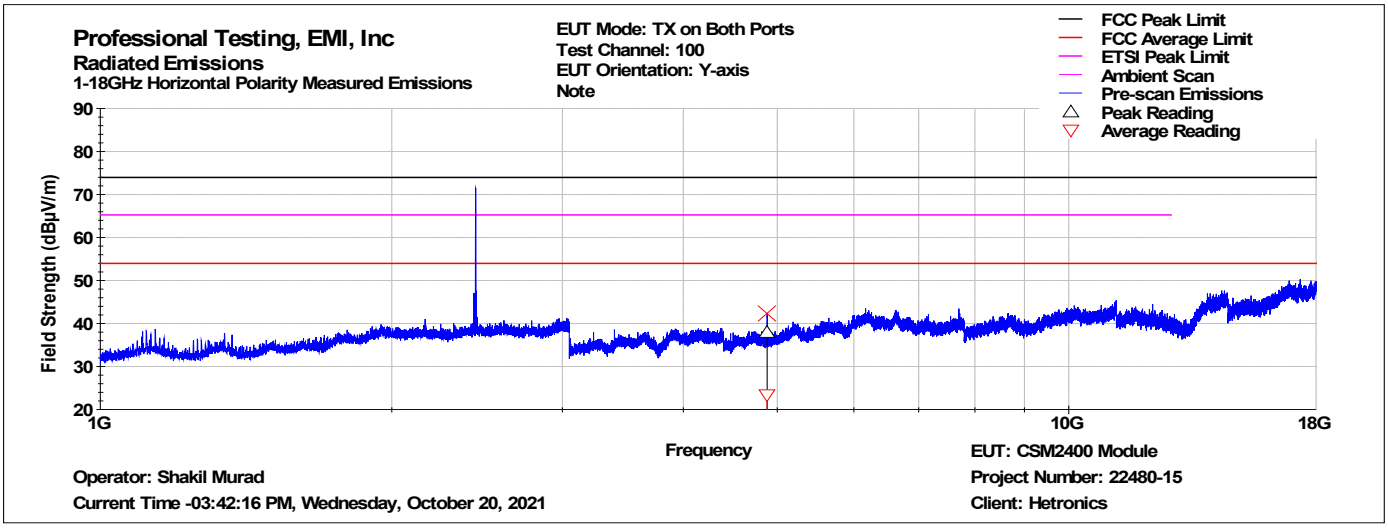
1GHz - 18GHz Vertical Polarity Measured Emissions Data



1GHz - 18GHz Vertical Polarity Measured Emissions Data - FCC

Frequency (MHz)	EUT Direction (Degrees)	Antenna Height (cm)	Peak Reading (dBµV)	Peak Limit (dBµV)	Peak Margin (dB)	Peak Results	Average Reading (dBµV)	Average Limit (dBµV)	Average Margin (dB)	Average Results
4886.32	2	102	32.241	73.958	-41.717	PASS	23.897	53.958	-30.061	PASS
7323.50	202	126	35.592	73.958	-38.366	PASS	25.941	53.958	-28.017	PASS

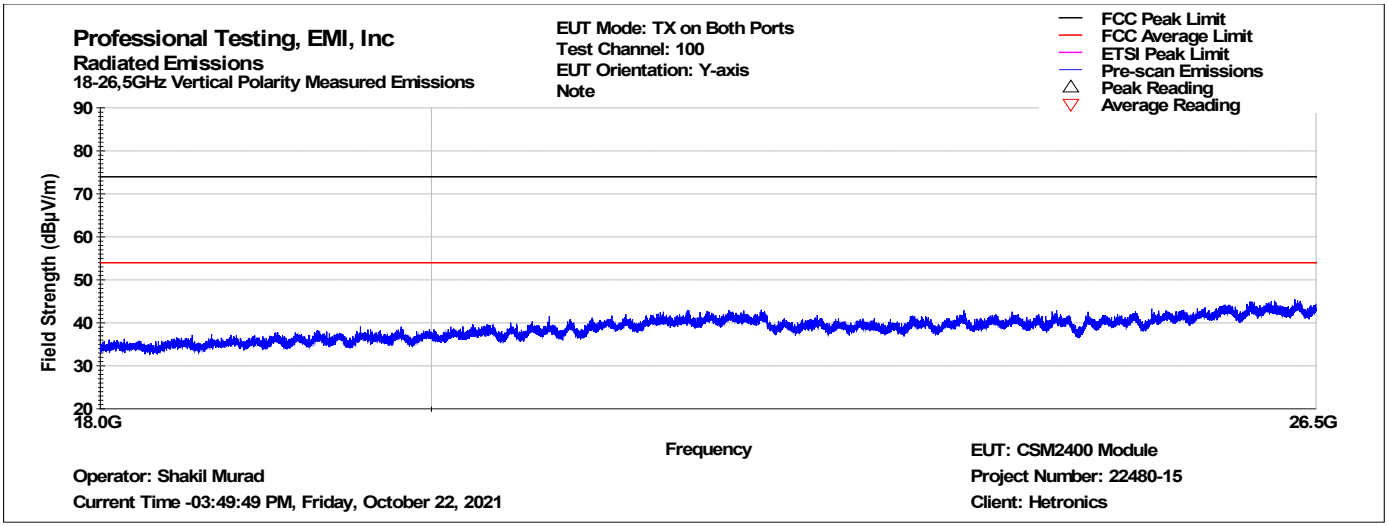
1GHz - 18GHz Horizontal Polarity Measured Emissions Data



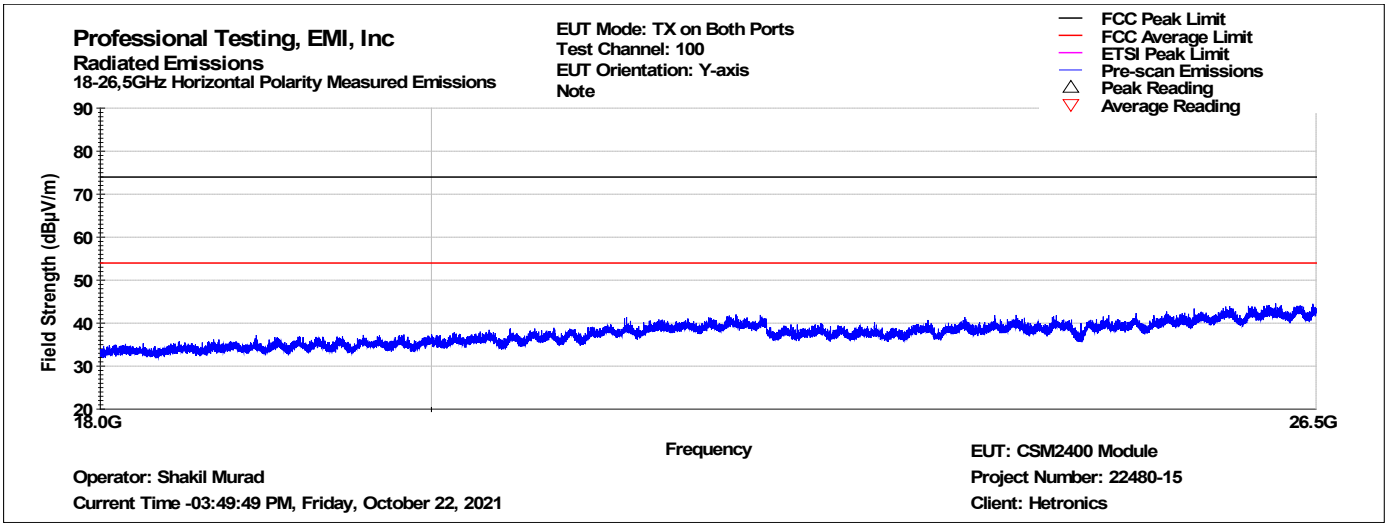
1GHz - 18GHz Horizontal Polarity Measured Emissions Data - FCC

Frequency (MHz)	EUT Direction (Degrees)	Antenna Height (cm)	Peak Reading (dBµV)	Peak Limit (dBµV)	Peak Margin (dB)	Peak Results	Average Reading (dBµV)	Average Limit (dBµV)	Average Margin (dB)	Average Results
4881.64	220	195	37.896	73.958	-36.062	PASS	23.385	53.958	-30.573	PASS

18GHz - 26.5GHz Vertical Polarity Measured Emissions Data

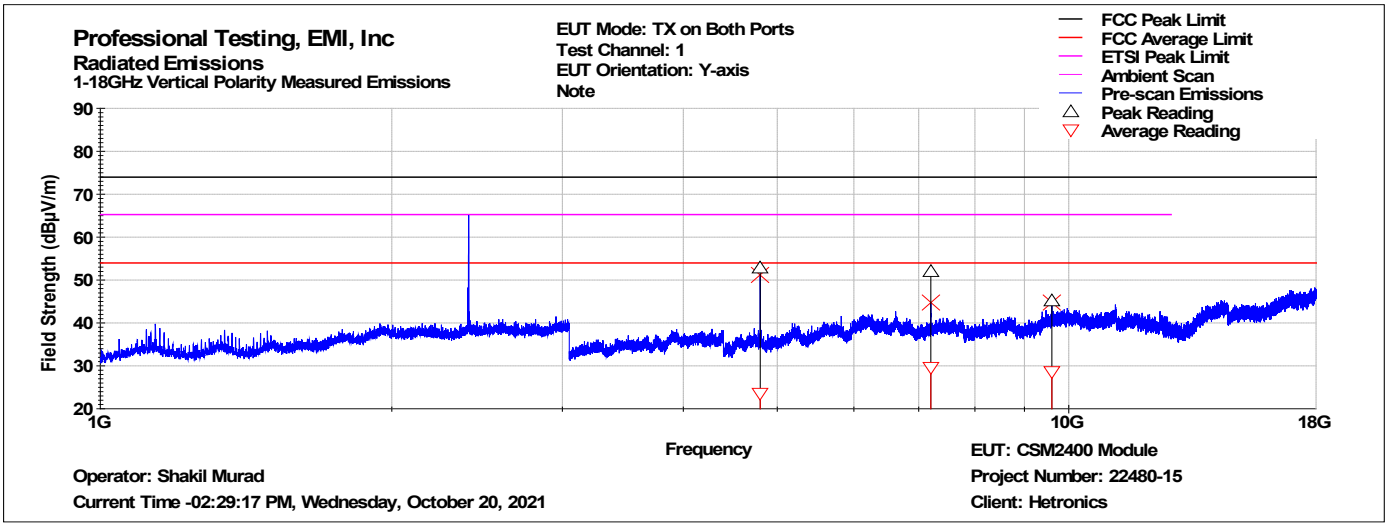


18GHz - 26.5GHz Horizontal Polarity Measured Emissions Data



8.3.2 Bottom Channel, 1 GHz to 26.5 GHz

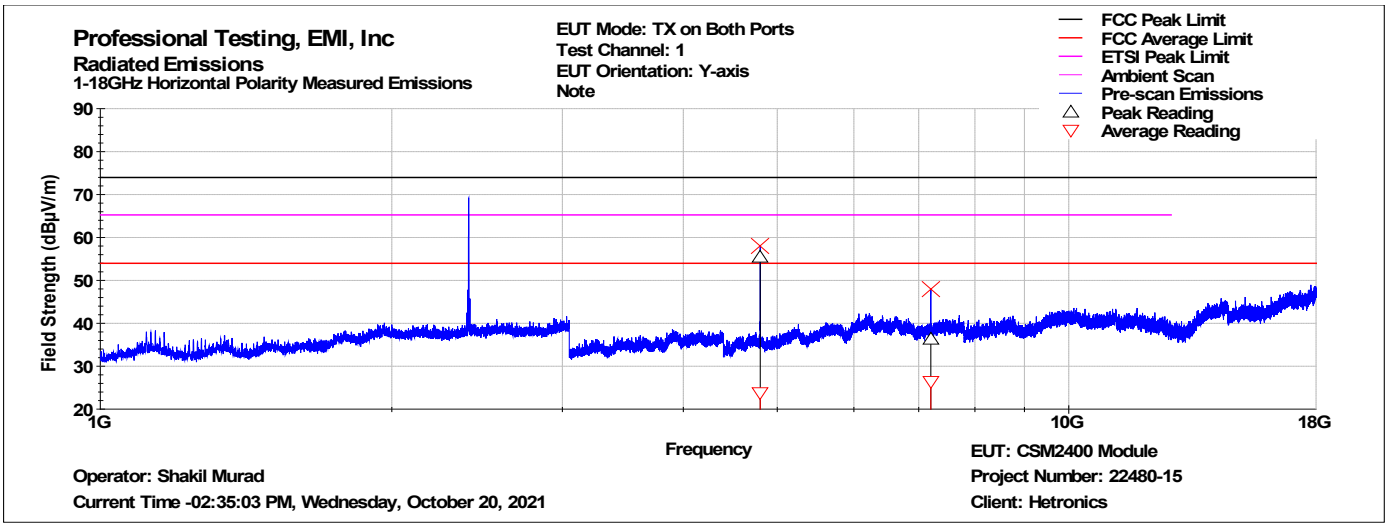
1GHz - 18GHz Vertical Polarity Measured Emissions Data



1GHz - 18GHz Vertical Polarity Measured Emissions Data - FCC

Frequency (MHz)	EUT Direction (Degrees)	Antenna Height (cm)	Peak Reading (dBµV)	Peak Limit (dBµV)	Peak Margin (dB)	Peak Results	Average Reading (dBµV)	Average Limit (dBµV)	Average Margin (dB)	Average Results
4802.48	237	102	52.803	73.958	-21.155	PASS	23.707	53.958	-30.251	PASS
7203.38	190	102	51.996	73.958	-21.962	PASS	29.728	53.958	-24.230	PASS
9605.14	33	102	45.051	73.958	-28.907	PASS	28.648	53.958	-25.310	PASS

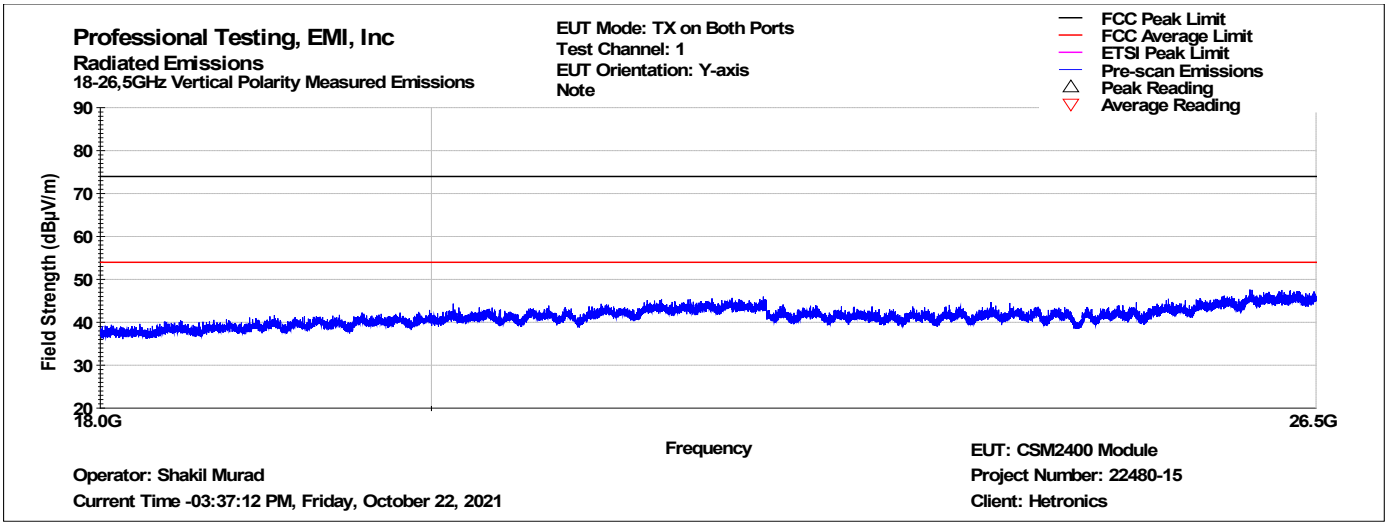
1GHz - 18GHz Horizontal Polarity Measured Emissions Data



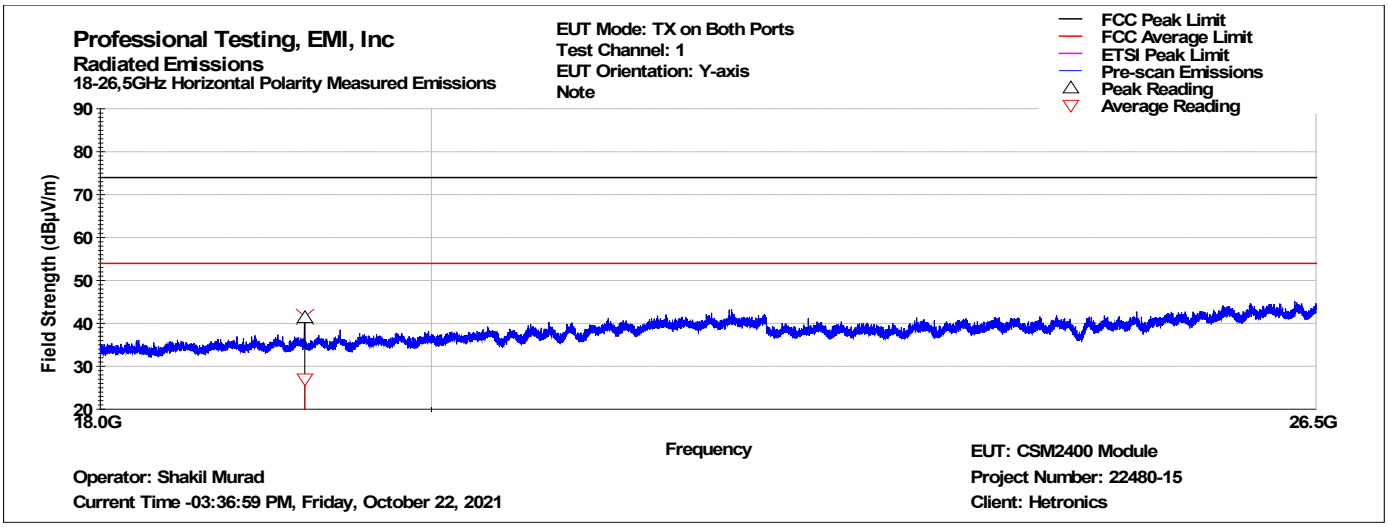
1GHz - 18GHz Horizontal Polarity Measured Emissions Data - FCC

Frequency (MHz)	EUT Direction (Degrees)	Antenna Height (cm)	Peak Reading (dBµV)	Peak Limit (dBµV)	Peak Margin (dB)	Peak Results	Average Reading (dBµV)	Average Limit (dBµV)	Average Margin (dB)	Average Results
4802.23	223	167	55.426	73.958	-18.532	PASS	23.798	53.958	-30.160	PASS
7204.28	228	102	36.264	73.958	-37.694	PASS	26.495	53.958	-27.463	PASS

18GHz - 26.5GHz Vertical Polarity Measured Emissions Data

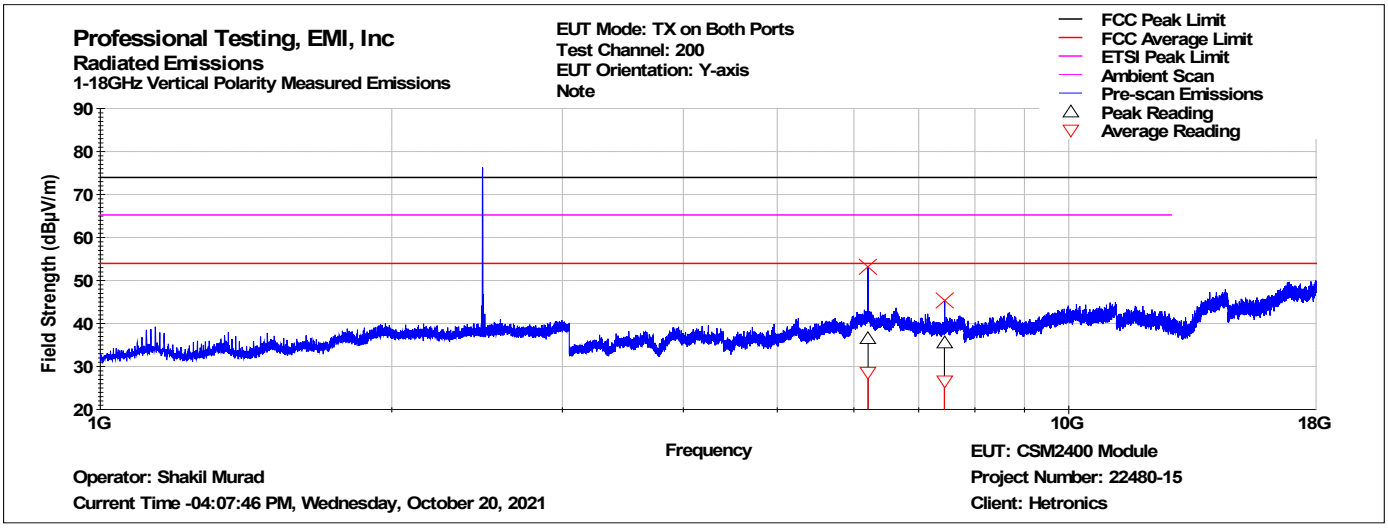


18GHz - 26.5GHz Horizontal Polarity Measured Emissions Data



8.3.3 Top Channel, 1 GHz to 26.5 GHz

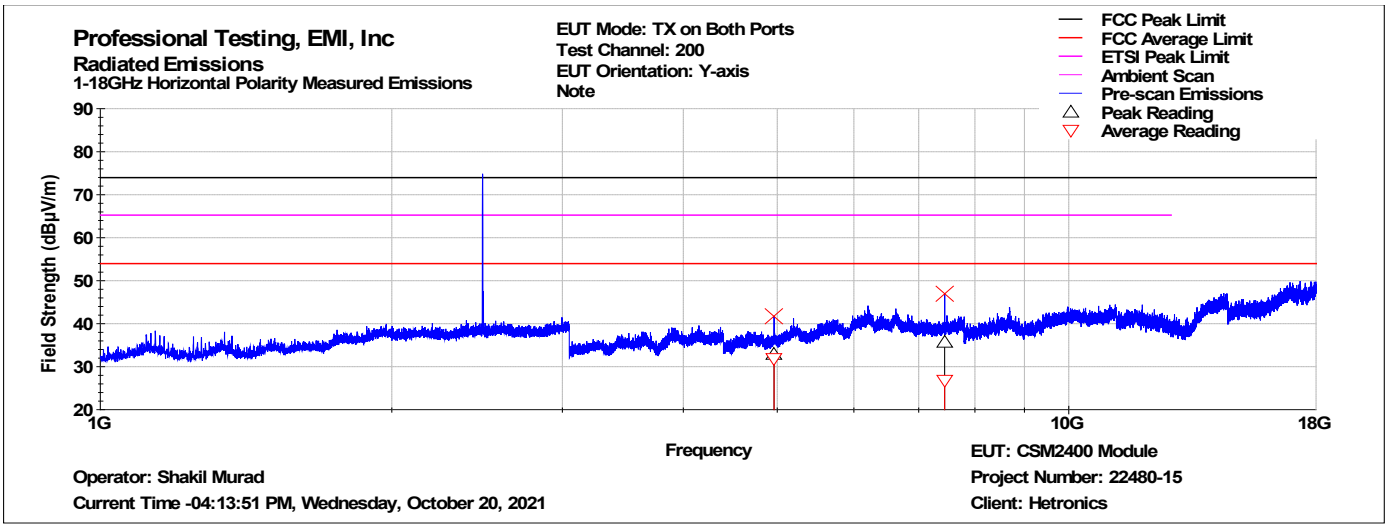
1GHz - 18GHz Vertical Polarity Measured Emissions Data



1GHz - 18GHz Vertical Polarity Measured Emissions Data - FCC

Frequency (MHz)	EUT Direction (Degrees)	Antenna Height (cm)	Peak Reading (dBµV)	Peak Limit (dBµV)	Peak Margin (dB)	Peak Results	Average Reading (dBµV)	Average Limit (dBµV)	Average Margin (dB)	Average Results
6206.11	356	101	36.493	73.958	-37.465	PASS	28.599	53.958	-25.359	PASS
7439.79	356	101	35.497	73.958	-38.461	PASS	26.577	53.958	-27.381	PASS

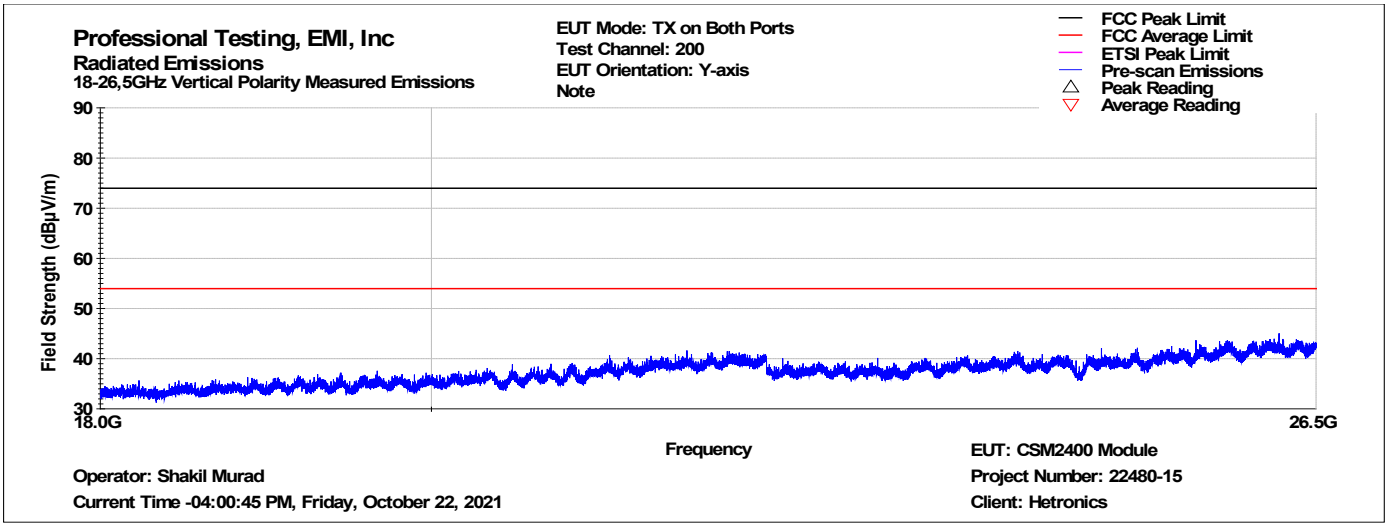
1GHz - 18GHz Horizontal Polarity Measured Emissions Data



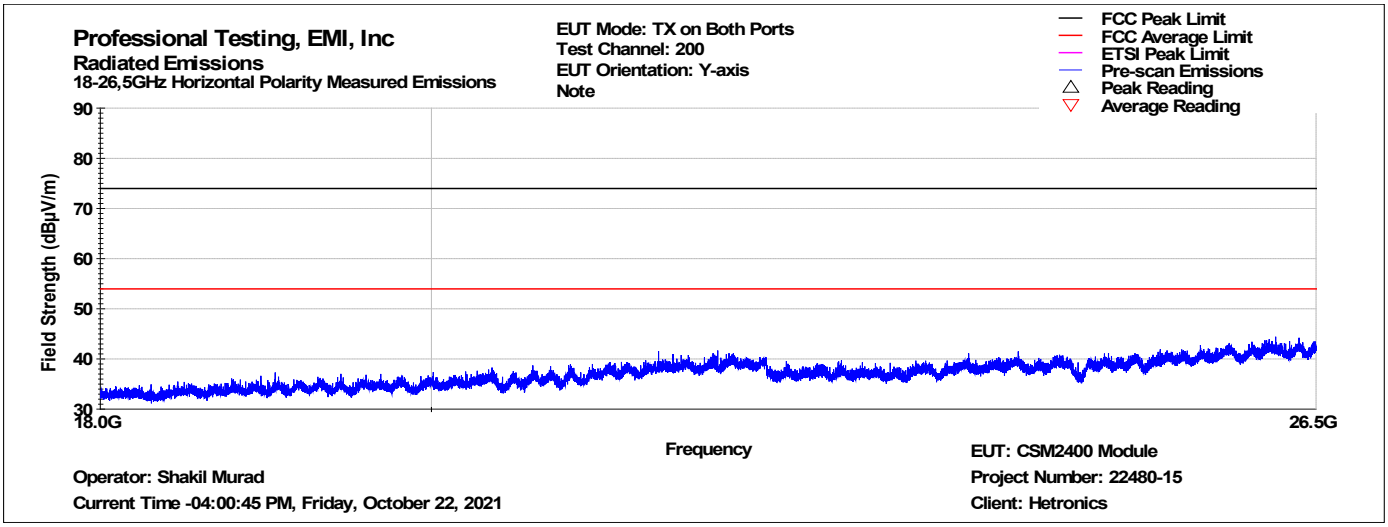
1GHz - 18GHz Horizontal Polarity Measured Emissions Data - FCC

Frequency (MHz)	EUT Direction (Degrees)	Antenna Height (cm)	Peak Reading (dBµV)	Peak Limit (dBµV)	Peak Margin (dB)	Peak Results	Average Reading (dBµV)	Average Limit (dBµV)	Average Margin (dB)	Average Results
4963.13	290	101	32.793	73.958	-41.165	PASS	31.879	53.958	-22.079	PASS
7445.26	356	101	35.698	73.958	-38.260	PASS	26.734	53.958	-27.224	PASS

18GHz - 26.5GHz Vertical Polarity Measured Emissions Data



18GHz - 26.5GHz Horizontal Polarity Measured Emissions Data



9.0 Radiated Spurious Emissions, Receive Mode; 15.247, 15.209; RSS-247 5.5, RSS-Gen 4.9 & 4.10

9.1 Test Procedure

Radiated emissions were measured with the EUT receiving on the center channel on 22 Oct 2021.

7.1.1 Test Distance, Table Height, and Detection Method		
30 MHz to 1 GHz	**1 GHz to 18 GHz**	**18 GHz to 25 GHz**
10 m, 80 cm	3 m, 80 cm	1 m, 80 cm
Quasi-peak	Peak & Average	Peak & Average

9.2 Test Criteria

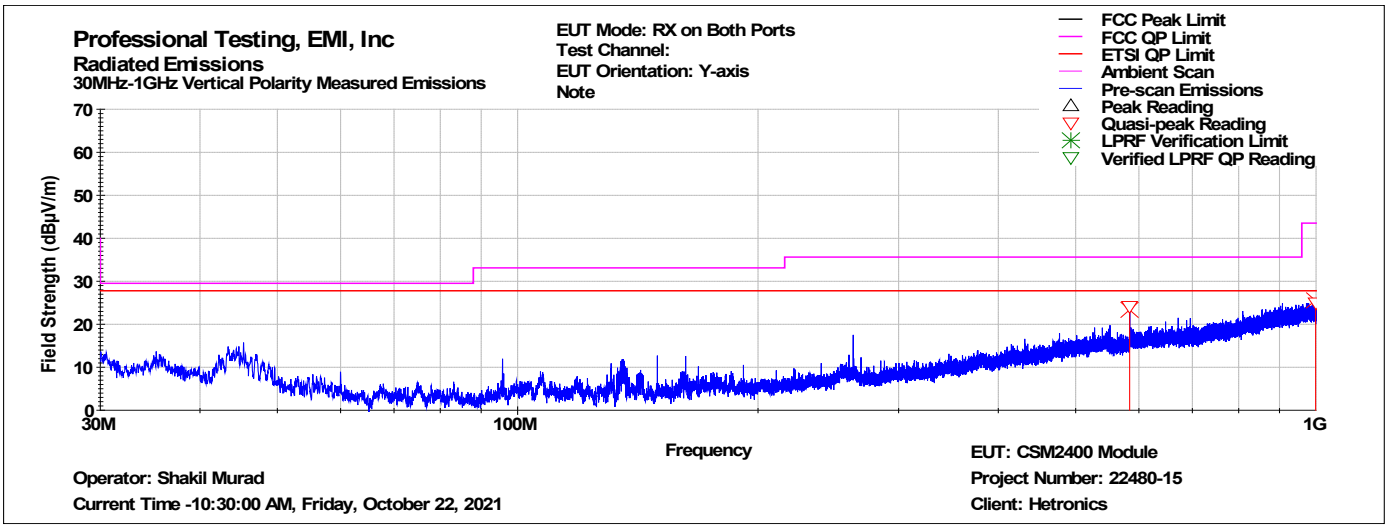
Unwanted Emissions
Field Strength of Radiated Spurious/Harmonic Emissions Receive Mode

9.3 Test Results

The requirement was satisfied.

9.3.1 Middle Channel, 30 MHz to 18 GHz

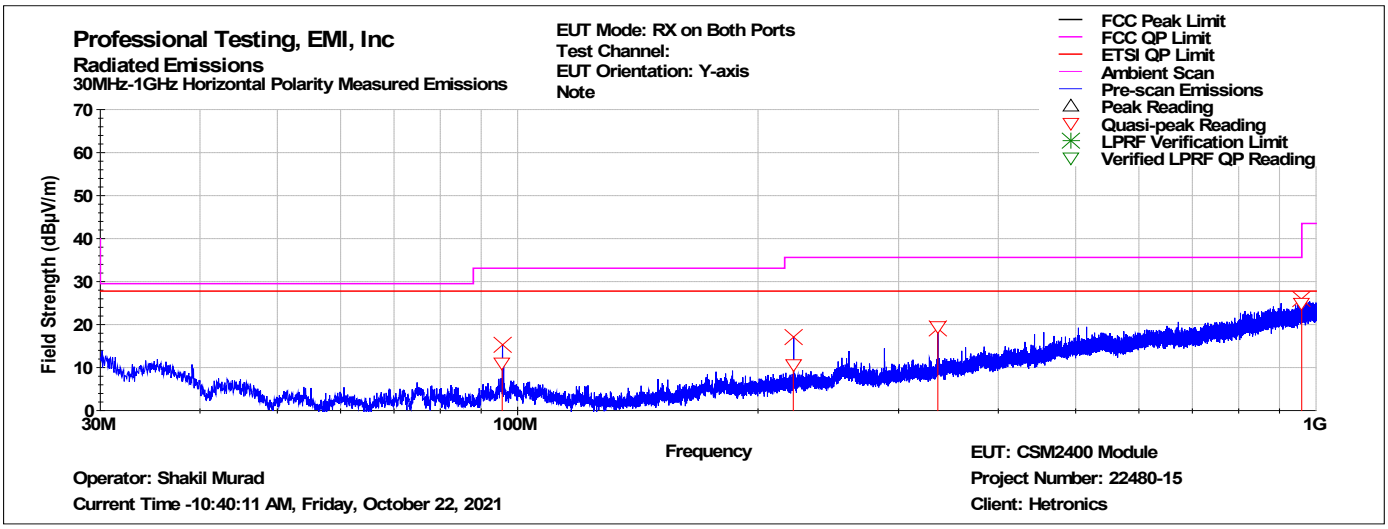
30MHz - 1GHz Vertical Polarity Measured Emissions Data



30MHz - 1GHz Vertical Polarity Measured Emissions Data - FCC

Frequency (MHz)	EUT Direction (Degrees)	Antenna Height (cm)	Quasi-peak Reading (dBµV)	Quasi-peak Limit (dBµV)	Quasi-peak Margin (dB)	Quasi-peak Results
584.290	193.000	387.000	24.189	35.600	-11.411	PASS
998.868	118.000	118.000	25.022	43.500	-18.478	PASS

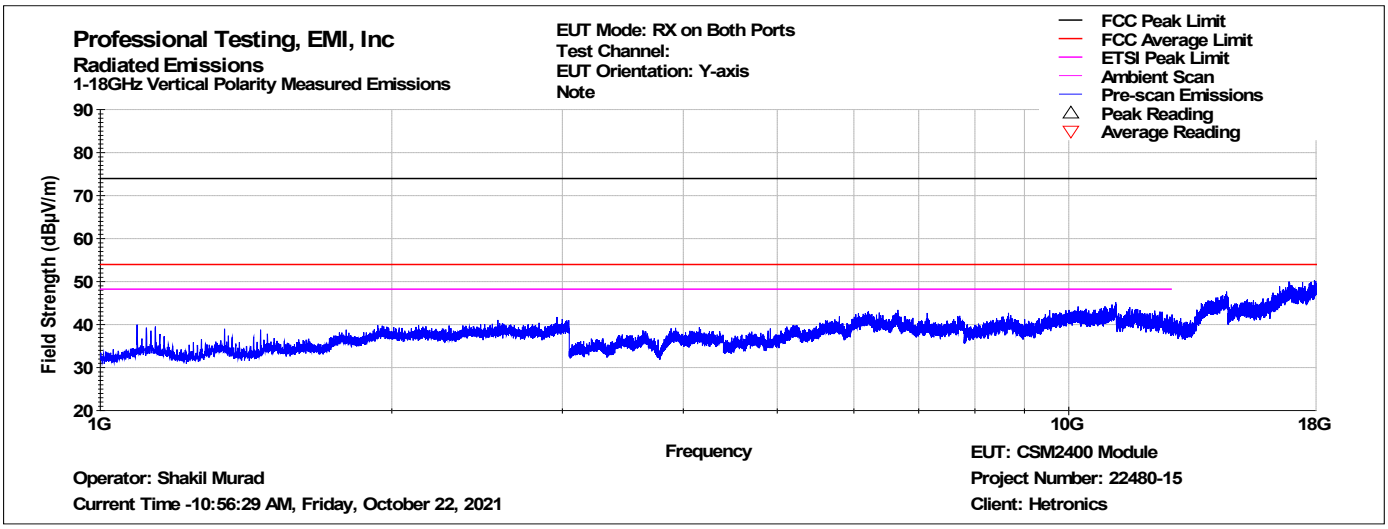
30MHz - 1GHz Horizontal Polarity Measured Emissions Data



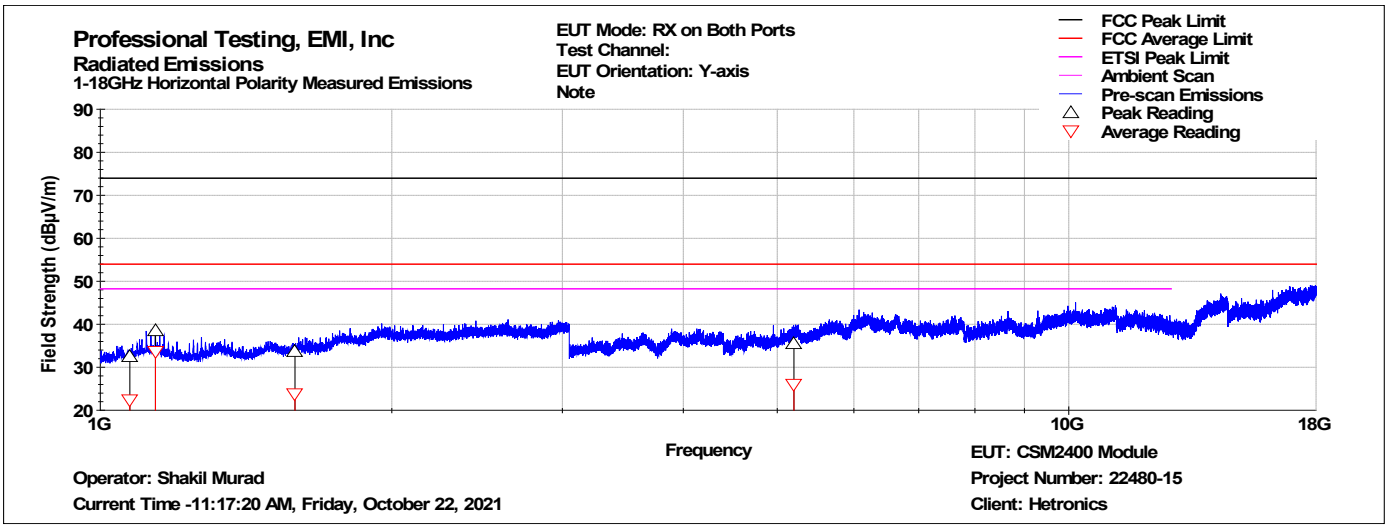
30MHz - 1GHz Horizontal Polarity Measured Emissions Data - FCC

Frequency (MHz)	EUT Direction (Degrees)	Antenna Height (cm)	Quasi-peak Reading (dBµV)	Quasi-peak Limit (dBµV)	Quasi-peak Margin (dB)	Quasi-peak Results
95.649	278.000	376.000	10.988	33.100	-22.112	PASS
221.438	119.000	398.000	10.565	35.600	-25.035	PASS
335.976	2.000	167.000	19.521	35.600	-16.079	PASS
959.566	108.000	253.000	24.978	35.600	-10.622	PASS

1GHz - 18GHz Vertical Polarity Measured Emissions Data



1GHz - 18GHz Horizontal Polarity Measured Emissions Data



1GHz - 18GHz Horizontal Polarity Measured Emissions Data - FCC

Frequency (MHz)	EUT Direction (Degrees)	Antenna Height (cm)	Peak Reading (dBµV)	Peak Limit (dBµV)	Peak Margin (dB)	Peak Results	Average Reading (dBµV)	Average Limit (dBµV)	Average Margin (dB)	Average Results
1073.03	2	102	32.465	73.958	-41.493	PASS	22.413	53.958	-31.545	PASS
1140.16	162	375	38.423	73.958	-35.535	PASS	33.607	53.958	-20.351	PASS
1588.99	1	102	33.716	73.958	-40.242	PASS	23.912	53.958	-30.046	PASS
5203.31	19	102	35.510	73.958	-38.448	PASS	26.037	53.958	-27.921	PASS

10.0 Antenna Construction; 15.203, 15.247; RSS-Gen 8.3

10.1 Procedure

A direct examination of the antenna construction is performed and compared to rule criteria that prevent wireless device antennas from being modified by end users.

10.2 Criteria

Antenna Construction
Type of Antenna(s)
Type of Connector
Gain

10.3 Results

Doodle Labs 2.4 GHz Antenna

ANT-2450-3-O

Specifications			
Electrical Data		**Environmental Data**	
Frequency range	22400-2482 MHz	Environmental Condition	Indoor/Outdoor
Gain	3 dBi	Operation temperature	-40 to 85 deg C
VSWR	<1.5:1	Storage temperature	-40 to 85 deg C
Horizontal pattern type	Omnidirectional	Transport temperature	-40 to 85 deg C
		IP Rating	IP67
General Data		**Mechanical Data**	
Color	Black	Length	137 mm
Pigtail	RG402	Diameter	25.4 mm
Connector type	RP SMB Female	Mounting type	Connector
Polarization	Multi-Polarized	Weight	22 g
Power	50 Watts Input		
Impedance	50 ohms nominal		
Construction	ABS/6061 ALU		

* With built in spatial and polarization diversity, performance in obstructed environments is greater than that of the standard antennas with similar or higher laboratory gains.

User cannot substitute antenna (Uses reverse polarity female SMB type connector)

Gain is under maximum limit of 6 dBi.

The requirement was satisfied.

11.0 Equipment

11.1 Radiated Emissions 30 MHz to 26.5 GHz

Radiated Emissions Test Equipment List					
Tile! Software Version:			**Version: 7.1.2.17 (Jan 08, 2016 - 02:12:48 PM) or 4.1.A.0, April 14, 2009, 11:01:00PM**		
Test Profile:			**2020_RE_Unintentional_TILE7_v2.7.til**		
Asset #	**Manufacturer**	**Model**	**Equipment Nomenclature**	**Serial Number**	**Calibration Due Date**
1890	HP	8447F-H64	Preamp/Amp, 9kHz-1300MHz, 28/25dB	3313A05298	N/A
2295	Keysight	E4440A-AYZ	PSA Spectrum Analyzer	MY46186204	11/10/2021
1926	ETS-Lindgren	3142D	Antenna, Biconilog, 26 MHz - 6 GHz	135454	4/20/2022
C027	none	RG214	Cable Coax, N-N, 25m, 25MHz - 1GHz	None	9/14/2022
1327	EMCO	1050	Controller, Antenna Mast	none	N/A
942	EMCO	11968D	Turntable, 4ft.	9510-1835	N/A
1969	HP	11713A	Attenuator/Switch Driver	3748A04113	N/A
C030	none	none	Cable Coax, N-N, 30m, 1 - 18GHz	None	9/15/2022
1509B	Braden	TDK 10M	TDK 10M Chamber,sVSWR > 1 GHz	DAC-012915-005	4/9/2023
2004	Miteq	AFS44-00101800-2S-10P-44	Amplifier, 40dB, 100MHz-18GHz	None	1/9/2022
C030	none	none	Cable Coax, N-N, 30m, 1 - 18GHz	None	9/15/2022
1325	EMCO	1050	Controller, Antenna Mast	9003-1461	N/A
1780	ETS-Lindgren	3117	Antenna, Double Ridged Guide Horn, 1 - 18 GHz	110313	4/16/2023
1977	Agilent	87421A	Power Supply	MY44350145	N/A
1973	Agilent	83017A	Amplifier, Microwave 0.5-26.5 GHz	MY39500497	11/10/2022
1542	A.H. Systems	SAS-572	Antenna, Horn 18-26.5GHz, 20dB gain	225	N/A
1735	Pasternack	PE9850-20	Antenna, horn, WR28	N/A	N/A

11.2 Fundamental Power, Bandwidth, Duty Cycle, Band Edge, Conducted Antenna Port Emissions, Hopping parameters

Asset#	Manufacturer	Model	Equipment Nomenclature	Serial Number	Calibration Due Date
1937	Agilent	E4440A - AYZ	PSA , 3 Hz - 26.5 GHz, Opt. AYZ	MY44808298	11/11/2021
A118	Narda	768A-20	20 dB 20 W Attenuator, DC - 11GHz	105357	12/10/2022

12.0 Measurement Bandwidths

Radiated Emissions Spectrum Analyzer Bandwidth and Measurement Time - Peak Scan				
Frequency Band Start (MHz)	**Frequency Band Stop (MHz)**	**6 dB Bandwidth (kHz)**	**Number of Ranges Used**	**Measurement Time per Range**
0.009	0.15	0.3	2	Multiple Sweeps
0.15	30	9	6	Multiple Sweeps
30	1000	120	2	Multiple 800 mS Sweeps
1000	6000	1000	2	Multiple Sweeps
6000	18000	1000	2	Multiple Sweeps
18000	26500	1000	2	Multiple Sweeps

*Notes:
1. The settings above are specifically calculated for the E4440A series of spectrum analyzers, which have 8,000 data points per range.
2. The measurement receiver resolution bandwidth setting was 300 Hz for quasi-peak measurements from 9-150 kHz.
3. The measurement receiver resolution bandwidth setting was 9 kHz for quasi-peak measurements from 0.15-30 MHz.
4. The measurement receiver resolution bandwidth setting was 120 kHz for quasi-peak measurements from 30-1000 MHz.
5. The measurement receiver resolution bandwidth setting was 1 MHz for average measurements from 1-18 GHz.

Appendix: Policy, Rationale, and Evaluation of EMC Measurement Uncertainty

All uncertainty calculations, estimates and expressions thereof shall be in accordance with NIST policy. Since PTI operates in accordance with NIST (NVLAP) Handbook 150-11: 2007, all instrumentation having an effect on the accuracy or validity of tests shall be periodically calibrated or verified traceable to national standards by a competent calibration laboratory. The certificates of calibration or verification on this instrumentation shall include estimates of uncertainty as required by NIST Handbook 150-11.

1. Rationale and Summary of Expanded Uncertainty.

Each piece of instrumentation at PTI that is used in making measurements for determining conformance to a standard (or limit), shall be assessed to evaluate its contribution to the overall uncertainty of the measurement in which it is used. The assessment of each item will be based on either a type A evaluation or a type B evaluation. Most of the evaluations will be type B, since they will be based on the manufacturer's statements or specifications of the calibration tolerances, or uncertainty will be stated along with a brief rationale for the type of evaluation and the resulting stated uncertainties.

The individual uncertainties included in the combined standard uncertainty for a specific test result will depend on the configuration in which the item of instrumentation is used. The combination will always be based on the law of propagation of uncertainty. Any systematic effects will be accommodated by including their uncertainties, in the calculation of the combined standard uncertainty; except that if the direction and amount of the systematic effect cannot be determined and separated from its uncertainty, the whole effect will be treated as uncertainty and combined along with the other elements of the test setup.

Type A evaluations of standard uncertainty will usually be based on calculating the standard deviation of the mean of a series of independent observations, but may be based on a least-squares curve fit or the analysis of variance for unusual situations. Type B evaluations of standard uncertainty will usually be based on manufacturer's specifications, data provided in calibration reports, and experience. The type of probability distribution used (normal, rectangular, a priori, or u-shaped) will be stated for each Type B evaluation.

In the evaluation of the uncertainty of each type of measurement, the uncertainty caused by the operator will be estimated. One notable operator contribution to measurement uncertainty is the manipulation of cables to maximize the measured values of radiated emissions. The operator contribution to measurement uncertainty is evaluated by having several operators independently repeat the same test. This results in a Type A evaluation of operator-contributed measurement uncertainty.

A summary of the expanded uncertainties of PTI measurements is shown as Table 1. These are the worst-case uncertainties considering all operative influence factors.

Table 1: Summary of Measurement Uncertainties for Site 45

Type of Measurement	Frequency Range	Meas. Dist.	Expanded Uncertainty U, dB (k=2)
Mains Conducted Emissions	150 kHz to 30 MHz	N/A	2.9
Telecom Conducted Emissions	150 kHz to 30 MHz	N/A	2.8
Radiated Emissions	30 to 1,000 MHz	10 m	4.8
	1 to 18 GHz	3 m	5.7

End of Report