ESP32 & ESP8266 RF Performance Test Demonstration

Version 2.0

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About This Guide

This guide demonstrates how to run an RF performance tests on ESP8266 and ESP32 devices with an RF tester. ESP-WROOM-02 and ESP-WROOM-32 are used as examples in this document.

Release Notes

Date	Version	Release notes
2017.12	V1.0	First release
2018.03	V2.0	Major revision: An RF test tool is used to run the tests

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Table of Contents

1. Demonstration Setup

The setup required for conducting the RF performance test is shown below:

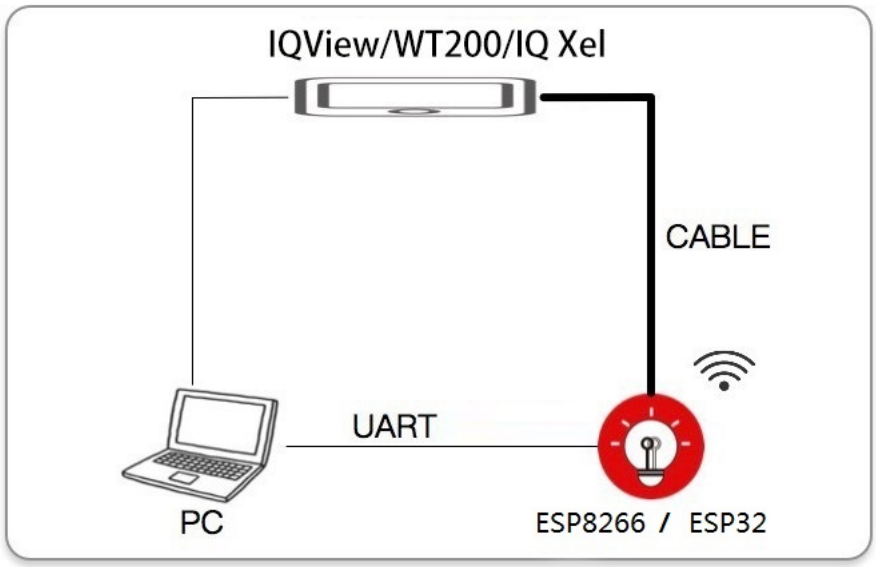


Figure 1-1. RF Performance Test Setup

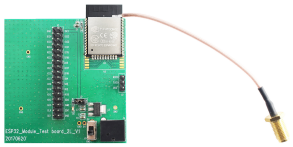
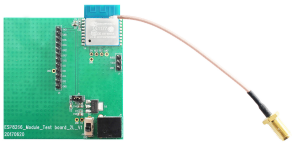
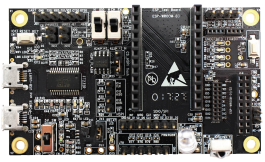
- Device Under Test (DUT): It is an ESP8266 or ESP32 module that runs the RF test program. ESP-WROOM-02 and ESP-WROOM-32 are used as examples in this demonstration.
- PC: The RF testing tool runs on the PC. It communicates with the DUT through the UART interface.
- RF tester: It is a piece of equipment that tests the RF performance of ESP-WROOM-02 and ESP-WROOM-32, working in different modes. IQView or other similar testers are recommended. This demo uses IQView as an example.

2. Environment Setup

2.1. Environment Preparation

2.1.1. Hardware Preparation

Table 2-1. Hardware Preparation

Name	Picture	Quantity	Description
ESP-WROOM-32 test board		1	It comes with an ESP-WROOM-32 module and a backplane.
ESP-WROOM-02 test board		1	It comes with an ESP-WROOM-02 module and a backplane.
Demo board (ESP-Launcher without a module)		1	The DUT communicates with the demo board through the serial port.
Micro-USB cable		1	It connects the DUT and the PC.
PC	-	1	The PC runs relevant software. Windows 7 OS is recommended.
5V power supply	-	1	It is the power supply for the DUT.
Tester (IQView)	-	1	It tests the RF performance and shows the test results.

2.1.2. Software Preparation

Table 2-2. Software Preparation

Name	Description
ft232r-usb-uart.zip	USB-UART converter driver
RF test tool (EspRFtestTool)	This is a program that integrates the downloading and running of the test firmware.

2.2. Hardware Connection

- Connect the SMA (SubMiniature version A) RF head to the antenna of the DUT. Users should cut off the PCB antenna of the DUT after soldering the RF cable to it; otherwise, the test results will be inaccurate.
- Connect the demo board and the PC via a micro-USB cable. For instructions on how to install the UART driver on the PC, please refer to ***Appendix I***.
- Use Dupont lines to connect the backplane's GND, TXD and RXD pins to the demo board's GND, TXD and RXD pins, respectively.

The hardware connection for ESP-WROOM-02 is shown in Figure 2-1. To enable its downloading mode, connect ESP-WROOM-02's GPIO0 and GPIO15 to GND. After downloading, leave GPIO0 floating and restart the module to enable its working mode.

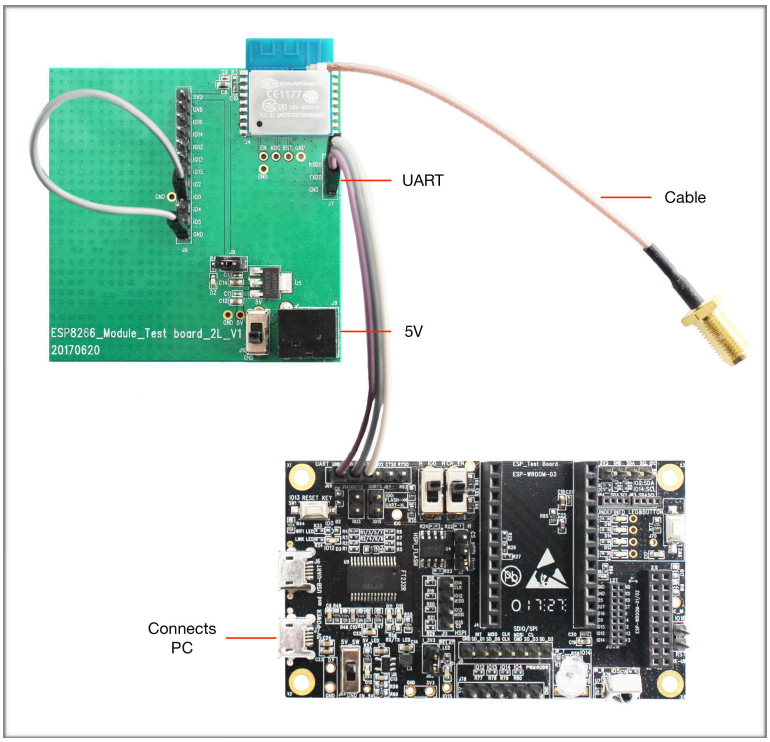


Figure 2-1. Hardware Connection for ESP-WROOM-02

The hardware connection for ESP-WROOM-32 is shown in Figure 2-2. To enable its downloading mode, connect ESP-WROOM-32's GPIO0 to GND. After downloading, leave GPIO0 floating and restart the module to enable its working mode.

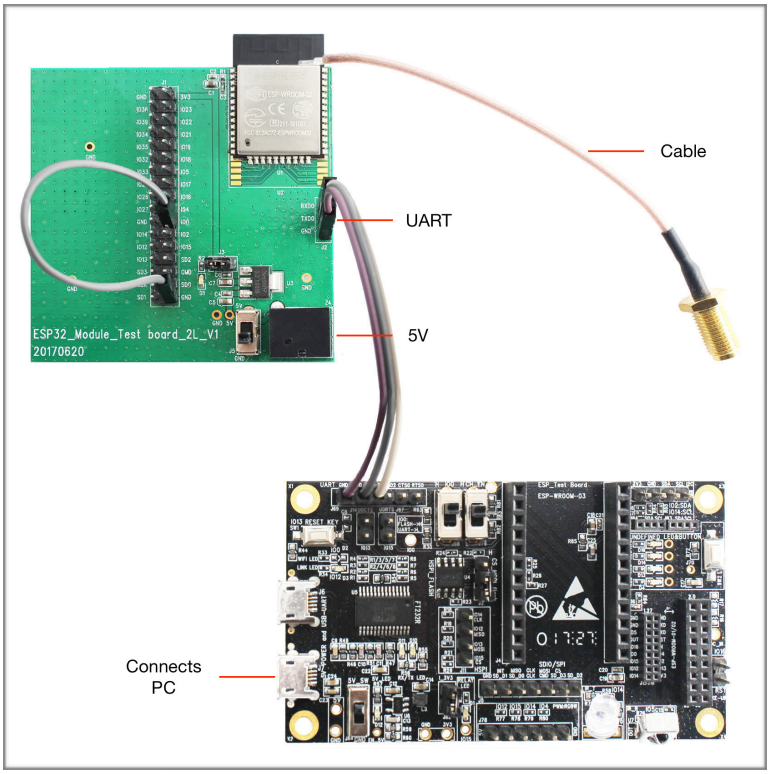


Figure 2-2. Hardware Connection for ESP-WROOM-32

2.3. Software Installation

- Download and install the EspRFtestTool.
- Install the software components of the RF tester (IQView).

2.4. ESP-Launcher

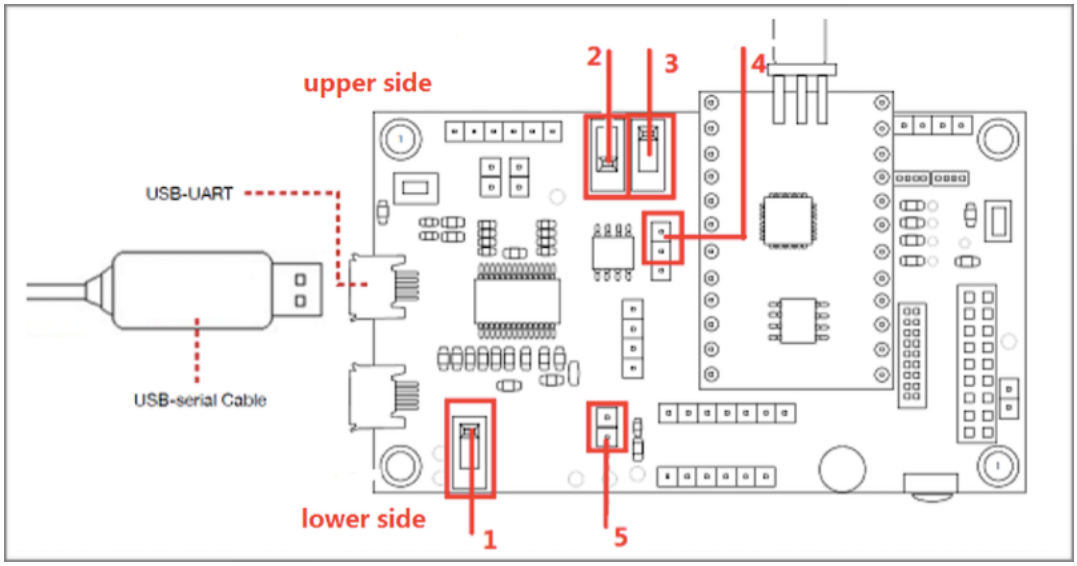


Figure 2-3. ESP-Launcher

- Switch "1": toggle it to the lower side
  - Lower side: power-off
  - Upper side: power-on
- Switch "2": toggle it to the lower side
  - Lower side: firmware download mode
  - Upper side: program execution mode

  Switch "2" is used to test ESP-Launcher. RF testing on ESP-WROOM-32 and ESP-WROOM-02 do not require switch "2".
- Switch "3": toggle it to the upper side

  This is the chip selection switch that should be toggled to the upper side by default.
- Pin "4": put a jumper cap on the upper two pins
- Pin "5": put a jumper cap on it
- The VDD33 and GND on ESP-Launcher can be used as the power supply for the DUT.

3. Introduction to the EspRFtestTool

The EspRFtestTool includes the following features:

- Configurable download addresses of firmware, including RAM and flash
- Three RF test items: Wi-Fi, BT and manually-input-command tests
- Log output can be printed or saved
- Online help documentation

Figure 3-1 shows the EspRFtestTool interface.

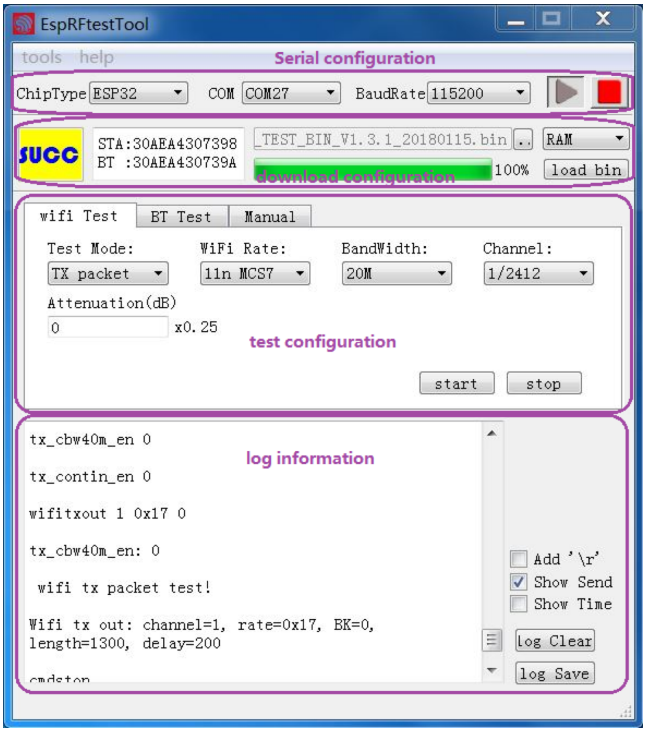


Figure 3-1. EspRFtestTool Interface

There are primarily four sections on the interface:

- Serial configuration: The configuration items include chip type, COM port, baud rate and the status of the serial port.
- Download configuration: The configuration items include BIN-selection button, download address (RAM or flash), download status and load bin (download button). The status block, highlighted in yellow shows "SYNC", "LOAD", "SUCC" or "FAIL".
- Test configuration: The test items include Wi-Fi, BT and manually-input-command tests. Click on "start" to begin the test, and "stop" to terminate the test.

- Log information: All operating data are printed in this block. Users can save or clear the log output.

4. RF Performance Test

This chapter takes ESP-WROOM-32 as an example to demonstrate how to use the EspRFtestTool to run the RF performance test.

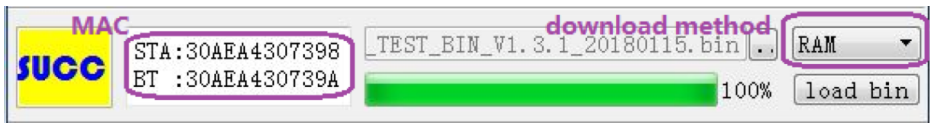
Follow the steps to start the test:

1. Configure the serial port

- Double-click ***espRFTool.exe*** to run the EspRFtestTool.
- Choose ESP32 for "ChipType".
- Choose the right port number (COM27 in this case).
- Set the baud rate to 115200.
- Set the status of the serial port to "open" (the port can switch between statuses).

2. Download the firmware

- Select the BIN file to be downloaded. ***ESP32_RF_TEST_BIN_V1.3.1_20180115.bin*** is downloaded in this document.
- Choose the download address: RAM or Flash.
- MAC address: The status block shows the MAC address of the chip. For ESP32, the STA and BT addresses appear; while for ESP8266, only the STA address appears.
- Click on "load bin" and start the downloading process. "SUCC" will appear if the downloading process finishes successfully.
- If the firmware is downloaded into flash, leave GPIO0 floating and re-power on the module after successful downloading. If the firmware is downloaded into RAM, run the firmware directly, without leaving GPIO0 floating or re-powering on the module.



> 📖 ***Note:***
>
> *If the BIN file is downloaded to flash, users need to download it only once, unless there is a later version of the BIN file.*

3. Run the RF test

3.1 Wi-Fi Tx performance test

1. Choose "wifi Test" in the test's configuration section.

2. Choose "Tx packet" for "Test Mode" and set the "WiFi Rate", "BandWidth", "Channel" and "Attenuation". Tx data rates are listed in Table 4-1.

   For example, if the data rate is set to MCS7, bandwidth to 20M, and channel to 1, as shown in Figure 4-1, you will get the log output described below:

```
tx_contin_en  1: continuous Tx mode with a duty ratio of 100%
tx_contin_en  0: Tx packet mode
tx_cbw40m_en  0: 11n HT20, 20M bandwidth
tx_cbw40m_en  1: 11n HT40, 40M bandwidth
```

3. Click on "stop" to end the Tx process and the returned message is "cmdstop".
4. Before switching to other channels or data rates, please click on “stop” to terminate the current transmission.

Table 4-1. Tx Data Rates

11b		11g		11n	
Parameter	Data rate	Parameter	Data rate	Parameter	Data rate
0x0	1 Mbps	0xb	6 Mbps	0x10	6.5 Mbps/MCS0
0x1	2 Mbps	0xf	9 Mbps	0x11	13 Mbps/MCS1
0x2	5.5 Mbps	0xa	12 Mbps	0x12	19.5 Mbps/MCS2
0x3	11 Mbps	0xe	18 Mbps	0x13	26 Mbps/MCS3
-	-	0x9	24 Mbps	0x14	39 Mbps/MCS4
-	-	0xd	36 Mbps	0x15	52 Mbps/MCS5
-	-	0x8	48 Mbps	0x16	58.5 Mbps/MCS6
-	-	0xc	54 Mbps	0x17	65 Mbps/MCS7

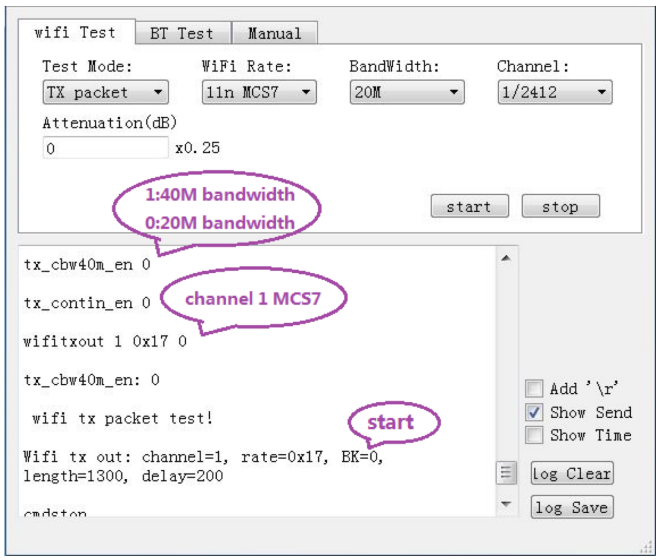


Figure 4-1. ESP32 Wi-Fi Tx Test Log Output

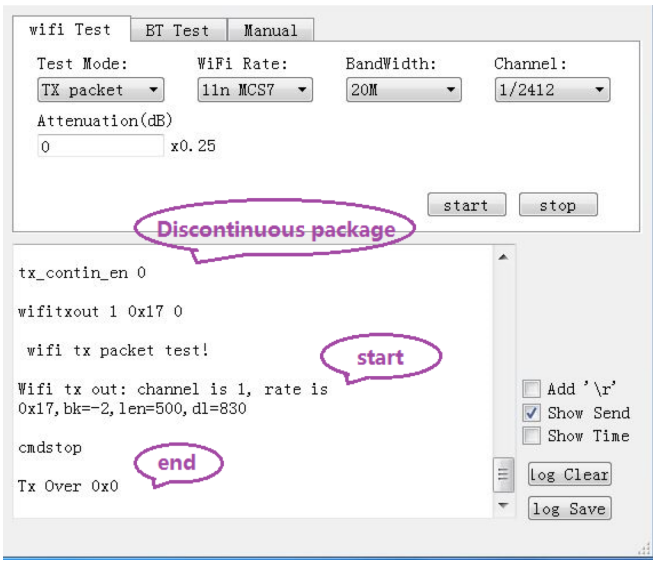


Figure 4-2. ESP8266 Log Output

3.2 Wi-Fi Rx performance test

1. Choose "wifi Test" in the test configuration section.
2. Choose "Rx packet" for "Test Mode" and set the "WiFi Rate", "BandWidth", "Channel" and "Attenuation". Click on "start" to begin the test and "stop" to end the test.

   In the log output shown in Figure 4-3:

   - "Correct" indicates the number of received packets.
   - "Desired" indicates the number of packets received with the corresponding data rate.
   - "RSSI" indicates the average power of the Desired packets received.

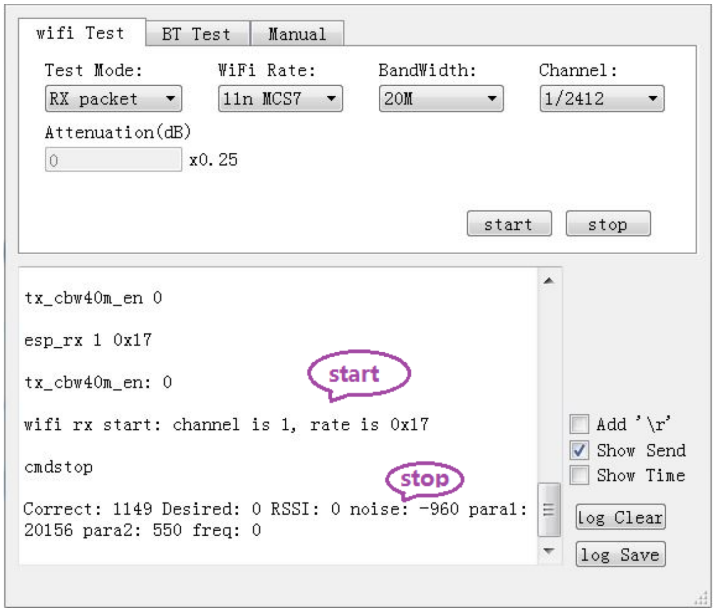


Figure 4-3. ESP32 Wi-Fi Rx Test Log Output

3.3 BT Tx performance test

1. Choose "BT Test" in the test configuration section.
2. Choose "BT TX" for "Test Mode" and set the "Power Level", "Channel" and "Hoppe".

   For example, to test the BT Tx performance on channel0 at a data rate of 1M_DH1_1010, set the configurations shown in Figure 4-4. After the testing process, you will get the log output described below.

   fcc_bt_tx is followed by seven parameters, each of which is described below:

   <Parameter1>: Tx power level with a range of 0-8 (typically 4), in multiples of 3 dB.

   <Parameter2>: Enables or disables frequency hopping. 1: enable; 0: disable.

   <Parameter3>: Selects the Tx channel from 0 ~ 78.

   <Parameter4>: Selects the frequency modulation type. 1: 1M, 2: 2M, 3: 3M.

   <Parameter5>: Selects the DH type: 1: DH1, 3: DH3, 5: DH5.

   <Parameter6>: Selects the data type. 0: 1010, 1: 00001111, 2: prbs9.

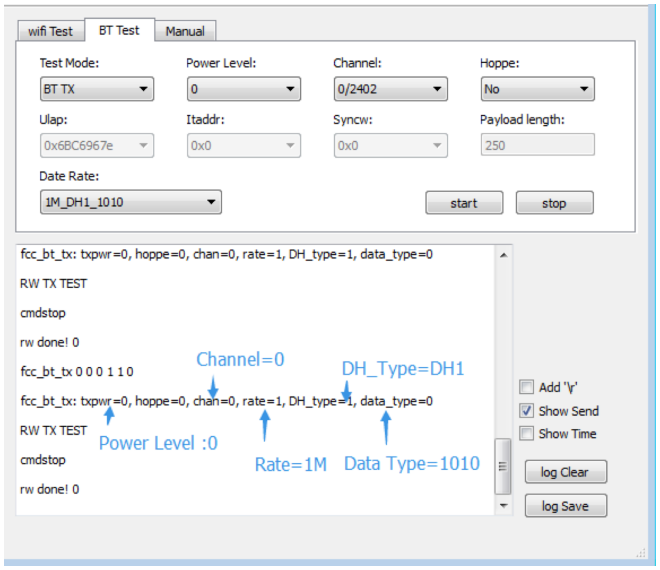


Figure 4-4. BT Tx Test Log Output

3.4 BT Rx performance test

Choose "BT RX" for "Test Mode", set the "Power Level", "Channel" and "Hoppe".

For example, to test the BT Rx performance on channel0 at a data rate of LE_prbs9, set the configurations shown in Figure 4-5. After the testing process, you will get log output.

The format of the number of received packets is:

```
0 0 0 0 0 0 0 0 w 0 0 0 0 0 0 0 0 p 0 0 0 b 0 0
```

There are four parameters in the log output, among which:

- The first parameter, based on the hexadecimal system, indicates the total number of received packets.

- The second parameter, based on the hexadecimal system, indicates the number of received packets at the corresponding data rate.
- The last parameter, based on the hexadecimal system, indicates the number of bit errors.
- The second-to-last parameter, based on the hexadecimal system, indicates the total number of received bits at the corresponding data rate.

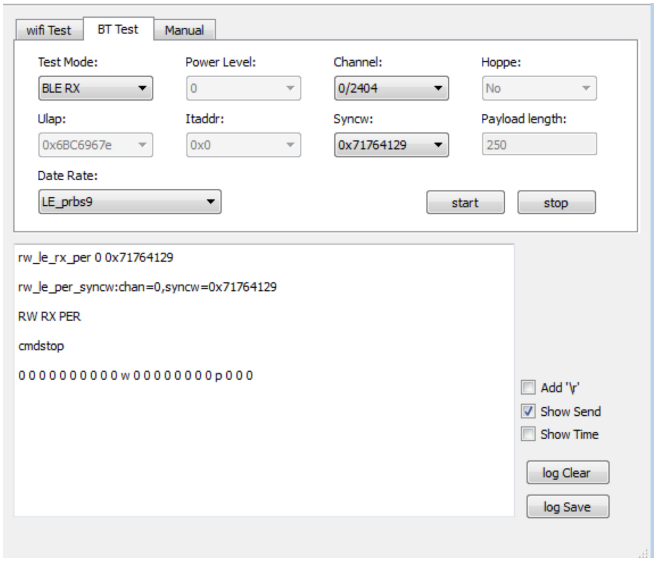


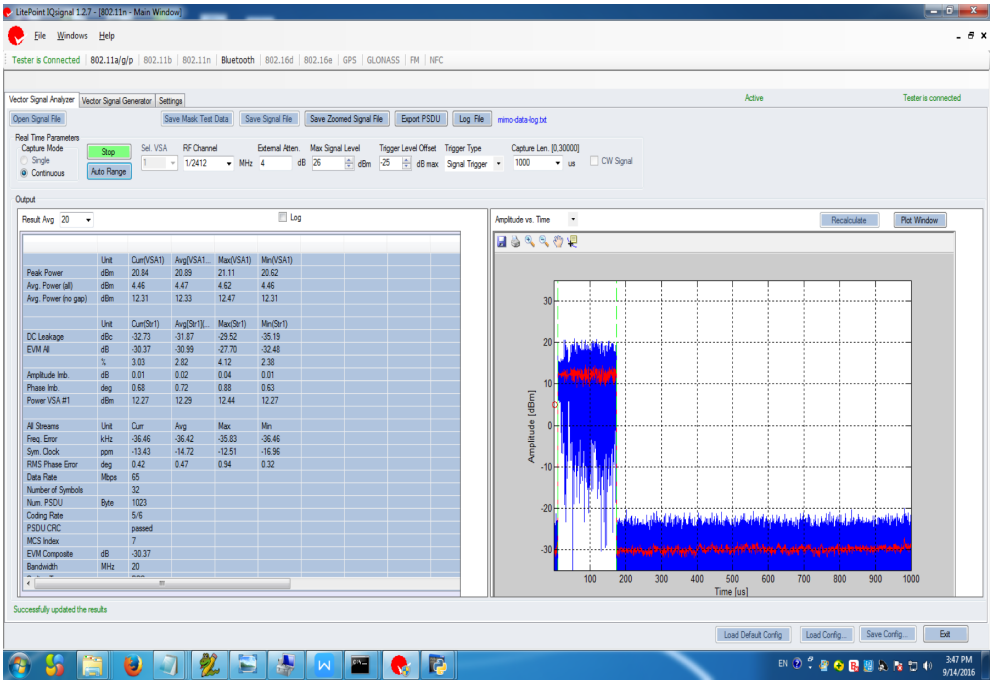
Figure 4-5. BT Rx Log Output

3.5 Manually-input-command test

Choose "Manual" in the test configuration section. Make sure you check "Add '\r'" before sending commands.

4. Get RF test results

Set the right test configurations (e.g., 11n MCS7, channel 1) on the tester interface. The tester will present the RF test results, as shown in the picture below.



> 📖 ***Notes:***
>
> - *Users need to set a correct vale for path loss, otherwise, the test results will be inaccurate.*
> - *The target test values can be found in **Appendix II**.*

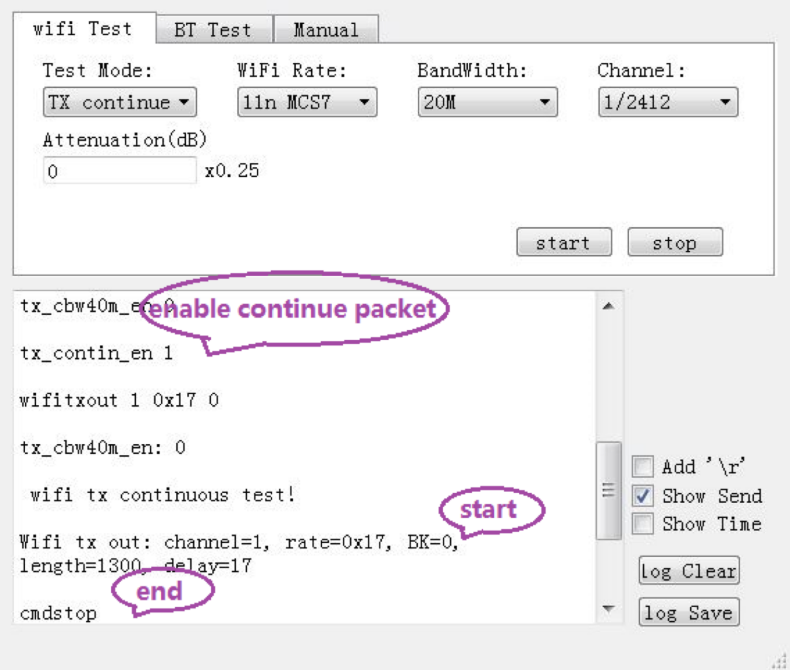
5. RF Certification Test

ESP8266 and ESP32 share the same RF certification testing process. This chapter takes the ESP32 RF certification test as an example.

The test BIN is ***ESP32_RF_TEST_BIN_V1.3.1_20180115.bin***, and the baud rate is 115200. Follow the instructions in chapter 4 to configure the serial port and download the firmware.

5.1 Wi-Fi certification test

1. Choose "wifi Test" in the test configuration section. Choose "TX continue" for the "Test Mode", set the "WiFi Rate", "BandWidth", "Channel" and "Attenuation", as shown in the picture below. "Attenuation" indicates the power attenuation in multiples of 0.25 dB. Users can set the value as required.



2. Click on "start" to send commands. Refer to Table 4-1 for data rates. Click on "stop" to end the test.
3. Before switching to other channels or data rates, please click on “stop” to terminate the current transmission.

5.2 BT certification test

The BT certification test shares the same testing process as the BT test that is described in the chapter 4.

I. Appendix - Install a UART Driver on ESP-Launcher

Use a micro-USB cable to connect the ESP-Launcher to the PC. The UART driver will be installed automatically. A dialogue window will appear as the following picture shows:

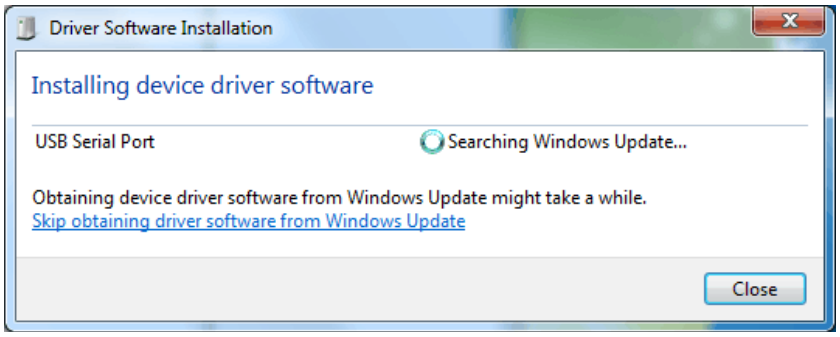


Figure I-1. Installing UART Driver on the PC

When the installation finishes, a dialogue window will appear as the following picture shows:

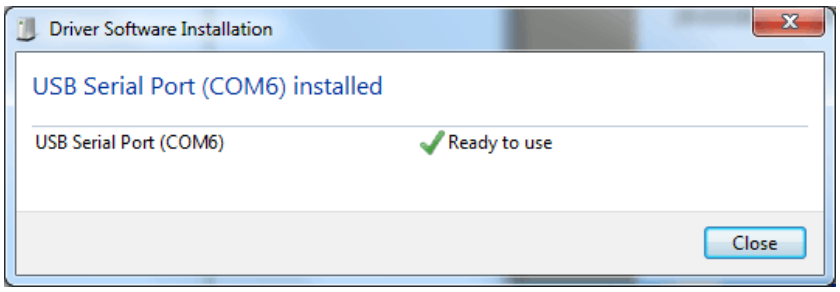


Figure I-2. UART Driver Installed

> 📖 ***Note:***
>
> *If the UART driver installation fails, users can install **./Tools/ft232r-usb-uart.zip** provided by Espressif.*

The EspRFtestTool will automatically check the port number that will appear in the drop-down menu in the serial configuration section.

II. Appendix - ESP32 & ESP8266 RF Test Target Values

Table II-1. RF Test Target Values of ESP32 Running in Different Modes

Modulation/Data rate (bps)	Standard TX EVM (dbm)	ESP32 TX Power (dbm)	ESP32 TX EVM (dbm)	ESP32 RX Sensitivity (dbm)
802.11b 1M	–10	19.5 ± 2 dB	–17	–98
802.11b 2M	–10	19.5 ± 2 dB	–17	–96
802.11b 5.5M	–10	19.5 ± 2 dB	–17	–94
802.11b 11M	–10	19.5 ± 2 dB	–17	–91
802.11g 6M	–5	18.0 ± 2 dB	–19	–93
802.11g 9M	–8	18.0 ± 2 dB	–19	–92
802.11g 12M	–10	18.0 ± 2 dB	–19	–90
802.11g 18M	–13	18.0 ± 2 dB	–20	–88
802.11g 24M	–16	16.5 ± 2 dB	–20	–85
802.11g 36M	–19	16.5 ± 2 dB	–24	–82
802.11g 48M	–22	15.0 ± 2 dB	–26	–78
802.11g 54M	–25	14.0 ± 2 dB	–27	–74
802.11n MCS0/6.5M/7.2M	–5	18.0 ± 2 dB	–19	–90
802.11n MCS1/13M/14.4M	–10	18.0 ± 2 dB	–19	–90
802.11n MCS2/19.5M/21.7M	–13	18.0 ± 2 dB	–21	–87
802.11n MCS3/26M/28.9M	–16	16.5 ± 2 dB	–20	–84
802.11n MCS4/39M/43.M	–19	16.5 ± 2 dB	–23	–81
802.11n MCS5/52M/57.8M	–22	15.0 ± 2 dB	–26	–77
802.11n MCS6/58.5M/65M	–25	14.0 ± 2 dB	–27	–75
802.11n HT20 MCS7/65M/72.2M	–27	13.0 ± 2 dB	–29	–71
802.11n HT40 MCS0/6.5M/7.2M	–5	18.0 ± 2 dB	–19	–89
802.11n HT40 MCS1/13M/14.4M	–10	18.0 ± 2 dB	–19	–87

Modulation/Data rate (bps)	Standard TX EVM (dbm)	ESP32 TX Power (dbm)	ESP32 TX EVM (dbm)	ESP32 RX Sensitivity (dbm)
802.11n HT40 MCS2/19.5M/21.7M	–13	18.0 ± 2 dB	–21	–84
802.11n HT40 MCS3/26M/28.9M	–16	16.5 ± 2 dB	–20	–82
802.11n HT40 MCS4/39M/43M	–19	16.5 ± 2 dB	–23	–79
802.11n HT40 MCS5/52M/57.8M	–22	15.0 ± 2 dB	–26	–75
802.11n HT40 MCS6/58.5M/65M	–25	14.0 ± 2 dB	–27	–73
802.11n HT40 MCS7/65M/72.2M	–27	13.0 ± 2 dB	–29	–69

Table II-2. RF Test Target Values of ESP8266 Running in Different Modes

Modulation/Data rate (bps)	Standard TX EVM (dbm)	ESP8266 TX Power (dbm)	ESP8266 TX EVM (dbm)	ESP8266 RX Sensitivity (dbm)
802.11b 1M	–10	19.5 ± 2 dB	–17	–98
802.11b 2M	–10	19.5 ± 2 dB	–17	–96
802.11b 5.5M	–10	19.5 ± 2 dB	–17	–94
802.11b 11M	–10	19.5 ± 2 dB	–17	–91
802.11g 6M	–5	19.5 ± 2 dB	–19	–93
802.11g 9M	–8	19.5 ± 2 dB	–19	–92
802.11g 12M	–10	19.5 ± 2 dB	–19	–90
802.11g 18M	–13	18.5 ± 2 dB	–20	–88
802.11g 24M	–16	18.5 ± 2 dB	–20	–85
802.11g 36M	–19	17.5 ± 2 dB	–24	–82
802.11g 48M	–22	16.0 ± 2 dB	–26	–78
802.11g 54M	–25	15.0 ± 2 dB	–27	–74
802.11n MCS0/6.5M/7.2M	–5	19.5 ± 2 dB	–19	–92
802.11n MCS1/13M/14.4M	–10	19.5 ± 2 dB	–19	–90
802.11n MCS2/19.5M/21.7M	–13	18.5 ± 2 dB	–21	–87
802.11n MCS3/26M/28.9M	–16	18.5 ± 2 dB	–20	–84
802.11n MCS4/39M/43.M	–19	17.5 ± 2 dB	–23	–81

Modulation/Data rate (bps)	Standard TX EVM (dbm)	ESP8266 TX Power (dbm)	ESP8266 TX EVM (dbm)	ESP8266 RX Sensitivity (dbm)
802.11n MCS5/52M/57.8M	–22	16.0 ± 2 dB	–26	–77
802.11n MCS6/58.5M/65M	–25	15.0 ± 2 dB	–28	–75
802.11n MCS7/65M/72.2M	–27	14.0 ± 2 dB	–30	–70

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