



RF TEST REPORT

Applicant Espressif Systems (Shanghai) Co.,Ltd.

FCC ID 2AC7Z-ESPPICOMINI

Product Wi-Fi & Bluetooth Internet of Things Module

Brand ESPRESSIF

Model ESP32-PICO-MINI-02;
 ESP32-PICO-MINI-02U

Report No. R2106A0560-R1V1

Issue Date December 15, 2021

TA Technology (Shanghai) Co., Ltd. tested the above equipment in accordance with the requirements in **FCC CFR47 Part 15C (2020)**. The test results show that the equipment tested is capable of demonstrating compliance with the requirements as documented in this report.

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TABLE OF CONTENT

1. Test Laboratory	5
1.1. Notes of the test report.....	5
1.2. Test facility	5
1.3. Testing Location	5
2. General Description of Equipment under Test.....	6
2.1. Applicant and Manufacturer Information.....	6
2.2. General information.....	6
3. Applied Standards	7
4. Test Configuration	9
5. Test Case Results	10
5.1. Maximum output power	10
5.2. 99% Bandwidth and 6dB Bandwidth	14
5.3. Band Edge	26
5.4. Power Spectral Density	30
5.5. Spurious RF Conducted Emissions.....	38
5.6. Unwanted Emission	53
5.7. Conducted Emission	164
6. Main Test Instruments.....	174
ANNEX A: The EUT Appearance	175
ANNEX B: Test Setup Photos	176



Version	Revision description	Issue Date
Rev.0	Initial issue of report.	October 22, 2021
Rev.1	Update Maximum output power and Power spectral density.	December 15, 2021
Note: This revised report (Report No. R2106A0560-R1V1) supersedes and replaces the previously issued report (Report No. R2106A0560-R1). Please discard or destroy the previously issued report and dispose of it accordingly.		

Summary of measurement results

Number	Test Case	Clause in FCC rules	Verdict
1	Maximum output power	15.247(b)(3)	PASS
2	6 dB bandwidth	15.247(a)(2)	PASS
3	Power spectral density	15.247(e)	PASS
4	Band Edge	15.247(d)	PASS
5	Spurious RF Conducted Emissions	15.247(d)	PASS
6	Unwanted Emissions	15.247(d),15.205,15.209	PASS
7	Conducted Emissions	15.207	PASS
Date of Testing: June 29, 2021 ~ September 15, 2021 and December 14, 2021 ~ December 15, 2021			
Date of Sample Received: June 26, 2021			
Note: All indications of Pass/Fail in this report are opinions expressed by TA Technology (Shanghai) Co., Ltd. based on interpretations and/or observations of test results. Measurement Uncertainties were not taken into account and are published for informational purposes only.			

1. Test Laboratory

1.1. Notes of the test report

This report shall not be reproduced in full or partial, without the written approval of **TA technology (shanghai) co., Ltd.** The results documented in this report apply only to the tested sample, under the conditions and modes of operation as described herein. Measurement Uncertainties were not taken into account and are published for informational purposes only. This report is written to support regulatory compliance of the applicable standards stated above.

1.2. Test facility

FCC (Designation number: CN1179, Test Firm Registration Number: 446626)

TA Technology (Shanghai) Co., Ltd. has been listed on the US Federal Communications Commission list of test facilities recognized to perform measurements.

A2LA (Certificate Number: 3857.01)

TA Technology (Shanghai) Co., Ltd. has been listed by American Association for Laboratory Accreditation to perform measurement.

1.3. Testing Location

Company: TA Technology (Shanghai) Co., Ltd.
Address: No.145, Jintang Rd, Tangzhen Industry Park, Pudong
City: Shanghai
Post code: 201201
Country: P. R. China
Contact: Xu Kai
Telephone: +86-021-50791141/2/3
Fax: +86-021-50791141/2/3-8000
Website: <http://www.ta-shanghai.com>
E-mail: xukai@ta-shanghai.com

2. General Description of Equipment under Test

2.1. Applicant and Manufacturer Information

Applicant	Espressif Systems (Shanghai) Co.,Ltd.
Applicant address	Suite 204, Block 2, 690 Bibo Road, Zhang Jiang Hi-Tech Park, Shanghai, China
Manufacturer	Espressif Systems (Shanghai) Co.,Ltd.
Manufacturer address	Suite 204, Block 2, 690 Bibo Road, Zhang Jiang Hi-Tech Park, Shanghai, China

2.2. General information

EUT Description		
Model	ESP32-PICO-MINI-02; ESP32-PICO-MINI-02U	
Lab internal SN	R2106A0560/S01	
Hardware Version	V1.0	
Software Version	V179	
Power Supply	External power supply	
Antenna Type	ESP32-PICO-MINI-02: PCB Antenna ESP32-PICO-MINI-02U: External Antenna	
Antenna Connector	A permanently attached antenna (meet with the standard FCC Part 15.203 requirement	
Antenna Gain	ESP32-PICO-MINI-02	3.96dBi
	ESP32-PICO-MINI-02U	2.33dBi
additional beamforming gain	NA	
Test Mode	802.11b, 802.11g, 802.11n(HT20/HT40) Bluetooth LE V4.2	
Modulation Type	802.11b: DSSS 802.11g/n(HT20/HT40): OFDM Bluetooth LE: GFSK	
Max. Conducted Power	Wi-Fi 2.4G: 16.88dBm Bluetooth LE: 6.19dBm	
Operating Frequency Range(s)	802.11b/g/n(HT20): 2412 ~ 2462 MHz 802.11n(HT40): 2422 ~ 2452 MHz Bluetooth LE: 2402 ~2480 MHz	
Note: 1. The EUT is sent from the applicant to TA and the information of the EUT is declared by the applicant.		



Differences between the two models		
Model	ESP32-PICO-MINI-02	ESP32-PICO-MINI-02U
Antenna	PCB Antenna	External Antenna
Antenna Gain	3.96dBi	2.33dBi
Others	The same	The same

3. Applied Standards

According to the specifications of the manufacturer, it must comply with the requirements of the following standards:

Test standards:

FCC CFR47 Part 15C (2020) Radio Frequency Devices

ANSI C63.10 (2013)

Reference standard:

KDB 558074 D01 15.247 Meas Guidance v05r02

4. Test Configuration

Test Mode

The EUT has been associated with peripherals and configuration operated in a manner tended to maximize its emission characteristics in a typical application.

The radiated emission was measured in the following position: EUT stand-up position (Z axis), lie-down position (X, Y axis). The worst emission was found in lie-down position (X axis) and the loop antenna is vertical, the others are vertical and horizontal. and the worst case was recorded.

In order to find the worst case condition, Pre-tests are needed at the presence of different data rate. Preliminary tests have been done on all the configuration for confirming worst case. Data rate below means worst-case rate of each test item.

Worst-case data rates are shown as following table.

Test Mode	Data Rate
802.11b	1 Mbps
802.11g	6 Mbps
802.11n HT20	MCS0
802.11n HT40	MCS0
Bluetooth(Low Energy)	1Mbps

5. Test Case Results

5.1. Maximum output power

Ambient condition

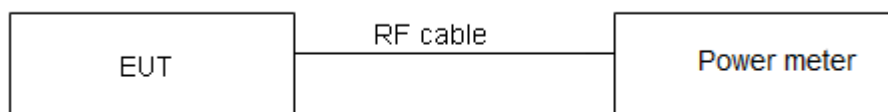
Temperature	Relative humidity	Pressure
23°C ~25°C	45%~50%	101.5kPa

Methods of Measurement

During the process of the testing, The EUT was connected to Power meter with a known loss. The EUT is max power transmission with proper modulation.

The conducted Power is measured at each antenna port. The measured results at the various antenna ports are then summed mathematically.

Test Setup



Limits

Rule Part 15.247 (b) (3) specifies that " For systems using digital modulation in the 902–928 MHz, 2400–2483.5 MHz: 1 Watt."

Average Output Power	$\leq 1\text{W}$ (30dBm)
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Measurement Uncertainty

The assessed measurement uncertainty to ensure 95% confidence level for the normal distribution is with the coverage factor $k = 2$, $U = 0.44$ dB.

Test Results

WiFi2.4G:

Power Index					
Channel	802.11b	802.11g	802.11n HT20	Channel	802.11n HT40
CH1	34	6	8	CH3	12
CH2	-	0	0	CH4	8
CH6	24	0	0	CH5	4
CH10	-	0	0	CH6	0
CH11	24	10	10	CH7	0
/	/	/	/	CH8	4
/	/	/	/	CH9	20

Bluetooth LE:

Power Index			
Channel	CH0	CH19	CH39
TP Set	6	6	6

Test Mode	T _{on} (ms)	T _(on+off) (ms)	Duty cycle	Duty cycle correction Factor(dB)
802.11b	1.00	1.00	1.00	NA
802.11g	1.00	1.00	1.00	NA
802.11n HT20	1.00	1.00	1.00	NA
802.11n HT40	2.43	2.53	0.96	0.170
Bluetooth LE	2.08	2.50	0.833	0.793

Note: when Duty cycle ≥ 0.98 , Duty cycle correction Factor not required.

Test Mode	Carrier frequency (MHz)	Average Power Measured (dBm)	Average Power with duty factor (dBm)	Limit (dBm)	Conclusion
802.11b	2412	10.36	10.36	30	PASS
	2417	16.02	16.02	30	PASS
	2432	15.14	15.14	30	PASS
	2437	12.41	12.41	30	PASS
	2442	14.82	14.82	30	PASS
	2457	14.30	14.30	30	PASS
	2462	12.46	12.46	30	PASS
802.11g	2412	15.84	15.84	30	PASS
	2417	16.84	16.84	30	PASS

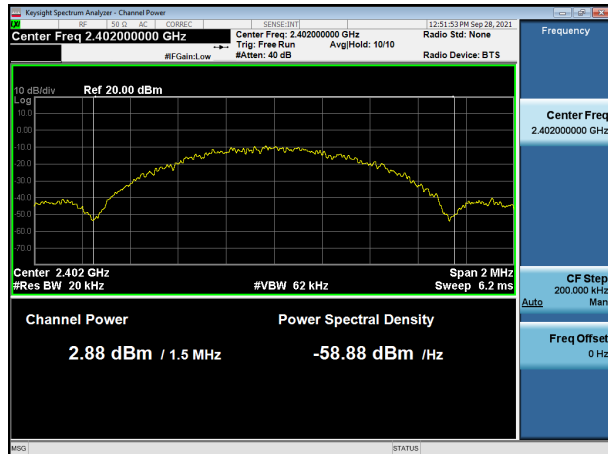


	2437	16.87	16.87	30	PASS
	2457	16.88	16.88	30	PASS
	2462	14.98	14.98	30	PASS
802.11n HT20	2412	15.22	15.22	30	PASS
	2417	16.73	16.73	30	PASS
	2437	16.56	16.56	30	PASS
	2457	16.72	16.72	30	PASS
	2462	14.86	14.86	30	PASS
802.11n HT40	2422	13.72	13.89	30	PASS
	2427	14.53	14.70	30	PASS
	2432	15.33	15.50	30	PASS
	2437	16.13	16.30	30	PASS
	2442	16.15	16.32	30	PASS
	2447	15.63	15.80	30	PASS
	2452	11.97	12.14	30	PASS
Bluetooth (Low Energy)	2402	2.88	3.67	30	PASS
	2440	2.26	3.05	30	PASS
	2480	2.16	2.95	30	PASS

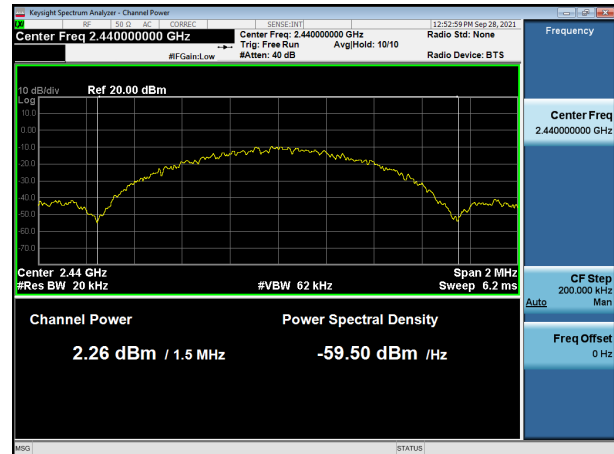
Note: Average Power with duty factor = Average Power Measured +Duty cycle correction factor



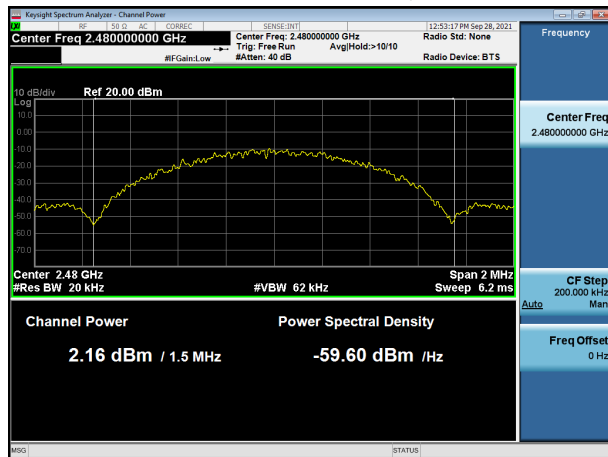
Bluetooth LE Carrier frequency (MHz): 2402



Bluetooth LE Carrier frequency (MHz): 2440



Bluetooth LE Carrier frequency (MHz): 2480



5.2. 99% Bandwidth and 6dB Bandwidth

Ambient condition

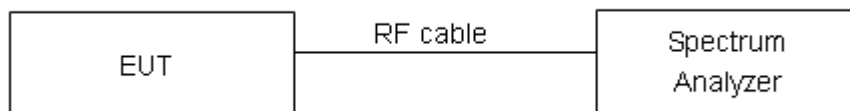
Temperature	Relative humidity	Pressure
23°C ~25°C	45%~50%	101.5kPa

Method of Measurement

The EUT was connected to the spectrum analyzer through an external attenuator (20dB) and a known loss cable. RBW is set to 100 kHz; VBW is set to 300 kHz on spectrum analyzer.
Dector=Peak, Trace mode=max hold.

The EUT was connected to the spectrum analyzer through a known loss cable. The resolution bandwidth (RBW) shall be in the range of 1% to 5% of the actual occupied / x dB bandwidth and the video bandwidth (VBW) shall not be smaller than three times the RBW value.

Test Setup



Limits

Rule Part 15.247 (a) (2) specifies that “Systems using digital modulation techniques may operate in the 902–928 MHz, 2400–2483.5 MHz bands. The minimum 6 dB bandwidth shall be at least 500 kHz.”

minimum 6 dB bandwidth	≥ 500 kHz
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Measurement Uncertainty

The assessed measurement uncertainty to ensure 95% confidence level for the normal distribution is with the coverage factor $k = 2$, $U = 936$ Hz.

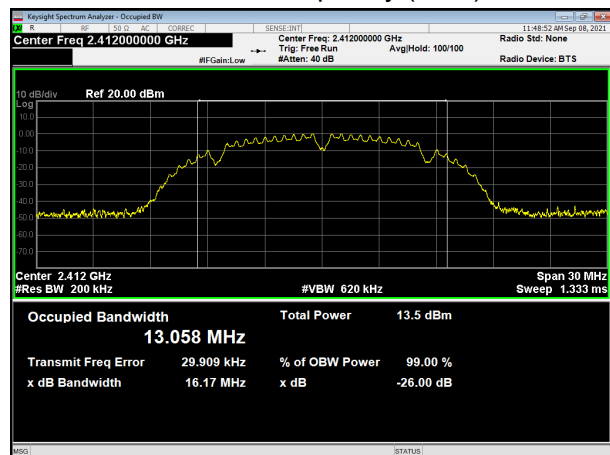
Test Results:

Test Mode	Carrier frequency (MHz)	99% bandwidth (MHz)	Minimum 6 dB bandwidth (MHz)	Limit (kHz)	Conclusion
802.11b	2412	13.058	9.11	500	PASS
	2417	13.251	9.56	500	PASS
	2432	13.200	10.02	500	PASS
	2437	13.037	10.01	500	PASS
	2442	13.324	10.01	500	PASS
	2457	13.271	9.54	500	PASS
	2462	13.039	10.07	500	PASS
802.11g	2412	16.449	15.84	500	PASS
	2417	16.561	15.83	500	PASS
	2437	16.601	15.81	500	PASS
	2457	16.666	15.67	500	PASS
	2462	16.430	16.06	500	PASS
802.11n HT20	2412	17.197	15.80	500	PASS
	2417	17.308	15.67	500	PASS
	2437	17.338	15.67	500	PASS
	2457	17.340	15.65	500	PASS
	2462	17.190	15.79	500	PASS
802.11n HT40	2422	34.142	32.61	500	PASS
	2427	34.224	30.20	500	PASS
	2432	34.302	31.38	500	PASS
	2437	34.550	32.61	500	PASS
	2442	34.362	34.414	500	PASS
	2447	34.261	34.188	500	PASS
	2452	34.118	30.52	500	PASS
Bluetooth (Low Energy)	2402	1.020	0.63	500	PASS
	2440	1.019	0.63	500	PASS
	2480	1.018	0.64	500	PASS

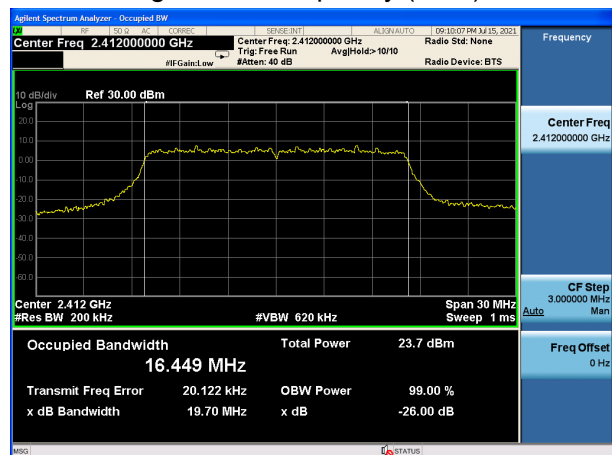


99%bandwidth

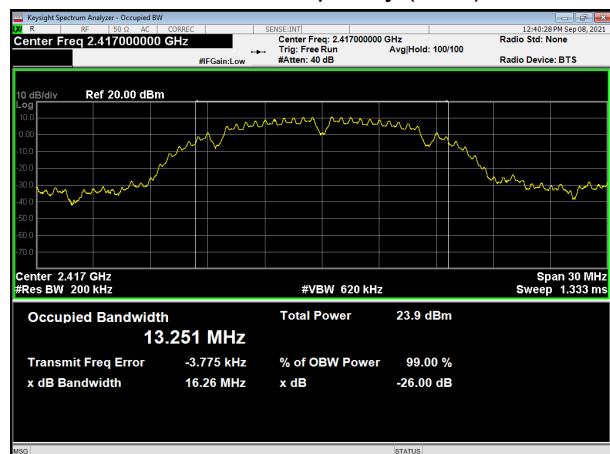
802.11b, Carrier frequency (MHz): 2412



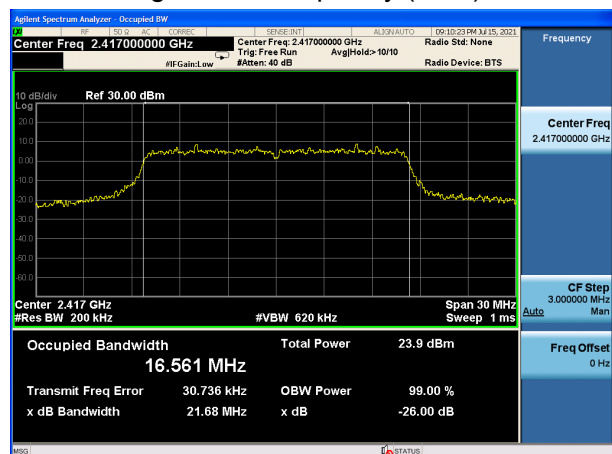
802.11g, Carrier frequency (MHz): 2412



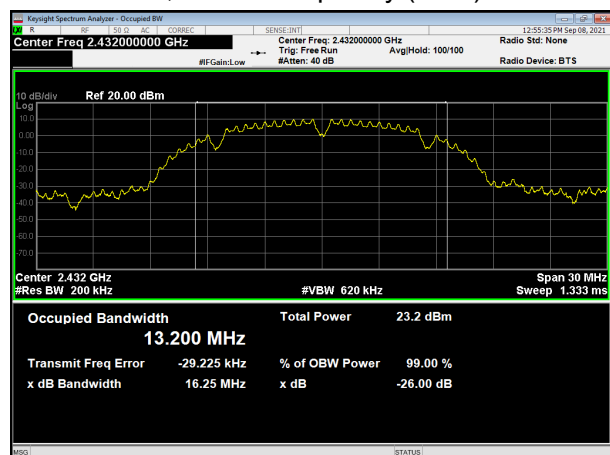
802.11b, Carrier frequency (MHz): 2417



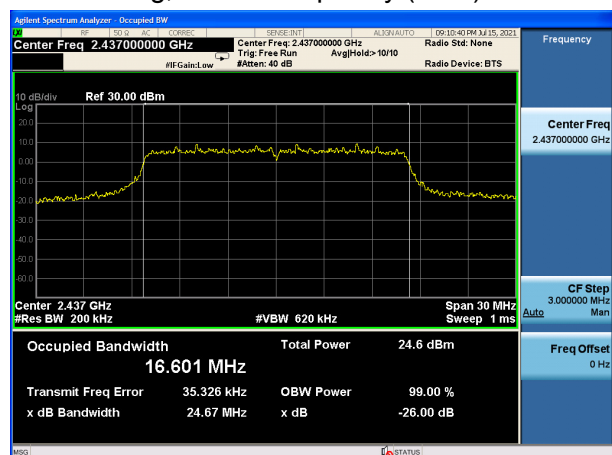
802.11g, Carrier frequency (MHz): 2417



802.11b, Carrier frequency (MHz): 2432

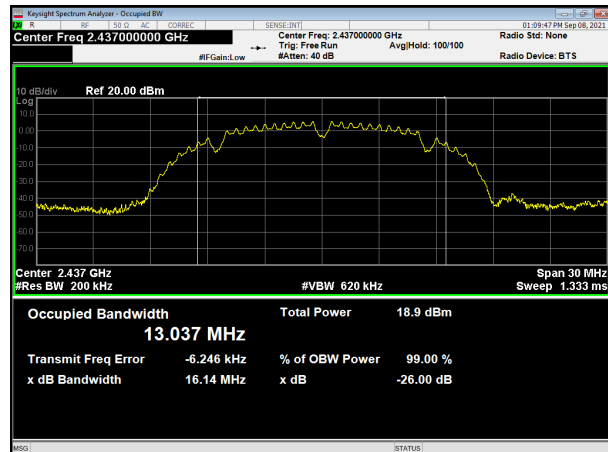


802.11g, Carrier frequency (MHz): 2437

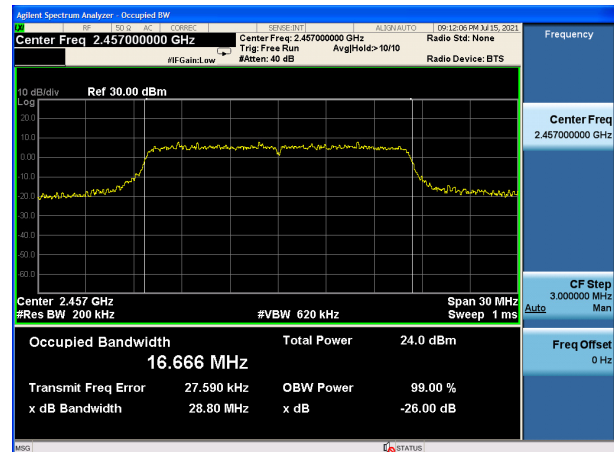




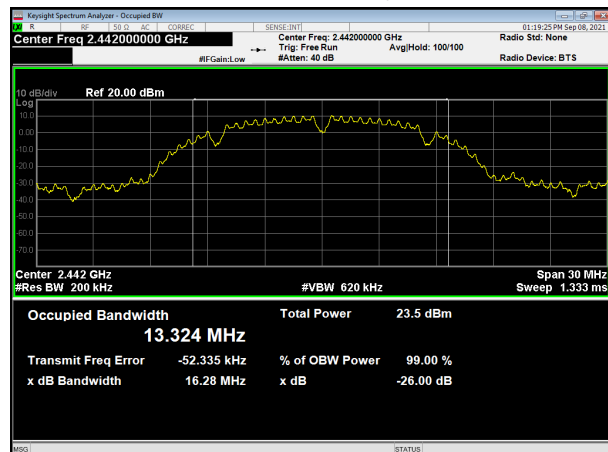
802.11b, Carrier frequency (MHz): 2437



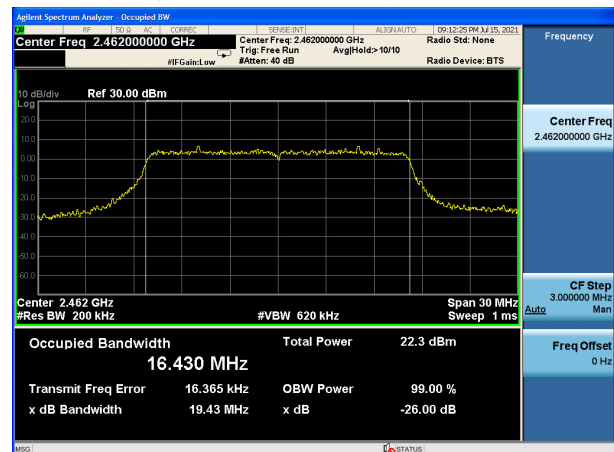
802.11g, Carrier frequency (MHz): 2457



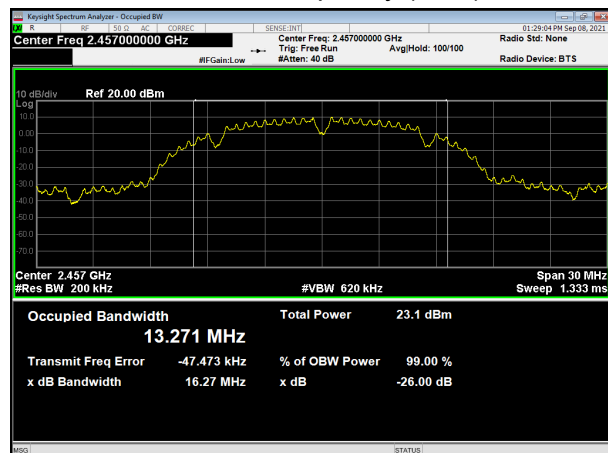
802.11b, Carrier frequency (MHz): 2442



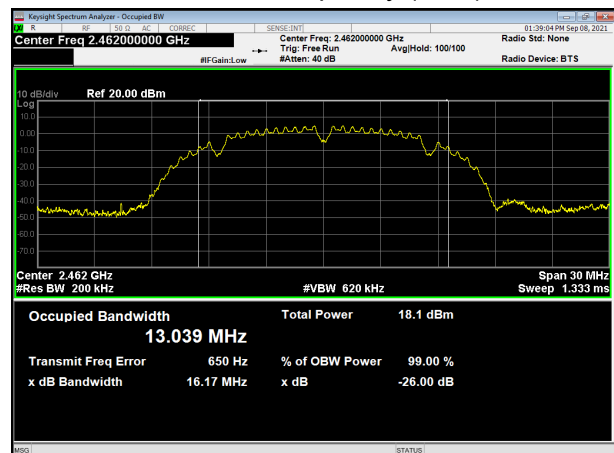
802.11g, Carrier frequency (MHz): 2462



802.11b, Carrier frequency (MHz): 2457

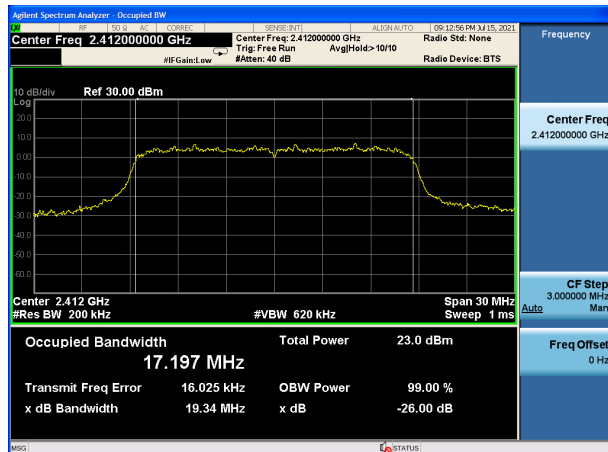


802.11b, Carrier frequency (MHz): 2462

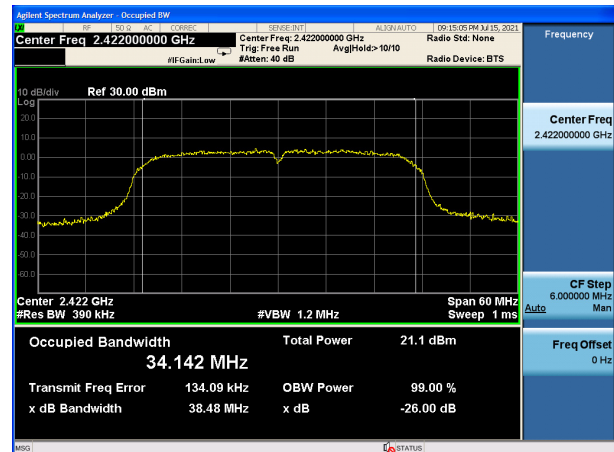




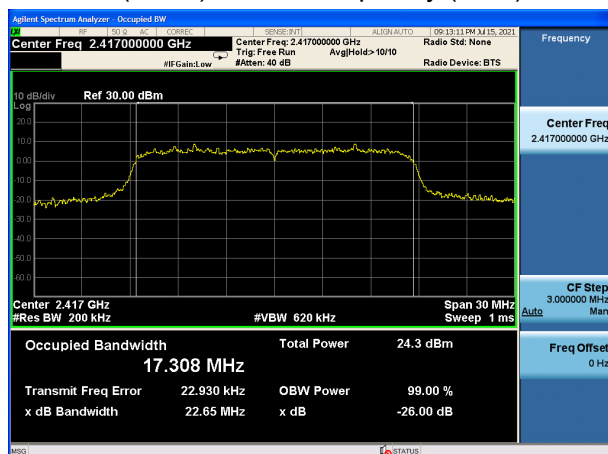
802.11n(HT20), Carrier frequency (MHz): 2412



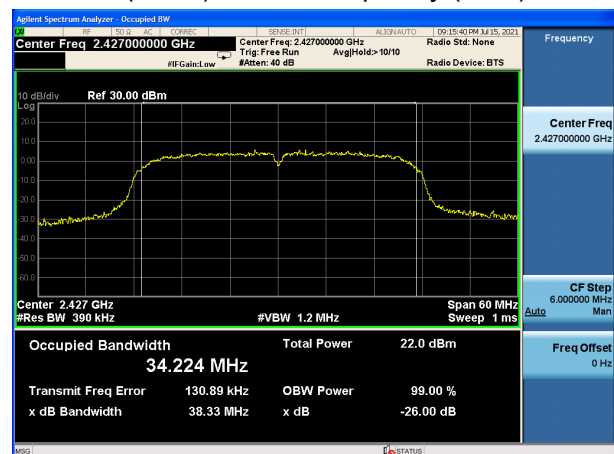
802.11n(HT40), Carrier frequency (MHz): 2422



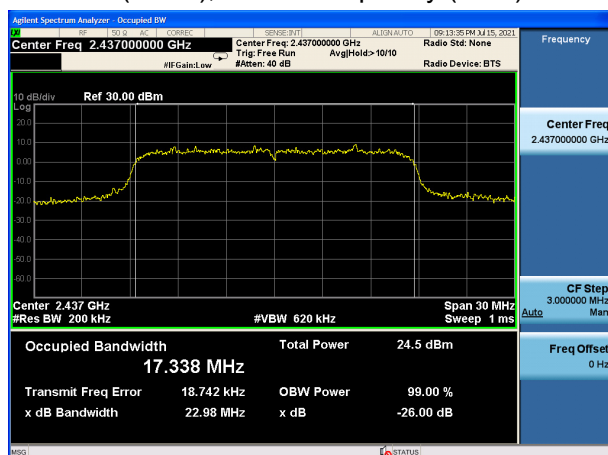
802.11n(HT20), Carrier frequency (MHz): 2417



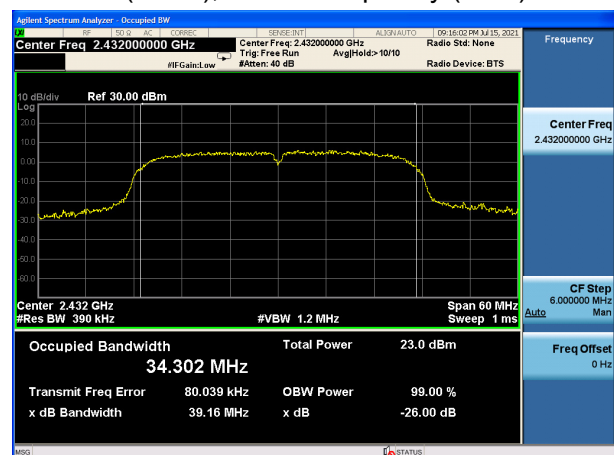
802.11n(HT40), Carrier frequency (MHz): 2427



802.11n(HT20), Carrier frequency (MHz): 2437

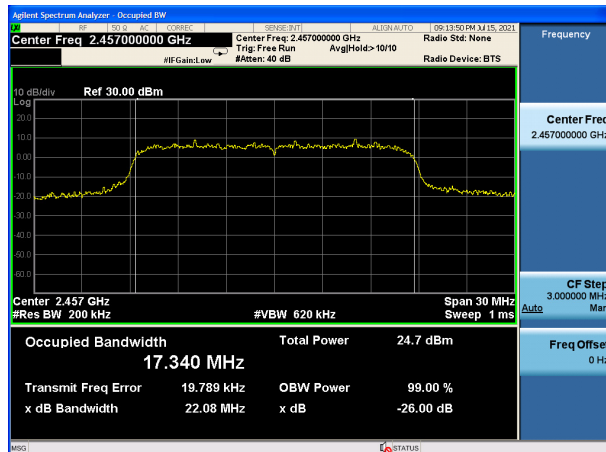


802.11n(HT40), Carrier frequency (MHz): 2432

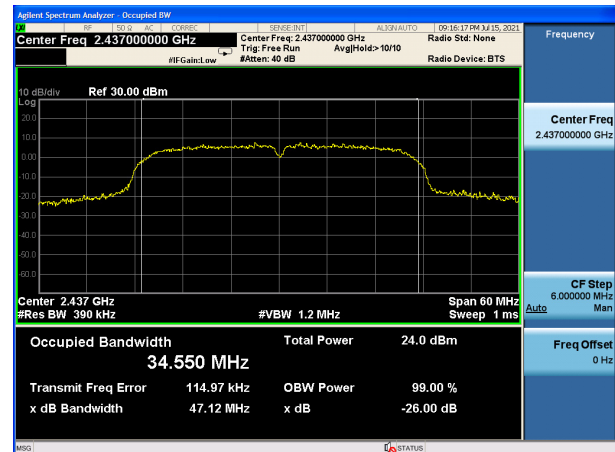




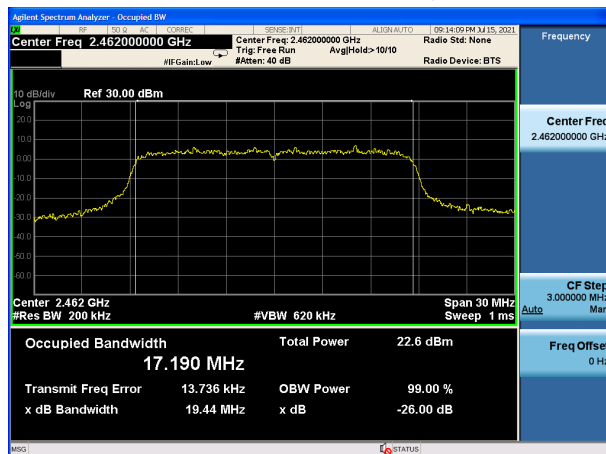
802.11n(HT20), Carrier frequency (MHz): 2457



802.11n(HT40), Carrier frequency (MHz): 2437



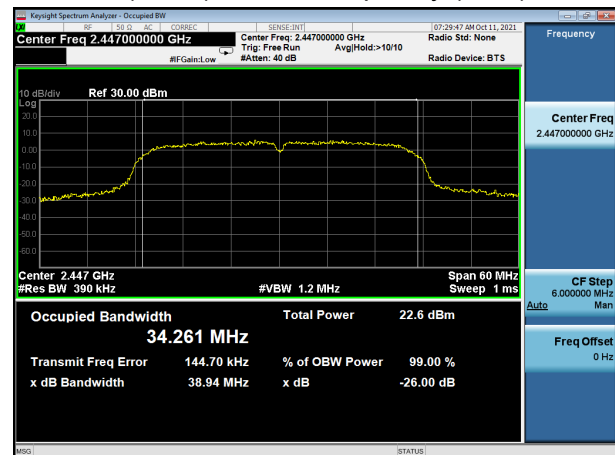
802.11n(HT20), Carrier frequency (MHz): 2462



802.11n(HT40), Carrier frequency (MHz): 2442

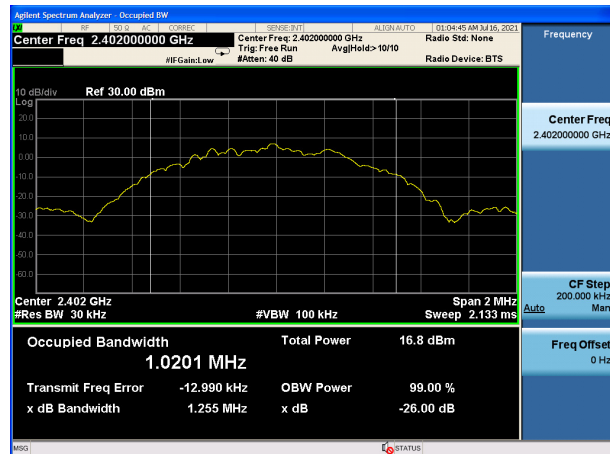


802.11n(HT40), Carrier frequency (MHz): 2447

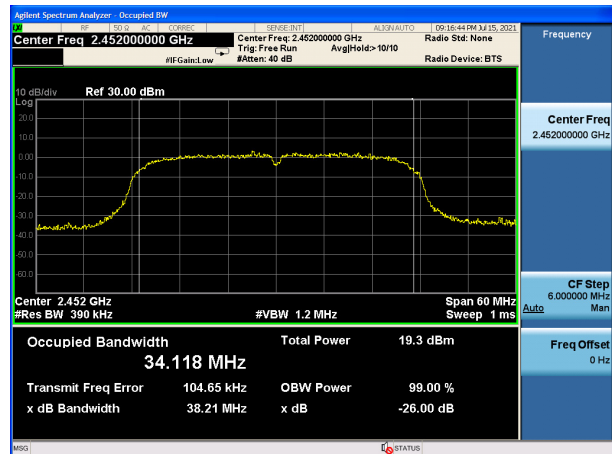




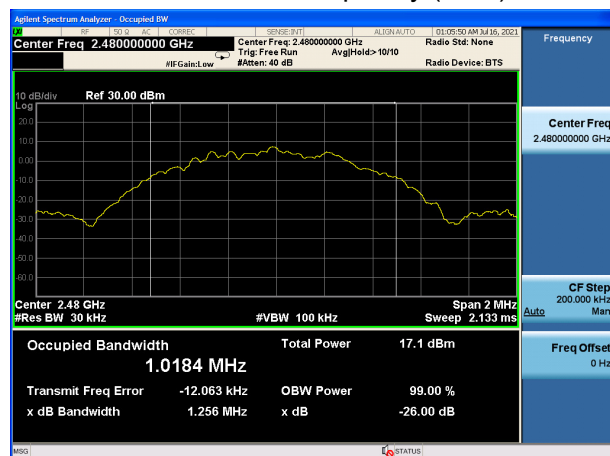
Bluetooth LE Carrier frequency (MHz): 2402



802.11n(HT40), Carrier frequency (MHz): 2452



Bluetooth LE Carrier frequency (MHz): 2480



Bluetooth LE Carrier frequency (MHz): 2440

