Keysight X-Series Signal Analyzers

This manual provides documentation for the following Analyzers:

PXA Signal Analyzer N9030A
EXA Signal Analyzer N9010A

MXA Signal Analyzer N9020A
CXA Signal Analyzer N9000A

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N9077A & W9077A
WLAN Measurement
Application
Measurement Guide

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Safety Notices

CAUTION

A **CAUTION** notice denotes a hazard. It calls attention to an operating procedure, practice, or the like that, if not correctly performed or adhered to, could result in damage to the product or loss of important data. Do not proceed beyond a CAUTION notice until the indicated conditions are fully understood and met.

WARNING

A **WARNING** notice denotes a hazard. It calls attention to an operating procedure, practice, or the like that, if not correctly performed or adhered to, could result in personal injury or death. Do not proceed beyond a WARNING notice until the indicated conditions are fully understood and met.

Where to Find the Latest Information

Documentation is updated periodically. For the latest information about these products, including instrument software upgrades, application information, and product information, browse to one of the following URLs, according to the name of your product:

http://www.keysight.com/find/pxa

http://www.keysight.com/find/mxa

http://www.keysight.com/find/exa

http://www.keysight.com/find/cxa

To receive the latest updates by email, subscribe to Keysight Email Updates at the following URL:

http://www.keysight.com/find/emailupdates

Information on preventing analyzer damage can be found at:

http://www.keysight.com/find/tips

Is your product software up-to-date?

Periodically, Keysight releases software updates to fix known defects and incorporate product enhancements. To search for software updates for your product, go to the Keysight Technical Support website at:

http://www.keysight.com/find/techsupport

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1   About WLAN Measurement Application

This chapter provides overall information on the Keysight N9077A & W9077A WLAN Measurement Application and describes the measurements made by the analyzer.

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What Does the Keysight N9077A & W9077A WLAN Measurement Application Do?

The Keysight N9077A & W9077A WLAN measurement application can be used to quickly ensure a product development conforms to regulatory requirements, as well as providing RF diagnostic and troubleshooting capability for a WLAN device.

The WLAN measurement application supports the following standards:

- IEEE Standard 802.11a 1999 (R2003)

- IEEE Standard 802.11b 1999 (R2003).

- IEEE Standard 802.11g 2003

- IEEE Standard 802.11n 2009

- IEEE Standard 802.11ac Draft 5.0

For 802.11n, the WLAN measurement application fully supports Legacy mode, HT-Mixed mode and HT-Greenfield mode.

Besides the standards above, Turbo mode (40 MHz), 802.11j (20 MHz / 40 MHz) and 802.11p (5 MHz / 10 MHz) are also supported by performing a manual setting based on the preset of the related standards.

NOTE   You can select the standard by pressing **Mode Setup**, **Radio Standard**.

The Option N9077A & W9077A WLAN measurement application provides the following one-button measurements:

- Channel Power Measurement

- Occupied Bandwidth (OBW) Measurement

- Power Stat CCDF Measurement

- Spectrum Emission Mask Measurement

- Spurious Emissions Measurement

- Power vs Time Measurement

- Spectral Flatness Measurement

- Modulation Analysis Measurement

- Monitor Spectrum Measurement

- I/Q Waveform Measurement

When you select the standard format for use, the instrument automatically makes measurements using the measurement methods and limits defined in the standards. Detailed measurement results are displayed allowing you to make further analysis.

Measurement parameters may be altered for specialized analysis via the **Meas Setup** menu.

The WLAN measurement application also offers a List Sequence measurement for fast results on MXA and EXA with Option B40. This measurement is capable of providing multi-results on a sequence of multi-bursts at different frequency and different WLAN standards.

The following table briefs the IEEE WLAN 802.11a/b/g/n/ac WLAN Transmitter test requirements and the corresponding measurement that N9077A & W9077A WLAN measurement application supports.

Table 1-1   *WLAN Test Requirements and N9077A & W9077A Measurement Compliance (802.11a/b/g/n/ac)*

Test Requirement	WLAN Radio Standard					N9077A & W9077A Measurement Result
	802.11a	802.11b	802.11g	802.11n	802.11aca	
Transmit Power	17.3.9.1	18.4.7.1	19.4.7.1/ 18.4.7.1	20.3.21.3		Channel Power
Spectrum Mask	17.3.9.2	18.4.7.3	17.3.9.2/ 18.4.7.3	20.3.21.1	22.3.18.1	Spectrum Emission Mask
Transmission Spurious	17.3.9.3	18.4.6.8	17.3.9.3	N/A		Spurious Emissions
Center Frequency Tolerance	17.3.9.4	18.4.7.4	19.4.7.2	20.3.21.4	22.3.18.3	Freq. Errorb
Symbol (Chip) Clock Frequency Tolerance	17.3.9.5	18.4.7.5	19.4.7.3	20.3.21.6	22.3.18.3	Symbol (Chip) Clock Errorb
Center Frequency Leakage	17.3.9.6.1		17.3.9.6.1	20.3.21.7.2	22.3.18.4.2	IQ Origin Offsetb
Power On/Down Ramp		18.4.7.6				Power vs Time
RF Carrier Suppression		18.4.7.7				Carrier Suppressionb
Spectral Flatness	17.3.9.6.2		17.3.9.6.2	20.3.21.2	22.3.18.2	Spectral Flatness
Constellation Error (EVM rms)	17.3.9.6.3		17.3.9.6.3	20.3.21.7.3	22.3.18.4.3	RMS EVM
Modulation Accuracy	17.3.9.7c	18.4.7.8	17.3.9.7c	20.3.21.7.4c	22.3.18.4.4	Modulation Analysis

About WLAN Measurement Application

What Does the Keysight N9077A & W9077A WLAN Measurement Application Do?

NOTE	a: W9077A does not support 802.11ac standard.
	b: These results can be read in Numeric Results view of Modulation Analysis measurement.
	c: The standard only describes the procedure how to make the measurement and does not provides specific test limits.

N9077A & W9077A WLAN Measurement Application Licensing

The measurement application requires the following licenses as briefed in the tables below.

Table 1-2   *License Summary (for PXA, MXA, EXA)*

License	N9030A PXA	N9020A MXA N9010A EXA
N9077A-2FP/TP	802.11a, b, g	802.11a, b, g
N9077A-2FP/TP plus N9077A-3FP/TP	802.11a, b, g, 802.11n	802.11a, b, g, 802.11n
N9077A-2FP/TP plus N9077A-3FP/TP plus N9077A-4FP/TP	802.11a, b, g, 802.11n*, 802.11ac**	802.11a, b, g, 802.11n*, 802.11ac**
N9077A-5FP/TP	N/A	List Sequence measurement only (requires Option B40)

NOTE   * To fully support 802.11n (both 20 MHz and 40 MHz) functionality, it is required to install one of the following hardware:

- 40 MHz Analysis Bandwidth (Option B40) for PXA, MXA and EXA,
  or,

- 160 MHz Analysis Bandwidth (Option B1X) for PXA

** To fully support 802.11ac (160 MHz) functionality, it is required to install 160 MHz Analysis Bandwidth (Option B1X).

*** It is required to install microwave pre-selector bypass (Option MPB) for center frequency above 3 GHz, for PXA, MXA or EXA.

Table 1-3   *License Summary (for CXA)*

License	N9000A CXA
W9077A-2FP	802.11a, b, g
W9077A-2FP plus W9077A-3FP	802.11a, b, g, 802.11n (20 MHz only)

The following table lists the recommended modulation analysis bandwidth options for the N/W9077A measurement application.

For more information, refer to *WLAN 802.11a/b/g/n/ac X-Series Measurement Application N9077A & W9077A Technical Overview*.

	Support 802.11a/b/g/j/p	Support 802.11n		Support 802.11ac	
		20 MHz	40 MHz	80 MHz	160 MHz
N9030A PXA	B25	B25	B40	B85	B1X
N9020A MXA	Default	Default	B40	B85 or B1A (125 MHz)	B1X
N9010A EXA	Default	Default	B40	N/A	N/A
N9000A CXA	B25	B25	N/A	N/A	N/A

NOTE   If you have installed N9077A-3FP/TP license and don't install 40 MHz or above bandwidth hardware, when you make a 802.11n 40 MHz measurement, you will get an error message.

If you have installed N9077A-4FP/TP license and don't install 160 MHz bandwidth hardware, when you make a 802.11ac 160 MHz measurement, you will get an error message.

2 Making WLAN Measurements

This chapter describes procedures to set up and perform measurements for analysis of WLAN signals. Details of the steps necessary for accurate signal analysis are provided as well.

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Introduction

This chapter provides measurement procedures and also shows example results obtained using the WLAN measurement application.

There are eleven measurements available in this mode:

- **Channel Power**

- **Occupied Bandwidth (OBW)**

- **Power Stat CCDF**

- **Spectrum Emission Mask**

- **Spurious Emissions**

- **Power vs Time**

- **Spectral Flatness**

- **Modulation Analysis**

- **List Sequence (MXA/EXA with Option B40 only)**

- **Monitor Spectrum**

- **I/Q Waveform**

NOTE　　　　Before you can begin making measurements, make sure you have installed the required license.

1. Press **Mode**, and check to make sure that **WLAN** is available.

2. Press **Meas**, and check to make sure that all the measurements are available.

The following main subjects are presented in this chapter:

NOTE	For more information on how to make Channel Power measurement, Occupied Bandwidth measurement, Power Stat CCDF measurement, Spectrum Emission measurement, Spurious Emissions measurement, or Waveform measurement, please refer to *Signal Analyzer Mode Measurement Guide*.

Setting Up and Making a Measurement

Making the Initial Signal Connection

CAUTION	Before connecting a signal to the analyzer, make sure the analyzer can safely accept the signal level provided. The signal level limits are marked next to the RF Input connectors on the front panel.

Connect the RF output of the device under test (DUT), which generates WLAN signals, to the signal analyzer RF input port as shown in "WLAN Measurement Setup" on page 18.

Figure 2-1   *WLAN Measurement Setup*
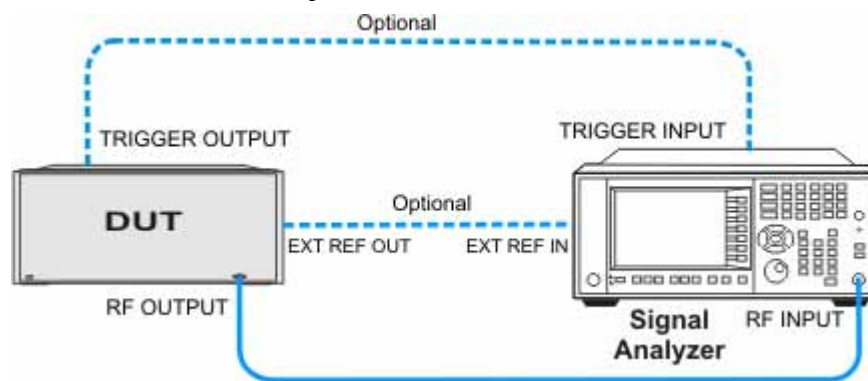
NOTE	If it is available, for time alignment, it is recommended to connect external reference output of the DUT to the external reference input of the analyzer and the trigger output of the DUT to the trigger input of the analyzer.

See the Input Key menu for details on selecting input ports, and the AMPTD Y Scale menu, for details on setting internal attenuation to prevent overloading the analyzer.

Using Analyzer Mode and Measurement Presets

To set your current measurement mode to a known factory default state, press **Mode Preset**. This initializes the analyzer by returning the mode setup and all of the measurement setups in the mode to the factory default parameters.

To preset the parameters that are specific to an active, selected measurement, press **Meas Setup**, **Meas Preset**. This returns all the measurement setup parameters to the factory defaults, but only for the currently selected measurement.

The 3 Steps to Set Up and Make Measurements

All measurements can be set up using the following three steps. The sequence starts at the Mode level, is followed by the Measurement level, then finally, the result displays may be adjusted.

Step	Action	Notes
1 Select and Set Up the Mode	a. Press **Mode** b. Press **WLAN**. c. Press **Mode Preset**. d. Press **Mode Setup**	All licensed, installed modes available are shown under the **Mode** key. Using **Mode Setup**, make any required adjustments to the mode settings. These settings will apply to all measurements in the mode.
2 Select and Set Up the Measurement	a. Press **Meas.** b. Select the specific measurement to be performed. c. Press **Meas Setup**	The measurement begins as soon as any required trigger conditions are met. The resulting data is shown on the display or is available for export. Use Meas Setup to make any required adjustment to the selected measurement settings. The settings only apply to this measurement.
3 Select and Set Up a View of the Results	Press **View/Display**. Select a display format for the current measurement data.	Depending on the mode and measurement selected, other graphical and tabular data presentations may be available. X-Scale and Y-Scale adjustments may also be made now.

NOTE   A setting may be reset at any time, and will be in effect on the next measurement cycle or view.

Table 2-1   *Main Keys and Functions for Making Measurements*

Step	Primary Key	Setup Keys	Related Keys
1 Select and set up a mode.	**Mode**	**Mode Setup**, **FREQ Channel**	**System**
2 Select and set up a measurement.	**Meas**	**Meas Setup**	**Sweep/Control**, **Restart, Single, Cont**
3 Select and set up a view of the results.	**View/Display**	**SPAN X Scale**, **AMPTD Y Scale**	**Peak Search**, **Quick Save, Save**, **Recall, File, Print**

Making Channel Power Measurements

Making successful measurements of WLAN signals is easy when you follow the main steps below.

Measurement results are available in graphical displays that can be presented in preset groups or adjusted to suit your specific application. Most results are also available in tabular format.

Configuring the Measurement System

This step configures the analyzer connections for measuring WLAN signals.

CAUTION   Before connecting a signal to the analyzer, make sure the analyzer can safely accept the signal level provided. The signal level limits are marked next to the RF Input connectors on the front panel.

Connect the RF output of the device under test (DUT), which generates WLAN signals, to the signal analyzer RF input port as shown in "WLAN Measurement Setup" on page 21.

Figure 2-2   *WLAN Measurement Setup*

NOTE   If it is available, for time alignment, it is recommended to connect external reference output of the DUT to the external reference input of the analyzer and the trigger output of the DUT to the trigger input of the analyzer.

See the Input Key menu for details on selecting input ports, and the AMPTD Y Scale menu, for details on setting internal attenuation to prevent overloading the analyzer.

Measurement Example Signal Settings

Frequency: 2412 MHz

Output Power: -30 dBm (at analyzer input)

WLAN signal radio standard: 802.11n/40 MHz

Data Rate: 270 Mbps 64 QAM

Measurement Procedure

Step	Action	Notes
1 Select WLAN Mode.	Press **MODE**, **WLAN**.	
2 Preset the analyzer.	a. Press **Mode Preset** button for the factory preset. b. To recall a user-defined Preset: Press **User Preset**, **User Preset** to preset the current mode.	
3 Select the desired radio standard.	Press **MODE Setup**, **Radio Std**, **802.11n**, **802.11n (40 MHz)**.	
4 If necessary, select the frequency settings.	Press **FREQ Channel**, **2412**, **MHz**.	
5 Select the measurement.	Press **MEAS**, **Channel Power**.	
6 Examine the keys that are available to change measurement parameters from their default conditions.	Press **Meas Setup,** then select the parameters you want to change and input your settings.	If **PSD Limit** is set to **Off**, the limit test always shows `Pass`.
7 Select the channel power measurement again or restart the measurement.	Press **Meas, Channel Power**, or press **Restart**.	

Viewing Channel Power Measurement Results

Measurement results available include a graphical window and a text window showing the absolute power and its peak power spectral density values over 1 MHz integration bandwidth.

For more information on what these data are, see the *N9077A & W9077A WLAN Measurement Application User's and Programmer's Reference*.

Click to Go Back to .

Example of One-Button-Measurement - Channel Power

This example assumes the signal is correctly applied to the input.

Step 1. Press **Mode Preset**

Step 2. Press **Meas, Channel Power**

Step 3. View the measurement default view. (See Figure 2-3).

Figure 2-3   *Channel Power (Default View)*
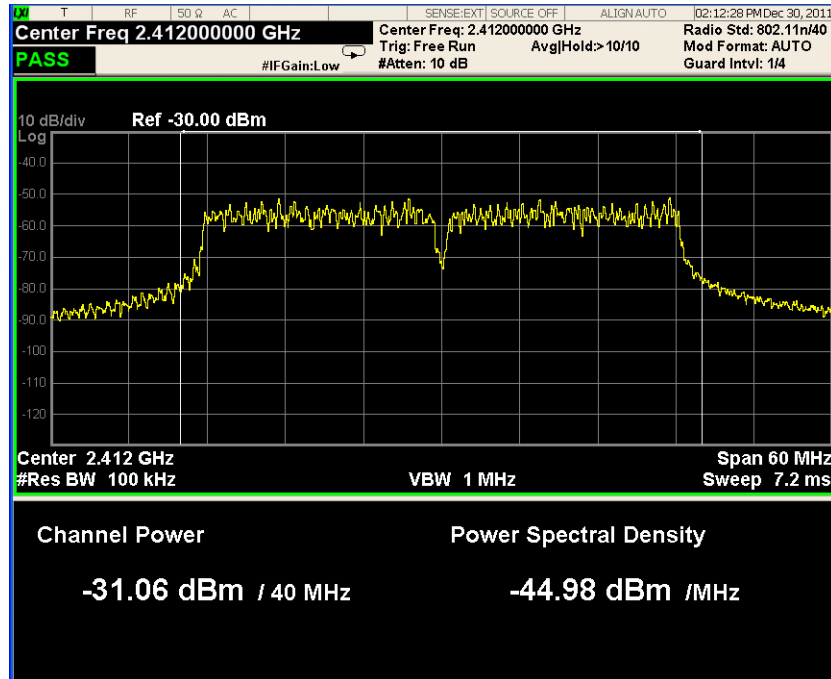
If you have a problem, and get an error message, see *Instrument Messages*.

Example of Using SCPI Commands

Select WLAN mode

INST WLAN

Select the Channel Power measurement

CONF:CHP

Get the measurement result Channel Power (dBm).

READ:CHP:CHP?

Making Occupied Bandwidth Measurements

Making successful measurements of WLAN signals is easy when you follow the main steps below.

Measurement results are available in graphical displays that can be presented in preset groups or adjusted to suit your specific application. Most results are also available in tabular format.

Configuring the Measurement System

This step configures the analyzer connections for measuring WLAN signals.

CAUTION   Before connecting a signal to the analyzer, make sure the analyzer can safely accept the signal level provided. The signal level limits are marked next to the RF Input connectors on the front panel.

Connect the RF output of the device under test (DUT), which generates WLAN signals, to the signal analyzer RF input port as shown in "WLAN Measurement Setup" on page 21.

Figure 2-4   *WLAN Measurement Setup*

NOTE   If it is available, for time alignment, it is recommended to connect external reference output of the DUT to the external reference input of the analyzer and the trigger output of the DUT to the trigger input of the analyzer.

See the Input Key menu for details on selecting input ports, and the AMPTD Y Scale menu, for details on setting internal attenuation to prevent overloading the analyzer.

Measurement Example Signal Settings

Frequency:	2412 MHz
Output Power:	-30 dBm (at analyzer input)
WLAN signal radio standard:	802.11n/40 MHz
Data Rate:	270 Mbps 64 QAM

Measurement Procedure

Step		Action	Notes
1	Select WLAN Mode.	Press **MODE**, **WLAN**.	
2	Preset the analyzer.	a. Press **Mode Preset** button for the factory preset.	
		b. To recall a user-defined Preset: Press **User Preset**, **User Preset** to preset the current mode.	
3	Select the desired radio standard.	Press **MODE Setup**, **Radio Std**, **802.11n**, **802.11n (40 MHz)**.	
4	If necessary, select the frequency settings.	Press **FREQ Channel**, **2412**, **MHz**.	
5	Select the measurement.	Press **MEAS**, **Occupied BW**.	
6			
7	Examine the keys that are available to change measurement parameters from their default conditions.	Press **Meas Setup,** then select the parameters you want to change and input your settings.	
8	Select the Occupied BW measurement again or restart the measurement.	Press **Meas, Occupied BW**, or press **Restart**.	

Viewing Occupied BW Measurement Results

Measurement results available include a graphical window showing if any distortion produces undesirable power outside the specified bandwidth and a text window showing the following results:

- Occupied Bandwidth
- Total Power
- Transmit Freq Error
- x dB Bandwidth

NOTE	If an asterisk is shown next to the x dB bandwidth value, you can optimize the results by sending SCPI command `OBW:MAXH ON` and selecting **Trace/Detector**, **Detector**, **Peak** and then make the measurement again.

For more information on what these data are, see the *N9077A & W9077A WLAN Measurement Application User's and Programmer's Reference*.

Click to Go Back to "Making Occupied Bandwidth Measurements" on page 24.

Example of One-Button-Measurement - Occupied BW

This example assumes the signal is correctly applied to the input.

Step 1. Press **Mode Preset**

Step 2. Press **Meas, Occupied BW**

Step 3. View the measurement default view. (See Figure 2-5).

Figure 2-5   *Occupied BW (Default View)*
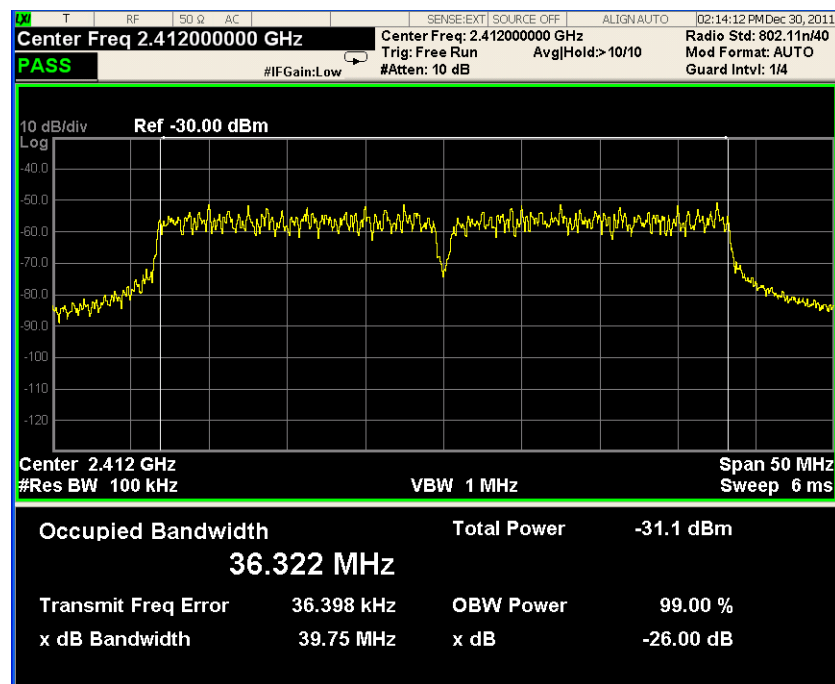
If you have a problem, and get an error message, see *Instrument Messages*.

Example of Using SCPI Commands

Select WLAN mode

INST WLAN

Select the Occupied BW measurement

CONF:OBW

Get the measurement result bandwidth (Hz) occupied by a given percentage of the total mean power.

READ:OBW:OBW?

Making Power Stat CCDF Measurements

Making successful measurements of WLAN signals is easy when you follow the main steps below.

Measurement results are available in graphical displays that can be presented in preset groups or adjusted to suit your specific application. Most results are also available in tabular format.

Configuring the Measurement System

This step configures the analyzer connections for measuring WLAN signals.

CAUTION   Before connecting a signal to the analyzer, make sure the analyzer can safely accept the signal level provided. The signal level limits are marked next to the RF Input connectors on the front panel.

Connect the RF output of the device under test (DUT), which generates WLAN signals, to the signal analyzer RF input port as shown in .

Figure 2-6   *WLAN Measurement Setup*

NOTE   If it is available, for time alignment, it is recommended to connect external reference output of the DUT to the external reference input of the analyzer and the trigger output of the DUT to the trigger input of the analyzer.

See the Input Key menu for details on selecting input ports, and the AMPTD Y Scale menu, for details on setting internal attenuation to prevent overloading the analyzer.

Measurement Example Signal Settings

Frequency:	2412 MHz
Output Power:	-30 dBm (at analyzer input)
WLAN signal radio standard:	802.11n/40 MHz
Data Rate:	270 Mbps 64 QAM

Measurement Procedure

Step		Action	Notes
1	Select WLAN Mode.	Press **MODE**, **WLAN**.	
2	Preset the analyzer.	a. Press **Mode Preset** button for the factory preset.	
		b. To recall a user-defined Preset: Press **User Preset**, **User Preset** to preset the current mode.	
3	Select the desired radio standard.	Press **MODE Setup**, **Radio Std**, **802.11n**, **802.11n (40 MHz)**.	
4	If necessary, select the frequency settings.	Press **FREQ Channel, 2412, MHz**.	
5	Select the measurement.	Press **MEAS, Power Stat CCDF**.	
6	Optimize the attenuation level and attenuation settings suitable for the measurement.	Press **AMPTD**, **Attenuation**, **Adjust Atten for Min Clip**.	
7	Store your current measurement trace for future reference.	Press **Trace/Detector**, **Store Ref Trace**.	
8	Display the stored trace.	Press **Trace/Detector**, **Ref Trace (On)**.	
9	Examine the keys that are available to change measurement parameters from their default conditions.	a. Press **Meas Setup,** then select the parameters you want to change and input your settings.	
		b. Press **BW, Info BW,** then input your settings.	
		c. Press **SPAN X Scale** and select the parameter you want to change then input your settings.	

Step	Action	Notes
10 Set the time gate parameter to capture the desired part of the burst signal.	Press **Meas Setup**, **Meas Interval**, then input your settings according to your signal.	"Meas Interval" equals to the time gate effect on the signal.
11 Select the Power Stat CCDF measurement again or restart the measurement.	Press **Meas, Power Stat CCDF**, or press **Restart**.	

Viewing Power Stat CCDF Measurement Results

Measurement results available include a graphical window and a text window. When the measurement is first made, the graphical display shows a Gaussian signal in blue. Your CCDF measurement is displayed as a yellow plot. The stored trace is displayed in magenta.

For more information on what these data are, see the *N9077A & W9077A WLAN Measurement Application User's and Programmer's Reference*.

Click to Go Back to "Making Power Stat CCDF Measurements" on page 28.

Example of One-Button-Measurement - Power Stat CCDF

This example assumes the signal is correctly applied to the input.

Step 1. Press **Mode Preset**

Step 2. Press **Meas, Power Stat CCDF**

Step 3. View the measurement default view. (See Figure 2-7).

Figure 2-7   *Power Stat CCDF (Default View)*
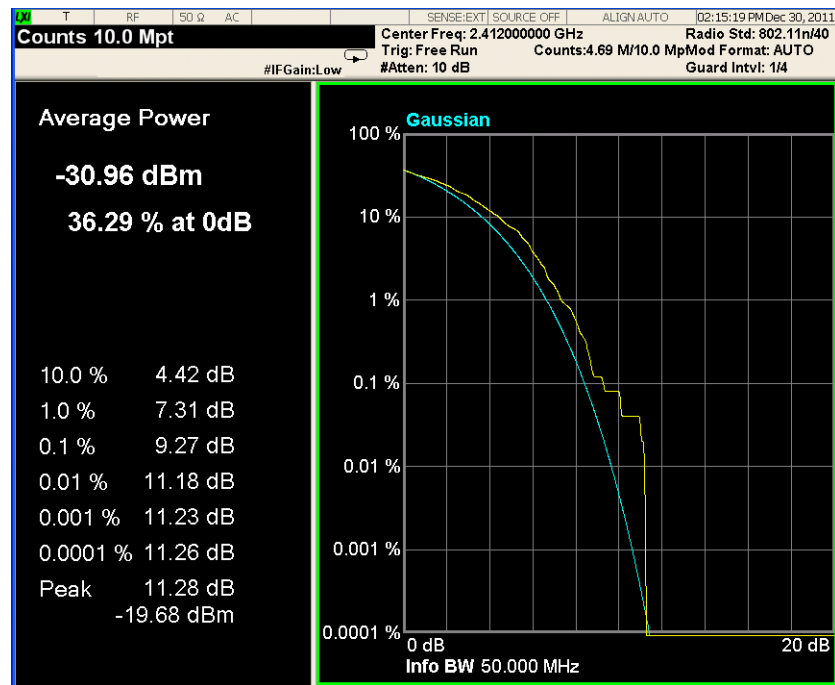
If you have a problem, and get an error message, see *Instrument Messages*.

Example of Using SCPI Commands

Select WLAN mode

> INST WLAN

Select the Power Stat CCDF measurement

> CONF:PST

Get the measurement result unprocessed I/Q trace data, as a series of trace point values in volts.

> READ:PST[0]?

Optimizing CCDF Measurements

To accurately perform a useful CCDF measurement of a device such as a power amplifier (PA), the measurement must be made on the data portion of the OFDM burst. In an 802.11g ERP-OFDM signal, the burst includes training symbols (the first 16 µs of the burst) followed by the signal field, and then the data field.

In order to accurately characterize the PA, only the signal and data portions of the burst should be measured. This can be done by adjusting the trigger parameters within the CCDF measurement.

OFDM bursts are variable in length. Therefore, the first task is to identify the total length of the burst. This can be done using the Power vs Time measurement.

The total length of the burst can be found using markers. Place a marker on the left edge of the burst, to indicate the start of that burst. Then place a delta marker at the end of the same burst. Read the marker value to get the total length of burst.

In the measurement shown below, the burst is 180 µs long. the training portion of the OFDM burst occupied the first 16 µs. Therefore, the CCDF measurement should only analyze the portion of the burst between 16 µs and 180 µs, for a total length of 164 µs.

The total trigger offset that will be set for the CCDF measurement includes two parts: the hardware-caused trigger delay (25 µs) plus the training portion of the OFDM burst (16 µs). The user can read the hardware-caused trigger delay using marker function.

Table 2-2   *Steps to optimize CCDF measurements*

Step		Action	Notes
1	Select WLAN Mode.	Press **MODE**, **WLAN**.	
2	Select the desired radio standard.	Press **MODE Setup**, **Radio Std**, **802.11a/b/g**, **802.11a/g**.	
3	If necessary, select the frequency settings.	Press **FREQ Channel**, **5.18**, **MHz**.	
4	Select the measurement.	Press **MEAS, Power vs Time**.	
5	Select trigger and zoom in on the first burst.	Press **Trigger**, **External 1**.	
6	Set a marker and set a delta marker to measure the burst length.	a. Press **Marker**, **Select Marker**, **Marker 1**. Use the knob to place the marker at the rising edge of the burst. b. Use the knob to place the marker at the rising edge of the burst. c. Press **Delta** and use the knob to place the marker at the falling edge of the burst. d. Read the delta marker value, for example, 180 µs.	
7	Turn off the Trig Delay.	Press **Trigger, External 1**, **Trig Delay** and switch to **Off**.	
8	Set a marker to measure the hardware delay.	a. Press **Marker**, **More**, **All Markers Off**. b. Press **Marker**, **Select Marker**, **Marker 1**. Use the knob to place the marker at the rising edge of the burst. c. Read the marker value, for example, 25 µs.	
9	Select the Power Stat CCDF measurement.	Press **Meas, Power Stat CCDF**.	
10	Set the Trig Delay that includes hardware delay time plus training symbols.	Press **Trigger, External 1**, **Trig Delay** and enter the trigger delay (25 + 16 = 41 µs).	
11	Restart the Power Stat CCDF measurement.	Press **Restart**.	

NOTE   To measure the burst length, you can also use IQ Waveform measurement.

Figure 2-8   *Time-domain view of the 802.11a burst (to measure total length)*
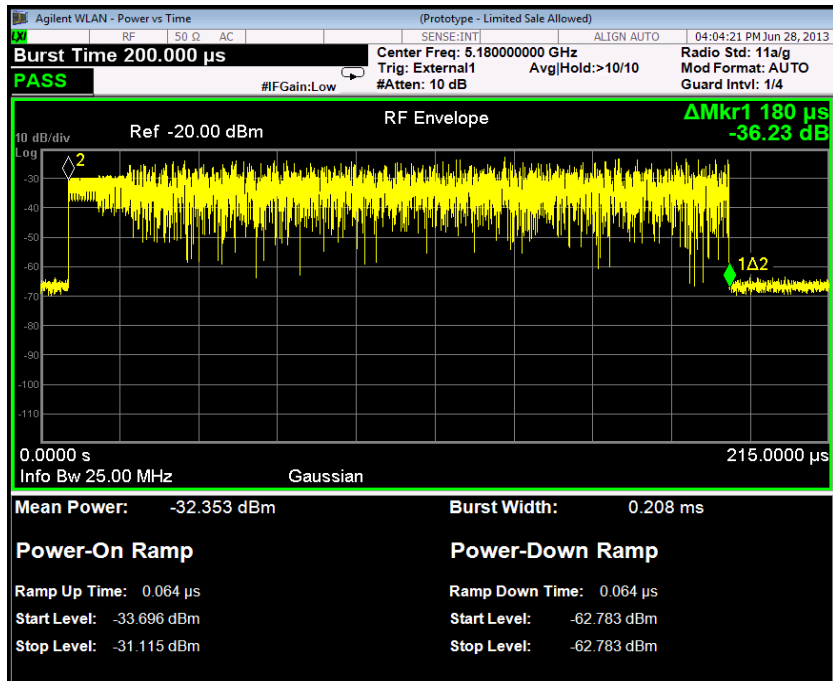
Figure 2-9   *Time-domain view of the 802.11a burst (to measure hardware delay)*
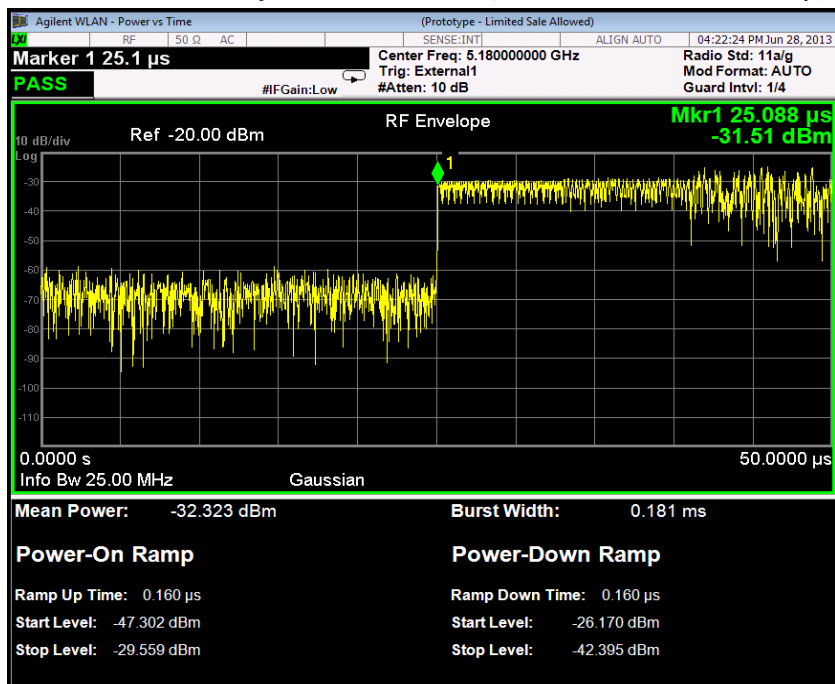
Figure 2-10   *CCDF measurement of the 802.11a burst*
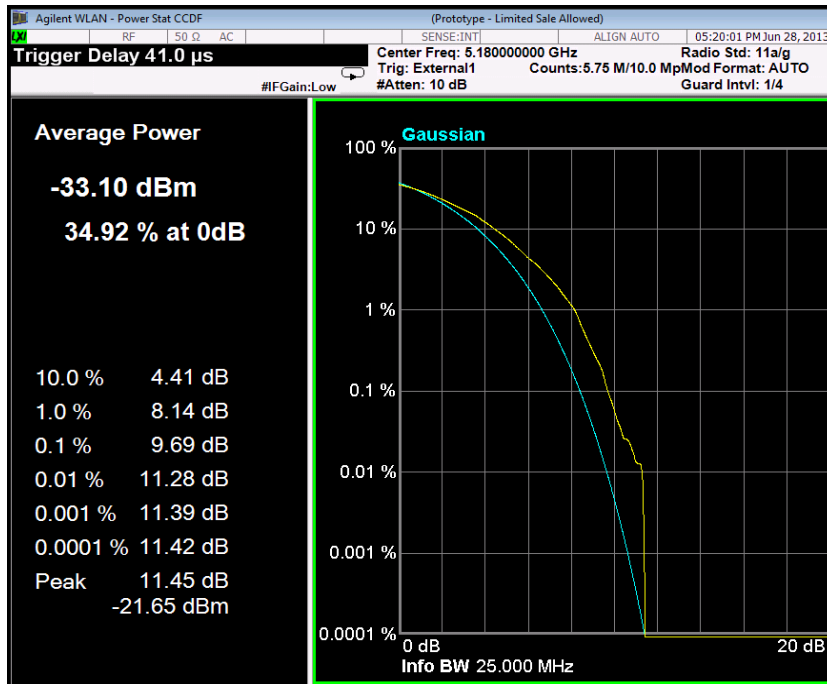
Making Spectrum Emission Mask Measurements

Making successful measurements of WLAN signals is easy when you follow the main steps below.

Measurement results are available in graphical displays that can be presented in preset groups or adjusted to suit your specific application. Most results are also available in tabular format.

Configuring the Measurement System

This step configures the analyzer connections for measuring WLAN signals.

CAUTION   Before connecting a signal to the analyzer, make sure the analyzer can safely accept the signal level provided. The signal level limits are marked next to the RF Input connectors on the front panel.

Connect the RF output of the device under test (DUT), which generates WLAN signals, to the signal analyzer RF input port as shown in "WLAN Measurement Setup" on page 21.

Figure 2-11   *WLAN Measurement Setup*

NOTE   If it is available, for time alignment, it is recommended to connect external reference output of the DUT to the external reference input of the analyzer and the trigger output of the DUT to the trigger input of the analyzer.

See the Input Key menu for details on selecting input ports, and the AMPTD Y Scale menu, for details on setting internal attenuation to prevent overloading the analyzer.

Measurement Example Signal Settings

Frequency: 2412 MHz

Output Power: -30 dBm (at analyzer input)

WLAN signal radio standard: 802.11n/40 MHz

Data Rate: 270 Mbps 64 QAM

Measurement Procedure

Step		Action	Notes
1	Select WLAN Mode.	Press **MODE**, **WLAN**.	
2	Preset the analyzer.	a. Press **Mode Preset** button for the factory preset.	
		b. To recall a user-defined Preset: Press **User Preset**, **User Preset** to preset the current mode.	
3	Select the desired radio standard.	Press **MODE Setup**, **Radio Std**, **802.11n**, **802.11n (40 MHz)**.	
4	If necessary, select the frequency settings.	Press **FREQ Channel, 2412, MHz**.	
5	Select the measurement.	Press **MEAS, Spectrum Emission Mask**.	
6	Examine the keys that are available to change measurement parameters from their default conditions.	Press **Meas Setup,** then select the parameters you want to change and input your settings.	
7	Select the spectrum emission mask measurement again or restart the measurement.	Press **Meas, Spectrum Emission Mask**, or press **Restart**.	

NOTE	Before making SEM measurements for a 802.11p signal, you need to load the desired 802.11p limit mask file for your test.

Table 2-3   *Steps to Load Limit Mask Files*

Step	Action	Notes
1 Select the radio standard.	Press **MODE Setup**, **Radio Std**, **802.11a/b/g**, **802.11a/g (OFDM)**.	
2 Examine the available mask files for 802.11p 5MHz and 10 MHz system.	Press **Recall**, **Data (Import)**, **Open**.	The available mask files: 11p_5MHz_A.mask 11p_5MHz_B.mask 11p_5MHz_C.mask 11p_5MHz_D.mask 11p_10MHz_A.mask 11p_10MHz_B.mask 11p_10MHz_C.mask 11p_10MHz_D.mask
3 Select the desired limit mask file.	Use arrow button to select the file name and press **Enter**.	
4 Select the spectrum emission mask measurement again or restart the measurement.	Press **Meas, Spectrum Emission Mask**, or press **Restart**.	

Viewing Spectrum Emission Mask Measurement Results

This measurement provides three views:

- Abs Pwr Freq view displays the absolute power levels in dBm and the corresponding frequencies in the text window.

- Rel Pwr Freq view displays the relative power levels in dBc and the corresponding frequencies in the text window.

- Integrated Power view displays the absolute and relative power levels integrated throughout the bandwidths between the start and stop frequencies in the text window.

For more information on what these data are, see the *N9077A & W9077A WLAN Measurement Application User's and Programmer's Reference*.

Example of One-Button-Measurement - Spectrum Emission Mask

This example assumes the signal is correctly applied to the input.

Step 1. Press **Mode Preset**

Step 2. Press **Meas, Spectrum Emission Mask**

Step 3. View the measurement default view. (See Figure 2-12).

Figure 2-12   *Spectrum Emission Mask (Default View)*
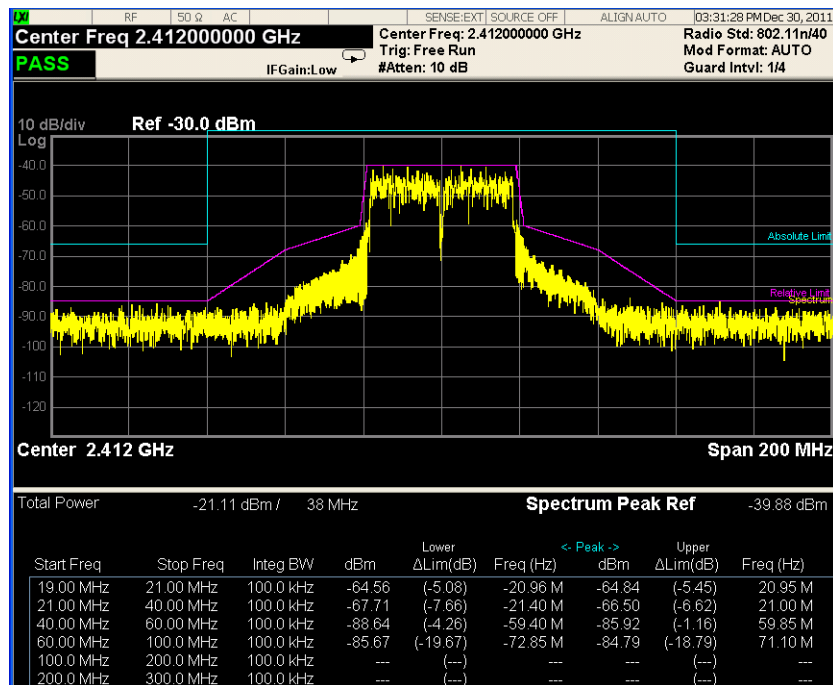
If you have a problem, and get an error message, see *Instrument Messages*.

Example of Using SCPI Commands

Select WLAN mode

    INST WLAN

Select the Spectrum Emission Mask measurement

    CONF:SEM

Get the 14 comma-separated pass/fail test results (0=passed, 1=failed) determined by testing the minimum margin point from the limit line.

    READ:SEM[7]?

Optimizing 802.11ac SEM Measurements

Sometimes SEM measurements fail because of using inaccurate Gate settings for the WLAN burst signal.

The following steps describe how to optimize your analyzer Gate settings and get the best 802.11ac SEM measurements.

NOTE	To measure the burst length, you can use Power vs Time measurement. See "Optimizing CCDF Measurements" on page 32.

Table 2-4   *Steps to Optimize SEM Measurements*

Steps	Action	Notes
1 Select the desired radio standard.	Press **MODE Setup**, **Radio Std**, **802.11ac**, **802.11ac (80 MHz)**.	
2 Enter the center frequency.	Press **FREQ Channel**, **5.18**, **GHz**.	
3 Select the measurement.	Press **MEAS**, **Spectrum Emission Mask**.	
4 If necessary, reduce the mechanical attenuator manually down to 0 dB.	Press **AMPTD Y Scale**, **Attenuation**, **Mech Atten** and enter **0 dB**.	When the signal level is low, for example, -30 dBm, set the attenuation to 0 dB.
5 Turn on the Gate View.	Press **Sweep/Control**, **Gate**, and switch **Gate View** to **On**.	
6 Change the Res BW for Ref Channel from 100 kHz to 8 MHz.	Press **Meas Setup**, **Ref Channel**, **Res BW**, and enter **8 MHz**.	The maximum Res BW setting is 8 MHz to set the accurate Gate Delay and Gate Length in time domain.
7 Change the Res BW for each Offset from 100 kHz to 8 MHz.	a. Press **Meas Setup**, **Offset/Limits**, **Select Offset**, **Offset A**, **More**, **Res BW** and enter **8 MHz**. b. Set the same Res BW for Offset B, C, D, E, F, respectively.	By default, Offset E and F are turned off.
8 Adjust the settings for Gate Start and Gate Stop.	a. Press **Gate Delay** and use Knob to move GATE START line to the rising edge of a burst. b. Press **Gate Length** and use Knob to move GATE STOP line to the falling edge of the same burst.	Make sure the MIN FAST line (blue) is on the left of the GATE START line (green). See the Figure 2-13 on page 41.

Table 2-4   *Steps to Optimize SEM Measurements*

Steps	Action	Notes
9 Change the Res BW for Ref Channel from 8 MHz to 100 kHz.	Press **Meas Setup**, **Ref Channel**, **Res BW**, and enter **100 kHz**.	
10 Change the Res BW for each Offset from 8 MHz to 100 kHz.	a. Press **Meas Setup**, **Offset/Limits**, **Select Offset**, **Offset A**, **More**, **Res BW** and enter **100 kHz**. b. Set the same Res BW for Offset B, C, D, E, F, respectively.	By default, Offset E and F are turned off.
11 Turn on Average function to smooth the display, if necessary.	Press **Meas Setup**, **Avg/Hold Num**, and enter the average number for your test, like **10**.	

Figure 2-13   *Using RBW = 8 MHz to get accurate Gate settings*

Figure 2-14   *Using RBW = 100 kHz to get accurate SEM measurement results*

Making Spurious Emissions Measurements

Making successful measurements of WLAN signals is easy when you follow the main steps below.

Measurement results are available in graphical displays that can be presented in preset groups or adjusted to suit your specific application. Most results are also available in tabular format.

Configuring the Measurement System

This step configures the analyzer connections for measuring WLAN signals.

CAUTION   Before connecting a signal to the analyzer, make sure the analyzer can safely accept the signal level provided. The signal level limits are marked next to the RF Input connectors on the front panel.

Connect the RF output of the device under test (DUT), which generates WLAN signals, to the signal analyzer RF input port as shown in "WLAN Measurement Setup" on page 21.

Figure 2-15   *WLAN Measurement Setup*

NOTE   If it is available, for time alignment, it is recommended to connect external reference output of the DUT to the external reference input of the analyzer and the trigger output of the DUT to the trigger input of the analyzer.

See the Input Key menu for details on selecting input ports, and the AMPTD Y Scale menu, for details on setting internal attenuation to prevent overloading the analyzer.

Measurement Example Signal Settings

Frequency: 2412 MHz

Output Power: -30 dBm (at analyzer input)

WLAN signal radio standard: 802.11n/40 MHz

Data Rate: 270 Mbps 64 QAM

Measurement Procedure

Step	Action	Notes
1 Select WLAN Mode.	Press **MODE**, **WLAN**.	
2 Preset the analyzer.	a. Press **Mode Preset** button for the factory preset. b. To recall a user-defined Preset: Press **User Preset**, **User Preset** to preset the current mode.	
3 Select the desired radio standard.	Press **MODE Setup**, **Radio Std**, **802.11n**, **802.11n (40 MHz)**.	
4 If necessary, select the frequency settings.	Press **FREQ Channel**, **2412**, **MHz**.	
5 Select the measurement.	Press **MEAS**, **Spurious Emissions**.	
6 Examine the keys that are available to change measurement parameters from their default conditions.	Press **Meas Setup,** then select the parameters you want to change and input your settings.	
7 Select the spurious emissions measurement again or restart the measurement.	Press **Meas, Spurious Emissions**, or press **Restart**.	

Viewing Spurious Emissions Measurement Results

Measurement results available include a spectrum window and a text window showing the spurs that are within the current value of the Maker Peak Excursion setting of the absolute limit.

The measurement result of the selected spur in **Spur** under **Meas Setup** is shown in yellow.

The measurement result of the selected range in **Range** under **Meas Setup**, **Range Table** is shown in yellow.

For more information on what these data are, see the *N9077A & W9077A WLAN Measurement Application User's and Programmer's Reference*.

Click to Go Back to .

Example of One-Button-Measurement - Spurious Emissions

This example assumes the signal is correctly applied to the input.

Step 1. Press **Mode Preset**

Step 2. Press **Meas, Spurious Emissions**

Step 3. View the measurement default view. (See Figure 2-16).

Figure 2-16   *Spurious Emissions (Default View)*
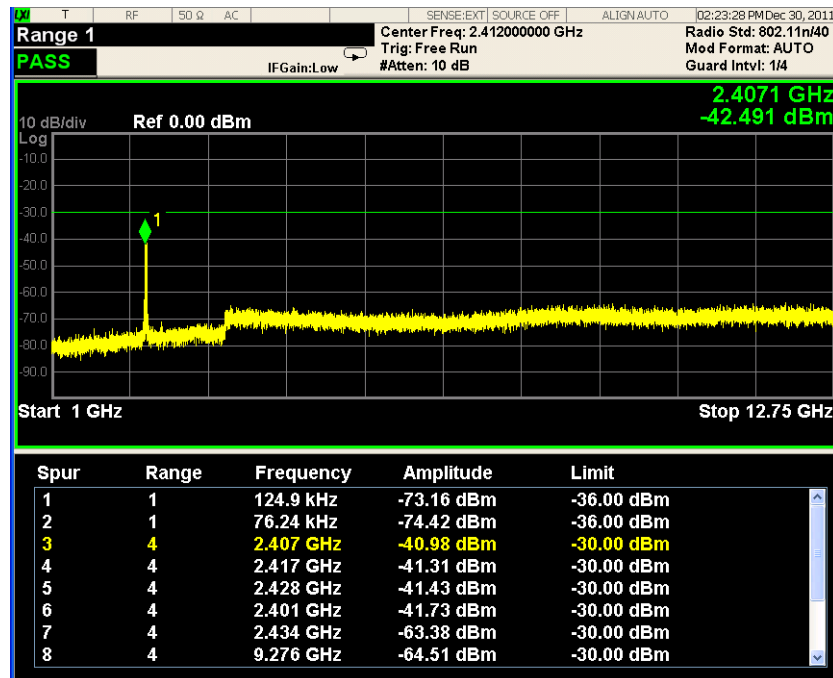
If you have a problem, and get an error message, see *Instrument Messages*.

Example of Using SCPI Commands

Select WLAN mode

INST WLAN

Select the Spurious Emissions measurement

CONF:SPUR

Get the measurement result the number of spurs found.

READ:SPUR[22]?

Making Power vs Time Measurements

Making successful measurements of WLAN signals is easy when you follow the main steps below.

Measurement results are available in graphical displays that can be presented in preset groups or adjusted to suit your specific application. Most results are also available in tabular format.

Configuring the Measurement System

This step configures the analyzer connections for measuring WLAN signals.

CAUTION   Before connecting a signal to the analyzer, make sure the analyzer can safely accept the signal level provided. The signal level limits are marked next to the RF Input connectors on the front panel.

Connect the RF output of the device under test (DUT), which generates WLAN signals, to the signal analyzer RF input port as shown in .

Figure 2-17   *WLAN Measurement Setup*

NOTE   If it is available, for time alignment, it is recommended to connect external reference output of the DUT to the external reference input of the analyzer and the trigger output of the DUT to the trigger input of the analyzer.

See the Input Key menu for details on selecting input ports, and the AMPTD Y Scale menu, for details on setting internal attenuation to prevent overloading the analyzer.

Measurement Example Signal Settings

Frequency: 2412 MHz

Output Power: -30 dBm (at analyzer input)

WLAN signal radio standard: 802.11n/40 MHz

Data Rate: 270 Mbps 64 QAM

Measurement Procedure

Step	Action	Notes
1 Select WLAN Mode.	Press **MODE**, **WLAN**.	
2 Preset the analyzer.	a. Press **Mode Preset** button for the factory preset. b. To recall a user-defined Preset: Press **User Preset**, **User Preset** to preset the current mode.	
3 Select the desired radio standard.	Press **MODE Setup**, **Radio Std**, **802.11n, 802.11n (40 MHz)**.	
4 If necessary, select the frequency settings.	Press **FREQ Channel**, **2412**, **MHz**.	
5 Select the measurement.	Press **MEAS**, **Power vs Time**.	
6 Examine the keys that are available to change measurement parameters from their default conditions.	Press **Meas Setup,** then select the parameters you want to change and input your settings.	Make sure **Burst Time** is set as accurate as possible and **Ramp Time Length** is no shorter than the actual ramp time, otherwise the ramp may be lost.
7 Select the power vs time measurement again or restart the measurement.	Press **Meas, Power vs Time**, or press **Restart**.	

Viewing Power vs Time Measurement Results

This measurement provides two views:

* Burst View includes two windows: RF Envelope window showing signal waveform trace in yellow and ramp-up/ramp-down lines in blue and Result Metrics window showing mean power, burst width, power-on/power-don ramp results.

* Rise & Fall View includes three windows: Rising RF Envelope window, Falling RF Envelope window and Numeric Results window.

For more information on what these data are, see the *N9077A & W9077A WLAN Measurement Application User's and Programmer's Reference*.

Click to Go Back to .

Example of One-Button-Measurement - Power vs Time

This example assumes the signal is correctly applied to the input.

Step 1. Press **Mode Preset**

Step 2. Press **Meas, Power vs Time**

Step 3. View the measurement default view. (See Figure 2-18).

Figure 2-18   *Power vs Time (Burst View - Default View)*
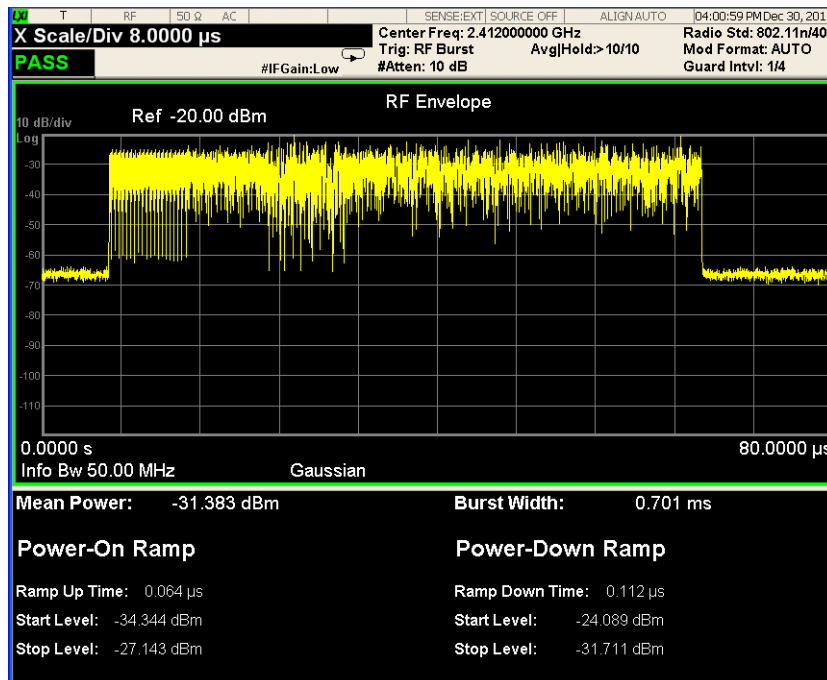
Figure 2-19 *Power vs Time (Rise & Fall View)*
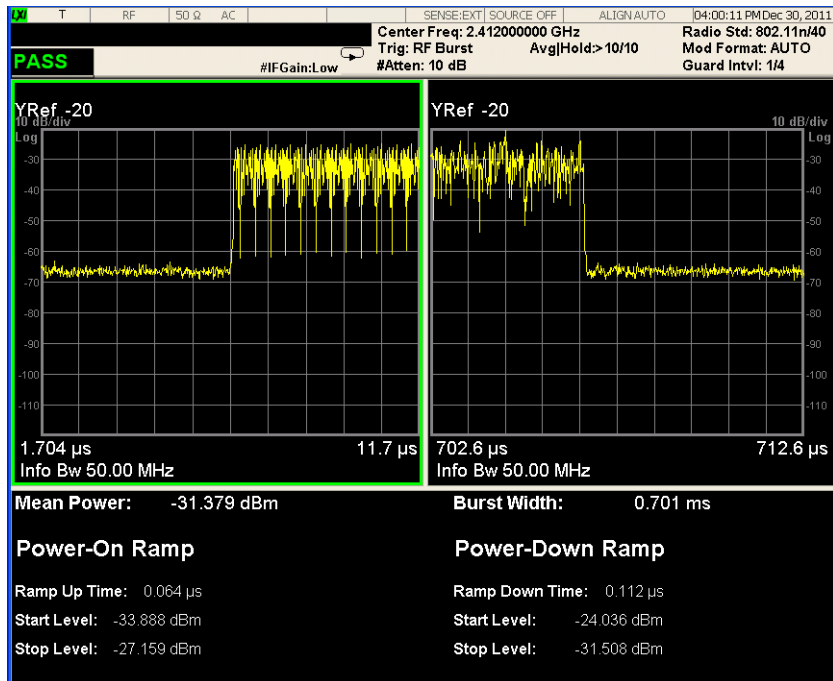
If you have a problem, and get an error message, see *Instrument Messages*.

Example of Using SCPI Commands

Select WLAN mode

INST WLAN

Select the Power Stat CCDF measurement

CONF:PVT

Get the measurement result waveform of full bust (the length is actual burst length).

READ:PVT[4]?

Making Spectral Flatness Measurements

Making successful measurements of WLAN signals is easy when you follow the main steps below.

Measurement results are available in graphical displays that can be presented in preset groups or adjusted to suit your specific application. Most results are also available in tabular format.

Configuring the Measurement System

This step configures the analyzer connections for measuring WLAN signals.

CAUTION   Before connecting a signal to the analyzer, make sure the analyzer can safely accept the signal level provided. The signal level limits are marked next to the RF Input connectors on the front panel.

Connect the RF output of the device under test (DUT), which generates WLAN signals, to the signal analyzer RF input port as shown in .

Figure 2-20   *WLAN Measurement Setup*

NOTE   If it is available, for time alignment, it is recommended to connect external reference output of the DUT to the external reference input of the analyzer and the trigger output of the DUT to the trigger input of the analyzer.

See the Input Key menu for details on selecting input ports, and the AMPTD Y Scale menu, for details on setting internal attenuation to prevent overloading the analyzer.

Measurement Example Signal Settings

Frequency: 2412 MHz

Output Power: -30 dBm (at analyzer input)

WLAN signal radio standard: 802.11n/40 MHz

Data Rate: 270 Mbps 64 QAM

Measurement Procedure

Step	Action	Notes
1 Select WLAN Mode.	Press **MODE**, **WLAN**.	
2 Preset the analyzer.	a. Press **Mode Preset** button for the factory preset. b. To recall a user-defined Preset: Press **User Preset**, **User Preset** to preset the current mode.	
3 Select the desired radio standard.	Press **MODE Setup**, **Radio Std**, **802.11n**, **802.11n (40 MHz)**.	
4 If necessary, select the frequency settings.	Press **FREQ Channel**, **2412**, **MHz**.	
5 Select the measurement.	Press **MEAS**, **Spectral Flatness**.	
6 Examine the keys that are available to change measurement parameters from their default conditions.	Press **Meas Setup,** then select the parameters you want to change and input your settings. For example, to avoid the FFT transition region covers the following symbol, press **Advanced**, **Symbol Timing Adjust**, then enter the desired percentage number to adjust the start of FFT part of a symbol time.	The value is clipped to times of 1/128.
7 Select the spectral flatness measurement again or restart the measurement.	Press **Meas, Spectral Flatness**, or press **Restart**.	

Viewing Spectral Flatness Measurement Results

Measurement results available include a graphical window and a text window.

The graphic window shows three traces: Upper Limit trace, Lower Limit trace and Flatness trace. Limit traces will not include the unused subcarriers, like #0 subcarrier in 802.11a. Flatness trace will be combined with some blue points which indicate the position of subcarriers. If all the blue points fall between the limit lines, the measurement will pass.

The text window shows Radio Format Info, Max Point to Upper Limit and Min Point to Lower Limit for Section 1 and Section 2.

For more information on what these data are, see the *N9077A & W9077A WLAN Measurement Application User's and Programmer's Reference*.

Click to Go Back to .

Example of One-Button-Measurement - Spectral Flatness

This example assumes the signal is correctly applied to the input.

Step 1. Press **Mode Preset**

Step 2. Press **Meas, Spectral Flatness**

Step 3. View the measurement default view. (See Figure 2-3).

Figure 2-21   *Spectral Flatness (Default View)*
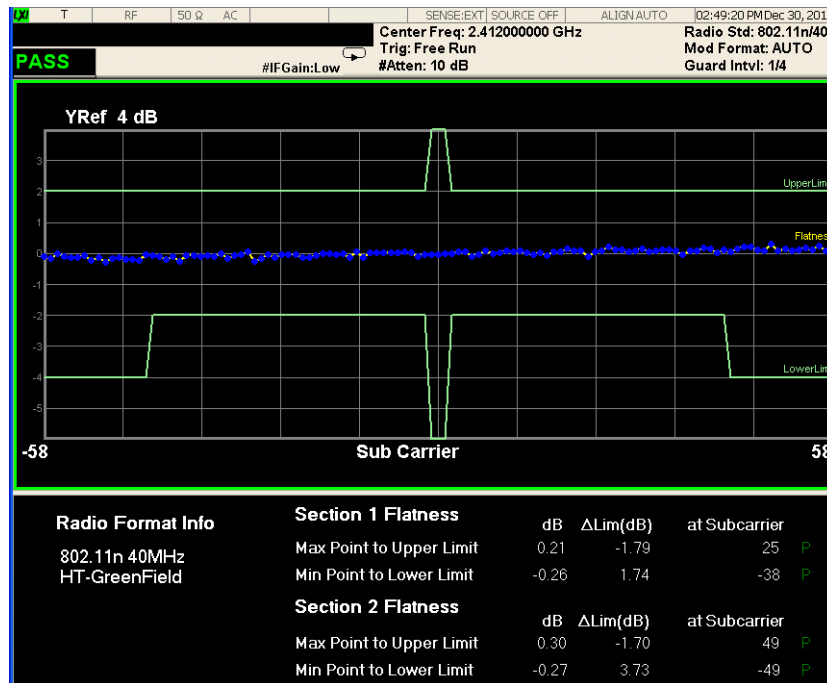
If you have a problem, and get an error message, see *Instrument Messages*.

Example of Using SCPI Commands

Select WLAN mode

INST WLAN

Select the Spectral Flatness measurement

CONF:FLAT

Get the Spectral Flatness results of each section.

READ:FLAT?

Making Modulation Analysis Measurements

Making successful measurements of WLAN signals is easy when you follow the main steps below.

Measurement results are available in graphical displays that can be presented in preset groups or adjusted to suit your specific application. Most results are also available in tabular format.

Configuring the Measurement System

This step configures the analyzer connections for measuring WLAN signals.

CAUTION   Before connecting a signal to the analyzer, make sure the analyzer can safely accept the signal level provided. The signal level limits are marked next to the RF Input connectors on the front panel.

Connect the RF output of the device under test (DUT), which generates WLAN signals, to the signal analyzer RF input port as shown in "WLAN Measurement Setup" on page 21.

Figure 2-22   *WLAN Measurement Setup*

NOTE   If it is available, for time alignment, it is recommended to connect external reference output of the DUT to the external reference input of the analyzer and the trigger output of the DUT to the trigger input of the analyzer.

See the Input Key menu for details on selecting input ports, and the AMPTD Y Scale menu, for details on setting internal attenuation to prevent overloading the analyzer.

Measurement Example Signal Settings

Frequency: 2412 MHz

Output Power: -30 dBm (at analyzer input)

WLAN signal radio standard: 802.11n/40 MHz

Data Rate: 270 Mbps 64 QAM

Measurement Procedure

Step	Action	Notes
1 Select WLAN Mode.	Press **MODE**, **WLAN**.	
2 Preset the analyzer.	a. Press **Mode Preset** button for the factory preset. b. To recall a user-defined Preset: Press **User Preset, User Preset** to preset the current mode.	
3 Select the desired radio standard.	Press **Mode Setup**, **Radio Std**, **802.11n**, **802.11n (40 MHz)**.	
4 If necessary, select the frequency settings.	Press **FREQ Channel**, **2412**, **MHz**.	
5 Select the measurement.	Press **MEAS**, **Modulation Analysis**.	
6 Examine the keys that are available to change measurement parameters from their default conditions.	Press **Meas Setup,** then select the parameters you want to change and input your settings.	Pressing **Optimize EVM** can improve your EVM results of OFDM signals.
7 Specify the demodulation results for a single subcarrier.	Press **Meas Setup**, **Subcarrier**, **Single** then enter the subcarrier number you want to monitor.	
8 Adjust the pass/fail criteria limits for your test.	Press **Meas Setup**, **Limits**, then select and change the desired limit item.	By default the limits are preset according to the selected standard.
9 Select the channel power measurement again or restart the measurement.	Press **Meas, Modulation Analysis**, or press **Restart**.	

NOTE	To make Modulation Analysis measurements for a 802.11p signal, you need to follow the steps below.	

Step	Action	Notes
1 Select the radio standard.	Press **Mode Setup**, **Radio Std**, **802.11a/b/g**, and **802.11a/g**.	
2 Adjust the subcarrier spacing for your test.	Press **Subcarrier Spacing**, and enter the desired value.	For a 10 MHz 802.11p signal, you can enter 156.25 kHz (that is half of the preset Subcarrier Spacing 312.5 kHz); For a 5 MHz 802.11p signal, you can enter 78.125 kHz (that is one fourth of the preset Subcarrier Spacing 312.5 kHz).
3 Select the Modulation Analysis measurement again or restart the measurement.	Press **Meas, Modulation Analysis**, or press **Restart**.	

Viewing Modulation Analysis Measurement Results

The measurement provides following views for 802.11b/g (DSSS/CCK/PBCC):

- IQ Measured Polar Graph
- I/Q Error
- Demod Bits
- Numeric Results

The measurement provides following views for 802.11a/g (OFDM), 802.11g (DSSS-OFDM):

- IQ Measured Polar Graph
- OFDM EVM
- Demod Bits
- Numeric Results
- Preamble Freq Error vs. Time

The measurement provides following views for 802.11n (20 MHz & 40 MHz):

- IQ Measured Polar Graph

- OFDM EVM

- Demod Bits

- Numeric Results

- Burst Info & HT-Sig Info

- Preamble Freq Error vs. Time

- I/Q Impairment

The measurement provides following views for 802.11ac (20 MHz, 40 MHz, 80 MHz, 80+80MHz & 160 MHz):

- IQ Measured Polar Graph

- OFDM EVM

- Demod Bits

- Numeric Results

- Burst Info & HT-Sig Info

- Preamble Freq Error vs. Time

- I/Q Impairment

For more information on what these data are, see the *N9077A & W9077A WLAN Measurement Application User's and Programmer's Reference*.

Click to Go Back to "Making Modulation Analysis Measurements" on page 55.

Example of One-Button-Measurement - Modulation Analysis

This example assumes the signal is correctly applied to the input.

Step 1. Press **Mode Preset**

Step 2. Press **Meas, Modulation Analysis**

Step 3. View the measurement views. (See Figure 2-23).

The default measurement results should look like Figure 2-23. For the 802.11n example signal, the Polar Vector view graph shows the constellation states for 64QAM. The data summary on the left side shows various error measurement results, including RMS EVM, Peak EVM, Pilot EVM, Data EVM, Freq Error, Symbol Clock Error and IQ Original Offset (CFL).

Figure 2-23   *Modulation Analysis (I/Q Measured Polar Graph - Default View)*
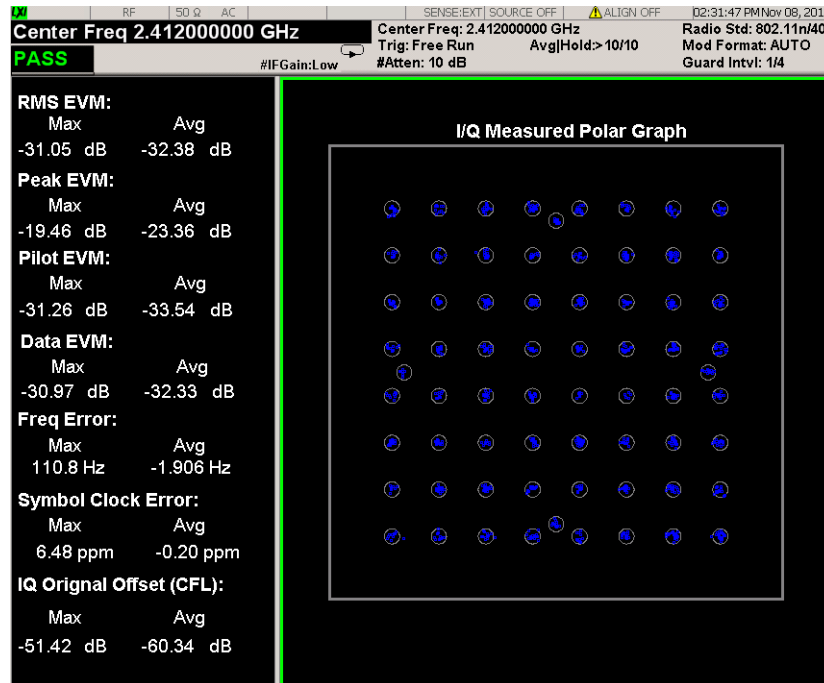
For the 802.11n example signal, the Burst Info & HT-Sig Info view should look like Figure 2-24 and shows the OFDM Data Burst Info window and the HT-Sig Info window. The Burst Info window shows the information about the analyzed burst. The HT-Sig shows the decode info on HT-Sig and L-Sig.

Figure 2-24   *Modulation Analysis (Burst Info & HT-Sig Info view)*
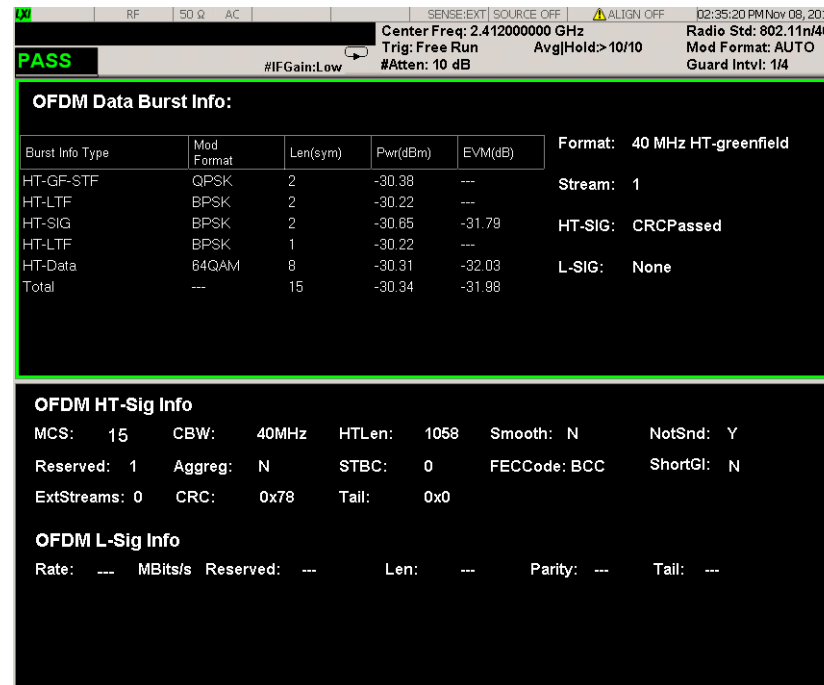
For the 802.11n example signal, the Demod Bits view should look like Figure 2-25 and shows the demodulated bits.

Figure 2-25   *Modulation Analysis (Demod Bits view)*
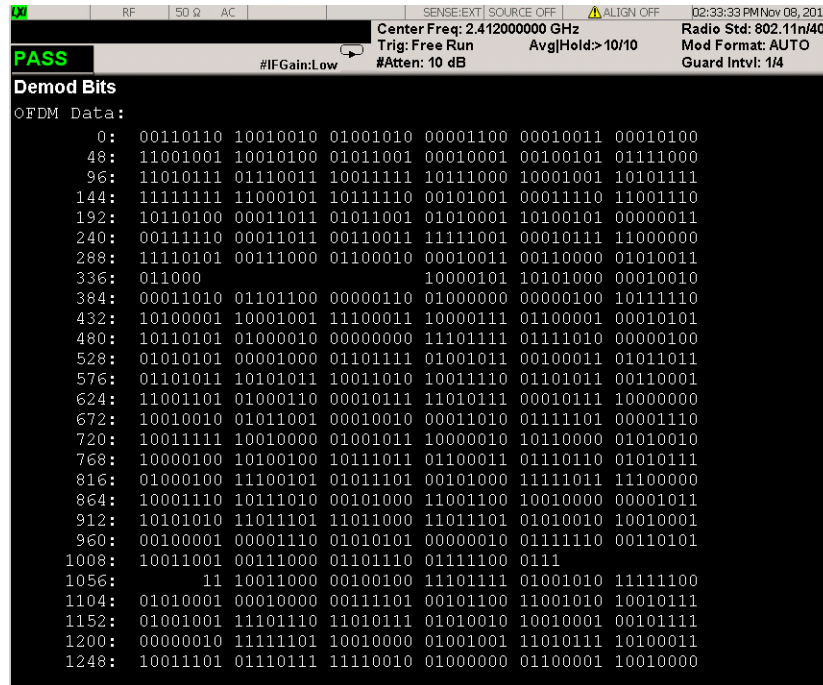
For the 802.11n example signal, the Numeric Results view should look like Figure 2-26 and shows a summary for the measurement result and information.

Figure 2-26　　　　*Modulation Analysis (Numeric Results view)*

For the 802.11n example signal, the OFDM EVM view should look like Figure 2-27 and shows a combination of RMS EVM vs. Symbol window, RMS EVM vs. Subcarrier window, I/Q Measured Polar Graph window and Numeric Results window.

Figure 2-27   *Modulation Analysis (OFDM EVM view)*
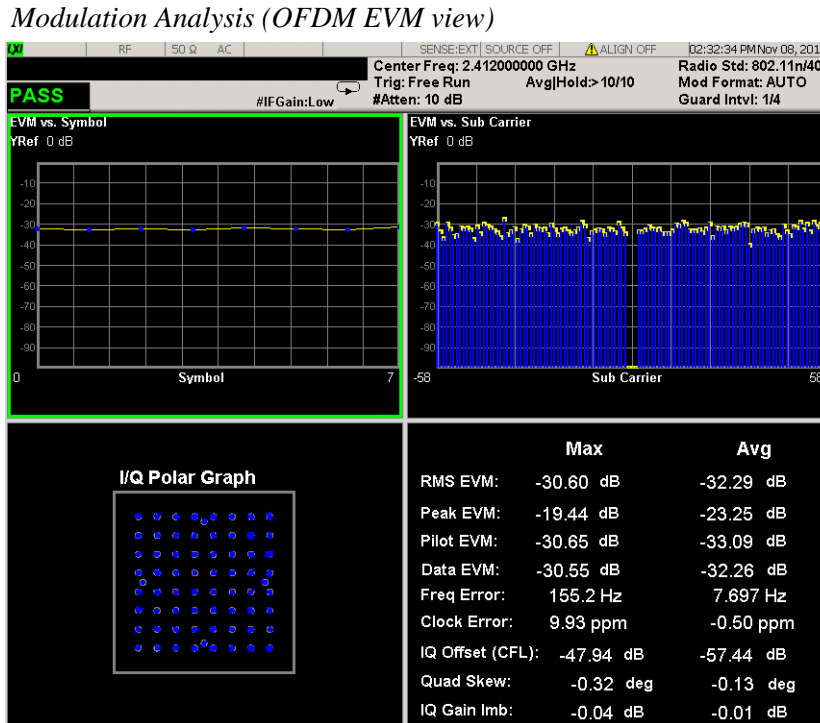
For the 802.11n example signal, the Preamble Freq Error vs. Time view should look like Figure 2-28 and shows a Preamble Freq Error vs. Time window. It shows the total frequency error in Hz for the preamble part of the burst.

Figure 2-28   *Modulation Analysis (Preamble Freq Error vs. Time view)*
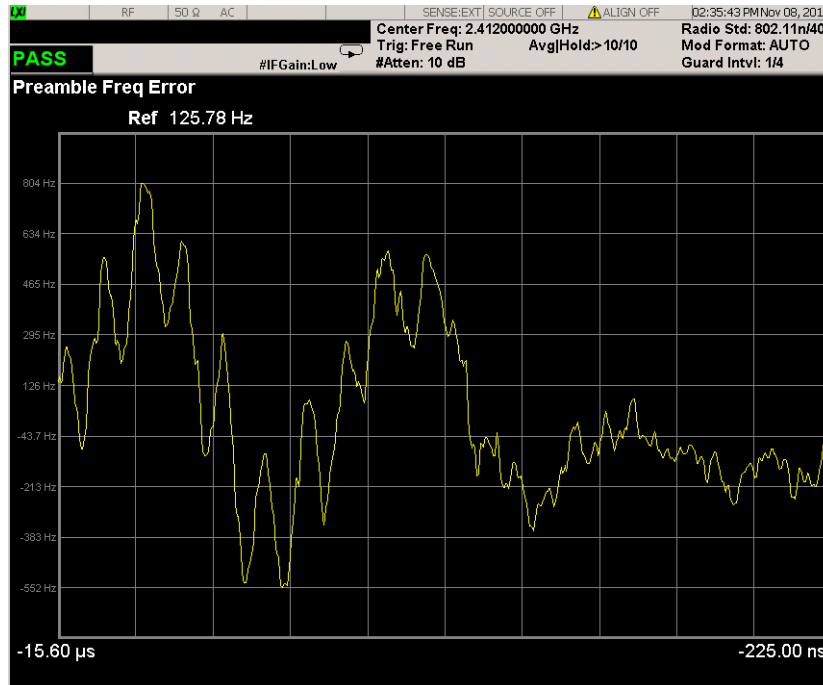
If you have a problem, and get an error message, see *Instrument Messages*.

Example of Using SCPI Commands

Select WLAN mode

    INST WLAN

Select the Channel Power measurement

    CONF:EVM

Get the measurement result Demod Bits.

    READ:EVM[8]?

Optimizing EVM Measurements

The following sections describe how to optimize your analyzer settings and get the best EVM measurements of OFDM signals.

Optimizing Input Level to ADC

You have control of 3 parameters to optimize the signal level to the ADC:

- Attenuation (mechanical and electronic attenuator if present),

- IF Gain

- Preamplifier

To achieve better EVM results, the instrument need the best balance between distortion and signal-to-noise ratio, while avoiding Input Overload error.

There is a One Button Function to perform EVM optimization: press **Meas Setup**, **Optimize EVM**.

NOTE	**Optimize EVM** key is not available when
	- **802.11b/g** is selected, or,
	- **802.11ac 80MHz + 80MHz** is selected, or,
	- Option B25 is only installed, or,
	- N9000A CXA is used.

If **Optimize EVM** is not available in your case, you can follow the steps below to do it manually.

Table 2-5   *Steps to Optimize Signal Input Level*

Steps	Action	Notes
For signals with power level around -10 dBm or higher		
1 Set the attenuator automatically for minimal clipping	Press **AMPTD**, **Attenuation**, **Adjust Atten for Min Clip**.	The firmware limits the mechanical attenuator from going below 6 dB to protect the input from overloading.
2 Manually adjust the attenuator lower from this level to improve the EVM	Press **Mech Atten** and enter the attenuation value as suggested below.	The instrument will display a warning message of "Input overload; ADC Over Range" in the lower right corner of the display if the attenuation value is too low.

Table 2-5   *Steps to Optimize Signal Input Level*

Steps	Action	Notes
For signals with power level around -20 dBm		
Reduce the mechanical attenuator manually down to 0 dB.	Press **Mech Atten** and enter 0 dB.	
For signals with power level around -30 dBm		
Turn on the IF Gain.	a. Press **Meas Setup**, **Advanced**, **More**, **IF Gain**, and select **High Gain**. b. Adjust the **Mech Atten** setting, if needed.	This adds 10 dB of gain to the signal.
For signals with power level around -40 dBm		
1 Switch the IF Gain to Low Gain.	Press **Meas Setup**, **Advanced**, **More**, **IF Gain**, and select **Low Gain**.	
2 Turn on the preamplifier.	a. Press **AMPTD**, **More**, **Internal Preamp**, **Full Range**. b. Adjust the **Mech Atten** setting, if needed.	The attenuation settings can be used to lower the power if the preamplifier causes an input overload.
For signals with power level around -50 dBm or less		
1 Switch the IF Gain to High Gain.	Press **Meas Setup**, **Advanced**, **More**, **IF Gain**, and select **High Gain**.	
2 Turn on the preamplifier.	Press **AMPTD**, **More**, **Internal Preamp**, **Full Range**.	Get the maximum input to the ADC.

Once this has been done, you can save the settings in a file for later recall and reuse.

NOTE   When IF Gain setting to Auto, the process may take more time. To achieve faster measurements, you need to manually set the IF Gain to "High Gain" or "Low Gain".

Optimizing Equalizer Training Setting

Changing the Equalizer Training from using only the preamble to using the preamble, pilots, and data may improve EVM measurements. Press **Meas Setup**, **More**, **Advanced**, **Eq Training**, and select **Channel Est Seq & Data**.

Calculating the maximum search length for multi-burst signals

WLAN signals in time domain vary in length and spacing. The maximum search time length is dependent on IF bandwidth of hardware, using the following equation to calculate the maximum search length for multi-burst signals:

Search Time Length = IQ Sample Points / Sample Rate

Where, IQ Sample Points = 4,000,000, Sample Rate is dependent on the IF bandwidth.

The Max Search Time Length is shown is the table below.

Analysis Bandwidth Option	Bandwidth	Sample Rate	Max Search Time Length
B25	25 MHz	45 M	88 ms
B40	40 MHz	40 M * 1.25	80 ms
B1X	160 MHz	160 M * 1.25	20 ms

How to calculate the maximum number of burst in a given signal that the instrument can capture? Here is an example using PXA with Option B1X to capture the signal below.

WLAN signal radio standard: 802.11ac/80 MHz

MCS Index: 8

Data Length: 1024 bytes

The Max Search Time Length is 20 ms and each frame duration of the signal above is 88 μs, then

Max Number of Burst = 20 ms / 88 μs = 227

If any parameter of the WLAN signal is changed, like bandwidth, MCS, or data length, the frame duration will change and the max number of captured bursts will be changed accordingly.

Making WLAN List Sequence (WLS) Measurements

NOTE	This measurement is supported by MXA and EXA with Option B40 only.

Making successful measurements of WLAN signals is easy when you follow the main steps below.

Measurement results are available in graphical displays that can be presented in preset groups or adjusted to suit your specific application. Most results are also available in tabular format.

Configuring the Measurement System

This step configures the analyzer connections for measuring WLAN signals.

CAUTION	Before connecting a signal to the analyzer, make sure the analyzer can safely accept the signal level provided. The signal level limits are marked next to the RF Input connectors on the front panel.

Connect the RF output of the device under test (DUT), which generates WLAN signals, to the signal analyzer RF input port as shown in "WLAN Measurement Setup" on page 21.

Figure 2-29   *WLAN Measurement Setup*
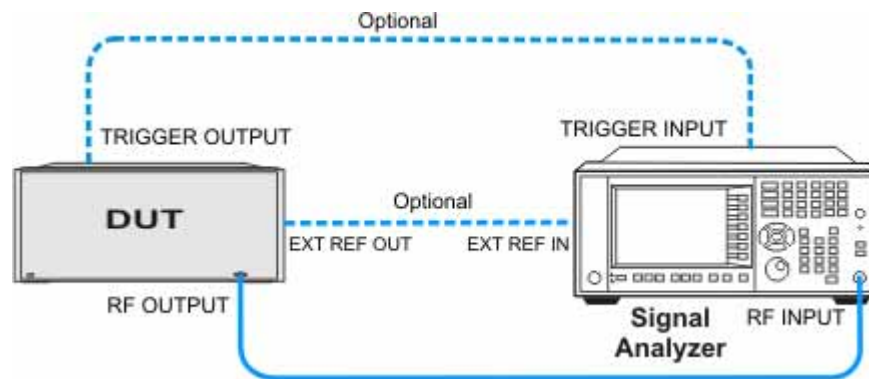
NOTE	If it is available, for time alignment, it is recommended to connect external reference output of the DUT to the external reference input of the analyzer and the trigger output of the DUT to the trigger input of the analyzer.

See the Input Key menu for details on selecting input ports, and the AMPTD Y Scale menu, for details on setting internal attenuation to prevent overloading the analyzer.

Measurement Example Signal Settings

Number of Burst: 12

Frequency: 1.98 GHz ~ 2.013 GHz

Power: -5 dBm ~ -15 dBm (at analyzer input)

WLAN Standard: 802.11ag

NOTE	The sequence of multi-bursts from Device Under Test (DUT) should be repeating 3 times, therefore, the valid bursts can be identified and analyzed.

In a sequence, the maximum number of bursts is 45.

Measurement Procedure

NOTE	The primary UI for this measurement is SCPI commands. There is no menu displayed under Meas Setup. All the settings under Meas Setup are SCPI only.

For the SCPI commands with different parameters and the detailed usage of each SCPI command, please refer to *N9077A & W9077A WLAN Measurement Application User's and Programmer's Reference*.

Step 1. Set up the SCPI communication with the analyzer.

The GPIB or LAN can be used for remote control. The Keysight I/O Library Suite is recommended for connecting the Keysight instruments to the PC and using the instruments from a measurement program. For more detailed information, see the URL: http://www.keysight.com/find/iolib.

Step 2. Set the analyzer to the WLAN mode and enable the WLS measurement:

Table 2-6   *SCPI Commands for WLS Measurement (1)*

SCPI Commands	Notes
INST:SEL WLAN	Select WLAN mode.
*RST	*RST is preferred over :SYST:PRES for remote operation. *RST performs a Mode Preset as done by the :SYST:PRES command and it sets the measurement mode to Single measurement rather than Continuous for optimal remote control throughput.
CONF:WLS	Select WLAN List Sequence measurement.
INIT:CONT OFF	Set to Single mode.

Step 3. Set up the general parameters for the entire sequence:

Table 2-7   *SCPI Commands for WLS Measurement (2)*

SCPI Commands	Notes
WLS:TIM:TRIG:STAT OFF WLS:TIM:TRIG 2s	Set the timeout for trigger events that occur throughout a sequence.
WLS:ABOR:LIM:FAIL OFF WLS:ABOR:ERR OFF	Set the abort mode.
:TRIG:WLS:RFBurst:SLOPe POSitive :TRIG:WLS:VIDeo:SLOPe POSitive :TRIG:WLS:EXTernal1:SLOPe POSitive :TRIG:WLS:EXTernal1:LEVel 1.2V :TRIG:WLS:EXTernal2:SLOPe POSitive :TRIG:WLS:EXTernal2:LEVel 1.2V	Set the input trigger parameters. These are used for the entire sequence.

Step 4. Set up the capture parameters:

Table 2-8   *SCPI Commands for WLS Measurement (3)*

SCPI Commands	Notes
WLS:CAPT:BURS:NUMB 12	Set the measured burst number. The maximum number of analyzed bursts is 45.
WLS:ACQ1:SET AG,1.98GHz,-5dBm,-15dBm,20us,700us,1.436ms,EXT1,-40dBm,0us WLS:ACQuire2:SETup AG,1.983GHz,-5dBm,-15dBm,20us,700us,1.436ms,RFB,-40dBm,0us ... WLS:ACQuire12:SETup AG,2.013GHz,-5dBm,-15dBm,20us,700us,1.436ms,RFB,-40dBm,0us	Specify the settings of radio standard, frequency, power, signal time, burst length and trigger for each burst. For more information about the parameters setting, see *N9077A & W9077A WLAN Measurement Application User's and Programmer's Reference*.

Step 5. Set up the measurement parameters:

Table 2-9   *SCPI Commands for WLS Measurement (4)*

SCPI Commands	Notes
WLS:TXP ON WLS:TOSP ON WLS:EVM ON	Turn on the measurements to be performed. Each measurement can be turned on or off separately.
:CALC:WLS:TXP:BURS:STAR 1 :CALC:WLS:TXP:BURS:STOP 12 :CALC:WLS:EVM:BURS:STAR 1 :CALC:WLS:EVM:BURS:STOP 12 :CALC:WLS:TOSP:BURS:STAR 1 :CALC:WLS:TOSP:BURS:STOP 12	Set the start and stop burst of measurements to be performed.
:CALC:WLS:TXP:LIM:STAT ON :CALC:WLS:TXP:LIM:STAN1:TPOW 16.0 :CALC:WLS:TXP:LIM:STAN1:PSD 4.0	Set the test limits for each standard and each measurement if needed. This command is optional.
:WLS:EVM:FILT:REF:TYPE GAUS :WLS:EVM:FILT:ALPH 0.22 :WLS:EVM:FILT:MEAS:TYPE NONE :WLS:EVM:CRAT 11.0MHz :WLS:EVM:CADJ -0.5 :WLS:EVM:EQU:LENG 21 :WLS:EVM:EQU OFF :WLS:EVM:DESC ALL	Set the parameters for 802.11b. Optional if you don't measure a 802.11b burst.
READ:WLS1?	Read the measurement result values. The total result length is variable and dependent on how many bursts are measured. For more information on results returned, see *N9077A & W9077A WLAN Measurement Application User's and Programmer's Reference.*
DISP:WLS:VIEW PAR	Select the Param List View.

An example of Parameter List View is shown in . You may set the parameters using SCPI or you can modify the value of each parameter by selecting the parameter then inputting the value using the mouse and front panel keys.

Step 6. Get the results:

Table 2-10   *SCPI Commands for WLS Measurement (5)*

SCPI Commands	Notes
READ:WLS1?	After this command is sent to the analyzer, all results are returned. For more information on results returned, see *N9077A & W9077A WLAN Measurement Application User's and Programmer's Reference.*
DISP:WLS:VIEW RES	All measurement results are displayed in the Result Metrics View with Pass/Fail indicator.

Viewing WLS Measurement Results

To view the measurement results, press **View/Display**, **Result Metrics**. This view provides a list of measurement results with Pass or Fail indicator highlighted in green or in red, respectively. You can use the DOWN/UP key to scroll the list by using either the front panel or the key board.

Figure 2-30   *WLS (Result Metrics View)*

Pressing **View/Display**, **Parameter List**, you can see the available SCPI commands listed alphabetically for this measurement. You can verify and change values with DOWN/UP key from either the front panel or key board.

Figure 2-31   *WLS (Parameter Metrics View)*

For more information on what these data are, see the *N9077A & W9077A WLAN Measurement Application User's and Programmer's Reference.*

Click to Go Back to "Making WLAN List Sequence (WLS) Measurements" on page 67.

Example of Making WLS Using SCPI Commands

```
:INST:SEL WLAN

:CONF:WLSequence

INIT:CONT OFF


:WLSequence:ASRLevels:ARULes IMAT

:WLSequence:ASRLevels:MSNRatio 15dB

:WLSequence:TIMeout:TRIGger:STATe OFF

:WLSequence:TIMeout:TRIGger 2s

:WLSequence:ABORt:LIMit:FAIL OFF

:WLSequence:ABORt:ERRor OFF

:TRIGger:WLSequence:RFBurst:SLOPe POSitive

:TRIGger:WLSequence:VIDeo:SLOPe POSitive

:TRIGger:WLSequence:EXTernal1:SLOPe POSitive

:TRIGger:WLSequence:EXTernal1:LEVel 1.2V

:TRIGger:WLSequence:EXTernal2:SLOPe POSitive

:TRIGger:WLSequence:EXTernal2:LEVel 1.2V

:WLSequence:POWer:ATTenuation 6dB

:WLSequence:ASRLevels:PPMargin 5dB


:WLSequence:CAPT:BURS:NUMB 12

:CALC:WLS:TXP:BURS:STAR 1

:CALC:WLS:TXP:BURS:STOP 12

:CALC:WLS:EVM:BURS:STAR 1

:CALC:WLS:EVM:BURS:STOP 12

:CALC:WLS:TOSP:BURS:STAR 1

:CALC:WLS:TOSP:BURS:STOP 12


WLS:ACQuire1:SETup
AG,1.98GHz,-5dBm,-15dBm,20us,700us,1.436ms,EXT1,-40dBm,0us

WLS:ACQuire2:SETup
AG,1.983GHz,-5dBm,-15dBm,20us,700us,1.436ms,RFB,-40dBm,0us

WLS:ACQuire3:SETup
AG,1.986GHz,-5dBm,-15dBm,20us,700us,1.436ms,RFB,-40dBm,0us
```

```
WLS:ACQuire4:SETup
AG,1.989GHz,-5dBm,-15dBm,20us,700us,1.436ms,RFB,-40dBm,0us

WLS:ACQuire5:SETup
AG,1.992GHz,-5dBm,-15dBm,20us,700us,1.436ms,RFB,-40dBm,0us

WLS:ACQuire6:SETup
AG,1.995GHz,-5dBm,-15dBm,20us,700us,1.436ms,RFB,-40dBm,0us

WLS:ACQuire7:SETup
AG,1.998GHz,-5dBm,-15dBm,20us,700us,1.436ms,RFB,-40dBm,0us

WLS:ACQuire8:SETup
AG,2.001GHz,-5dBm,-15dBm,20us,700us,1.436ms,RFB,-40dBm,0us

WLS:ACQuire9:SETup
AG,2.004GHz,-5dBm,-15dBm,20us,700us,1.436ms,RFB,-40dBm,0us

WLS:ACQuire10:SETup
AG,2.007GHz,-5dBm,-15dBm,20us,700us,1.436ms,RFB,-40dBm,0us

WLS:ACQuire11:SETup
AG,2.01GHz,-5dBm,-15dBm,20us,700us,1.436ms,RFB,-40dBm,0us

WLS:ACQuire12:SETup
AG,2.013GHz,-5dBm,-15dBm,20us,700us,1.436ms,RFB,-40dBm,0us


WLSequence:EVM:STANdard1:TIME:INTerval 60

WLSequence:EVM:STANdard1:SUBCarrier:SPACing 312.5kHz

WLSequence:EVM:STANdard1:GINTerval:LENGth 0.25

WLSequence:EVM:STANdard1:SYMBol:ADJust -3.125

WLSequence:EVM:STANdard1:STSequence SHORt

:CALCulate:WLSequence:EVM:STANdard1:PILot:TRACk:AMPLitude OFF

:CALCulate:WLSequence:EVM:STANdard1:PILot:TRACk:PHASe ON

:CALCulate:WLSequence:EVM:STANdard1:PILot:TRACk:TIMing OFF

:CALCulate:WLSequence:EVM:STANdard1:EQUalizer:TMODe SEQ

:CALCulate:WLSequence:EVM:STANdard1:IQNorm ON

WLSequence:EVM:STANdard1:COMPensate OFF

:CALCulate:WLSequence:EVM:STANdard1:SPECtrum NORMal


WLSequence:EVM:STANdard2:TIME:INTerval 2794

WLSequence:EVM:STANdard2:SUBCarrier:SPACing 312.5kHz

WLSequence:EVM:STANdard2:GINTerval:LENGth 0.25

WLSequence:EVM:STANdard2:SYMBol:ADJust -3.125

WLSequence:EVM:STANdard2:STSequence SHORt
```

```
:CALCulate:WLSequence:EVM:STANdard2:PILot:TRACk:AMPLitude OFF

:CALCulate:WLSequence:EVM:STANdard2:PILot:TRACk:PHASe ON

:CALCulate:WLSequence:EVM:STANdard2:PILot:TRACk:TIMing OFF

:CALCulate:WLSequence:EVM:STANdard2:EQUalizer:TMODe SEQ

:CALCulate:WLSequence:EVM:STANdard2:IQNorm ON

WLSequence:EVM:STANdard2:COMPensate OFF

:CALCulate:WLSequence:EVM:STANdard2:SPECtrum NORMal


WLSequence:EVM:STANdard3:TIME:INTerval 60

WLSequence:EVM:STANdard3:SUBCarrier:SPACing 312.5kHz

WLSequence:EVM:STANdard3:GINTerval:LENGth 0.25

WLSequence:EVM:STANdard3:SYMBol:ADJust -3.125

WLSequence:EVM:STANdard3:STSequence SHORt

:CALCulate:WLSequence:EVM:STANdard3:PILot:TRACk:AMPLitude OFF

:CALCulate:WLSequence:EVM:STANdard3:PILot:TRACk:PHASe ON

:CALCulate:WLSequence:EVM:STANdard3:PILot:TRACk:TIMing OFF

:CALCulate:WLSequence:EVM:STANdard3:EQUalizer:TMODe SEQ

:CALCulate:WLSequence:EVM:STANdard3:IQNorm ON

WLSequence:EVM:STANdard3:COMPensate OFF

:CALCulate:WLSequence:EVM:STANdard3:SPECtrum NORMal


WLSequence:EVM:STANdard4:TIME:INTerval 60

WLSequence:EVM:STANdard4:SUBCarrier:SPACing 312.5kHz

WLSequence:EVM:STANdard4:GINTerval:LENGth 0.25

WLSequence:EVM:STANdard4:SYMBol:ADJust -3.125

WLSequence:EVM:STANdard4:STSequence SHORt

:CALCulate:WLSequence:EVM:STANdard4:PILot:TRACk:AMPLitude OFF

:CALCulate:WLSequence:EVM:STANdard4:PILot:TRACk:PHASe ON

:CALCulate:WLSequence:EVM:STANdard4:PILot:TRACk:TIMing OFF

:CALCulate:WLSequence:EVM:STANdard4:EQUalizer:TMODe SEQ

:CALCulate:WLSequence:EVM:STANdard4:IQNorm ON

WLSequence:EVM:STANdard4:COMPensate OFF

:CALCulate:WLSequence:EVM:STANdard4:SPECtrum NORMal
```

```
WLSequence:EVM:STANdard5:TIME:INTerval 60

WLSequence:EVM:STANdard5:SUBCarrier:SPACing 312.5kHz

WLSequence:EVM:STANdard5:GINTerval:LENGth 0.25

WLSequence:EVM:STANdard5:SYMBol:ADJust -3.125

WLSequence:EVM:STANdard5:STSequence SHORt

:CALCulate:WLSequence:EVM:STANdard5:PILot:TRACk:AMPLitude OFF

:CALCulate:WLSequence:EVM:STANdard5:PILot:TRACk:PHASe ON

:CALCulate:WLSequence:EVM:STANdard5:PILot:TRACk:TIMing OFF

:CALCulate:WLSequence:EVM:STANdard5:EQUalizer:TMODe SEQ

:CALCulate:WLSequence:EVM:STANdard5:IQNorm ON

WLSequence:EVM:STANdard5:COMPensate OFF

:CALCulate:WLSequence:EVM:STANdard5:SPECtrum NORMal


WLSequence:EVM:STANdard6:TIME:INTerval 60

WLSequence:EVM:STANdard6:SUBCarrier:SPACing 312.5kHz

WLSequence:EVM:STANdard6:GINTerval:LENGth 0.25

WLSequence:EVM:STANdard6:SYMBol:ADJust -3.125

WLSequence:EVM:STANdard6:STSequence SHORt

:CALCulate:WLSequence:EVM:STANdard6:PILot:TRACk:AMPLitude OFF

:CALCulate:WLSequence:EVM:STANdard6:PILot:TRACk:PHASe ON

:CALCulate:WLSequence:EVM:STANdard6:PILot:TRACk:TIMing OFF

:CALCulate:WLSequence:EVM:STANdard6:EQUalizer:TMODe SEQ

:CALCulate:WLSequence:EVM:STANdard6:IQNorm ON

WLSequence:EVM:STANdard6:COMPensate OFF

:CALCulate:WLSequence:EVM:STANdard6:SPECtrum NORMal


WLSequence:EVM:STANdard7:TIME:INTerval 60

WLSequence:EVM:STANdard7:SUBCarrier:SPACing 312.5kHz

WLSequence:EVM:STANdard7:GINTerval:LENGth 0.25

WLSequence:EVM:STANdard7:SYMBol:ADJust -3.125

WLSequence:EVM:STANdard7:STSequence SHORt

:CALCulate:WLSequence:EVM:STANdard7:PILot:TRACk:AMPLitude OFF

:CALCulate:WLSequence:EVM:STANdard7:PILot:TRACk:PHASe ON

:CALCulate:WLSequence:EVM:STANdard7:PILot:TRACk:TIMing OFF
```

```
:CALCulate:WLSequence:EVM:STANdard7:EQUalizer:TMODe SEQ

:CALCulate:WLSequence:EVM:STANdard7:IQNorm ON

WLSequence:EVM:STANdard7:COMPensate OFF

:CALCulate:WLSequence:EVM:STANdard7:SPECtrum NORMal


:WLSequence:EVM:FILTer:REFerence:TYPE GAUSsian

:WLSequence:EVM:FILTer:ALPHa 0.22

:WLSequence:EVM:FILTer:MEASurement:TYPE NONE

:WLSequence:EVM:CRATe 11.0MHz

:WLSequence:EVM:CADJust -0.5

:WLSequence:EVM:EQUalizer:LENGth 21

:WLSequence:EVM:EQUalizer OFF

:WLSequence:EVM:DESCramble ALL


*OPC?

READ:WLS1?
```

Making Monitor Spectrum Measurements

Making successful measurements of WLAN signals is easy when you follow the main steps below.

Measurement results are available in graphical displays that can be presented in preset groups or adjusted to suit your specific application. Most results are also available in tabular format.

Configuring the Measurement System

This step configures the analyzer connections for measuring WLAN signals.

CAUTION	Before connecting a signal to the analyzer, make sure the analyzer can safely accept the signal level provided. The signal level limits are marked next to the RF Input connectors on the front panel.

Connect the RF output of the device under test (DUT), which generates WLAN signals, to the signal analyzer RF input port as shown in "WLAN Measurement Setup" on page 21.

Figure 2-32   *WLAN Measurement Setup*

NOTE	If it is available, for time alignment, it is recommended to connect external reference output of the DUT to the external reference input of the analyzer and the trigger output of the DUT to the trigger input of the analyzer.

See the Input Key menu for details on selecting input ports, and the AMPTD Y Scale menu, for details on setting internal attenuation to prevent overloading the analyzer.

Measurement Example Signal Settings

Frequency: 2412 MHz

Output Power: -30 dBm (at analyzer input)

WLAN signal radio standard: 802.11n/40 MHz

Data Rate: 270 Mbps 64 QAM

Measurement Procedure

Step	Action	Notes
1 Select WLAN Mode.	Press **MODE**, **WLAN**.	
2 Preset the analyzer.	a. Press **Mode Preset** button for the factory preset. b. To recall a user-defined Preset: Press **User Preset**, **User Preset** to preset the current mode.	
3 Select the desired radio standard.	Press **MODE Setup**, **Radio Std**, **802.11n**, **802.11n (40 MHz)**.	
4 If necessary, select the frequency settings.	Press **FREQ Channel**, **2412**, **MHz**.	
5 Select the measurement.	Press **MEAS**, **Monitor Spectrum**.	The default display shows the Current (yellow trace) data. To make viewing the display easier, you can view either the Current trace or Average separately.
6 Examine the keys that are available to change measurement parameters from their default conditions.	Press **Meas Setup,** then select the parameters you want to change and input your settings.	
7 Select the monitor spectrum measurement again or restart the measurement.	Press **Meas, Monitor Spectrum**, or press **Restart**.	

Viewing Monitor Spectrum Measurement Results

Measurement results are shown as a spectrum domain window.

For more information on what these data are, see the *N9077A & W9077A WLAN Measurement Application User's and Programmer's Reference.*

Click to Go Back to "Making Monitor Spectrum Measurements" on page 78.

Example of One-Button-Measurement - Monitor Spectrum

This example assumes the signal is correctly applied to the input.

Step 1. Press **Mode Preset**

Step 2. Press **Meas, Monitor Spectrum**

Step 3. View the measurement default view. (See Figure 2-33).

Figure 2-33   *Monitor Spectrum (Default View)*
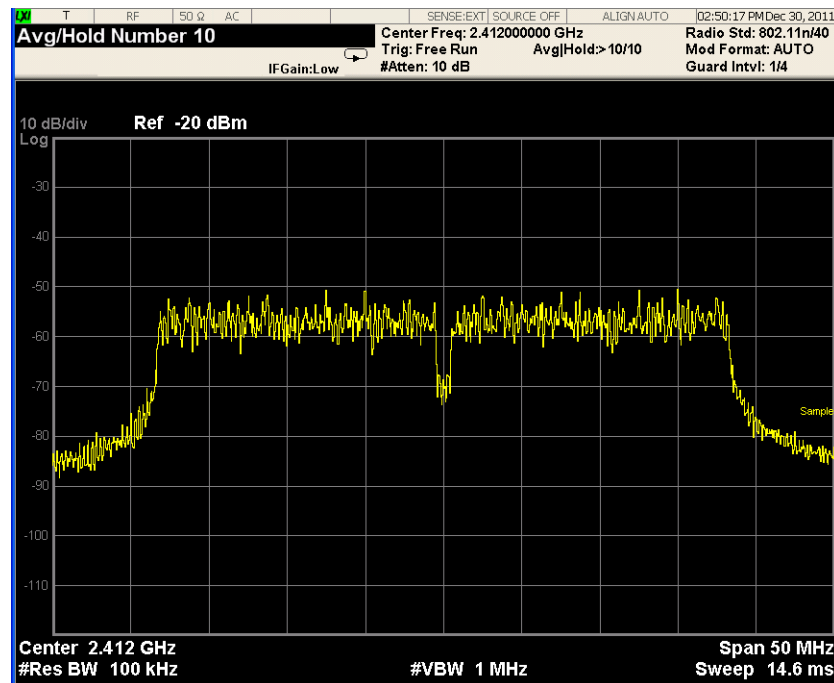
If you have a problem, and get an error message, see *Instrument Messages*.

Example of Using SCPI Commands

Select WLAN mode

INST WLAN

Select the Monitor Spectrum measurement

CONF:MON

Get the measurement result trace 1 data with comma separated floating numbers.

READ:MON?

Making I/Q Waveform Measurements

Making successful measurements of WLAN signals is easy when you follow the main steps below.

Measurement results are available in graphical displays that can be presented in preset groups or adjusted to suit your specific application. Most results are also available in tabular format.

Configuring the Measurement System

This step configures the analyzer connections for measuring WLAN signals.
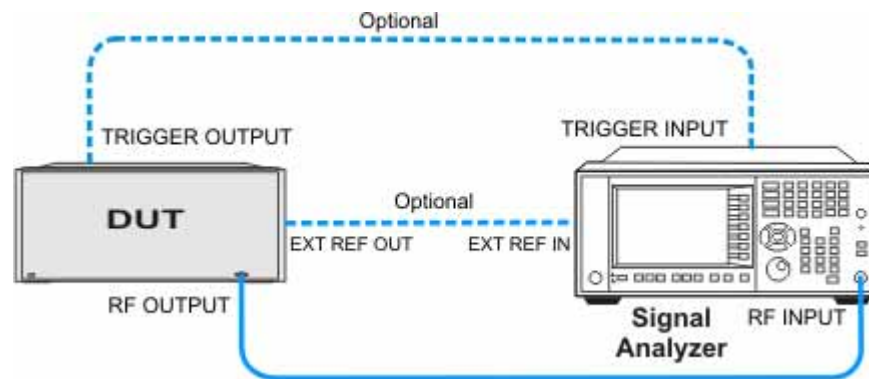

CAUTION   Before connecting a signal to the analyzer, make sure the analyzer can safely accept the signal level provided. The signal level limits are marked next to the RF Input connectors on the front panel.

Connect the RF output of the device under test (DUT), which generates WLAN signals, to the signal analyzer RF input port as shown in .

Figure 2-34   *WLAN Measurement Setup*

NOTE   If it is available, for time alignment, it is recommended to connect external reference output of the DUT to the external reference input of the analyzer and the trigger output of the DUT to the trigger input of the analyzer.

See the Input Key menu for details on selecting input ports, and the AMPTD Y Scale menu, for details on setting internal attenuation to prevent overloading the analyzer.

Measurement Example Signal Settings

Frequency: 2412 MHz

Output Power: -30 dBm (at analyzer input)

WLAN signal radio standard: 802.11n/40 MHz

Data Rate: 270 Mbps 64 QAM

Measurement Procedure

Step	Action	Notes
1 Select WLAN Mode.	Press **MODE**, **WLAN**.	
2 Preset the analyzer.	a. Press **Mode Preset** button for the factory preset. b. To recall a user-defined Preset: Press **User Preset**, **User Preset** to preset the current mode.	
3 Select the desired radio standard.	Press **MODE Setup**, **Radio Std**, **802.11n**, **802.11n (40 MHz)**.	
4 If necessary, select the frequency settings.	Press **FREQ Channel, 2412, MHz**.	
5 Select the measurement.	Press **MEAS**, **IQ Waveform**.	
6 Examine the keys that are available to change measurement parameters from their default conditions.	Press **Meas Setup,** then select the parameters you want to change and input your settings.	
7 Select the waveform measurement again or restart the measurement.	Press **Meas, IQ Waveform**, or press **Restart**.	

Viewing I/Q Waveform Measurement Results

Measurement results available include a graphical display of power versus time of the RF signal and a text window showing the mean and peak-to-mean power results.

For more information on what these data are, see the *N9077A & W9077A WLAN Measurement Application User's and Programmer's Reference*.

Click to Go Back to "Making I/Q Waveform Measurements" on page 82.

Example of One-Button-Measurement - I/Q Waveform

This example assumes the signal is correctly applied to the input.

Step 1. Press **Mode Preset**

Step 2. Press **Meas, IQ Waveform**

Step 3. View the measurement default view. (See Figure 2-35).

Figure 2-35   I/Q Waveform (Default View)
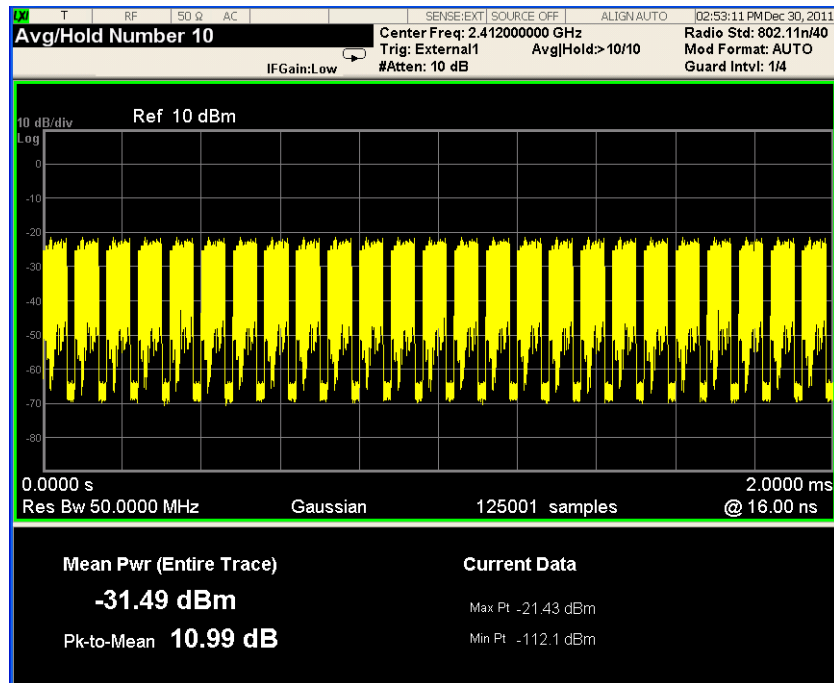
If you have a problem, and get an error message, see *Instrument Messages*.

Example of Using SCPI Commands

Select WLAN mode

INST WLAN

Select the I/Q Waveform measurement

CONF:WAV

Get the measurement result unprocessed I/Q trace data, as a series of trace point values in volts.

READ:WAV[0]?

Troubleshooting WLAN Measurements

The following table provides some with descriptions you might encounter when making WLAN measurements.

Table 2-11

Error Numbers	Messages	Notes
-221	Setting Conflict	The parameter setting is not available for current standard.
-224	Illegal Parameter	The parameter setting is not available for current settings.
215	Sync error; Preamble not found	The preamble code is not detected.
217	Demod error; Invalid packet type	Packet type detected is not recognized.
217	Demod error; Acq time too short	Not an entire Payload is captured, that is, the acquisition time is too short.
159	Settings Alert; Parm/data mismatch	The actual captured data length is not long enough, or, the offset from TxFrequency to center frequency is not an integer multiple of 1 MHz.

For more information on error messages see *Instrument Messages*.

3   Concepts

This chapter describes the concepts and theory of WLAN signals and explains how the various measurements are performed by the instrument. Suggestions for optimizing and troubleshooting your setup are provided, along with a list of related Keysight documents that are referenced for further information.

KEYSIGHT
TECHNOLOGIES

Introduction

This chapter introduces concepts of N9077A & W9077A WLAN measurement application.

- "WLAN Standards" on page 89 introduces the popular WLAN standards, IEEE 802.11 standard family and gives a summary table of IEEE 802.11 standards.

- "Digital Modulation Format Standards" on page 97 contains a general description of the modulation format families, including basic formats and WLAN specific formats.

- "Spread Spectrum Concepts" on page 102 explains the DSSS concepts and theories.

- "Orthogonal Frequency Division Multiplexing (OFDM) Concepts" on page 104 explains the OFDM concepts and theories.

- "WLAN Measurement Concepts" on page 107 explains the WLAN measurement concepts and theories.

WLAN Standards

Overview

IEEE 802.11 standards were introduced in 1997. Over the past few years, several different WLAN technologies and standards have been developed to increase data rates.

This section briefs the IEEE 802.11 standards: 802.11a, 802.11b, 802.11g, 802.11n and 802.11ac.

There are various modulation schemes, data rates, and frequency ranges contained in the IEEE 802.11 standards family, as summarized in the table below.

Table 3-1   *IEEE 802.11 Standards Family*

	Wireless LAN Standards				
	802.11a	**802.11b**	**802.11g**	**802.11n**	**802.11ac**
Frequency band	5 Hz	2.4 GHz	2.4 GHz	2.4 GHz 5 GHz	5 GHz
Channel bandwidth	20 MHz	22 MHz	20 MHz	20 MHz 40 MHz	20 MHz 40 MHz 80 MHz 160 MHz 80 +80 MHz
Maximum raw data rate	54 Mbps	11 Mbps	54 Mbps	600 Mbps	6.93 Gbps
Transmit Type	- OFDM	- CCK - PBCC (option)	- OFDM - CCK - PBCC (option) - Mixed-CCK-OFDM (option)	- OFDM - MIMO	- OFDM - MIMO
Modulation	- BPSK - QPSK - 16 QAM - 64 QAM	- BPSK - DQPSK	- BPSK - QPSK - 16 QAM - 64 QAM	- BPSK - QPSK - 16 QAM - 64 QAM	- BPSK - QPSK - 16 QAM - 64 QAM - 256 QAM

Table 3-1   *IEEE 802.11 Standards Family*

	Wireless LAN Standards				
	802.11a	802.11b	802.11g	802.11n	802.11ac
Number of carriers per channel	48 data & 4 pilot	1 (DSSS)	48 data & 4 pilot	- 52 data & 4 pilot (20 MHz) - 108 data & 6 pilot (40 MHz)	- 52 data & 4 pilot (20 MHz) - 108 data & 6 pilot (40 MHz) - 234 data & 8 pilot (80 MHz) - 468 data & 16 pilot (160 MHz)
MIMO	1	1	1	4 x 4	8 x 8, Multi-user MIMO

802.11a

802.11a operates in the 5 GHz band and uses orthogonal frequency division multiplexing (OFDM) as its transmission scheme. See "Orthogonal Frequency Division Multiplexing (OFDM) Concepts" on page 104.

The 802.11a offers 6, 12 and 24 Mbps and optionally 9, 18, 36, 48 and 54 Mbps bit-rates. The OFDM physical layer uses 52 sub-carriers with 0.3125 MHz spacing, of which 48 are used to carry data and 4 are used as pilots. The occupied bandwidth is 16.6 MHz. Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.

The modulation of the individual carriers in the OFDM depends on the data rates. For 6 and 9 Mbps BPSK is used, 12 and 18 Mbps uses QPSK, 24 and 36 Mbps uses 16 QAM, and 48 and 54 Mbps operation uses 64 QAM. Table 3-2 on page 90 provides a summary of the different modulation formats used in OFDM systems and their associated rate-dependent parameters.

Table 3-2   *802.11a Rate-dependent parameters*

Data rate (Mbps)	Modulation	Coding rate (R)	Coded bits per subcarrier (NBPSC)	Coded bits per OFDM symbol (NCBPS)	Data bits per OFDM symbol (NDBPS)
6	BPSK	1/2	1	48	24

Table 3-2   *802.11a Rate-dependent parameters*

Data rate (Mbps)	Modulation	Coding rate (R)	Coded bits per subcarrier (NBPSC)	Coded bits per OFDM symbol (NCBPS)	Data bits per OFDM symbol (NDBPS)
9	BPSK	3/4	1	48	36
12	QPSK	1/2	2	96	48
18	QPSK	3/4	2	96	72
24	16-QAM	1/2	4	192	96
36	16-QAM	3/4	4	192	144
48	64-QAM	2/3	6	288	192
54	64-QAM	3/4	6	288	216

OFDM systems use fixed modulation formats for the preamble. Varying data rates are achieved by changing the modulation for the data transmission portion of a packet. In some cases, the modulation format changes during the data transmission. Simpler modulation formats (such as BPSK) are often used in the early part of the burst, which contains important information such as frequency and burst length, because these formats are less prone to bit errors.

Figure 3-1, "802.11a Spectrum View," shows an 802.11 a signal burst. The spectrum is not very uniform. This is caused in part by the preambles, but mostly by the data being transmitted.

Figure 3-1   *802.11a Spectrum View*
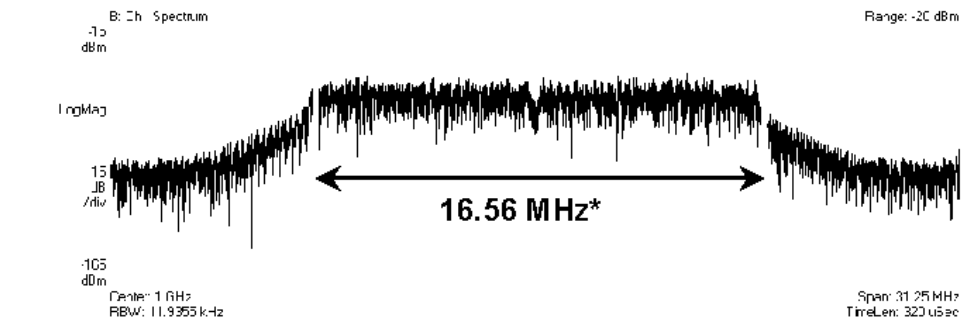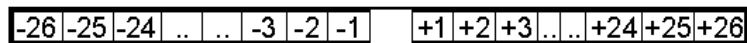
The 802.11a uses 5.15–5.25, 5.25–5.35 and 5.725–5.825 GHz unlicensed national information infrastructure (UNII) bands, each having restrictions imposed on the maximum allowed output power. Table defines the maximum allowable output power for the United States.

Table 3-3   *Transmit power level for the United States*

Frequency band (GHz)	Maximum output power with up to 6 dBi antenna gain (mW)
5.15-5.25	40 (2.5 mW/MHz)
5.25-5.35	200 (12.5 mW/MHz)
5.725-5.825	800 (50 mW/MHz)

Channel center frequencies are defined at every integral multiple of 5 MHz above 5 GHz. The relationship between center frequency and channel number is given by the following equation:

Channel center frequency = $5000 + 5 \times nch$ (MHz)

where

$nch = 0, 1, \ldots 200$

This definition provides a unique numbering system for all channels with 5 MHz spacing from 5 GHz to 6 GHz, as well as the flexibility to define channelization sets for all current and future regulatory domains. The set of valid operating channel numbers by regulatory domain is defined in Table 3-4.

Table 3-4   *Valid operating channel numbers by regulatory domain and band*

Regulatory domain	Band (GHz)	Operating channel numbers	Channel center frequencies (MHz)
United States	U-NII lower band (5.15 - 5.25)	36 40 44 48	5180 5200 5220 5240
United States	U-NII middle band (5.25 - 5.35)	52 56 60 64	5260 5280 5300 5320
United States	U-NII upper band (5.725 - 5.825)	149 153 157 161	5745 5765 5785 5805

802.11b

The 802.11b operates in the 2.4 GHz and uses direct sequence spread spectrum (DSSS) techniques to spread the energy in a single carrier over a wider spectrum. See "Direct Sequence Spread Spectrum (DSSS)" on page 102. Two coding schemes are used in the 802.11b to spread the spectrum of a single carrier. Complementary code keying (CCK) is mandatory, while packet binary convolutional coding (PBCC) is optional. CCK is used to increase the 802.11b peak data rate to 11 Mbps using QPSK modulation. See "Complementary Code Keying (CCK)" on page 102.. PBCC makes use of forward error correction to improve the link performance when noise is the limitation. See "Packet Binary Convolutional Coding (PBCC)" on page 103..

The 802.11b allows 1 Mbps, 2 Mbps, 5.5 Mbps and 11 Mbps operation using various modulation schemes. The 1 and 2 Mbps rates use DBPSK and DQPSK modulation schemes. For 5.5 and 11 Mbps operation, CCK modulation is used.

To achieve 5.5 and 11 Mbps rates, the spreading length is first reduced from 11 to 8. This increases the symbol rate from 1 Msps to 1.375 Msps. So, for 5.5 Mbps bit rates one needs to transmit 5.5/1.375 or 4 bits/symbol and for 11 Mbps, 8 bits/symbol.

Table 3-5   *802.11b Rate-dependent parameters*

Data rate (Mbps)	Modulation	Symbol rate (MSps)
1	DBPSK	
2	DQPSK	
5.5	CCK	1.375
	PBCC	
11	CCK	1.375
	PBCC	

The approach taken for 802.11b, which keeps the QPSK spread spectrum signal and still provides the required number of bits/symbol, uses all but two of the bits to select from a set of spreading sequences. It uses the remaining two bits to rotate the sequence.

An important difference between the sets of spreading sequences used here and the single Barker code sequence used for the 1 and 2 Mbps rates is that these sequences are complex. In other words, the signal is a (D)QPSK signal with QPSK spreading.

Figure 3-2, "802.11b signal," shows a plot of 802.11b signal burst. For all 802.11b bit rates, the preamble and header are sent at the 1 Mbps rate. The header is 192 µs long (192 bits). This translates to a total of 2112 chips. The payload data is then appended using one of the four modulation rates.

Figure 3-2   *802.11b signal*
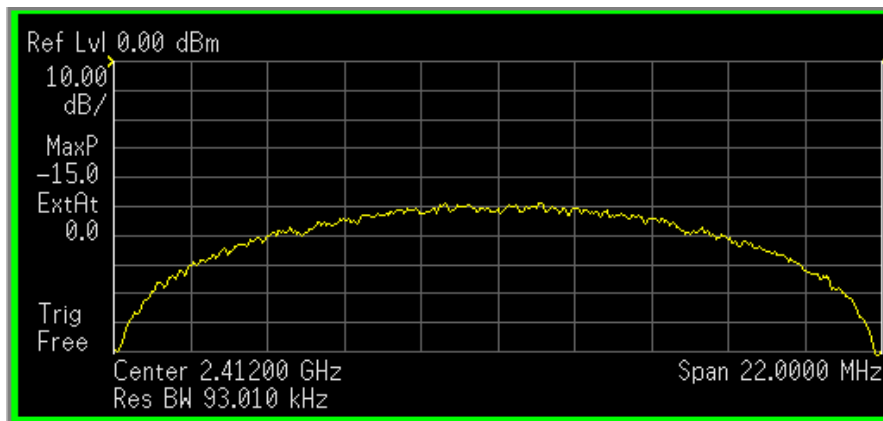
802.11g

IEEE 802.11g is an extension of the 802.11b standard. So the 802.11g system can interoperate with the 802.11b system. The 802.11g standard adds 802.11a OFDM transmission modes to the 802.11b standard. This provides the 802.11a throughput improvement in the 2.4 GHz band. In addition to the 802.11a OFDM modes, 802.11g also defines optional modes of increased throughput PBCC utilizing 8PSK, and an optional CCK-OFDM mode, which combines the 802.11b preamble with an OFDM packet.

In addition to data rates the 802.11b supports, the 802.11g also allows various data rates using various modulation schemes, such as 11 Mbps using PBCC-11, 22 Mbps using PBCC-22 or CCK-PBCC, 33 Mbps operation using PBCC-33, respectively. For 54 Mbps operation, CCK-OFDM modulation is used.

Similar to the 802.11a, 802.11g OFDM modes map data symbols using BPSK and QPSK for lower data rates and QAM for faster bit rates.

Figure 3-3   *Example 802.11g (OFDM) modulation types (left to right: BPSK, QPSK, 8PSK, and 64QAM)*
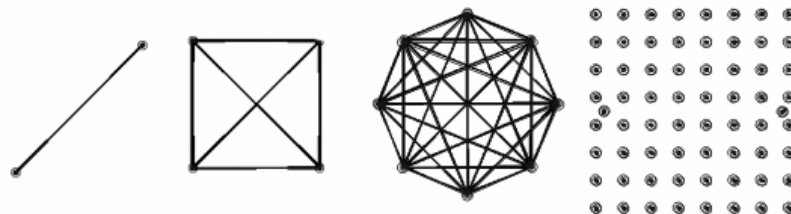
802.11n

The emerging 802.11n standard was ratified in 2009 based on several draft versions. The major evolution of the 802.11n technology includes MIMO (Multi-Input Multiple-Output), 40 MHz channels in the PHY layer, and frame aggregation in the

MAC layer. In addition, 802.11n is backward compatible with legacy 802.11 standards. High Throughput (Greenfield) mode, Non-HT (legacy) mode and HT Mixed mode are three operating modes of 802.11n. Technically, 802.11n will deliver a higher speed, up to 600 Mbps, which is more than 10 times the throughput of 802.11a/g. This increased speed also addresses the need for wireless networks to provide data transfer rates similar to those of Fast Ethernet.

There two other amendments to IEEE 802.11 which are not listed in Table 1. They are 802.11j for Japan and 802.11p for vehicular applications. Both use the half clock rate as defined in the standard.

Because 802.11n defines 77 possible permutations of the factors that determine data rate, a new concept has been defined for 802.11n, called MCS (Modulation and Coding Scheme). MCS assigns a simple integer to every permutation of modulation, coding rate, guard interval, channel width, and number of spatial streams.

Table below (Part 1) lists MCS values (index 0-9) currently supported by N9077A & W9077A WLAN measurement application.

MCS index	Type	Coding rate	Spatial streams	Data rate (Mbps) with 20 MHz BW		Data rate (Mbps) with 40 MHz BW	
				800 ns	400 ns (SGI)	800 ns	400 ns (SGI)
0	BPSK	1/2	1	6.50	7.20	13.50	15.00
1	QPSK	1/2	1	13.00	14.40	27.00	30.00
2	QPSK	3/4	1	19.50	21.70	40.50	45.00
3	16QAM	1/2	1	26.00	28.90	54.00	60.00
4	16QAM	3/4	1	39.00	43.30	81.00	90.00
5	64QAM	2/3	1	52.00	57.80	108.00	120.00
6	64QAM	3/4	1	58.50	65.00	121.50	135.00
7	64QAM	5/6	1	65.00	72.20	135.00	150.00
8	256QAM	3/4	1	78	86.7	162	180
9	256QAM	5/6	1	N/A	N/A	180	200

802.11ac

The latest WLAN technology, 802.11ac, as an extension of 802.11n, aims to provide very high throughput rates of over 1 Gbps to improve user experience and to enable new applications such as transmission of multiple streams of high-definition multimedia data. 802.11ac runs on 5 GHz bands, as there is no enough spectrum available at 2.4 GHz for high levels of performance. To achieve these data rates, the Very High Throughput (VHT) physical layer specification introduces wider RF bandwidth (up to 160 MHz), higher order modulation types (up to 256 QAM), and

more MIMO spatial streams (up to 8) to increase data rates over existing 802.11n products. The 802.11ac Technical Specification is currently in draft form, the Standard finalization is anticipated in late 2012, with final 802.11 working Group approval in late 2013.

The table below (Part 2) list MCS values (index 0-9) currently supported by N9077A & W9077A WLAN measurement application.

MCS index	Type	Coding rate	Spatial streams	Data rate (Mbps) with 80 MHz BW		Data rate (Mbps) with 160 MHz BW	
				800 ns	400 ns (SGI)	800 ns	400 ns (SGI)
0	BPSK	1/2	1	29.3	32.5	58.5	65
1	QPSK	1/2	1	58.5	65	117	130
2	QPSK	3/4	1	87.8	97.5	175.5	195
3	16QAM	1/2	1	117	130	234	260
4	16QAM	3/4	1	175.5	195	351	390
5	64QAM	2/3	1	234	260	468	520
6	64QAM	3/4	1	263.3	292.5	526.5	585
7	64QAM	5/6	1	292.5	325	585	650
8	256QAM	3/4	1	351	390	702	780
9	256QAM	5/6	1	390	433.3	780	866.7

Digital Modulation Format Standards

Introduction

This section introduces digital modulation formats supported by WLAN standards.

The RF carrier(s) must be modulated. All the WLAN systems described in this book use a form of phase-shift keying for the preamble. More complex schemes, such as 64QAM (Quadrature Amplitude Modulation) give faster bit rates for user data, but require better radio performance and less noise to work to their full potential. BPSK (Phase Shift Keying), QPSK, and QAM are described in standard RF texts. Often the modulation format changes during the transmission. This is because the early part of the burst contains important information about the burst, including analog characteristics such as frequency, and digital information such as burst length. Simpler modulation formats are less prone to bit errors, and thus are more suitable to use early in a burst.

Modulation Formats and WLAN standards

Table below shows modulation formats supported in WLAN measurement application, grouped by the IEEE standards.

Table 3-6   *Families of Digital Modulation Formats*

WLAN Standard	Carrier Type	Modulation Format
802.11a	OFDM	BPSK
		QPSK
		16 QAM
		64 QAM
802.11b	DSSS	DSSS 1 Mbps
		DSSS 2 Mbps
		CCK 5.5 Mbps
		CCK 11 Mbps
		PBCC 5.5 Mbps
		PBCC 11 Mbps

Table 3-6   *Families of Digital Modulation Formats*

WLAN Standard	Carrier Type	Modulation Format
802.11g	DSSS	DSSS 1 Mbps
		DSSS 2 Mbps
		CCK 5.5 Mbps
		CCK 11 Mbps
		PBCC 5.5 Mbps
		PBCC 11 Mbps
		PBCC 22Mbps
		PBCC 33Mbps
	OFDM	BPSK
		QPSK
		16 QAM
		64 QAM
802.11n	OFDM	BPSK
		QPSK
		16 QAM
		64 QAM
802.11ac	OFDM	BPSK
		QPSK
		16 QAM
		64 QAM
		256 QAM

To find out more about an individual format, see:

-

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Phase Shift Keying (PSK) Concepts

One of the simplest forms of digital modulation is Binary or Bi-Phase Shift Keying (BPSK). One application where this is used is for deep space telemetry. The phase of a constant amplitude carrier signal moves between zero and 180 degrees. On an I/Q

diagram, the I state has two different values. There are two possible locations in the constellation diagram, so a binary one or zero can be sent. The bit rate is one bit per symbol.

A more common type of phase modulation is Quadrature Phase Shift Keying (QPSK). It is used extensively in applications including CDMA (Code Division Multiple Access) cellular service, wireless local loop, and DVB-S (Digital Video Broadcasting — Satellite). Quadrature means that the signal shifts between phase states which are separated by 90 degrees. The signal shifts in increments of 90 degrees from 45 to 135, –45, or –135 degrees. These points are chosen as they can be easily implemented using an I/Q modulator. Only two I values and two Q values are needed and this gives two bits per symbol. There are four states because $2^2 = 4$. It is therefore a more bandwidth-efficient type of modulation than BPSK, potentially twice as efficient.

Figure 3-4   *Phase Shift Keying (PSK)*

BPSK
One Bit Per Symbol

QPSK
Two Bits Per Symbol
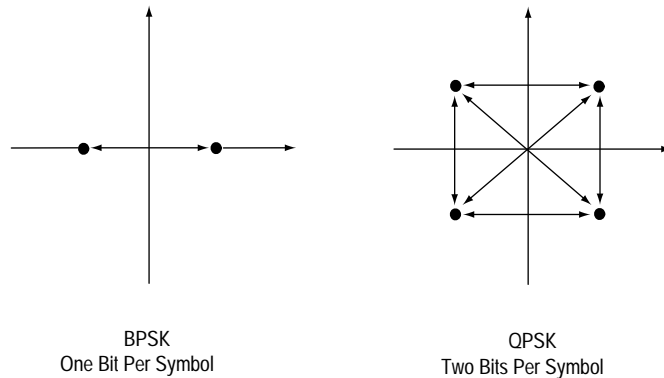
Quadrature Amplitude Modulation (QAM) Concepts

Quadrature amplitude modulation (QAM) is used in applications including microwave digital radio, DVB-C (Digital Video Broadcasting—Cable), and modems.

16 QAM

In 16-state quadrature amplitude modulation (16QAM), there are four I values and four Q values. This results in a total of 16 possible states for the signal. It can transition from any state to any other state at every symbol time. Since $16 = 2^4$ four bits per symbol can be sent. This consists of two bits for I, and two bits for Q. The symbol rate is one fourth of the bit rate. So this modulation format produces a more spectrally efficient transmission. It is more efficient than BPSK, QPSK, or 8PSK.

QPSK is practically the same as 4QAM.

32 QAM

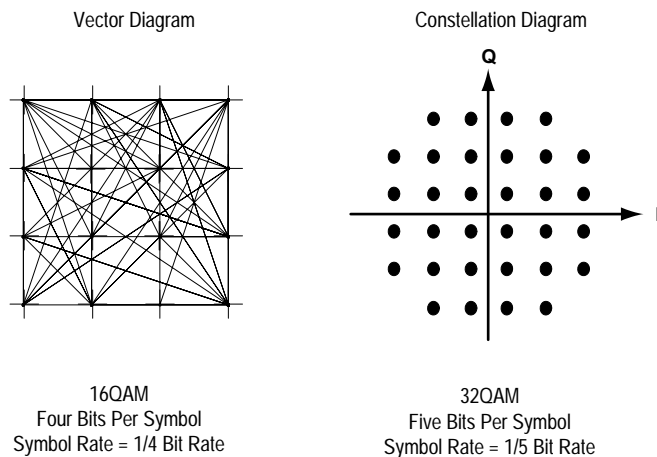Another variation of QAM is 32QAM. In this case there are six I values and six Q values resulting in a total of 36 possible states (6x6=36). This number is too many states for a power of two (the closest power of two is 32). So the four corner symbol

states, which take the most power to transmit, are omitted. This reduces the amount of peak power the transmitter has to generate. Since $2^5 = 32$, there are five bits per symbol and the symbol rate is one fifth of the bit rate.

The current practical limits for broadcast transmission of QAM signals are approximately 256 QAM, though work is underway to extend the limits to 512 or 1024 QAM. High state QAM formats are better suited to cable delivery where the noise is lessened.

A 256 QAM system uses 16 I-values and 16 Q-values, giving 256 possible states. Since $2^8 = 256$, each symbol can represent eight bits. A 256 QAM signal that can send eight bits per symbol is very spectrally efficient. However, for a given maximum power, the symbols are closer together than lower-valued QAM's and are thus more subject to errors due to noise and distortion. Such a signal may have to be transmitted with extra power (to effectively spread the symbols out more) and this reduces power efficiency as compared to simpler schemes.

Figure 3-5   *Quadrature Amplitude Modulation*

Vector Diagram

Constellation Diagram

16QAM
Four Bits Per Symbol
Symbol Rate = 1/4 Bit Rate

32QAM
Five Bits Per Symbol
Symbol Rate = 1/5 Bit Rate

However, bandwidth efficiency is better for higher QAM's. For example, BPSK uses 80 Ksymbols-per-second sending 1 bit per symbol. A system using 256QAM sends eight bits per symbol so the symbol rate would be 10 Ksymbols per second. A 256QAM system enables the same amount of information to be sent as BPSK using only one eighth of the bandwidth. It is eight times more bandwidth efficient. However, there is a trade-off. The radio becomes more complex and is more susceptible to errors caused by noise and distortion. Error rates of higher-order QAM systems such as this degrade more rapidly than QPSK as noise or interference is introduced. A measure of this degradation would be a higher bit error rate (BER).

In any digital modulation system, if the input signal is distorted or severely attenuated the receiver will eventually lose symbol lock completely. If the receiver can no longer recover the symbol clock, it cannot demodulate the signal or recover any information. With less degradation, the symbol clock can be recovered, but it is

noisy, and the symbol locations themselves are noisy. In some cases, a symbol will fall far enough away from its intended position that it will cross over to an adjacent position. The I and Q level detectors used in the demodulator would misinterpret such a symbol as being in the wrong location, causing bit errors. QPSK is not as efficient, but the states are much farther apart for a given power and the system can tolerate a lot more noise before suffering symbol errors. QPSK has no intermediate states between the four corner-symbol locations, so there is less opportunity for the demodulator to misinterpret symbols. QPSK requires less transmitter power than QAM to achieve the same bit error rate.

Spread Spectrum Concepts

Direct Sequence Spread Spectrum (DSSS)

DSSS (Direct Sequence Spread Spectrum) - The energy in a single carrier is spread over a wider spectrum by multiplying data bits with a special 11-bit pattern, called a Barker key. This is done at a chip rate of 11 MHz. This technique can help reduce interference from narrow-band sources. The IEEE 802.11b uses an 8-bit key. As shown in figure below, to create a DSSS signal, a lower rate signal is multiplied by a higher rate signal. For 1 Mbps, the 1 MHz (D)BPSK signal is multiplied by an 11 MHz BPSK signal. Although not generally true of DSSS signals, for this particular signal it can be said that the input bits determine the phase rotation of the spreading code or that it is a (D)BPSK data signal spread by a BPSK spreading sequence, producing a BPSK constellation.

Figure 3-6　　　　　*DSSS signal spreading for 2 Mbps data rate*
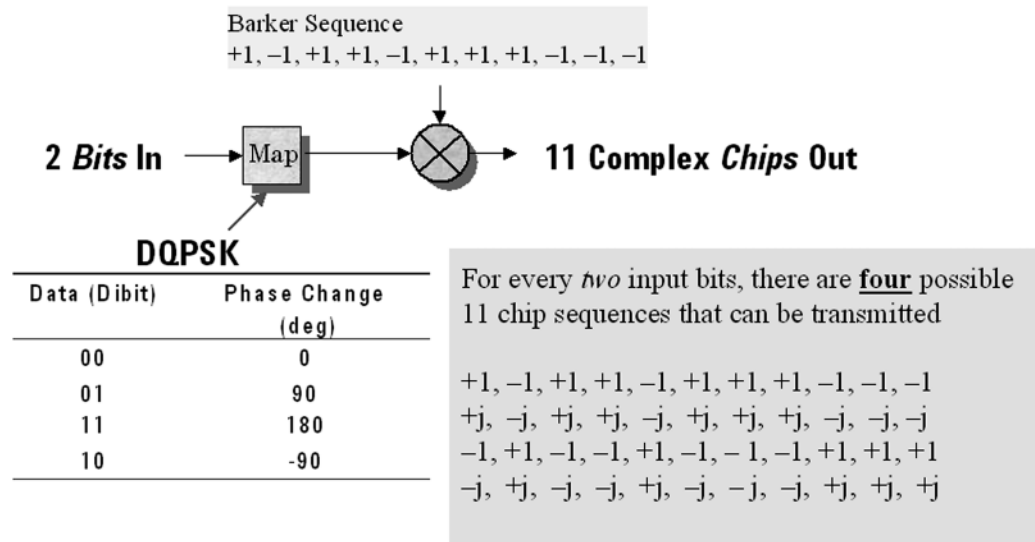
Complementary Code Keying (CCK)

CCK (Complementary Code Keying) - Changing both the spreading factor and/or the modulation format varies the bit rate. CCK is used to increase IEEE 802.11b's peak data rate from 2 to 11 Mbps, while still using QPSK (Quadrature Phase Shift Keying) modulation. To achieve 5.5 and 11 Mbps rates, the spreading length is first reduced from 11 to 8. This increase the symbol rate from 1 Msps to 1.375 Msps, then taking data in 4-bit blocks (4*1.375 = 5.5) or 8-bit blocks (8*1.375 = 11), i.e. 4 bits/symbol or 8 bits/symbol. Six of the 8 bits are used to choose 1 of 64 complementary codes, which are 8 chips long and clocked out at 11 MHz. Thus all 8 chips are "used up" in (1/1.375) us - the time before another byte is ready. The other 2 bits are combined with the code in the QPSK modulator.

Figure 3-7   *CCK Modulation*
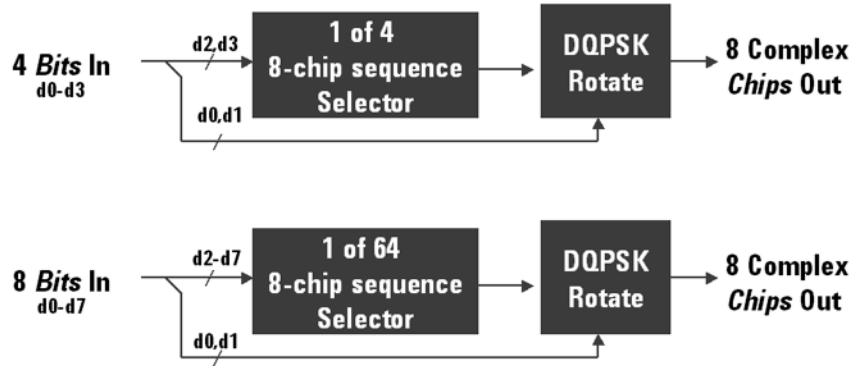
Packet Binary Convolutional Coding (PBCC)

PBCC (Packet Binary Convolutional Coding) - This scheme is optional for IEEE 802.11 b and g. It is basically a more complex version of CCK, allowing twice as much data to be encoded for a given bandwidth. Normally, a doubling of the data rate within a given bandwidth requires the signal-to-noise ratio of the channel to increase by 3 dB. By using PBCC, only a 0.5 dB increase is required for this data rate increase. In PBCC, the real data rate increase comes from moving from QPSK to 8PSK as the modulation technique, while the reduction in required signal-to-noise ratio comes from using PBCC over CCK. It makes use of Forward Error Correction to improve the link performance when noise is the limitation. Scrambled data is fed into a convolutional encoder. The encoder consists of a 6-stage memory, with specific taps combined to give two outputs. The four possible output states (00, 01, 10, 11) are mapped into two possible QPSK states (11 Mbps). A codeword controls how the chosen state alternates over time. The RF modulator is driven from this point.

Orthogonal Frequency Division Multiplexing (OFDM) Concepts

OFDM (Orthogonal Frequency Division Multiplexing) - OFDM uses multiple carriers, of which there are 52, spaced 312.5 kHz apart. Data is sent on 48 carriers simultaneously, with 4 used as pilots. The time to transmit each bit increases in proportion to the number of carriers. This makes the system less sensitive to multipath interference, a major source of distortion.

Figure 3-8   *OFDM Carriers Separation*
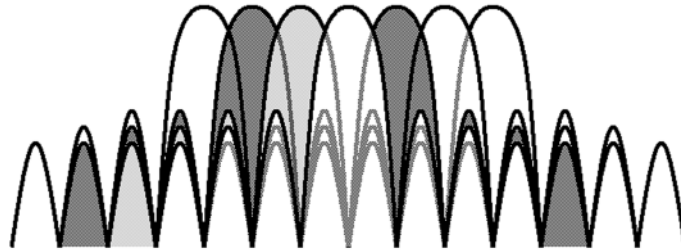
802.11a uses OFDM as its transmission scheme. For 802.11a there are 52 carriers in all, 48 of which are used to carry data and 4 which are used as pilots.

Orthogonal Frequency Division Multiplexing (OFDM) has been formally accepted as the method to achieve high data rates, better than 20 Mbps in the WLAN systems. OFDM provides multiple frequency channels at regular spacing, each modulated by M-ary QAM. An OFDM signal consists of the sum of a number of sub-carriers that are modulated using some form of PSK or QAM. Data interleavers "spread" the information throughout the carriers.

As shown in Figure 3-9, "OFDM training structure," an OFDM burst actually has four distinct regions. The first is the *Short training sequence*, followed by a *Long training sequence* and finally by the *Signal* and *Data symbols*. From a RF standpoint, the Signal symbol and the rest of the OFDM symbols are similar.

Figure 3-9   *OFDM training structure*
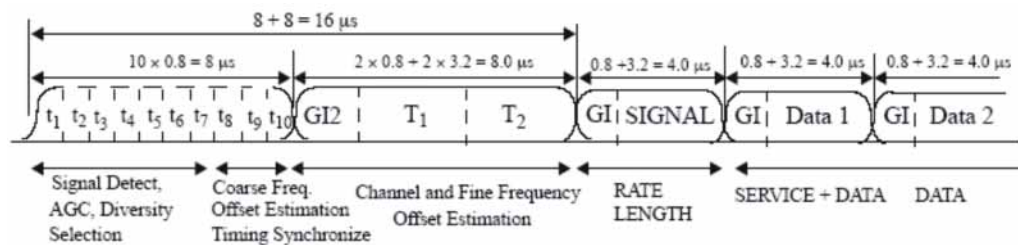
# MIMO (Multi Input Multi Output) Concepts

Multiple antenna techniques take advantage of spatial diversity in the radio channel. Multiple antenna techniques are of three main types: diversity, MIMO, and beamforming, to improve signal robustness and to increase system capacity and single-user data rates.

Figure 3-10 illustrates the range of possible antenna techniques from the simplest to the most complex, indicating how the radio channel is accessed by the system's transmitters and receivers.

Figure 3-10   *MIMO Radio-Channel Access Modes*
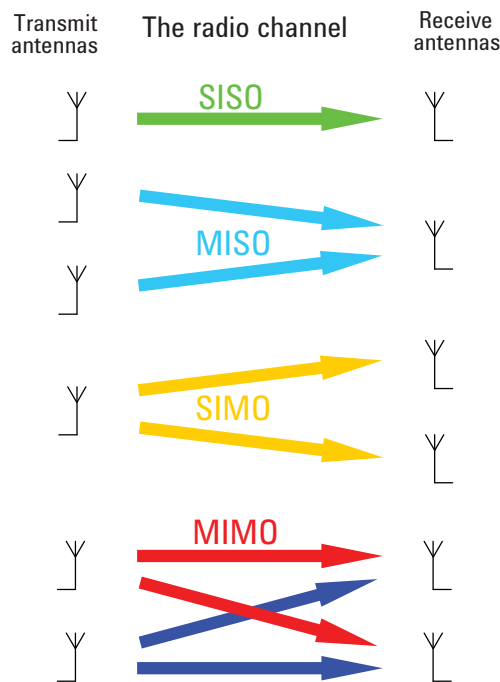
SISO - The most basic radio channel access mode is single input single output (SISO), in which only one transmit antenna and one receive antenna are used. This is the form of communications that has been the default since radio began and is the baseline against which all the multiple antenna techniques are compared.

MISO - Slightly more complex than SISO is multiple input single output (MISO) mode, which uses two or more transmitters and one receiver.

SIMO - The third mode shown in Figure 3-10 is single input multiple output (SIMO), which—in contrast to MISO—uses one transmitter and two or more receivers.

MIMO - The final mode is full MIMO, which requires two or more transmitters and two or more receivers. This mode is not just a superposition of SIMO and MISO since multiple data streams are now transmitted simultaneously in the same frequency and time, taking full advantage of the different paths in the radio channel. For a system to be described as MIMO, it must have at least as many receivers as there are transmit streams. The number of transmit streams should not be confused

with the number of transmit antennas. Consider the Tx diversity (MISO) case in which two transmitters are present but only one data stream. Adding receive diversity (SIMO) does not turn this into MIMO, even though there are now two Tx and two Rx antennas involved. SIMO + MISO ≠ MIMO. It is always possible to have more transmitters than data streams but not the other way around. If N data streams are transmitted from fewer than N antennas, the data cannot be fully descrambled by any number of receivers since overlapping streams without the addition of spatial diversity just creates interference. However, by spatially separating N streams across at least N antennas, N receivers will be able to fully reconstruct the original data streams provided the crosstalk and noise in the radio channel are low enough.

One other crucial factor for MIMO operation is that the transmissions from each antenna must be uniquely identifiable so that each receiver can determine what combination of transmissions has been received. This identification is usually done with pilot signals, which use orthogonal patterns for each antenna.

The theoretical gains from MIMO are a function of the number of transmit and receive antennas, the radio propagation conditions, the ability of the transmitter to adapt to the changing conditions, and the SNR. The ideal case is one in which the paths in the radio channel are completely uncorrelated, almost as if separate, physically cabled connections with no crosstalk existed between the transmitters and receivers. Such conditions are almost impossible to achieve in free space, and with the potential for so many variables, it is neither helpful nor possible to quote MIMO gains without stating the conditions. The upper limit of MIMO gain in ideal conditions is more easily defined, and for a 2x2 system with two simultaneous data streams a doubling of capacity and data rate is possible. MIMO works best in high SNR conditions with minimal line of sight. Line of sight equates to channel crosstalk and seriously diminishes the potential for gains. As a result, MIMO is particularly suited to indoor environments, which can exhibit a high degree of multi-path and limited line of sight.

WLAN Measurement Concepts

There are a number of different ways to measure the quality of a digitally modulated signal. These usually involve precision demodulation of the transmitted signal and comparison of this transmitted signal with a mathematically generated ideal or reference signal.

Channel Power Measurement Concepts

Purpose

The Channel Power measurement is used to find the total power presented in a specified bandwidth. This procedure also measures the power spectral density (the peak power on 1 MHz integration bandwidth). This measurement is applied to design, characterize, evaluate, and verify transmitters and their components.

Measurement Method

This measurement will include the following functionality:

- Averaging

- Flexibility for measuring any signal bandwidth

- Storage of a .CSV file to disk

- Integration BW markers

- Auto reference level setting key

- Root-Raised Cosine filter with user settable α and filter bandwidth

- Ability to turn the Root-Raised Cosine filter on or off

The Channel Power measurement uses Integration Bandwidth (IBW) method to calculate signal channel power. When the Channel Power measurement is activated, the appropriate integration bandwidth is set according to the selected radio standard. The power in the integration bandwidth is measured and reported along with the computed power spectral density. The peak power spectral density is defined as the maximum channel power in 1 MHz bandwidth.

The IBW method uses a swept spectrum as the basis for the calculation and select an appropriate RBW filter. If the RBW filter is too narrow, not all of the signal power will be measured. If the RBW filter is too wide, it will reduce the measurement accuracy.

The measurement integrates the linear trace power from (Center Freq - Integ BW/2) to (Center Freq + Integ BW/2) by considering the equivalent noise bandwidth and uses linear interpolation to calculate the residual lower and upper edge power of the integration bandwidth within the width of a sweep point (the span divided by the number of sweep points).

To improve repeatability, the user can increase either the number of averages or the number of data points with longer time record length. The channel power graph is shown in the graph window, while the absolute channel power in dBm and the peak power spectral density in dBm/MHz are shown in the text window.

Figure 3-11   *Channel Power Measurement Result (802.11n)*
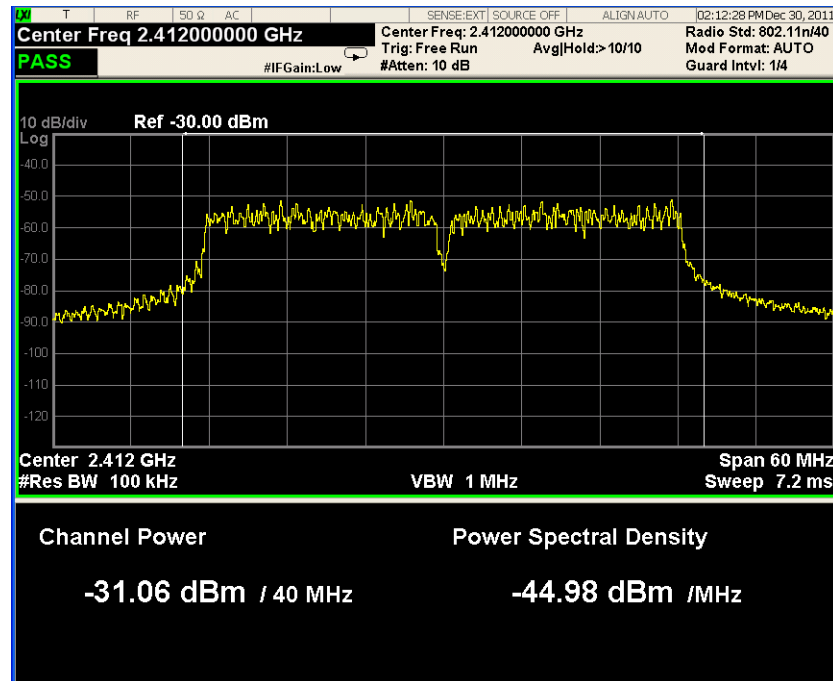
Occupied Bandwidth Measurement Concepts

Purpose

Occupied bandwidth measurements express the bandwidth occupied by a given percentage of the total mean power of a signal. This percentage is typically 99%.

Measurement Method

The Occupied Bandwidth measurement is performed in two calculation stages. First, the instrument uses Integration Bandwidth (IBW) method to capture the data and integrate the total power within the measurement frequency span for its 100% of power. Then, the frequencies of 0.5% of the total power are calculated to get 99.0% bandwidth.

Power Stat CCDF Measurement Concepts

Purpose

Many of the digitally modulated signals now look noise-like in the time and frequency domain. This means that statistical measurements of the signals can be a useful characterization. Power Complementary Cumulative Distribution Function

(CCDF) curves characterize the higher level power statistics of a digitally modulated signal. The curves can be useful in determining design parameters for digital communications systems.

In mobile communications, battery life is one of the most important characteristics of the device. The efficiency of the power amplifier is key to maximizing battery life. The Peak to Average Ratio (PAR) of the signal is a concern. The PAR is defined as the ratio of the peak envelope power to the average envelope power of a signal. A signal with a high PAR requires more headroom in the amplifier, which makes it less efficient. The PAR for the basic configuration (one DPDCH and one DPCCH) is equal or larger than 3.6 dB during 0.1 percent of the time.

The power statistics CCDF measurement can be affected by many factors. For example, modulation filtering, modulation format, combining the multiple signals at different frequencies, number of active codes, and correlation between symbols on different codes with spread spectrum systems will all affect measurement results. These factors are all related to modulation and signal parameters. External factors such as signal compression and expansion by nonlinear components, group delay distortion from filtering, and power control within the observation interval also affect the measurement.

The complementary cumulative distribution function (CCDF) fully characterizes the power statistics of a signal. It provides PAR versus probability. shows the CCDF curves for a WLAN 802.11n signal.

CCDF curves can help you in several situations:

- To determine the headroom required when designing a component.

- To confirm the power statistics of a given signal or stimulus. CCDF curves allow you to verify if the stimulus signal provided by another design team is adequate. For example, RF designers can use CCDF curves to verify that the signal provided by the digital signal processing (DSP) section is realistic.

- To confirm that a component design is adequate or to troubleshoot your subsystem or system design, you can make CCDF measurements at several points of a system. For example, if the ACLR of a transmitter is too high, you can make CCDF measurements at the input and output of the PA. If the PA design is correct, the curves will coincide. If the PA compresses the signal, the PAR of the signal is lower at the output of the PA.

Figure 3-12   *CCDF Measurement*
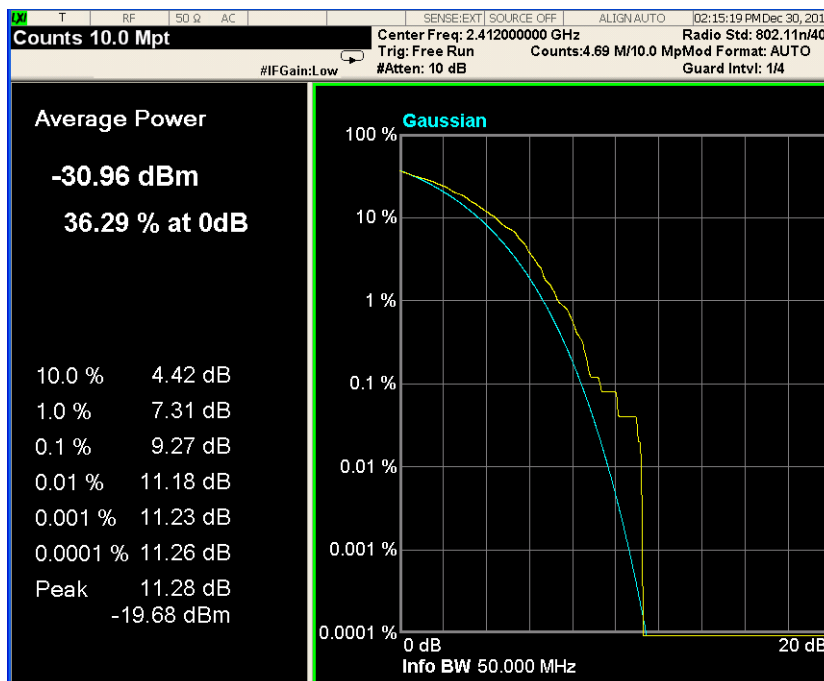
Measurement Method

The power measured in power statistics CCDF curves is actually instantaneous envelope power defined by the equation:

$$P = (I^2 + Q^2)/Z_0$$

(where I and Q are the quadrature voltage components of the waveform and Zo is the characteristic impedance).

A CCDF curve is defined by how much time the waveform spends at or above a given power level. The percent of time the signal spends at or above the level defines the probability for that particular power level. For capturing a lower probability down to 0.0001%, this measurement is made in the single mode. To make the power statistics CCDF measurement, the instrument uses digital signal processing (DSP) to sample the input signal in the channel bandwidth.

The Gaussian distribution line as the band-limited Gaussian noise CCDF reference line, the user-definable reference trace, and the currently measured trace can be displayed on a semi-log graph. If the currently measured trace is above the user reference trace, it means that the higher peak power levels against the average power are included in the input signal.

Spectrum Emission Mask Measurement Concepts

Purpose

The Spectrum Emission Mask measurement is used to test the in-band spurious emissions. It may be expressed as a ratio of power spectral densities between the carrier and the specified offset frequency band. The power spectral density of the transmitted signal shall fall within the spectral mask.

Measurement Method

The Spectrum Emission Mask measurement measures spurious signal levels in up to six pairs of offset frequencies and relates them to the carrier power. PSD (Power Spectral Density) is used for this measurement. Spectrum Emission Mask measurement is made with both sides centered at the carrier channel frequency bandwidth. The specifications require the reference to be the PSD of the signal. The reference power therefore can be obtained in 100kHz resolution bandwidth as a reference PSD related to 100kHz. Each offset peak PSD displayed is either a relative PSD to the peak PSD in the signal or an absolute PSD.

This measurement requires the user to specify measurement bandwidths of the carrier channel and each of the offset frequency pairs A to F. Each pair may be defined with unique measurement bandwidths. Test Limits are also defined in each offset. The results are displayed as relative PSD to peak reference channel PSD in dBc, or absolute peak PSD in dBm and minimum margin from limit line in dB at the minimum margin point. The minimum margin from limit line is the peak value relative to limit line in each offset.

Figure 3-13   *Spectrum Emission Mask Measurement (802.11n)*
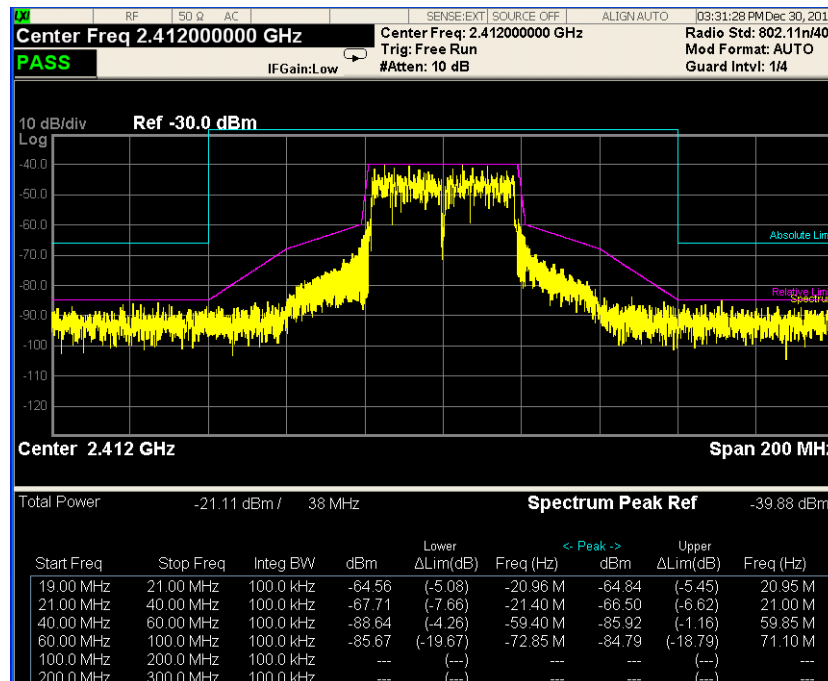
Spurious Emissions Measurement Concepts

Purpose

Spurious signals can be caused by different combinations of signals in the transmitter. The spurious emissions from the transmitter should be minimized to guarantee minimum interference with other frequency channels in the system. Harmonics are distortion products caused by nonlinear behavior in the transmitter. They are integer multiples of the transmitted signal carrier frequency.

Spurious Emissions measurement verifies the frequency ranges of interest are free of interference by measuring the power level of spurious emissions in certain frequency bands.

Measurement Method

The table-driven measurement has the flexibility to set up custom parameters such as frequency, span, resolution bandwidth, and video bandwidth.

For each range that you specify and activate, the analyzer scans the band using the specified Range Table settings. Then using the Peak Excursion and Peak Threshold values determines which spurs to report.

As each band is swept, any signal which is above the Peak Threshold value and has a peak excursion of greater than the Peak Excursion value will be added to a list of spurs displayed in the lower results window. A total of 200 spurs can be recorded for one measurement, with a limit of 10 spurs per frequency range. To improve repeatability, you can increase the number of averages.

From the spurs in the list, those with peak amplitude greater than the Absolute Limit for that range will be logged as a measurement failure and denoted by an 'F' in the 'Amplitude' column of the table. If no spurs are reported, but the measured trace exceeds the limit line for any range, the fail flag is set to fail.

This measurement has the ability to display two traces using different detectors on the display simultaneously. All spur detection and limit line testing are only applied to the trace associated with Detector 1, which will be colored yellow. The trace associated with Detector 2 will be colored cyan.

If the sweep time for the range exceeds 2 seconds, a flashing message "Sweeping...Please Wait" will appear in the annunciator area. This advises you that the time to complete the sweep is between 2 and 2000 seconds, and is used as without it the display would appear stagnant and you may think the measurement is not functional.

Power vs. Time Measurement Concepts

Purpose

The Power vs. Time (PvT) measurement is used to test power-on and power-down transition for 802.11b signals.

To prevent the interference caused by bursting the RF carrier, the associated standard specifies a power versus time template to which a device must conform.

This template defines the burst length, the rising and falling edges, the masks for regions of power on and power off. The instrument measures PvT in the time domain. From envelop of PvT trace, transient periods (power-on ramp period and power-down ramp period) can be detected, then the transient periods will be compared with limits specified for pass/fail judgment.

Measurement Method

A PvT measurement requires a bursted signal to be supplied periodically. Once supplied, a single burst is captured as a time domain data acquisition, with a single trigger. The rising and falling edges are detected at the crossing points with the burst search threshold level. The burst center point in time is determined, and then the required masks are aligned in time with the center point. To make a precise slope detection, its threshold level and detection interval techniques are incorporated to extract only steep enough slopes out from the noise-like signals.

In this measurement, trigger must be provided by the user. Depending on trigger, the signal which is a little bit longer than one burst is captured. It starts from -(Ramp Time Length)/2, in which Ramp Time Length indicates the ramp search window and also set by the user, and ends to (Burst Time + Ramp Time Length), where Burst Time is search length. Burst Time must be set long enough to include an actual RF burst. Otherwise, power-down ramp may be lost. The captured data in search window is then smoothed to determine max power point. By use of max power point, the ramp up and down can be determined in term of 10% to 90% power range of max power point. Some parameters mentioned above can be explained clearly from the figure below.

Figure 3-14   *Explanation for parameters in Power-on and Power-down Ramp*
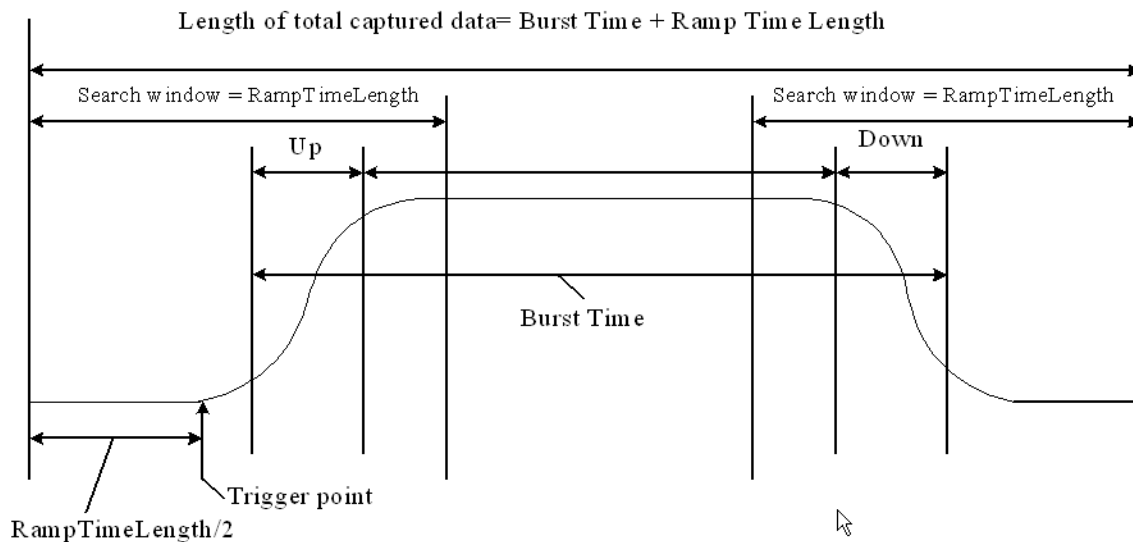
Spectral Flatness Measurement Concepts

Purpose

Variation in carrier flatness of OFDM signals in IEEE 802.11a/g/n/ac will reduce demodulation margins and degrade link performance. This measurement applies to test carrier flatness of OFDM signals in IEEE 802.11a/g/n/ac.

Measurement Method

For 802.11a and 802.11g (ERP-OFDM/DSSS-OFDM), the Spectrum Flatness measurement measures energy flatness of sub-carriers in OFDM system, the average energy of the constellations in each of the spectral lines –16… –1 and +1… +16 (defined as Section 1) will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26… –17 and +17… +26 (defined as Section 2) will deviate no more than +2/–4 dB from the average energy of spectral lines –16… –1 and +1… +16. The average energy can be computed by averaging energy on the sub-carriers from –16 to 16. Please note, zero sub-carrier is not included in this computation phase.

For 802.11n in a 20 MHz channel and in corresponding 20 MHz transmission in a 40 MHz channel, the average energy of the constellations in each of the subcarriers with indices –16… –1 and +1… +16 (defined as Section 1) shall deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the subcarriers with indices –28… –17 and +17… +28 (defined as Section 2) shall deviate no more than +2/–4 dB from the average energy of subcarriers with indices –16… –1 and +1… +16.

In a 40 MHz transmission (excluding PPDUs in MCS 32 format and non-HT duplicate format), the average energy of the constellations in each of the subcarriers with indices –42… –2 and +2… +42 (defined as Section 1) shall deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the subcarriers with indices –58… –43 and +43… +58 (defined as Section 2) shall deviate no more than +2/–4 dB from the average energy of subcarriers with indices –42… –2 and +2… +42.

In MCS 32 format and non-HT duplicate format, the average energy of the constellations in each of the subcarriers with indices –42… –33, –31… –6 and +6… +31, +33… +42 (defined as Section 1) shall deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the subcarriers with indices –58… –43 and +43… +58 (defined as Section 2) shall deviate no more than +2/–4 dB from the average energy of subcarriers with indices –42… –33, –31… –6 and +6… +31, +33… +42.

Figure 3-15   *Spectral Flatness Measurement*
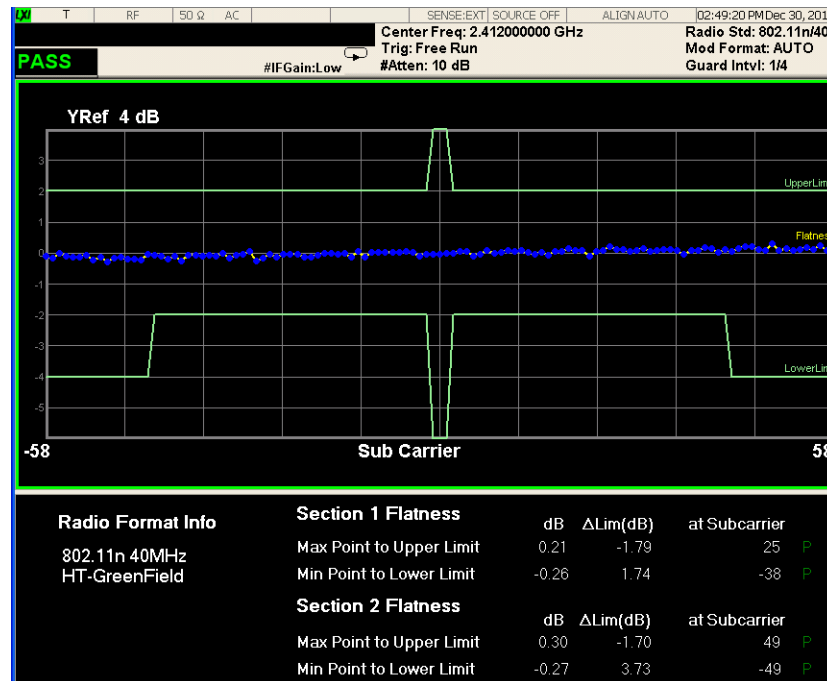
Modulation Analysis Measurement Concepts

Purpose

This measurement provides modulation analysis capabilities for signals complying with 802.11a/b/g/n/ac standards.

Error Vector Magnitude (EVM) is a very common modulation quality metric widely used in digital communication systems. EVM is the scalar distance between the measured signal and the time-aligned reference signal. In most standards, EVM is defined as the root-mean-square of error values at the symbol decision positions. Measurements of EVM and related quantities can pinpoint the causes for any problems uncovered by identifying exactly the type of degradation present in the signal and even help reveal any impairments that occur at the base-band filters, I/Q modulators, IF and RF sections of the transmitter.

The root mean square (RMS) of the error vectors is computed and expressed as a percentage of the square root of the mean power of the ideal signal[1].

For a regular QAM or a Phase Shift Keyed (PSK) signal, the ideal symbol points always map onto a few specific locations in the I/Q plane.

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1. The actual calculation method of the percentage depends on the specific standard. The EVM may be normalized to the amplitude of the outermost symbol, the square root of the average symbol power, or the square root of the mean power of the ideal signal. In the case of W-???, the specifications require normalization to the square root of the mean power of the ideal signal (see section on Composite EVM).
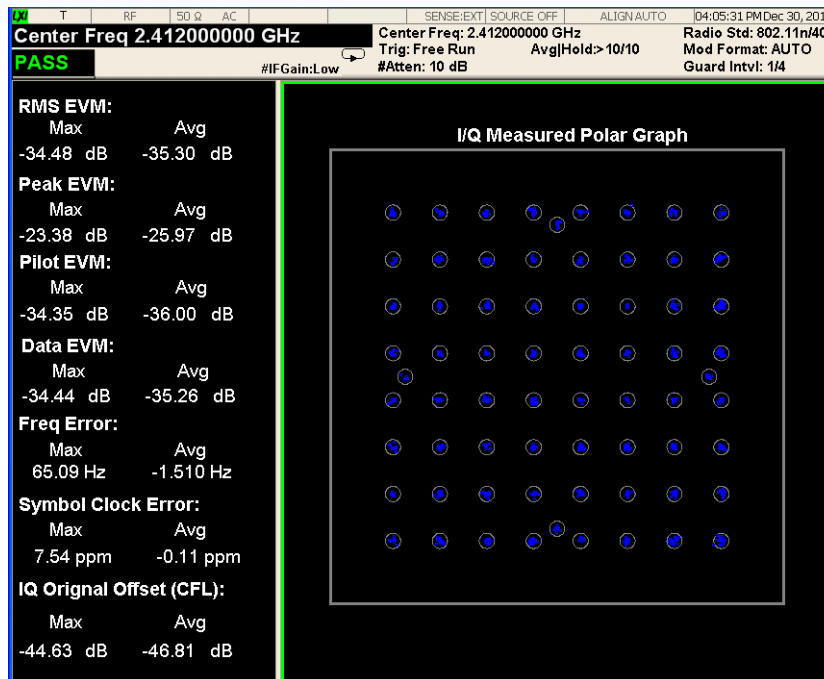
Measurement Method

The signal to be measured needs to be a single coded signal such as one DPCH, a single DPDCH, or a DPDCH and a DPCCH. The phase error of the unit under test is measured by computing the difference between the phase of the transmitted signal and the phase of a theoretically perfect signal.

The instrument samples the transmitter output in order to capture the actual phase trajectory and locate the first complete burst, then demodulates the burst and compute measurement results, in some cases computing averaged results, finally displays the measurement results in various views.

Figure 3-16   *I/Q Polar Constellation and Related Parameters*

List Sequence Measurement Concepts

Purpose

The List Sequence measurement is used to provide fast results on MXA and EXA. This measurement makes multiple acquisitions to acquire multiple WLAN bursts which have different frequency, different radio standards (one of 802.11a/g, 802.11b/g, 802.11n and 802.11ac), different power range, different trigger type, then performs Transmit Power, SEM, Modulation Analysis (EVM) and Spectral Flatness measurements for each burst. The List Sequence measurement is focused on manufacturing use cases.
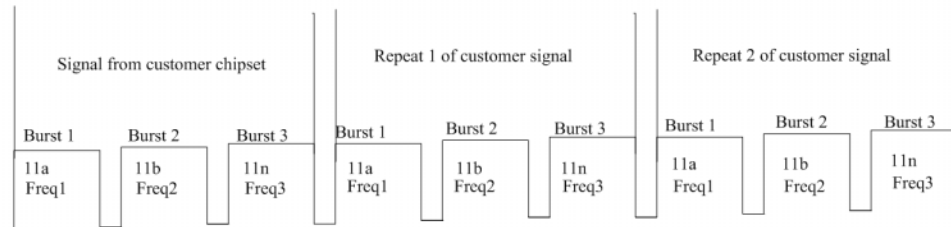
Measurement Method

This measurement will perform the following measurements for each burst:

• Transmit Power

- SEM (including Spectral Flatness)

- Modulation Analysis

The sequence of multi-bursts from Device Under Test (DUT) should be repeating 3 times (see the figure below), therefore, the valid bursts can be identified and analyzed. Up to 45 bursts can be analyzed.

As shown below, each burst contains three parts: Prefix, Burst and Transition Time. Prefix is defined as time spacing between this burst and the previous burst. Burst allows the user to specify the data time over which the measurement is made. Transition time is used to define the hardware switching time between this burst and the next burst. The user should ensure the exact alignment of the analyzer and the DUT in terms of these parameters.
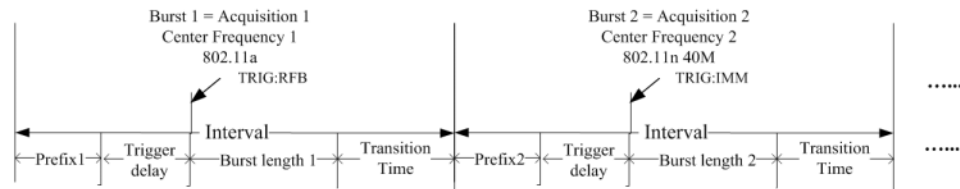
The user also need to set up the measurement parameters for making acquisitions and making List Sequence measurements. It is recommended to run this measurement in Single mode. The Averaging method is not supported in this measurement.

Monitor Spectrum Measurement Concepts

Purpose

The monitor spectrum measurement provides spectrum analysis capability for the instrument. It is used as a quick, convenient means of looking at the entire spectrum. While the look and feel are similar to the Spectrum Analyzer mode, the functionality is greatly reduced for easy operation. The main purpose of the measurement is to show the spectrum. The default span should cover an appropriate frequency range of the application.

Measurement Method

The measurement takes the sweep and acquires the data between the start frequency and stop frequency, then trace is displayed in the measurement window.

Troubleshooting Hints

Changes made by the user to advanced spectrum settings, particularly to ADC range settings, can inadvertently result in spectrum measurements that are invalid and cause error messages to appear. Care needs to be taken when using advanced features.

IQ Waveform Measurement Concepts

Purpose

The waveform measurement is a generic measurement for viewing the input signal waveforms in the time domain. This measurement is how the instrument performs the zero span functionality found in traditional spectrum analyzers.

Basic mode waveform measurement data may be displayed using either a Signal Envelope window, or an I/Q window which shows the I and Q signal waveforms in parameters of voltage versus time. The advantage of having an I/Q view available while making a waveform measurement is that it allows you to view complex components of the same signal without changing settings or measurements.

The waveform measurement can be used to perform general purpose power measurements in the time domain with excellent accuracy.

Measurement Method

The instrument makes repeated power measurements at a set frequency, similar to the way a swept-tuned spectrum analyzer makes zero span measurements. The input analog signal is converted to a digital signal, which then is processed into a representation of a waveform measurement. The measurement relies on a high rate of sampling to create an accurate representation of a time domain signal.