AN1491: SiWx917 RF Transmit & Receive Measurements

This App Note describes the procedure for Transmit Power & Receive Sensitivity measurements with SiWx917. CLI demo application is used to configure suitable RF parameters enabling Tx & Rx modes. The steps for running CLI demo via UART interface are mentioned in detail.

The CLI Demo application is a command-line interface (CLI) application designed to showcase various functionalities and capabilities of SiWx917 in different scenarios and configuration modes. CLI allows users to perform tasks quickly and efficiently by entering commands directly.

KEY POINTS

- WLAN RF Test Setup requirements
- Frame the CLI commands using any serial terminal e.g., Serial Debug Assistant and pass the commands via UART interface.
- Transmit test : Commands and Output waveforms showing the spectrum.
- Receive test : Commands and Stats showing various receive parameters.
- Spectrum Analyzer settings

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1. Introduction

SiWx917 has to be initialized and configured before it can be used for Transmit or Receive. There are various PER commands shown here that are used for initialization, configuration and transmit/receive. In this document, SiWG917 SoC Kit (BRD4338A radio board + 4002A base board) is used to run CLI demo and execute relevant PER commands in it. Here are the details for making this setup. However user can have similar customized setup to run the CLI demo and execute PER commands in it.

1.1 Hardware

- SiWG917 SoC Kit (BRD4338A radio board + WPK (BRD4002A base board))
- USB to Type C cable for powering the kit and flashing the application
- A PC with USB port
- Spectrum/Signal Analyzer for WLAN RF Tx measurement
- Signal Generator for WLAN RF Rx measurement
- Coaxial cable (or antenna) for connecting the RF port of the Si917 radio board to the Spectrum/Signal Analyzer or Signal Generator. BRD4338A board is equipped with an SWD type connector (connector type: MuRata - MM8430-2610)

1.2 Software

- Simplicity Studio IDE for creating the CLI project and flashing it onto the SiWG917 radio board with a GSDK suite with the WiSeConnect SDK included.

  (Optional) A Serial terminal software such as Serial Debug Assistant for transmitting and receiving commands. User can download it from the Microsoft store. Serial Debug Assistant is recommended because of the ease of saving the commands. Simplicity Studio can be used as well for serial connection

Note:

Note: The user can use the Simplicity studio's console window for sending and receiving the CLI commands.

Refer Perform Console Output and Input for BRD4338A .

1.3 Setup Diagram

The figure below shows the setup and the connections for the WLAN RF testing.

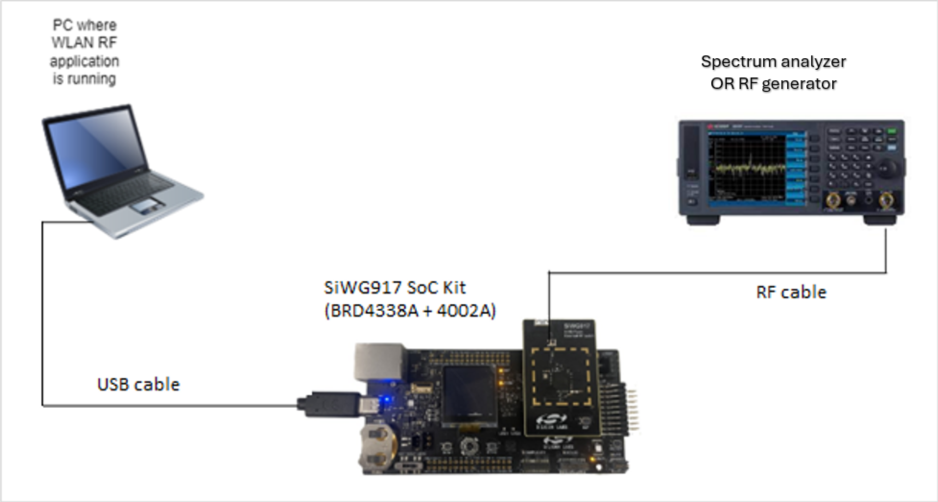


Figure 1.1. Setup Diagram – WLAN RF testing

1.4 Setting up the Development Environment

Thefollowing section describes about setting up SiWG917 SoC kit to use the CLI utility.

1. Launch the Simplicity Studio IDE.]
2. Select the CLI Demo under Examples Project & Demos from the Launcher page.
3. Build and flash the application.

Refer the Getting started guide of SoC for setting up the project and flashing it onto the device.

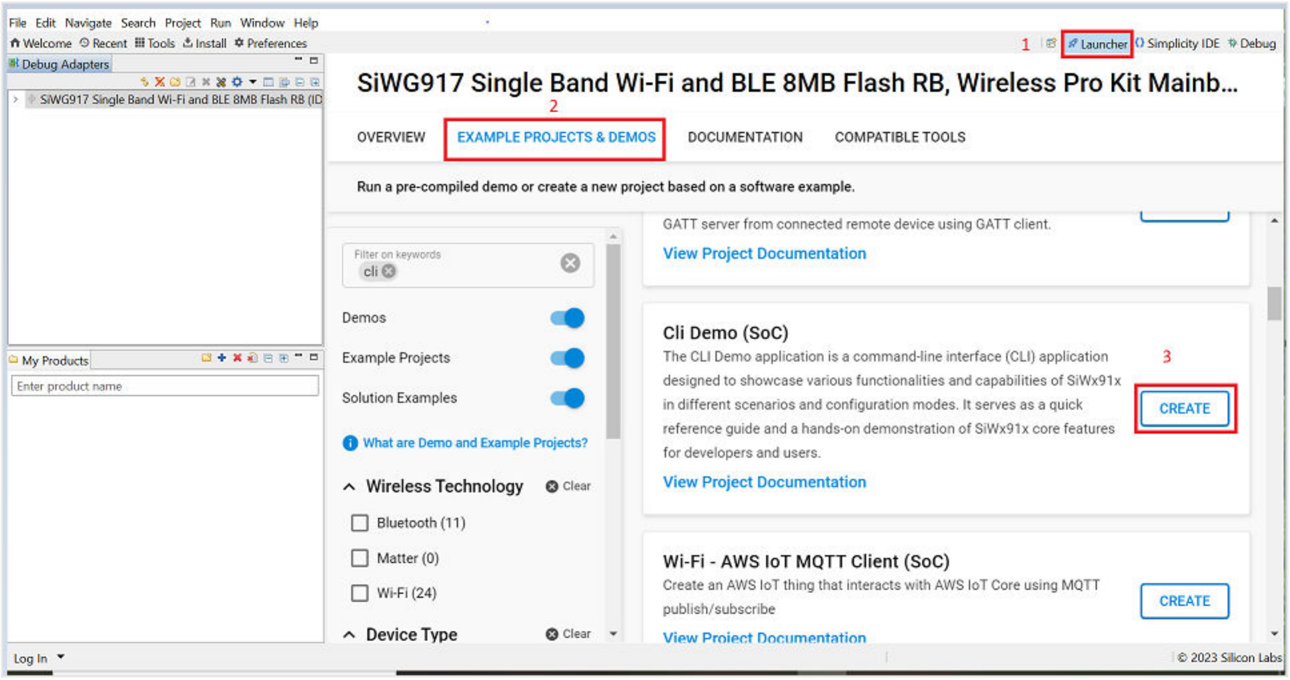


Figure 1.2. Setting up the Development Environment

2. CLI Commands

This section provides the steps to run the CLI utility on SiWG917 SoC.

Launch a **serial** terminal, and follow the below steps.

- Select the **Serial port**, For E.g.: FT232R USB UART or COM Port can be detected.
- Select the **Baud rate** as 115200.

1. Use the **help** command, which will display all the commands of the CLI demo.

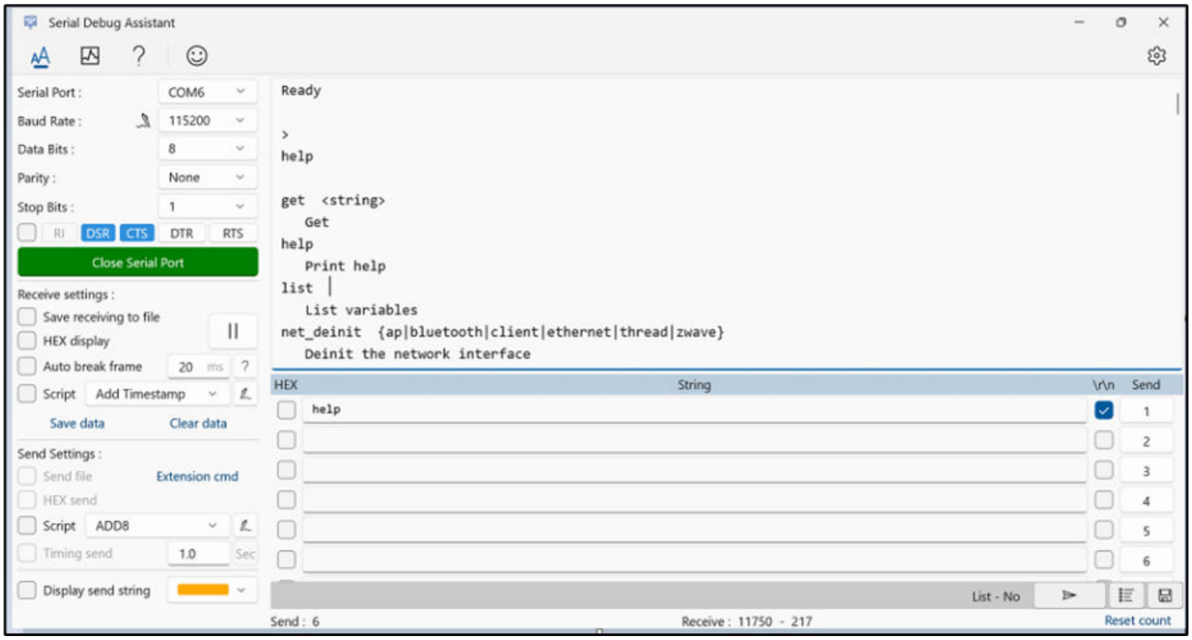


Figure 2.1. Help Command

Note:

- All the CLI commands should end/terminate with <CR><LF>.
- The help command will display all the commands of various functionalities, especially WLAN RF performance test.

3. WLAN RF Performance Test

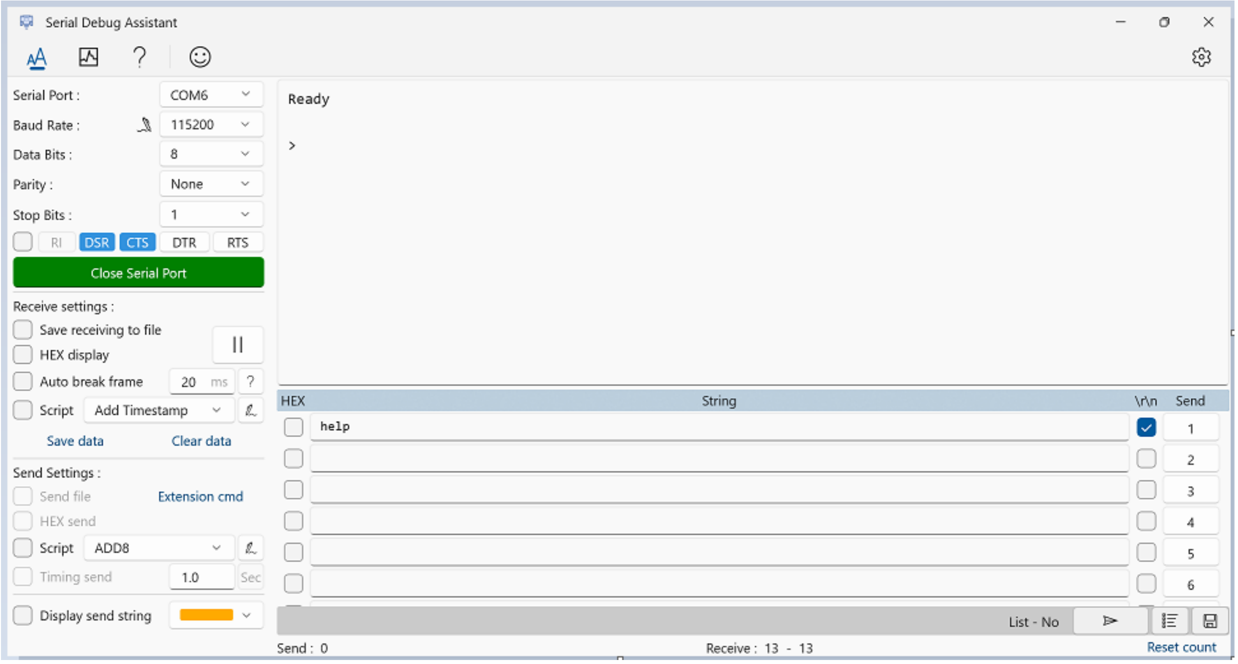
This section provides the transmit test commands for CLI and the steps to follow to send those commands.

3.1 Transmit Test

The following sections explain the steps to setup a serial termina, the CLI commands for transmit test and the expected output wave-forms.

3.1.1 Setup Serial Debug Assistant

1. Click the reset button on the base board and load the binary or application.
2. Once the application is flashed, Ready is displayed on the terminal.
3. Send the transmit test commands from the command window (bottom right portion).

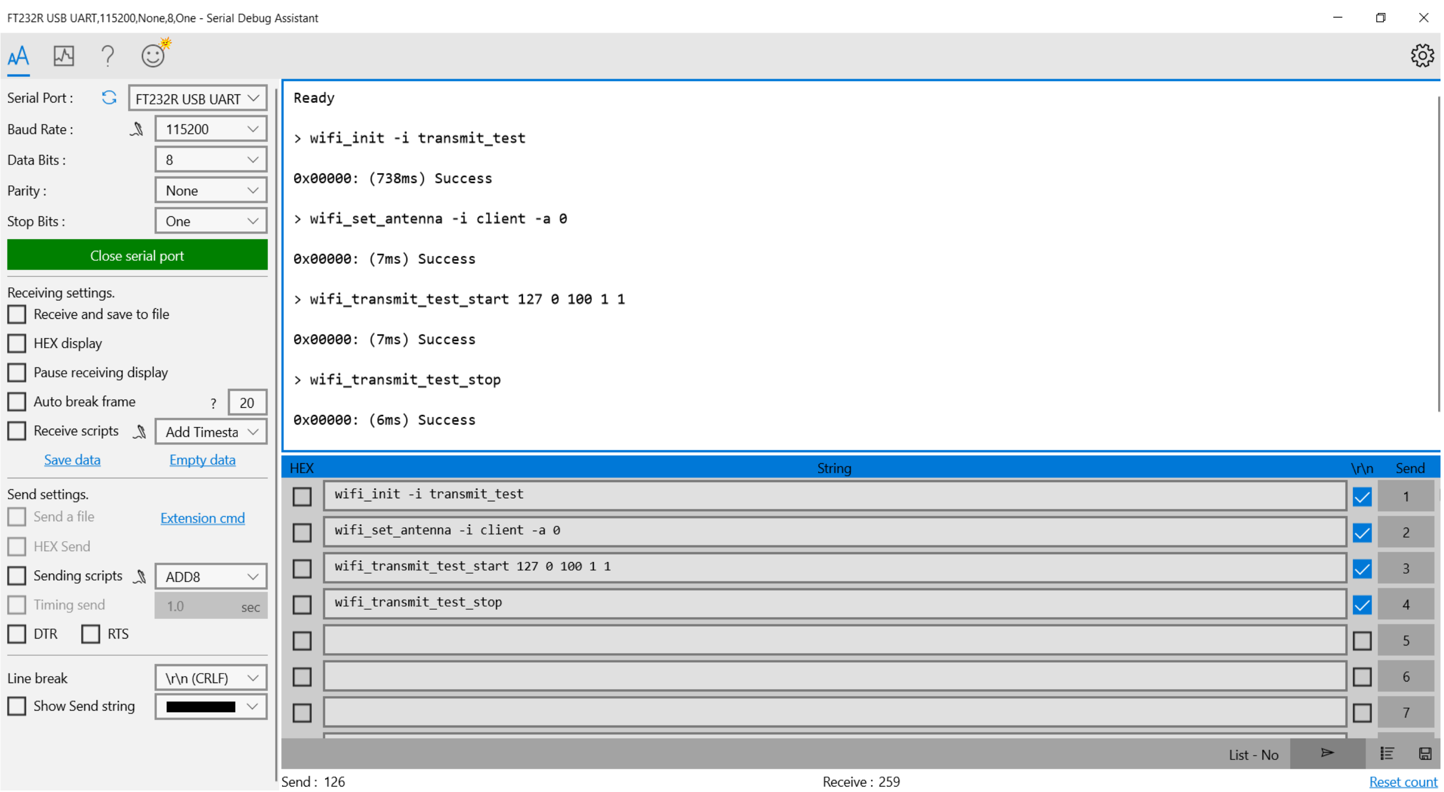


3.1.2 CLI Commands

The below commands are available for the Transmit Test. Their description and examples are shown below.

1	Command	Description	Example
1	wifi_init -i <mode>	For initializing the WiFi interface and for selecting the mode.	wifi_init -i transmit_test
2	wifi_set_antenna -i client -a <antenna type>	Used for selecting the antenna	wifi_set_antenna -i client -a 0 • By default antenna type should be set to 0
3	wifi_transmit_test_start <power> <data rate> <length> <mode> <channel>	To start the transmit test	wifi_transmit_test_start 127 0 100 1 1
4	wifi_transmit_test_stop	To stop the transmit test	wifi_transmit_test_stop

The image below shows the above Transmit Test CLI commands given in the Serial Debug Assistant.



The description of the specific wifi_transmit_test_start command is shown below.

```
wifi_transmit_test_start <power> <data rate> <length> <mode> <channel>
```

Parameter	Description	Example
<power>	Set transmit power. Valid values are from 2dBm to 21dBm and the valid input range is from 0-127. Note: This value is meant for configuring the power level for a particular frequency band. Value = 127 can be used to set the maximum power level passing IEEE spectral mask and EVM specs.	<power> = 127

<table>
<tr><th>Parameter</th><th>Description</th><th>Example</th></tr>
<tr><td><data rate></td><td>Set transmit data rate.
<table>
<tr><th><data rate></th><th>Selected Data Rate (Mbps)</th></tr>
<tr><td>0</td><td>1</td></tr>
<tr><td>2</td><td>2</td></tr>
<tr><td>4</td><td>5.5</td></tr>
<tr><td>6</td><td>11</td></tr>
<tr><td>139</td><td>6</td></tr>
<tr><td>143</td><td>9</td></tr>
<tr><td>138</td><td>12</td></tr>
<tr><td>142</td><td>18</td></tr>
<tr><td>137</td><td>24</td></tr>
<tr><td>141</td><td>36</td></tr>
<tr><td>136</td><td>48</td></tr>
<tr><td>140</td><td>54</td></tr>
<tr><td>256</td><td>MCS0</td></tr>
<tr><td>257</td><td>MCS1</td></tr>
<tr><td>258</td><td>MCS2</td></tr>
<tr><td>259</td><td>MCS3</td></tr>
<tr><td>260</td><td>MCS4</td></tr>
<tr><td>261</td><td>MCS5</td></tr>
<tr><td>262</td><td>MCS6</td></tr>
<tr><td>263</td><td>MCS7</td></tr>
</table></td><td><data rate> = 0</td></tr>
<tr><td><length></td><td>Configure length of the transmit packet.
Valid values are as below:
[24 ... 1500] bytes in burst mode
[24 ... 260] bytes in continuous mode</td><td><length>=1500</td></tr>
<tr><td><mode></td><td>Transmit mode.
<table>
<tr><th>Mode</th><th>Transmit Mode</th></tr>
<tr><td>0</td><td>Burst Mode</td></tr>
<tr><td>1</td><td>Continuous Mode</td></tr>
<tr><td>2</td><td>CW Mode (unmodulated) in DC mode</td></tr>
<tr><td>3</td><td>CW Mode (unmodulated) with a single tone at: center frequency - 2.5 MHz</td></tr>
<tr><td>4</td><td>CW Mode (unmodulated) with a single tone at: center frequency + 5 MHz</td></tr>
</table>
For description on each of these modes refer to Section 3.1.3 Transmit Modes.</td><td><mode>=0</td></tr>
</table>

<table>
<tr><th>Parameter</th><th>Description</th><th>Example</th></tr>
<tr><td><channel></td><td>Set the Channel number.
<table>
<tr><th>Channel Number
(2.4 GHz)</th><th>Center frequency in MHz for 20MHz channel width</th></tr>
<tr><td>1</td><td>2412</td></tr>
<tr><td>2</td><td>2417</td></tr>
<tr><td>3</td><td>2422</td></tr>
<tr><td>4</td><td>2427</td></tr>
<tr><td>5</td><td>2432</td></tr>
<tr><td>6</td><td>2437</td></tr>
<tr><td>7</td><td>2442</td></tr>
<tr><td>8</td><td>2447</td></tr>
<tr><td>9</td><td>2452</td></tr>
<tr><td>10</td><td>2457</td></tr>
<tr><td>11</td><td>2462</td></tr>
<tr><td>12</td><td>2467</td></tr>
<tr><td>13</td><td>2472</td></tr>
<tr><td>14</td><td>2484</td></tr>
</table>
</td><td><channel>=4</td></tr>
</table>

3.1.3 Transmit Modes

Here are the details of transmit modes available for SiWG917. Understanding of these will help in framing the relevant `wifi_transmit_test_start` command.

3.1.3.1 Burst Mode

The DUT transmits a burst of packets with the given power, rate, length in the channel configured.

- The burst size (packet length) will be determined by the <length> parameter in the `wifi_transmit_test_start` command. If the <`length`> parameter is zero, then DUT keeps transmitting until `wifi_transmit_test_stop` command is given.

3.1.3.2 Continuous Mode

The DUT transmits a modulated waveform continuously.

3.1.3.3 Continuous Wave Mode (Non-Modulation) in DC Mode

The DUT transmits a spectrum at the center frequency of the channel only. Continuous wave (CW) signal has no modulation and it is of a sine wave. In the frequency domain, it is viewed as a single line at the specified center frequency.

3.1.3.4 Continuous Wave Mode (Non-Modulation) in Single Tone Mode (Center frequency -2.5 MHz)

The DUT transmits a spectrum that is generated at -2.5 MHz from the center frequency of the selected channel. Some amount of carrier leakage will be seen at Center Frequency.

- Example, for 2412 MHz center frequency, the output will be seen at 2409.5 MHz.

3.1.3.5 Continuous Wave Mode (Non-Modulation) in Single Tone Mode (Center frequency +5 MHz)

The DUT transmits a spectrum that is generated at 5MHz from the center frequency of the selected channel. Some amount of carrier leakage will be seen at Center Frequency.

- Example, for 2412 MHz center frequency, the output will be seen at 2417 MHz.

Note:

- Before starting Continuous Wave mode (CW mode), it is required to first start transmitting at Continuous mode with power and channel values that is intended to be used in CW mode. Here are the steps to be followed.
  1. Start Continuous mode with intended power value and channel value. Use the valid values for rate and length.
  2. Stop Continuous mode.
  3. Start CW mode with the same above power value and channel value.
- To switch CW mode, stop PER mode by giving wifi_transmit_test_stop command and then use the other relevant CW mode.
- It is recommended to measure the TX power with Burst mode or Continuous mode only.
- Continuous wave mode is not recommended for TX power measurement. Continuous wave mode can be used for measuring the frequency error.

3.1.4 Spectral Measurements

3.1.4.1 Measurement Procedure

After commissioning any transmission on the SoC, the radio will generate various signals. The following section shows some examples and gives a general description, about how these spectral measurements can be carried out. Setting up spectral mask measurements on a generic spectrum analyzer

This document doesn’t intend to give a full description how a spectrum analyzer to be used as all models have different behavior and user interface, although we can specify some general settings. Based on the Spectrum Analyzer models, these settings may vary. In the following section the general spectrum, channel power and spectrum mask measurement is demonstrated.

General spectrum measurement settings:

1. Select the **Spectrum analyzer** mode from the Spectrum settings.
2. Set the **Frequency** of the Spectrum analyzer in which the DUT is transmitting.
   Example: If the DUT is transmitting in channel 1, then set the Frequency to 2412 MHz and set the Center Frequency to the same Frequency. If Spectrum Analyzers have the marker option, then set the marker on the same frequency.
3. Select **Span** and type in the frequency value of 50 MHz or 100MHz for WLAN.
4. Set the **RBW** (Resolution Bandwidth) to 100 KHz and **VBW** (Video Bandwidth) to 30 KHz or leave both of them on Auto settings.
5. Set the **Ref level** slightly higher than the expected maximum output power (23 dB for instance).
6. Select **Sweep** button and set the value to 1 sec to update the sweep of the analyzer to every one second or leave on auto setting.
7. Set the Trace settings to Max hold or Average to catch even short transient signals.

If Spectral mask measurement is required and available:

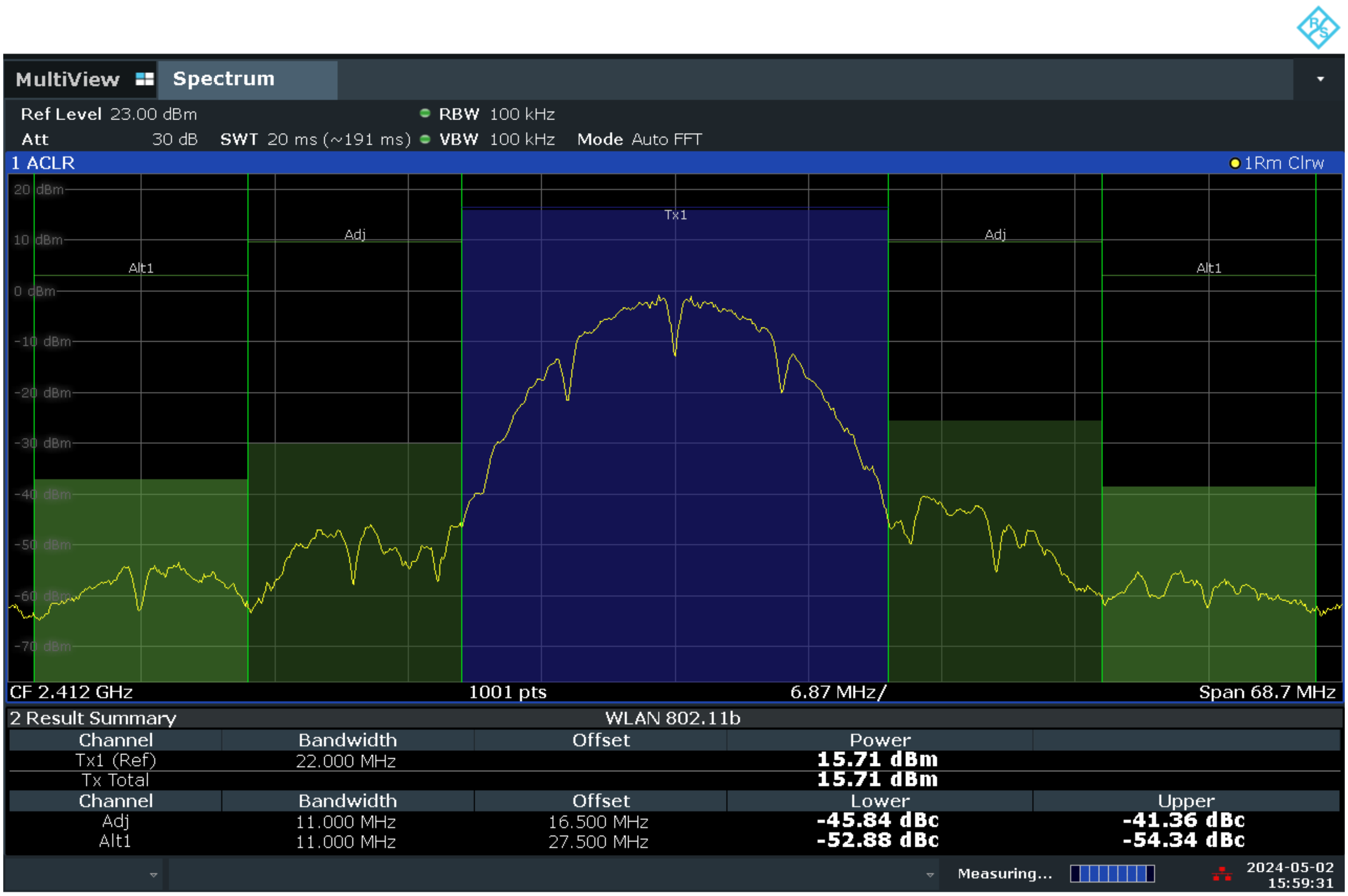
1. Go to measurements and select Spectrum Emission Mask
2. In the measurement configuration set the mask settings manually or select an already defined standard measurement like a WLAN mode 802.11.ax. The spectral mask measurement settings may be described differently for various standard or regulatory testing. Please refer to the corresponding standards.

If Channel power measurement is required and available:

1. Go to measurements menu and select Channel Power
2. In the measurement configuration set the channel (channel width) settings manually or select an already defined standard measurement like a WLAN mode 802.11.b. The channel power measurement settings may be described differently for various standard or regulatory testing. Please refer to the corresponding standards.

3.1.4.2 Measurement Results

802.11b mode (1Mbps data rate) channel power :



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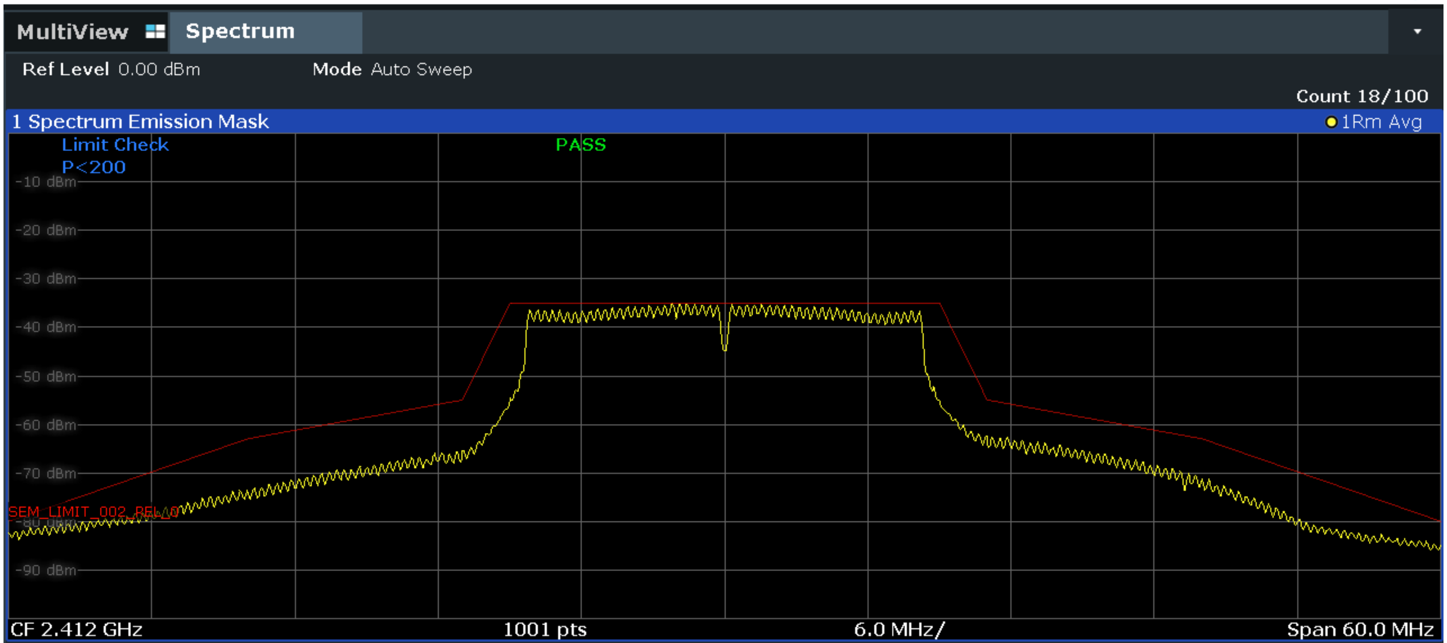
802.11g mode (6Mbps data rate) spectrum mask measurement :



Range Low	Range Up	RBW	Frequency	Power Abs	Power Rel	ΔLimit
-30.000 MHz	-20.000 MHz	100.000 kHz	2.382 03 GHz	-82.09 dBm	-47.13 dB	-2.13 dB
-20.000 MHz	-11.000 MHz	100.000 kHz	2.395 75 GHz	-69.31 dBm	-34.36 dB	-9.69 dB
-11.000 MHz	-9.000 MHz	100.000 kHz	2.401 03 GHz	-65.38 dBm	-30.42 dB	-10.42 dB
9.000 MHz	11.000 MHz	100.000 kHz	2.422 97 GHz	-62.55 dBm	-27.59 dB	-7.59 dB
11.000 MHz	20.000 MHz	100.000 kHz	2.426 09 GHz	-64.29 dBm	-29.33 dB	-6.60 dB
20.000 MHz	30.000 MHz	100.000 kHz	2.441 97 GHz	-84.82 dBm	-49.87 dB	-4.87 dB

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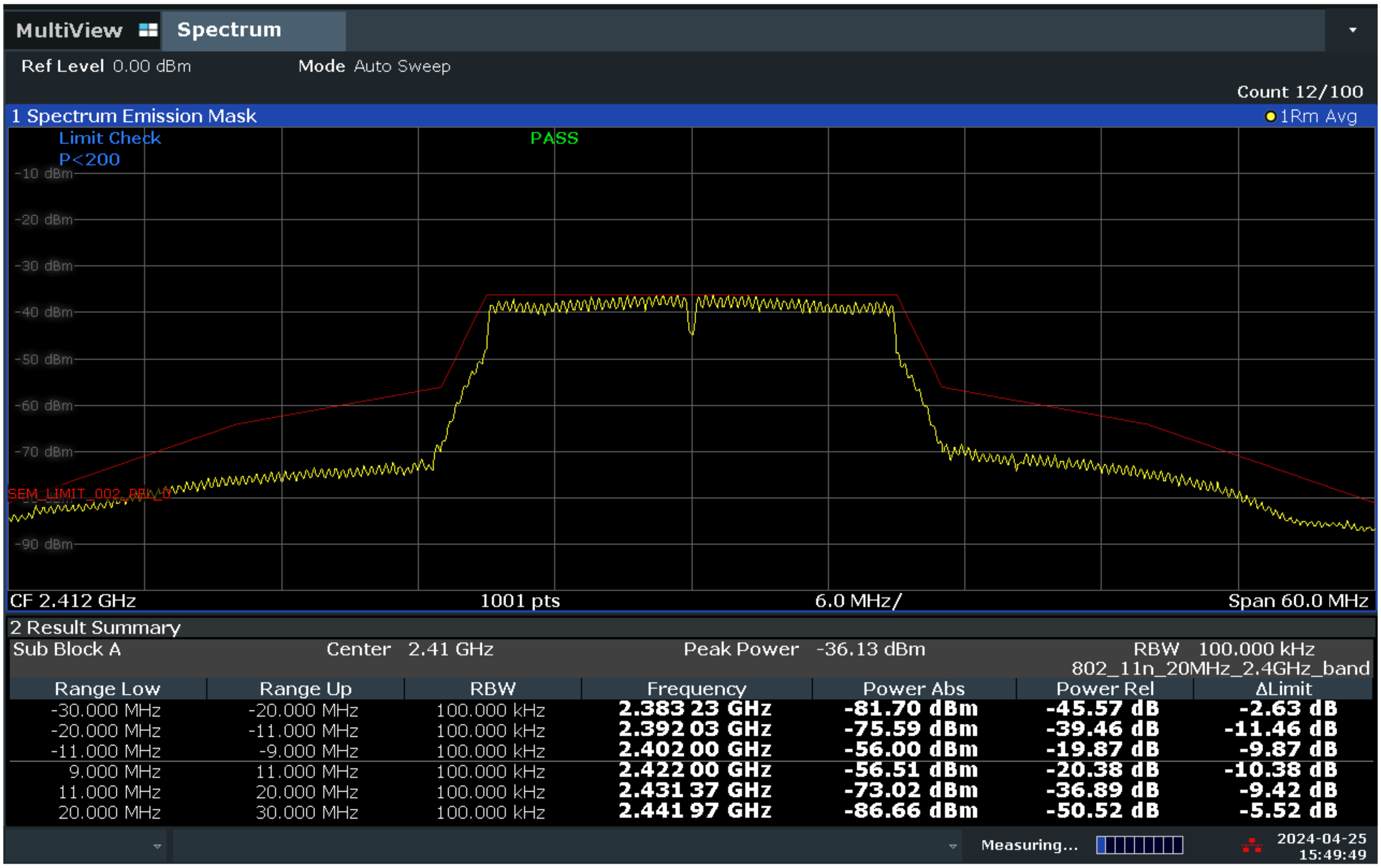
802.11n mode (MCS0 data rate) spectrum mask measurement:



Range Low	Range Up	RBW	Frequency	Power Abs	Power Rel	ΔLimit
-30.000 MHz	-20.000 MHz	100.000 kHz	2.383 23 GHz	-81.70 dBm	-45.57 dB	-2.63 dB
-20.000 MHz	-11.000 MHz	100.000 kHz	2.392 03 GHz	-75.59 dBm	-39.46 dB	-11.46 dB
-11.000 MHz	-9.000 MHz	100.000 kHz	2.402 00 GHz	-56.00 dBm	-19.87 dB	-9.87 dB
9.000 MHz	11.000 MHz	100.000 kHz	2.422 00 GHz	-56.51 dBm	-20.38 dB	-10.38 dB
11.000 MHz	20.000 MHz	100.000 kHz	2.431 37 GHz	-73.02 dBm	-36.89 dB	-9.42 dB
20.000 MHz	30.000 MHz	100.000 kHz	2.441 97 GHz	-86.66 dBm	-50.52 dB	-5.52 dB

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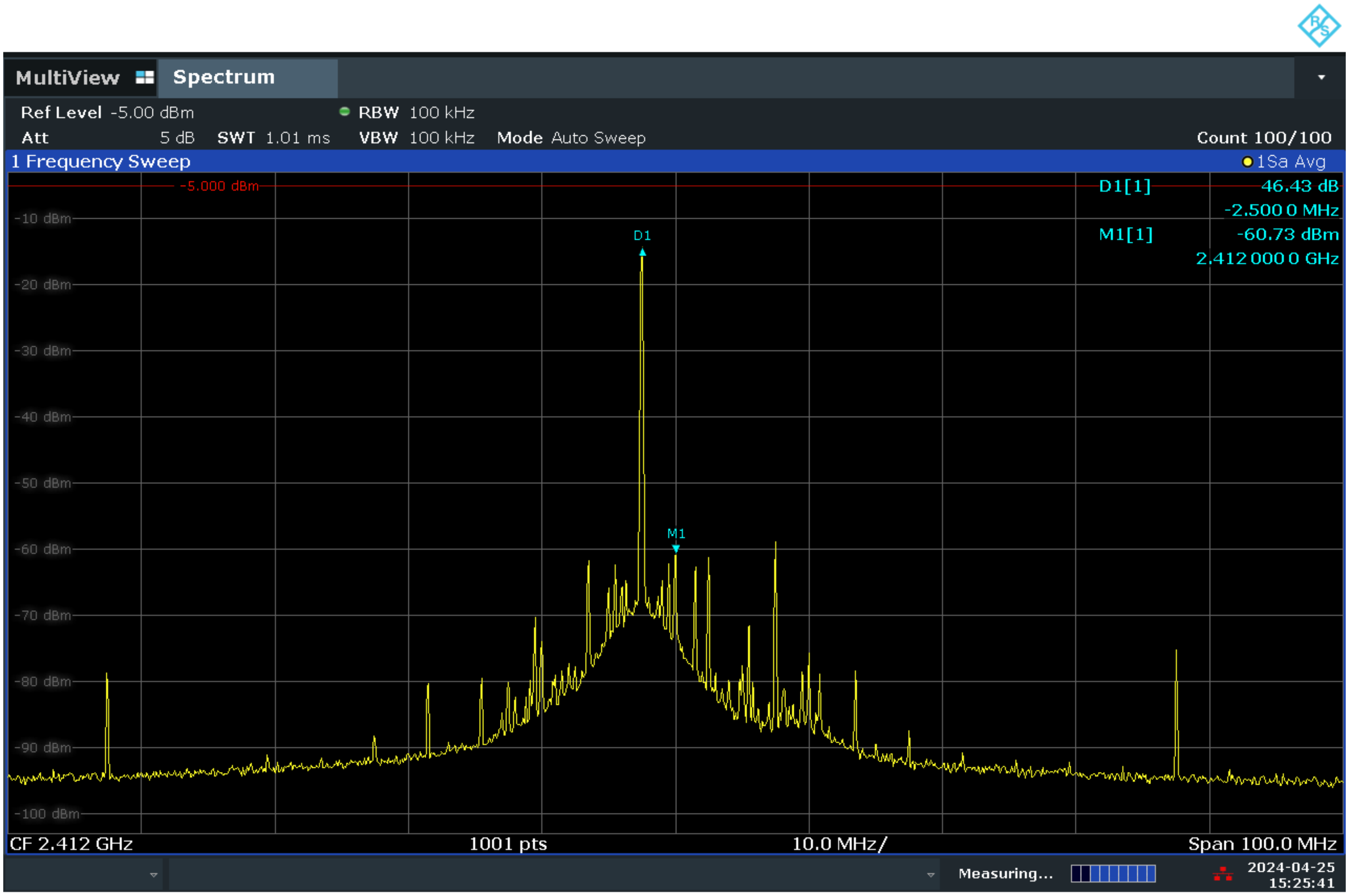
CW Mode (unmodulated) with a single tone at center frequency - 2.5 MHz :



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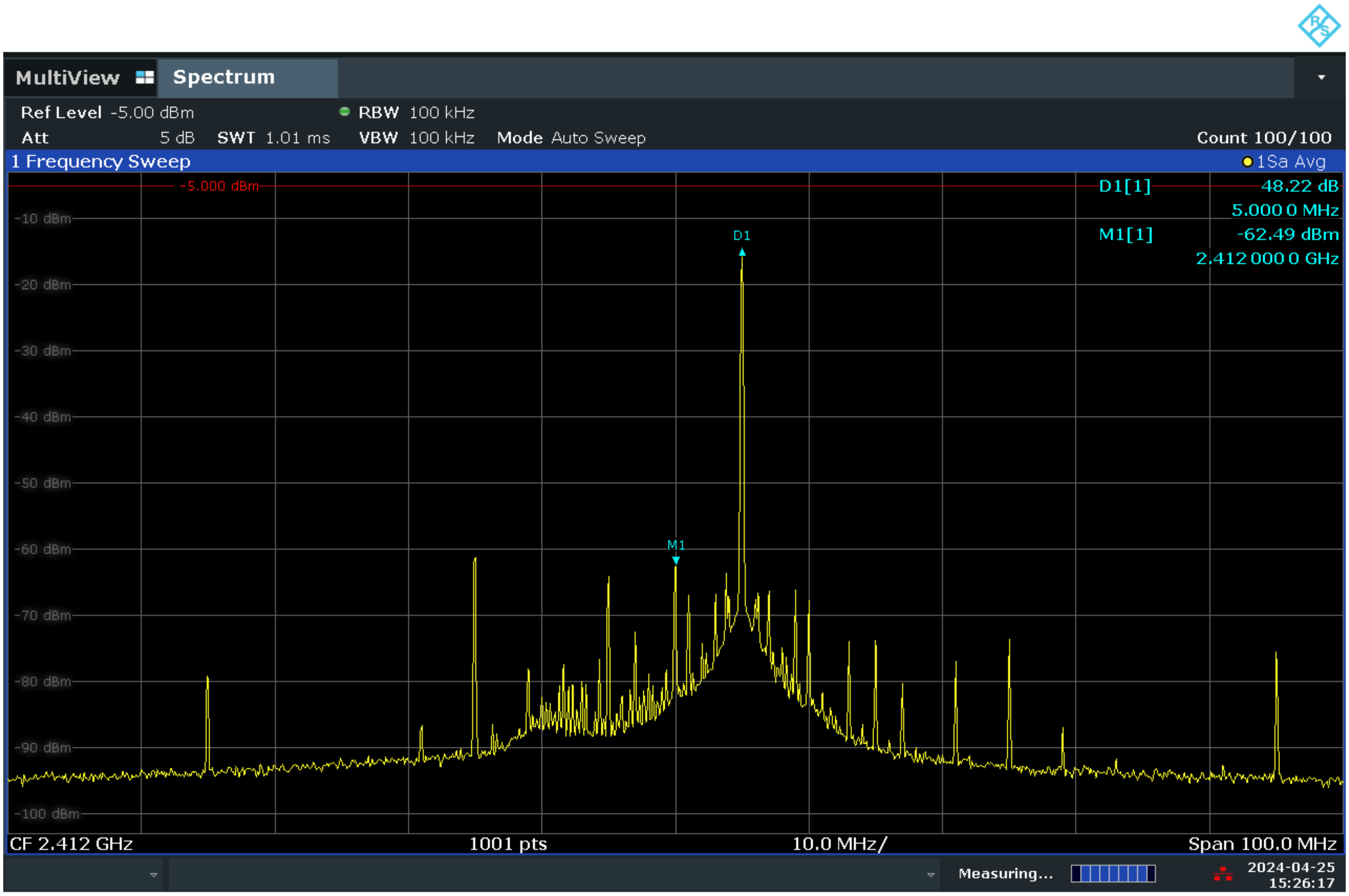
CW Mode (unmodulated) with a single tone at center frequency + 5 MHz :



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3.1.5 Error Vector Magnitude Measurement

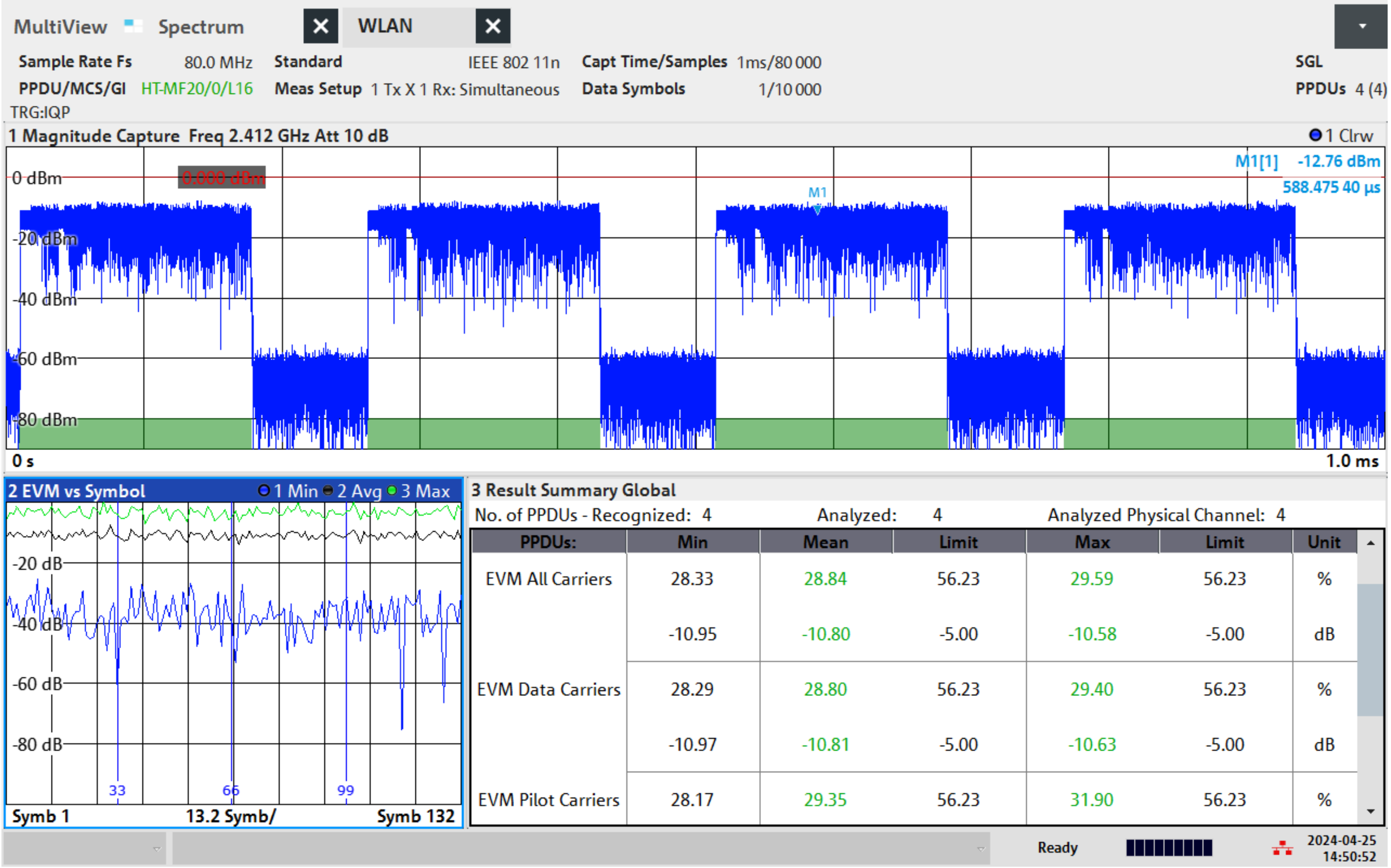
The Transmit Error Vector Magnitude (EVM) test verifies that the device's EVM is within specified limits. The EVM is measured with a spectrum analyzer and measures how the modulated symbols deviate from the ideal constellation points. It's usually expressed in percentage [%] or in decibel [dB], and the smaller the better.

3.1.5.1 Setting up an EVM Measurement on a Spectrum Analyzer

1. Set the spectrum analyzer to VSA or WLAN mode. The key is to measure a time domain signal and demodulate it instead of doing spectrum analysis measurement. This feature is not guaranteed to most generic spectrum analyzer and may be requested as a plus feature.
2. Select a measurement to EVM or modulation accuracy.
3. Set the **Ref level** slightly higher than the expected maximum output power (23 dB for instance).
4. Set the **Frequency** of the Spectrum analyzer in which the DUT is transmitting.
   Example: If the DUT is transmitting in channel 1, then set the Frequency to 2412 MHz and set the Center Frequency to the same Frequency. If Spectrum Analyzers have the marker option, then set the marker on the same frequency.
5. Set the signal description to a corresponding WLAN standard (802.11 n for instance)

The measurement should be visible on the screen. If the transmitted packets on the DUT and the spectrum analyzer is set up correctly, then the packet synchronization (PPDU search) should be correct, and the measurement results should be visible.

3.1.5.2 Measurement Result Example



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3.2 Receive test

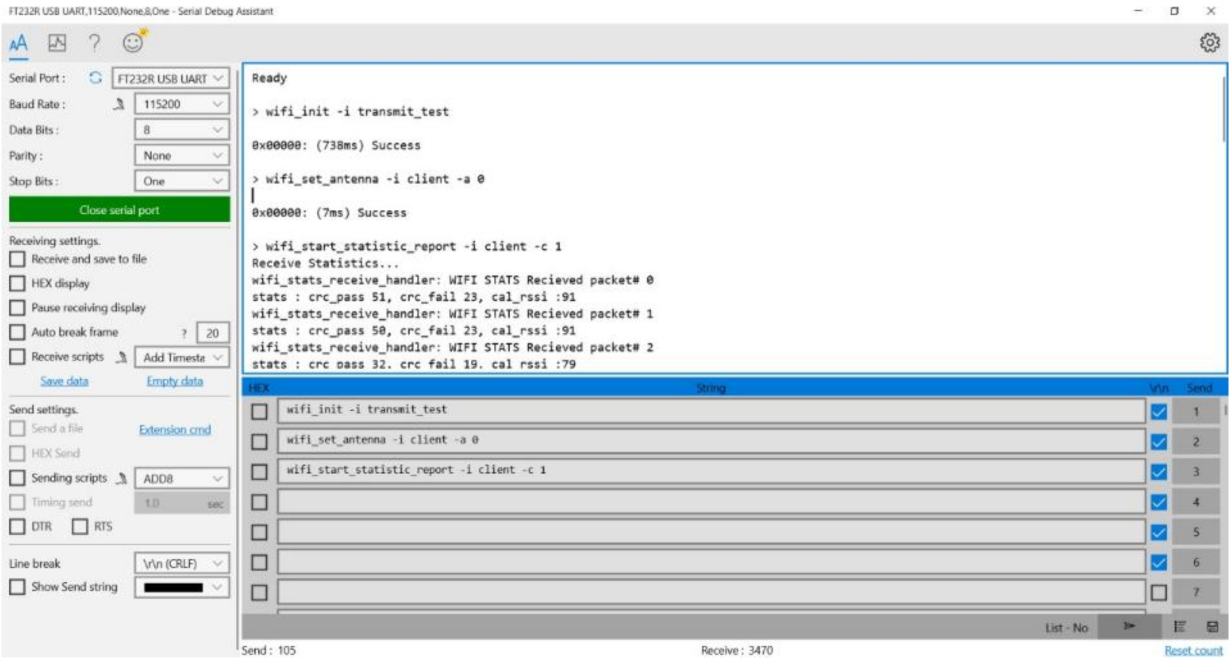
The following sections explain the relevant CLI commands needed for receiving the packets. While packets are received, various stats are shown that represent the receiving performance of the DUT.

3.2.1 CLI Commands

The below commands are available for receiving the packets and getting relevant statistics.

S.No	Command	Description	Example
1	`wifi_init -i <mode>`	For initializing the WiFi interface and for selecting the mode.	`wifi_init -i transmit_test`
2	`wifi_set_antenna -i client -a <antenna type>`	Used for selecting the antenna	`wifi_set_antenna -i client -a 0` By default, antenna type should be set to 0
3	`wifi_start_statistic_report -i client -c <channel> -n <stats_count>`	Used to receive the packet statistics ‘once per second’ in that selected channel. If ‘n’ is configured to 30, then 30 stats will be printed in total. The packet statistics are reset every time after calling this command.	`wifi_start_statistic_report -i client -c 1 -n 30`

The below image shows the CLI commands entered through a serial terminal.



3.2.2 Reception measurements

3.2.2.1 Packet Error Rate

Packet Error Rate (PER) and Bit Error Rate (BER) are error ratios that could measure various reception tests like:

- Sensitivity
- Selectivity
- Blocking
- Intermodulation
- Maximum input power

These measurements are there to show what is the minimum required Rx power level, where the device under thest is capable to receive under various conditions.

Basics of the Packet Error Rate

To measure PER, the accurate packet symbols must be known. PER [%] is calculated by the following:

$$PER = \frac{P_{Error}}{P_{Sent}} * 100$$

where

- Perror = the number of packets not received correctly
- Psent = the number of packets sent

  and the result is displayed as a percentage.

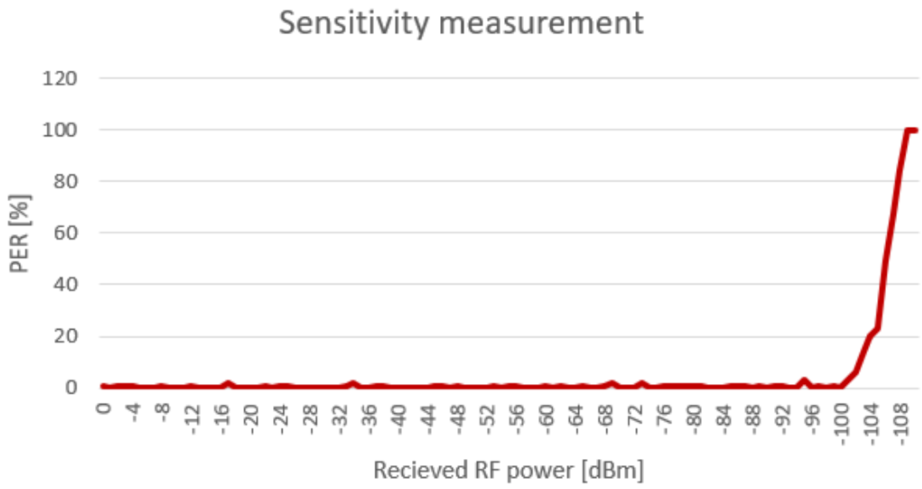
PER measurement requires an accurate device that is able to send the packets the device under test (DUT) expects to receive. An RF vector signal generator is a good fit for these measurements.

Typical PER measurement procedure is the following:

1. Record the packet that should be transmitted to the DUT (device under test / Wi-Fi SoC in this case) and load it to the RF signal generator. It’s possible that the RF generator is already preloaded with such packets. It may be there as a packet of a specific WLAN standard.
2. Connect the RF signal generator and the DUT with the proper RF cable.
3. Initialize the DUT with the wifi_init -i transmit_test command.
4. Set the proper antenna if necessary with the wifi_set_antenna -i client -a <antenna type> command.
5. Send 100 to 1000 packets to the DUT. (Psent)
6. View the received number of packets by using wifi_start_statistic_report -i client -c 1 -n 1 command for example. The “CRC pass” value gives the successfully received number of packets. (Psent - packets received = Perror)
7. Calculate PER.

3.2.2.2 The Sensitivity Measurement

Sensitivity of a device is the minimum level of received RF power that the device is capable of receiving. Sensitivity is often expressed in dBm. It is usually defined for a 10% packet error rate, which means that at the sensitivity level (in dBm) the receiver is capable to produce 10% PER. By adjusting the output power of the generator, the sensitivity of the radio can be determined.



From this graph it can be determined that the sensitivity of a device at 10% PER is -102 dBm. In practice the sensitivity of a device depends on the radio configuration, such as modulation, deviance, and frequency. To measure the sensitivity of a receiver, PER must be measured at various receiver power levels, in practice between 0 to -120 dBm values with 1 to 5 dB steps. The measurement results are more accurate if the RF signal generators power steps finer and more packets are sent at each power step. In the above example, the PF power step is 1 dB and 100 packets were sent at each frequency step.

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