



# 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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| 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  
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E-mail: [xukai@ta-shanghai.com](mailto: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<br>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)<br>Bluetooth LE V4.2                                            |         |
| Modulation Type                                                                                                | 802.11b: DSSS<br>802.11g/n(HT20/HT40): OFDM<br>Bluetooth LE: GFSK                                    |         |
| Max. Conducted Power                                                                                           | Wi-Fi 2.4G: 16.88dBm<br>Bluetooth LE: 6.19dBm                                                        |         |
| Operating Frequency Range(s)                                                                                   | 802.11b/g/n(HT20): 2412 ~ 2462 MHz<br>802.11n(HT40): 2422 ~ 2452 MHz<br>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

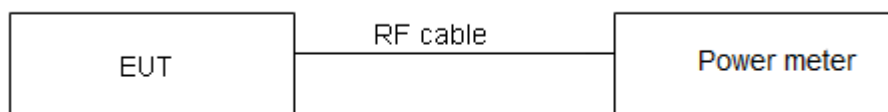
| Temperature | Relative humidity | Pressure |
|-------------|-------------------|----------|
| 23°C ~25°C  | 45%~50%           | 101.5kPa |

#### 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) |
|----------------------|--------------------------|

#### 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 <sub>on</sub> (ms) | T <sub>(on+off)</sub> (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  $\geq 0.98$ , 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       |

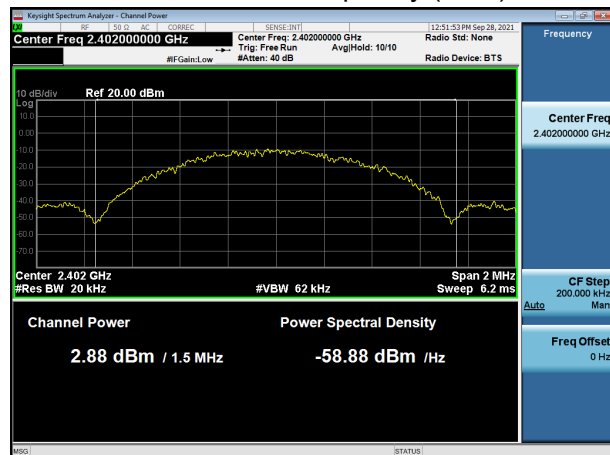


|                           |      |       |       |    |      |
|---------------------------|------|-------|-------|----|------|
|                           | 2437 | 16.87 | 16.87 | 30 | PASS |
|                           | 2457 | 16.88 | 16.88 | 30 | PASS |
|                           | 2462 | 14.98 | 14.98 | 30 | PASS |
| 802.11n<br>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<br>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<br>(Low Energy) | 2402 | 2.88  | 3.67  | 30 | PASS |
|                           | 2440 | 2.26  | 3.05  | 30 | PASS |
|                           | 2480 | 2.16  | 2.95  | 30 | PASS |

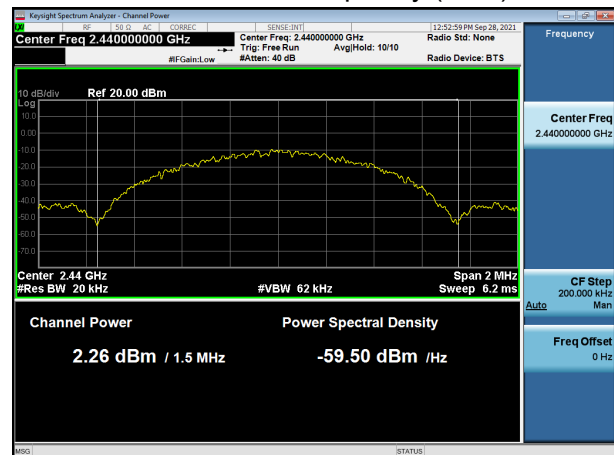
Note: Average Power with duty factor = Average Power Measured +Duty cycle correction factor



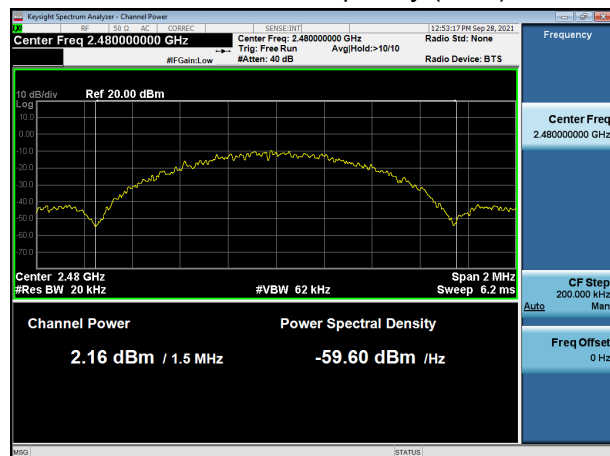
## Bluetooth LE Carrier frequency (MHz): 2402



## Bluetooth LE Carrier frequency (MHz): 2440



## Bluetooth LE Carrier frequency (MHz): 2480



## 5.2. 99% Bandwidth and 6dB Bandwidth

### Ambient condition

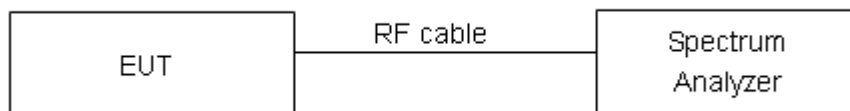
| Temperature | Relative humidity | Pressure |
|-------------|-------------------|----------|
| 23°C ~25°C  | 45%~50%           | 101.5kPa |

### 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 |
|------------------------|-----------|

### 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.

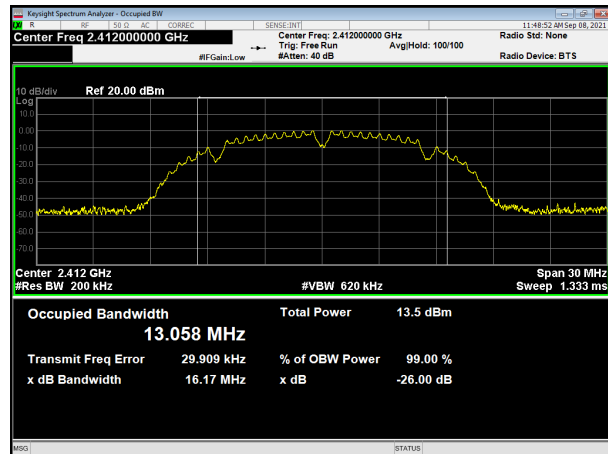
**Test Results:**

| 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<br>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<br>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<br>(Low Energy) | 2402                    | 1.020               | 0.63                         | 500         | PASS       |
|                           | 2440                    | 1.019               | 0.63                         | 500         | PASS       |
|                           | 2480                    | 1.018               | 0.64                         | 500         | PASS       |

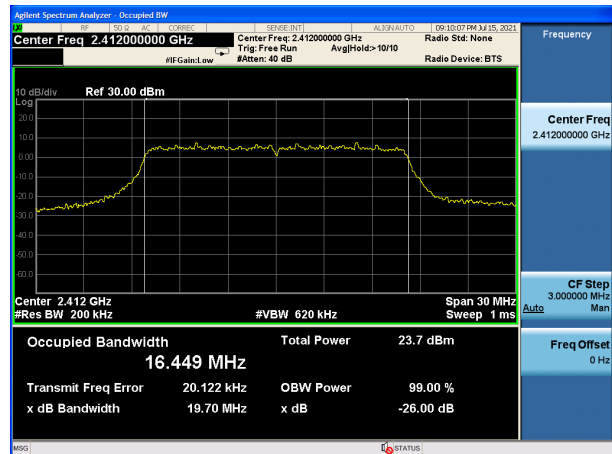


## 99%bandwidth

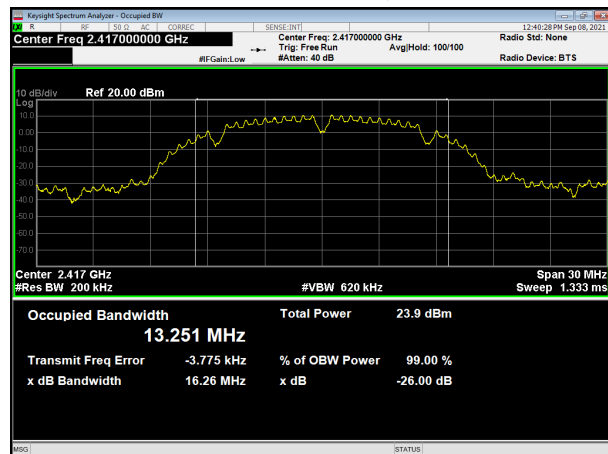
## 802.11b, Carrier frequency (MHz): 2412



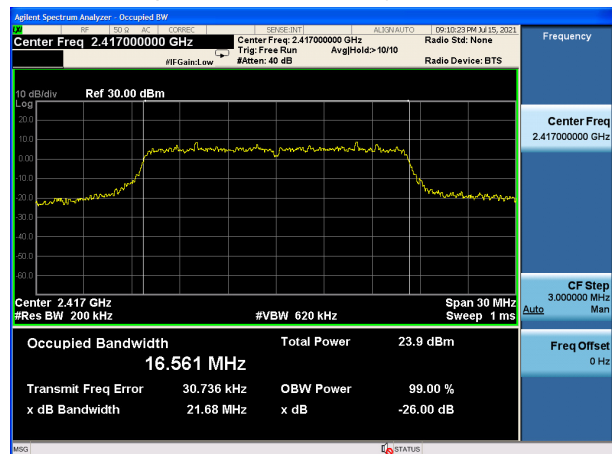
## 802.11g, Carrier frequency (MHz): 2412



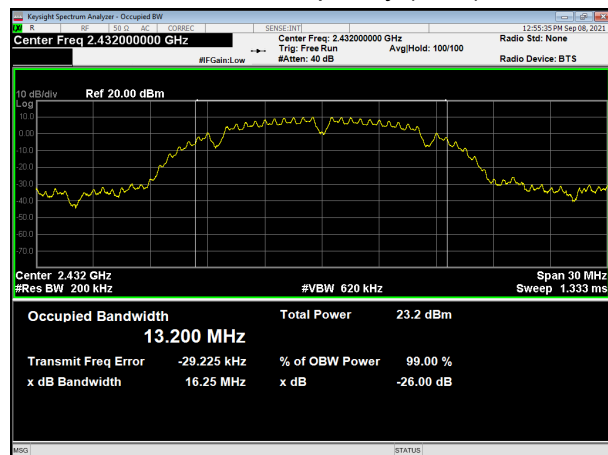
## 802.11b, Carrier frequency (MHz): 2417



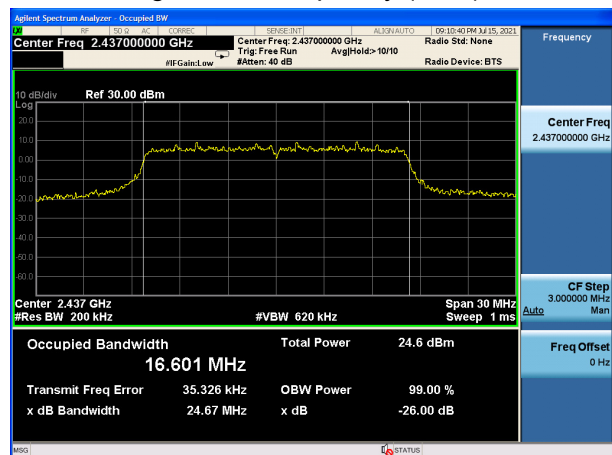
## 802.11g, Carrier frequency (MHz): 2417



## 802.11b, Carrier frequency (MHz): 2432

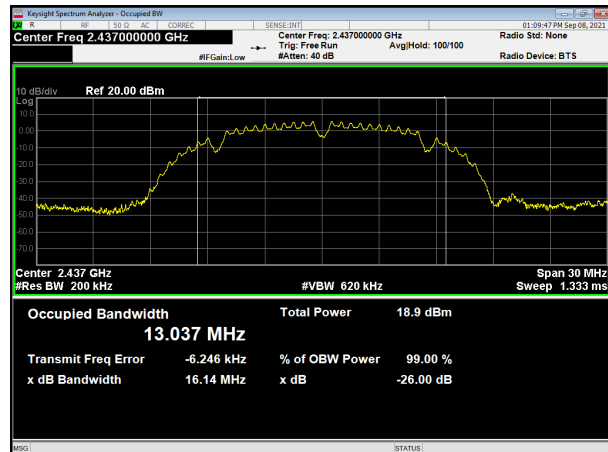


## 802.11g, Carrier frequency (MHz): 2437

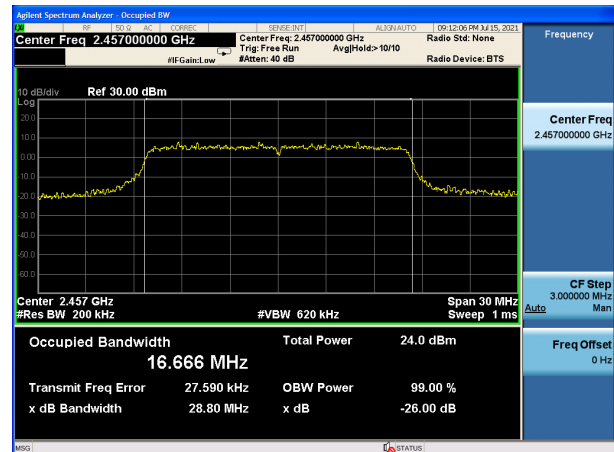




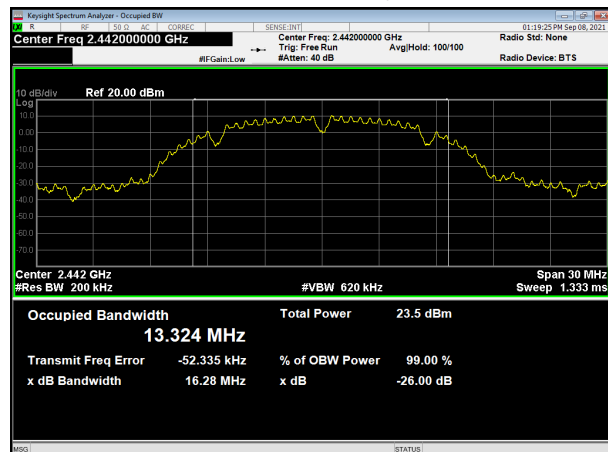
## 802.11b, Carrier frequency (MHz): 2437



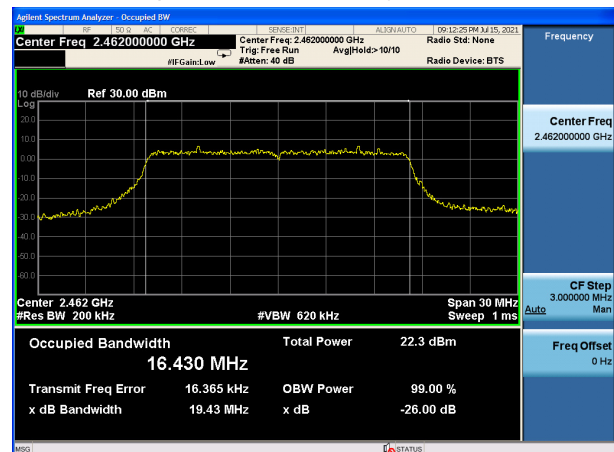
## 802.11g, Carrier frequency (MHz): 2457



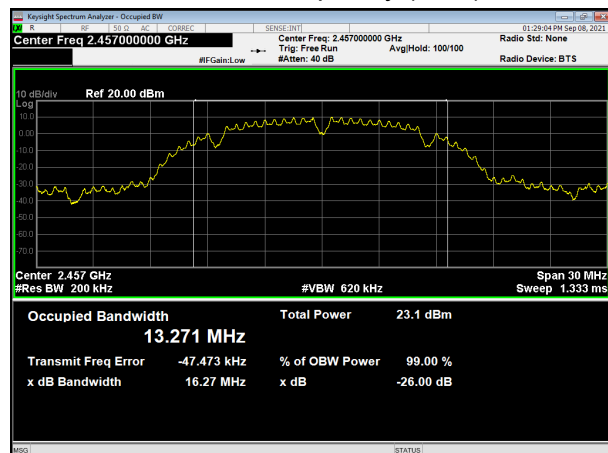
## 802.11b, Carrier frequency (MHz): 2442



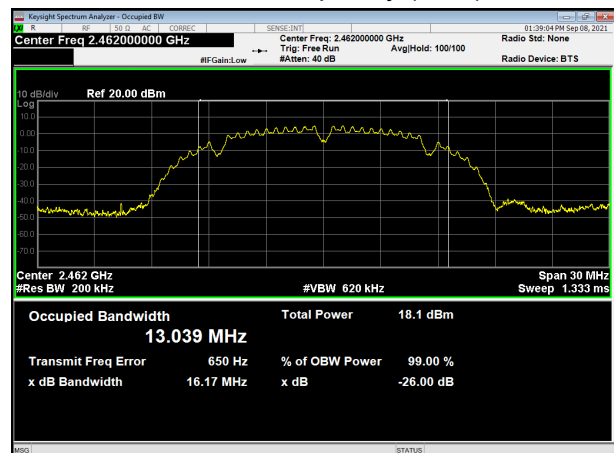
## 802.11g, Carrier frequency (MHz): 2462



## 802.11b, Carrier frequency (MHz): 2457

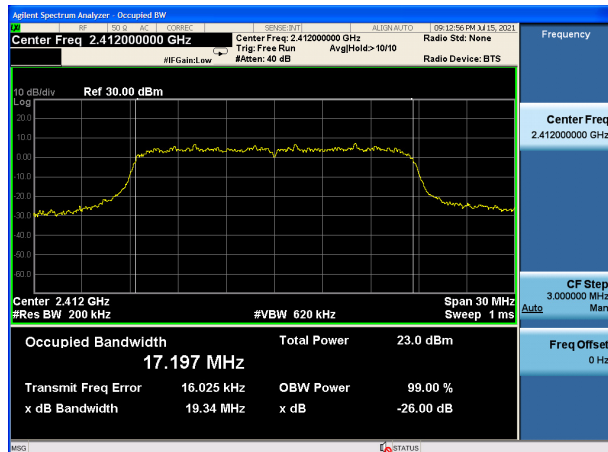


## 802.11b, Carrier frequency (MHz): 2462

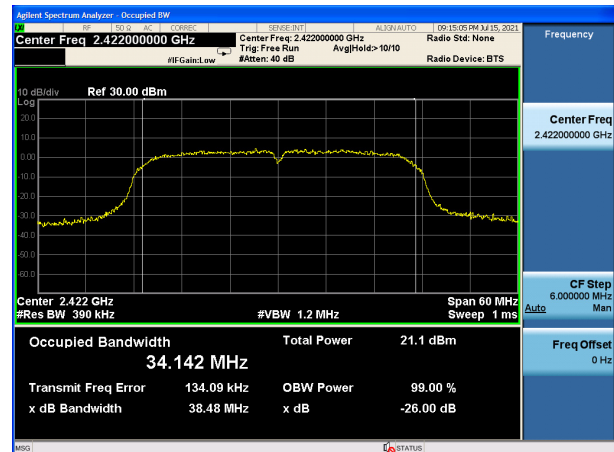




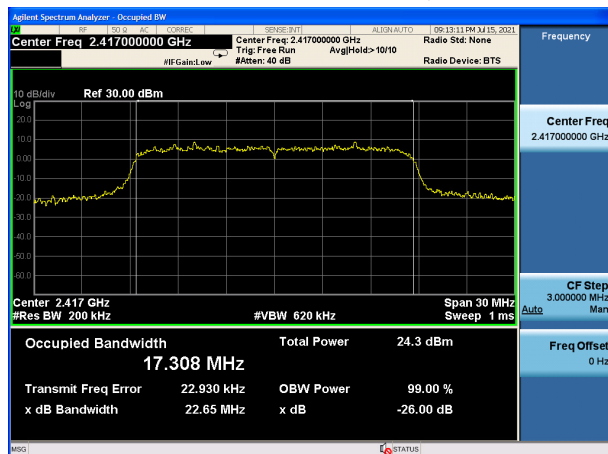
## 802.11n(HT20), Carrier frequency (MHz): 2412



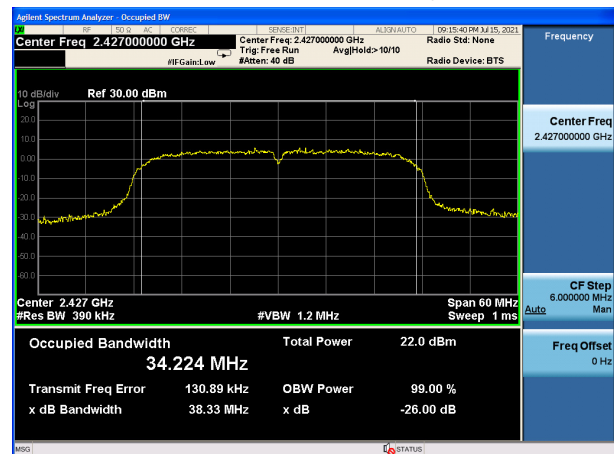
## 802.11n(HT40), Carrier frequency (MHz): 2422



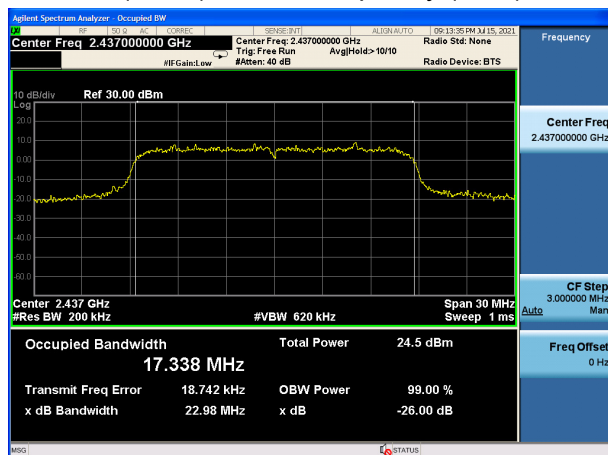
## 802.11n(HT20), Carrier frequency (MHz): 2417



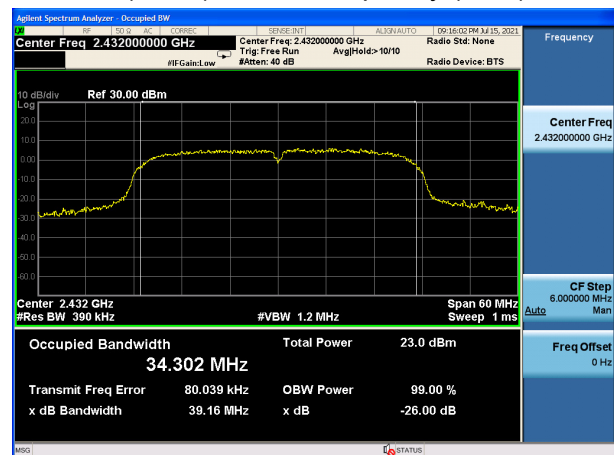
## 802.11n(HT40), Carrier frequency (MHz): 2427



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

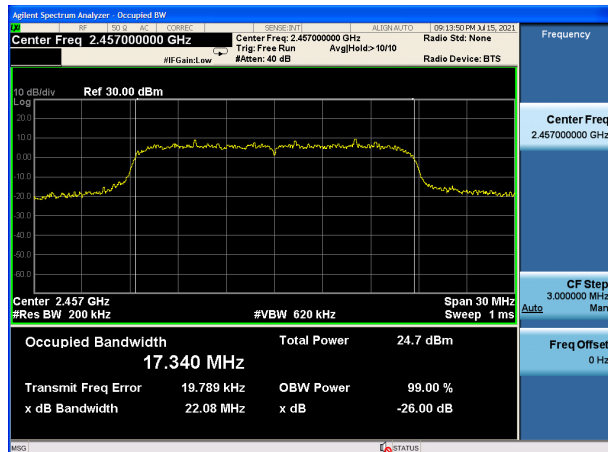


## 802.11n(HT40), Carrier frequency (MHz): 2432

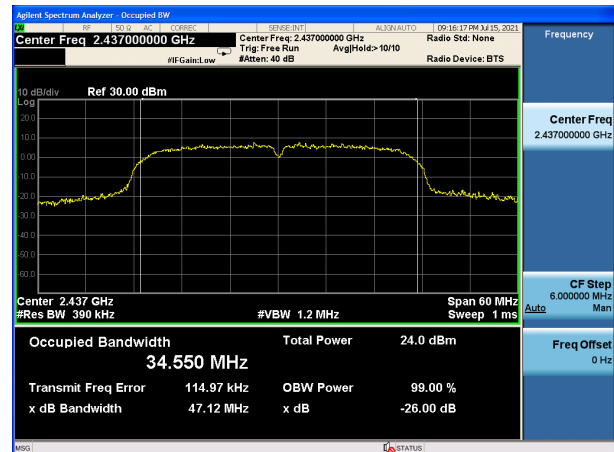




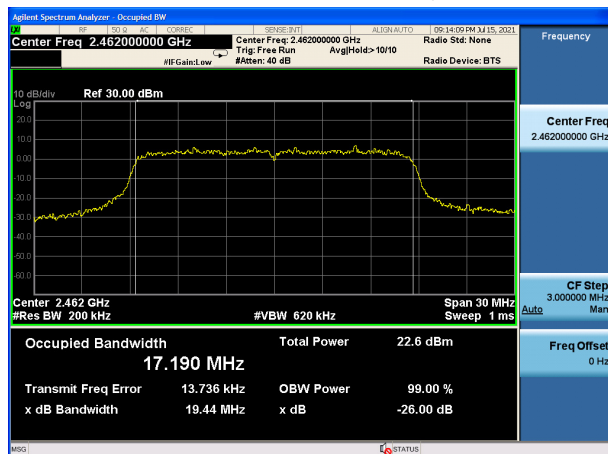
## 802.11n(HT20), Carrier frequency (MHz): 2457



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



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



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

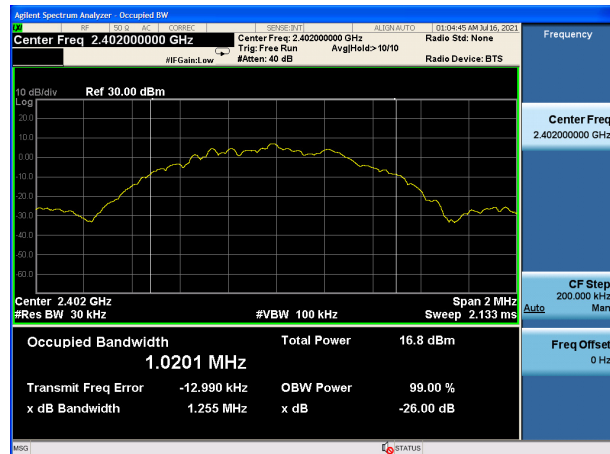


## 802.11n(HT40), Carrier frequency (MHz): 2447

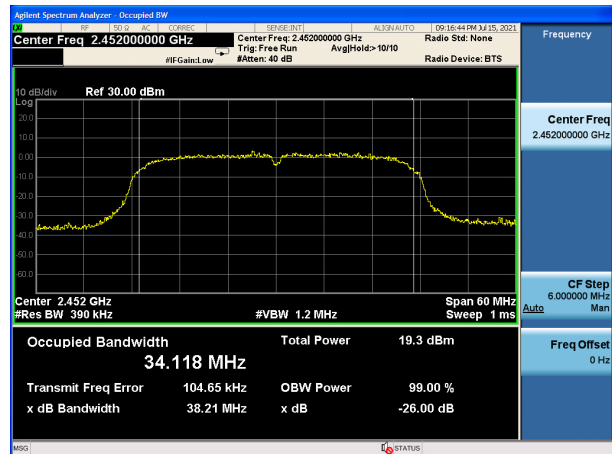




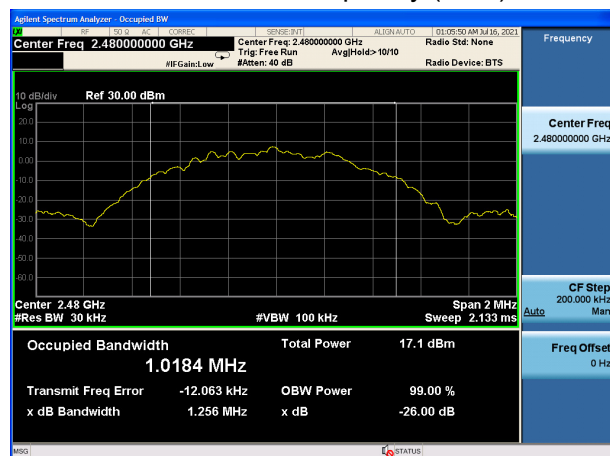
## Bluetooth LE Carrier frequency (MHz): 2402



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



## Bluetooth LE Carrier frequency (MHz): 2480



## Bluetooth LE Carrier frequency (MHz): 2440

