Agilent X-Series Signal Analyzer

This manual provides documentation for the following analyzers:

MXA Signal Analyzer N9020A

EXA Signal Analyzer N9010A

N9077A - XFP Single Acquisition Combined WLAN Measurement Application Measurement Guide

Agilent Technologies

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1 Making Single Acquisition Combined WLAN Measurements

This chapter explains how to make a combined WLAN measurement on a WLAN signal. Three measurement examples, including SCPI programming commands are provided for measuring Transmit Power, Transmit Output Spectrum, and Modulation Accuracy of the WLAN signal.

What Does the Single Acquisition Combined WLAN Measurement Application Do?

Single Acquisition Combined WLAN adopts the concept of SACM (Single Acquisition Combined Measurements). It performs as many measurements as possible on one capture.

Combined Measurement is capture centered and a traditional measurement is measurement centered. In other words, in the combined measurements, all the measurements are based on one capture, there is no switch time among different measurements and in a traditional measurement, measurement controls the capture activity, the capture will restart when the measurement is changed.

The Combined WLAN mode includes one measurement, Combined WLAN. The following measurement results are presented by this measurement:

- Transmit Power
- Transmit Output Spectrum
- Modulation Accuracy

The following tables brief the measurements and features supported by different bandwidth options.

Table 1-1 *Key Measurements and Features Supported by Option B25 (25 MHz analysis bandwidth)*

Measurements and Features	**802.11 a/b/g**	**802.11n**
Tansmit Power	Y[a]	N/A[b]
Transmit Output Spectrum	Y	N/A
Modulation Accuracy	Y	20 MHz EVM only
Measuring Frequency Hopping Signals	Y	N/A

[a] "Y" means this measurement or feature is supported.
[b] "N/A" means this is not applicable.

Table 1-2 *Key Measurements and Features Supported by Option B40 (40 MHz analysis bandwidth)*

Measurements and Features	**802.11 a/b/g**	**802.11n**
Tansmit Power	Y[a]	N/A[b]
Transmit Output Spectrum	Y	N/A
Modulation Accuracy	Y	Y
Measuring Frequency Hopping Signals	N/A	N/A

[a] "Y" means this measurement or feature is supported.
[b] "N/A" means this is not applicable.

NOTE Option B40 is required to perform 40 MHz Modulation Accuracy measurements on 802.11n signals.

With installing Option B40, the frequency-hopping signal cannot be measured for any of the standard 802.11a/b/g/n.

With Option B25, you can only perform 20 MHz Modulation Accuracy measurements on 802.11n signals.

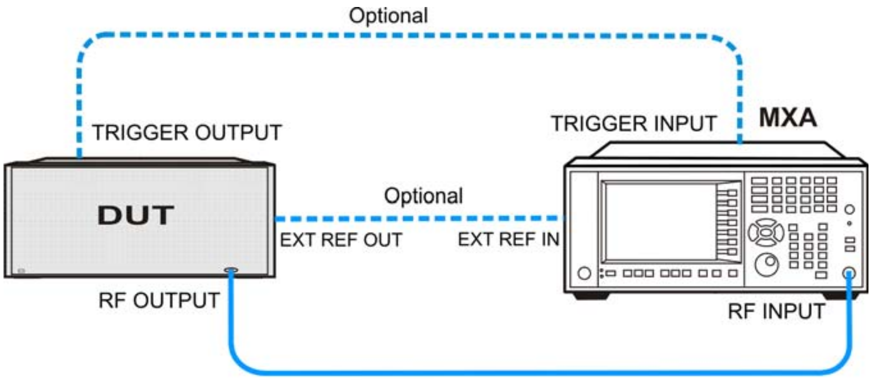
Measuring Transmit Power on Static Bursts

The following example details the measurement procedure and SCPI commands for measuring transmit power on static bursts which have the same burst settings.

Configuring the Measurement System

Connect the RF OUTPUT of the DUT (Device Under Test) to the analyzer RF INPUT as shown in Figure 1-1. MXA needs LAN or GPIB connection for SCPI control.

Figure 1-1 *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.

Measurement Example Signal Settings

Frequency: 2412 MHz

Output Power: -10 dBm (at analyzer input)

WLAN signal radio standard: 802.11g

Data Rate: 6 Mbps OFDM

Data length in the burst: 480us

Idle length in the burst: 480us

Measurement Procedure

NOTE The primary UI for this measurement is SCPI commands. For the SCPI commands with different parameters and the detailed usage of each SCPI command, please refer to N9077A-XFP Single Acquisition Combined 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 Agilent I/O Library Suite is recommended for connecting the Agilent instruments to the PC and using the instruments from a measurement program. For more detailed information, see the URL: http://www.agilent.com/find/iolib.

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

Table 1-3 *SCPI Commands for Transmit Power Measurement on Static Bursts (4-1)*

SCPI Commands	Notes
INST:SEL CWLAN	Select Combined 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:CWL	Select Combined WLAN measurement.
RAD:STAN W11GOFDM	Configure the radio standard.
CWL:TRIG:SOUR RFB TRIG:RFB:LEV:TYPE ABS TRIG:RFB:LEV:ABS -25 TRIG:DEL 0	Select the RF Burst Trigger (default) and setup the trigger type to be absolute and trigger level to be -25 dBm.

Step 3. Set up the capture parameters as following:

Table 1-4 *SCPI Commands for Transmit Power Measurement on Static Bursts (4-2)*

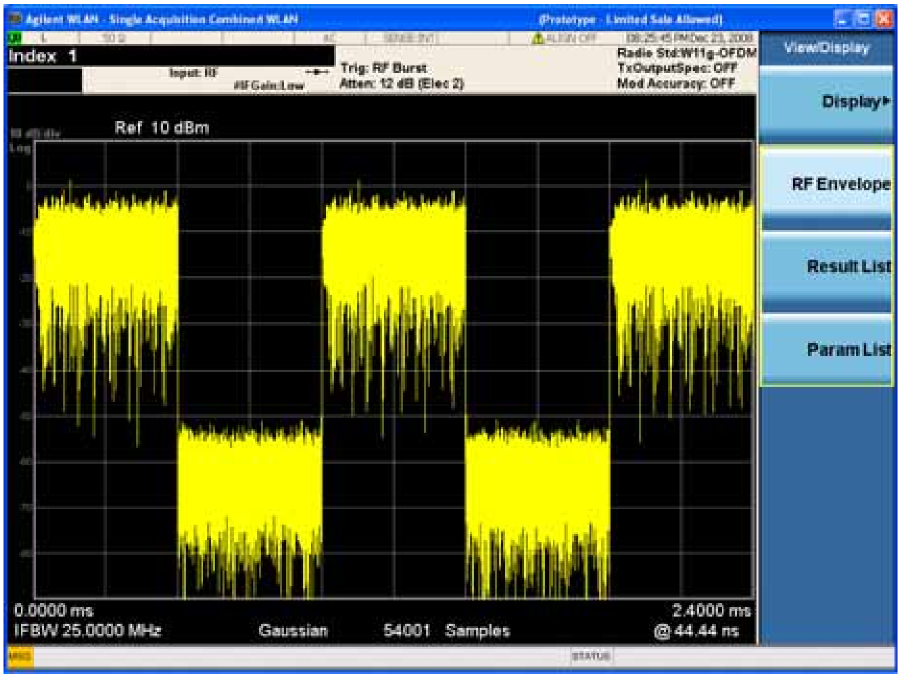
SCPI Commands	Notes
CWL:CAPT:BURS:NUMB 3	Set the measured burst number.
CWL:CAPT:BURS:TYPE STAT	Set the burst type to Static.

Table 1-4 *SCPI Commands for Transmit Power Measurement on Static Bursts (4-2)*

SCPI Commands	Notes
CWL:METH ACC	Select the measure method to be best accuracy.
CWL:CAPT:BURS:FREQ 2412MHz,2412MHz,2412MHz	Set the center frequency of the bursts.
CWL:CAPT:BURS:LOAD 0.00048,0.00048,0.00048	Set the target burst which is captured and calculated during the setting time.
CWL:CAPT:BURS:PREF 0,0.00048,0.00048	Set the prefix of the burst.
CWL:CAPT:BURS:SUFF 0,0,0	There is no suffix in static mode. This command is optional.
INIT:CONT ON	Turn on Continuous Sweep.
DISP:CWL:VIEW RFEN	Select the RF Envelope View to display the result of signal vs. time. This view gives you the idea of what RF envelope of the signal looks like.
DISP:CWL:VIEW PAR	Select the Parameter List View.

An example of the RF Envelope view is shown below:

Figure 1-2 *Transmit Power Measurement on Static Burst RF Envelope View*



Index 1
Input: RF
#IFGain:Low
Trig: RF Burst
Atten: 12 dB (Elec 2)
Radio Std:W11g-OFDM
TxOutputSpec: OFF
Mod Accuracy: OFF
Ref 10 dBm
0.0000 ms
2.4000 ms
IFBW 25.0000 MHz
Gaussian
54001 Samples
@ 44.44 ns

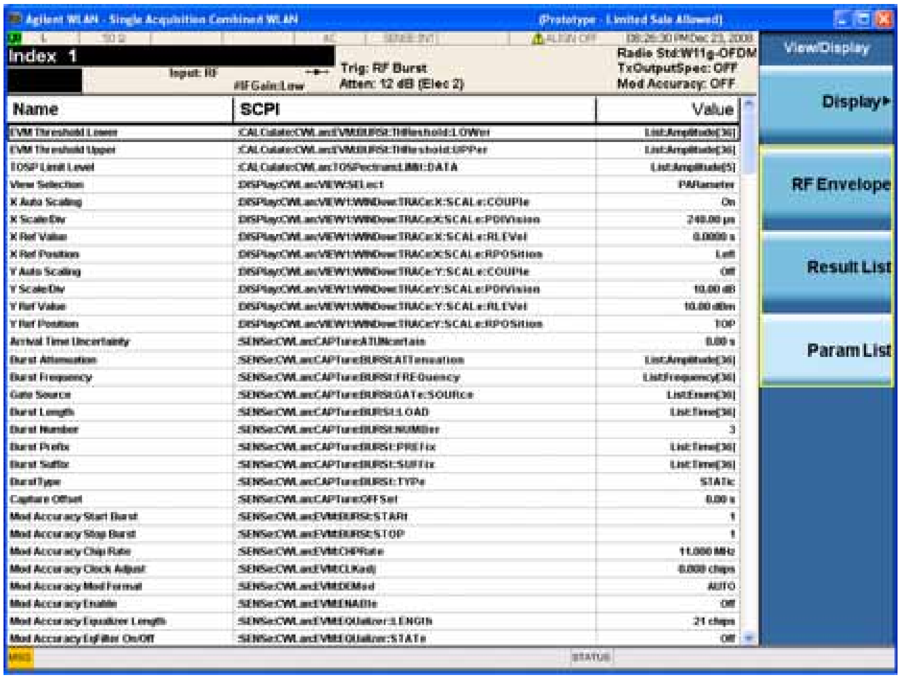
Step 4. Setup the measurements:

Table 1-5 *SCPI Commands for Transmit Power Measurement on Static Bursts (4-3)*

SCPI Commands	Notes
CWL:TXP:BURS:STAR 1 CWL:TXP:BURS:STOP 3	Set the start and stop burst of transmit power measurement.
INIT:CONT ON	Turn on Continuous Sweep.
DISP:CWL:VIEW PAR	Select the Parameter List View.

An example of Parameter List View is shown in Figure 1-3. 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. Some parameters, such as Burst Length, that may be “List:Time[36]” in the column of Value, which means this parameter has a maximum of 36 values to set. In this case, enter the index value from 1 to 36.

Figure 1-3 *Transmit Power Measurement on Static Burst Parameter List View*



Index 1

Input: RF
#IF Gain:Low
Trig: RF Burst
Atten: 12 dB (Elec 2)
Radio Std:W11g-OFDM
TxOutputSpec: OFF
Mod Accuracy: OFF

Name	SCPI	Value
EVM Threshold Lower	:CALCulate:CWLan:EVM:BURSt:THReshold:LOWer	List:Amplitude[36]
EVM Threshold Upper	:CALCulate:CWLan:EVM:BURSt:THReshold:UPPer	List:Amplitude[36]
TOSP Limit Level	:CALCulate:CWLan:TOSPectrum:LIMit:DATA	List:Amplitude[5]
View Selection	:DISPlay:CWLan:VIEW:SELect	PARameter
X Auto Scaling	:DISPlay:CWLan:VIEW1:WINDow:TRACe:X:SCALe:COUPle	On
X Scale/Div	:DISPlay:CWLan:VIEW1:WINDow:TRACe:X:SCALe:PDIVision	240.00 μs
X Ref Value	:DISPlay:CWLan:VIEW1:WINDow:TRACe:X:SCALe:RLEVel	0.0000 s
X Ref Position	:DISPlay:CWLan:VIEW1:WINDow:TRACe:X:SCALe:RPOSition	Left
Y Auto Scaling	:DISPlay:CWLan:VIEW1:WINDow:TRACe:Y:SCALe:COUPle	Off
Y Scale/Div	:DISPlay:CWLan:VIEW1:WINDow:TRACe:Y:SCALe:PDIVision	10.00 dB
Y Ref Value	:DISPlay:CWLan:VIEW1:WINDow:TRACe:Y:SCALe:RLEVel	10.00 dBm
Y Ref Position	:DISPlay:CWLan:VIEW1:WINDow:TRACe:Y:SCALe:RPOSition	TOP
Arrival Time Uncertainty	:SENSe:CWLan:CAPTure:ATUNcertain	0.00 s
Burst Attenuation	:SENSe:CWLan:CAPTure:BURSt:ATTenuation	List:Amplitude[36]
Burst Frequency	:SENSe:CWLan:CAPTure:BURSt:FREQuency	List:Frequency[36]
Gate Source	:SENSe:CWLan:CAPTure:BURSt:GATe:SOURce	List:Enum[36]
Burst Length	:SENSe:CWLan:CAPTure:BURSt:LOAD	List:Time[36]
Burst Number	:SENSe:CWLan:CAPTure:BURSt:NUMBer	3
Burst Prefix	:SENSe:CWLan:CAPTure:BURSt:PREFix	List:Time[36]
Burst Suffix	:SENSe:CWLan:CAPTure:BURSt:SUFFix	List:Time[36]
Burst Type	:SENSe:CWLan:CAPTure:BURSt:TYPe	STATic
Capture Offset	:SENSe:CWLan:CAPTure:OFFSet	0.00 s
Mod Accuracy Start Burst	:SENSe:CWLan:EVM:BURSt:STARt	1
Mod Accuracy Stop Burst	:SENSe:CWLan:EVM:BURSt:STOP	1
Mod Accuracy Chip Rate	:SENSe:CWLan:EVM:CHPRate	11.000 MHz
Mod Accuracy Clock Adjust	:SENSe:CWLan:EVM:CLKadj	0.000 chips
Mod Accuracy Mod Format	:SENSe:CWLan:EVM:DEMod	AUTO
Mod Accuracy Enable	:SENSe:CWLan:EVM:ENABle	Off
Mod Accuracy Equalizer Length	:SENSe:CWLan:EVM:EQUalizer:LENGth	21 chips
Mod Accuracy EqFilter On/Off	:SENSe:CWLan:EVM:EQUalizer:STATe	Off

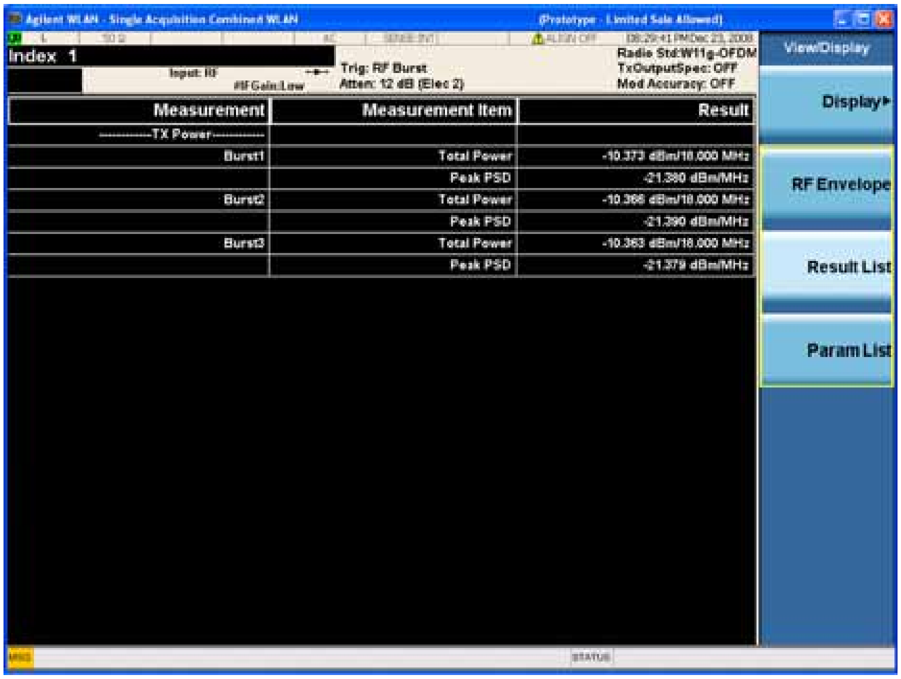
Step 5. Get the results:

Table 1-6 *SCPI Commands for Transmit Power Measurement on Static Burst (4-4)*

SCPI Commands	Notes
READ:CWL4?	After this command is sent to the analyzer, the transmit power results are returned. For more commands about reading the result, refer to N9077A-XFP Combined WLAN Measurement Application User's and Programmer's Reference.
DISP:CWL:VIEW RES	The transmit power measurement result is available in the Result List View.

An example of TX Power Result List view is shown below.

Figure 1-4 *Transmit Power Measurement on Static Burst Result List View*



Index 1

Input: RF
#IFGain:Low
Trig: RF Burst
Atten: 12 dB (Elec 2)
Radio Std:W11g-OFDM
TxOutputSpec: OFF
Mod Accuracy: OFF

Measurement	Measurement Item	Result
------------TX Power------------		
Burst1	Total Power	-10.373 dBm/18.000 MHz
	Peak PSD	-21.380 dBm/MHz
Burst2	Total Power	-10.366 dBm/18.000 MHz
	Peak PSD	-21.390 dBm/MHz
Burst3	Total Power	-10.363 dBm/18.000 MHz
	Peak PSD	-21.379 dBm/MHz

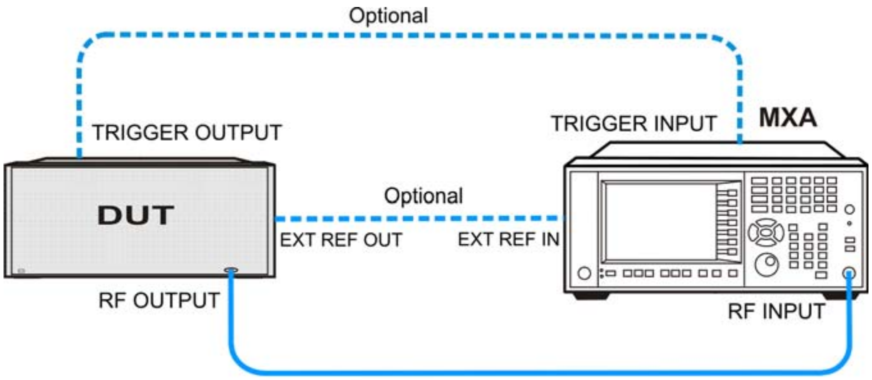
Measuring Transmit Output Spectrum and Modulation Accuracy

The following example details the measurement procedure and SCPI commands for measuring transmit output spectrum and modulation accuracy of the signal.

Configuring the Measurement System

Connect the source RF OUTPUT of the DUT (Device Under Test) to the analyzer RF INPUT as shown in Figure 1-5. MXA needs LAN or GPIB connection for SCPI control.

Figure 1-5 *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.

Measurement Example Signal Settings

Frequency:	2412 MHz
Output Power:	-20 dBm (at analyzer input)

WLAN signal radio standard: 802.11g

Data Rate:	6 Mbps OFDM

Data length in the burst: 480us

Idle length in the burst: 480us

Measurement Procedure

NOTE The primary UI for this measurement is SCPI commands. For the SCPI commands with different parameters and the detailed usage of each SCPI command, please refer to N9077A-XFP Single Acquisition Combined WLAN Measurement Application User's and Programmer's Reference.

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

The GPIB or LAN can be used for remote control. The Agilent I/O Library Suite is recommended for connecting the Agilent instruments to PC and using the instruments from a measurement program without extra charge. The more detailed information, see the URL: http://www.agilent.com/find/iolib.

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

Table 1-7 *SCPI Commands for Transmit Output Spectrum and Modulation Accuracy Measurement(4-1)*

SCPI Commands	Notes
INST:SEL CWLAN	Select Combined 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:CWL	Select Combined WLAN measurement.
RAD:STAN W11GOFDM	Configure the radio standard.
CWL:TRIG:SOUR RFB TRIG:RFB:LEV:TYPE ABS TRIG:RFB:LEV:ABS -35	Select the RF Burst Trigger (default) and setup the trigger type to be absolute and trigger level to be -35 dBm.

Step 3. Setup the capture parameters:

Table 1-8 *SCPI Commands for Transmit Output Spectrum and Modulation Accuracy Measurement(4-2)*

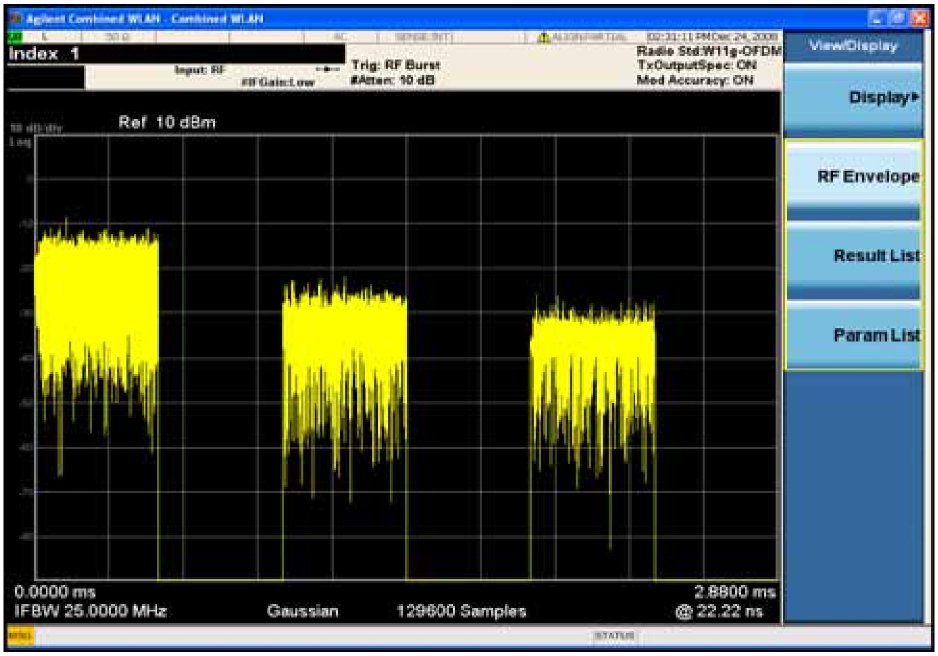
SCPI Commands	Notes
CWL:CAPT:BURS:TYPE DYN	Set the burst type to Dynamic.

Table 1-8 *SCPI Commands for Transmit Output Spectrum and Modulation Accuracy Measurement(4-2)*

SCPI Commands	Notes
CWL:METH ACC	Select the measure method to best accuracy.
CWL:CAPT:BURS:NUMB 3	Setup the capture number of bursts.
CWL:CAPT:BURS:FREQ 2412MHz,2434MHz,2390MHz	Set the center frequency of the burst. Three bursts are needed to measure the transmit output spectrum and the frequency hops every 22MHz. The first burst is used as the reference, the second burst is used as the positive offset and the third burst is used as the negative offset. For details, please refer to “TX output spectrum configuration guidelines” on page 47.
CWL:CAPT:BURS:LOAD 0.00048,0.00048,0.00048	Set the target burst which is captured and calculated during this time.
CWL:CAPT:BURS:PREF 0,0,0	Set the prefix of the burst.
CWL:CAPT:BURS:SUFF 0.00048,0.00048,0.00048	Set the suffix of the burst.
INIT:IMM	Resume a sweep.
DISP:CWL:VIEW RFEN	Select the RF Envelope View to display the result of signal vs. time. You can check the signal envelop at this time.

An example of the RF Envelope View is shown below:

Figure 1-6 *RF Envelope View of Transmit Output Spectrum and Modulation Accuracy Measurement*


Agilent Combined WLAN - Combined WLAN

02:31:11 PM Dec 24, 2008

Index 1

Input: RF

#IFGain:Low

Trig: RF Burst
#Atten: 10 dB

Radio Std:W11g-OFDM
TxOutputSpec: ON
Mod Accuracy: ON

Ref 10 dBm

0.0000 ms
IFBW 25.0000 MHz
Gaussian
129600 Samples
2.8800 ms
@ 22.22 ns

Step 4. Setup the measurements:

Table 1-9 *SCPI Commands for Transmit Output Spectrum and Modulation Accuracy Measurement(4-3)*

SCPI Commands	Notes
CWL:TXP:BURS:STAR 1 CWL:TXP:BURS:STOP 1	Setup the measurement burst for transmit power.
CWL:TOSP ON CWL:TOSP:BURS:STAR 1 CWL:TOSP:BURS:STOP 3	Setup the measurement bursts for transmit output spectrum. Bursts in triple group are used.
CWL:EVM ON CWL:EVM:BURS:STAR 1 CWL:EVM:BURS:STAR 1 CWL:EVM:TIME:SEAR 0.00048 CWL:EVM:TIME:RES:LENG 50 CWL:EVM:TIME:RES:MAX 118 CWL:EVM:TIME:INT 50 CWL:EVM:TIME:OFFS 0	Setup the burst and measurement symbols for modulation accuracy. For 802.11a or 11g-OFDM, Data length = (2+ Max Result Length *(1+Guard Interval)) / Subcarrier Spacing For 802.11b or 11g-DSSS, Data length = Max Result Length / Chip Rate
INIT:CONT ON	Turn on Continuous Sweep.

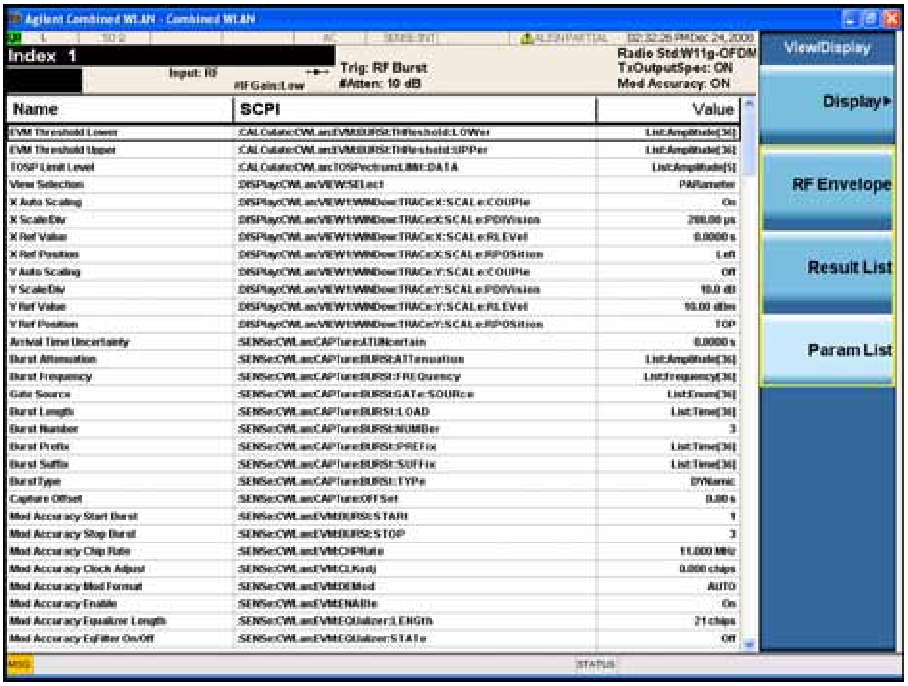
Table 1-9 *SCPI Commands for Transmit Output Spectrum and Modulation Accuracy Measurement(4-3)*

SCPI Commands	Notes
DISP:CWL:VIEW PAR	Select the Parameter List View.

NOTE If the error message “Settings conflict: Burst 1 data length is not enough to do EVM measurement” appears, that means the length of burst interval is not enough to calculate the EVM. In this case, you need to enter a larger value.

An example of Parameter List View is shown in Figure 1-7. 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. Some parameters, such as Burst Length, that may be “List:Time[36]” in the column of Value, which means this parameter has a maximum of 36 values to set. In this case, enter the index value from 1 to 36.

Figure 1-7 *Parameter List View of Transmit Output Spectrum and Modulation Accuracy Measurement*



Index 1
Input: RF
#IFGain:Low
Trig: RF Burst
#Atten: 10 dB
Radio Std:W11g-OFDM
TxOutputSpec: ON
Mod Accuracy: ON

Name	SCPI	Value
EVM Threshold Lower	:CALCulate:CWLan:EVM:BURSt:THReshold:LOWer	List:Amplitude[36]
EVM Threshold Upper	:CALCulate:CWLan:EVM:BURSt:THReshold:UPPer	List:Amplitude[36]
TOSP Limit Level	:CALCulate:CWLan:TOSPectrum:LIMit:DATA	List:Amplitude[5]
View Selection	:DISPlay:CWLan:VIEW:SELect	PARameter
X Auto Scaling	:DISPlay:CWLan:VIEW1:WINDow:TRACe:X:SCALe:COUPle	On
X Scale/Div	:DISPlay:CWLan:VIEW1:WINDow:TRACe:X:SCALe:PDIVision	200.00 µs
X Ref Value	:DISPlay:CWLan:VIEW1:WINDow:TRACe:X:SCALe:RLEVel	0.0000 s
X Ref Position	:DISPlay:CWLan:VIEW1:WINDow:TRACe:X:SCALe:RPOSition	Left
Y Auto Scaling	:DISPlay:CWLan:VIEW1:WINDow:TRACe:Y:SCALe:COUPle	Off
Y Scale/Div	:DISPlay:CWLan:VIEW1:WINDow:TRACe:Y:SCALe:PDIVision	10.0 dB
Y Ref Value	:DISPlay:CWLan:VIEW1:WINDow:TRACe:Y:SCALe:RLEVel	10.00 dBm
Y Ref Position	:DISPlay:CWLan:VIEW1:WINDow:TRACe:Y:SCALe:RPOSition	TOP
Arrival Time Uncertainty	:SENSe:CWLan:CAPTure:ATUNcertain	0.0000 s
Burst Attenuation	:SENSe:CWLan:CAPTure:BURSt:ATTenuation	List:Amplitude[36]
Burst Frequency	:SENSe:CWLan:CAPTure:BURSt:FREQuency	List:frequency[36]
Gate Source	:SENSe:CWLan:CAPTure:BURSt:GATe:SOURce	List:Enum[36]
Burst Length	:SENSe:CWLan:CAPTure:BURSt:LOAD	List:Time[36]
Burst Number	:SENSe:CWLan:CAPTure:BURSt:NUMBer	3
Burst Prefix	:SENSe:CWLan:CAPTure:BURSt:PREFix	List:Time[36]
Burst Suffix	:SENSe:CWLan:CAPTure:BURSt:SUFFix	List:Time[36]
Burst Type	:SENSe:CWLan:CAPTure:BURSt:TYPe	DYNamic
Capture Offset	:SENSe:CWLan:CAPTure:OFFSet	0.00 s
Mod Accuracy Start Burst	:SENSe:CWLan:EVM:BURSt:STARt	1
Mod Accuracy Stop Burst	:SENSe:CWLan:EVM:BURSt:STOP	3
Mod Accuracy Chip Rate	:SENSe:CWLan:EVM:CRATe	11.000 MHz
Mod Accuracy Clock Adjust	:SENSe:CWLan:EVM:CLKadj	0.000 chips
Mod Accuracy Mod Format	:SENSe:CWLan:EVM:DEMod	AUTO
Mod Accuracy Enable	:SENSe:CWLan:EVM:ENABle	On
Mod Accuracy Equalizer Length	:SENSe:CWLan:EVM:EQUalizer:LENGth	21 chips
Mod Accuracy EqFilter On/Off	:SENSe:CWLan:EVM:EQUalizer:STATe	Off

Step 5. Read the results:

Table 1-10 *SCPI Commands for Transmit Output Spectrum and Modulation Accuracy Measurement(4-4)*

SCPI Commands	Notes
READ:CWL4?	This command is used to see the transmit power results. For more commands about reading the result, refer to N9077A-XFP Combined WLAN Measurement Application User’s and Programmer’s Reference.
DISP:CWL:VIEW RES	The transmit power measurement results are available in the Result List View.

An example of Result List view is shown below:

Figure 1-8 *Result List View of Transmit Output Spectrum and Modulation Accuracy Measurement*

Index 1

Input: RF
#IFGain:Low
Trig: RF Burst
#Atten: 10 dB
Radio Std:W11g-OFDM
TxOutputSpec: ON
Mod Accuracy: ON

Measurement	Measurement Item	Result
------------TX Power------------		
Burst1	Total Power	-20.277 dBm/18.000 MHz
	Peak PSD	-31.358 dBm/MHz
------TX Output Spectrum------		
Burst1	------Reference Channel------	
	Total Power	-20.277 dBm/18.000 MHz
	Peak PSD	-36.055 dBm/100.00 kHz
	------Negative Offset A------	
	Min Margin Level	-65.317 dBm/100.00 kHz
	Min Margin from Limit Line	-11.112 dB/100.00 kHz
	Minimum margin offset frequency	-10.849 MHz
	Pass/Fail	Pass
	------Positve Offset A------	
	Min Margin Level	-63.009 dBm/100.00 kHz
	Min Margin from Limit Line	-10.782 dB/100.00 kHz
	Minimum margin offset frequency	10.795 MHz
	Pass/Fail	Pass
	------Negative Offset B------	
	Min Margin Level	-65.639 dBm/100.00 kHz
	Min Margin from Limit Line	-11.000 dB/100.00 kHz
	Minimum margin offset frequency	-11.234 MHz
	Pass/Fail	Pass
	------Positve Offset B------	
	Min Margin Level	-63.893 dBm/100.00 kHz

Measuring Modulation Accuracy on Frequency Hopping Signal

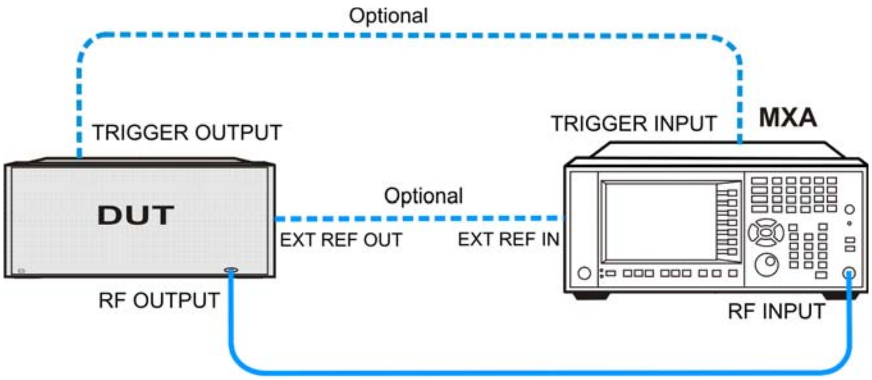
The following example details the measurement procedure and SCPI commands for measuring modulation accuracy on frequency hopping signal.

NOTE If you have installed the Option B40 (40 MHz analysis bandwidth), you cannot perform this measurement on frequency hopping signals for any of the standard 802.11`a/b/g/n`.

Configuring the Measurement System

Connect the source RF OUTPUT of the DUT (Device Under Test) to the analyzer RF INPUT as shown in Figure 1-9. MXA needs LAN or GPIB connection for SCPI control.

Figure 1-9 *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.

Measurement Example Signal Settings

Frequency: 2412 MHz and 2434MHz

Output Power: -17 dBm (at analyzer input)

WLAN signal radio standard: 802.11b

Data Rate: 5.5 Mbps DSSS

Data length in the burst: 0.5ms

Idle length in the burst: 1ms

Measurement Procedure

NOTE The primary UI for this measurement is SCPI commands. For the SCPI commands with different parameters and the detailed usage of each SCPI command, please refer to N9077A-XFP Single Acquisition Combined WLAN Measurement Application User's and Programmer's Reference.

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

The GPIB or LAN can be used for remote control. The Agilent I/O Library Suite is recommended for connecting the Agilent instruments to PC and using the instruments from a measurement program without extra charge. The more detailed information, see the URL: http://www.agilent.com/find/iolib.

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

Table 1-11 *SCPI Commands for Transmit Power Measurement on Frequency Hopping Signal (4-1)*

SCPI Commands	Notes
INST:SEL CWLAN	Select Combined 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:CWL	Select Combined WLAN measurement.
RAD:STAN W11B	Configure the radio standard.
TRIG:RFB:SOUR RFB TRIG:RFB:LEV:TYPE ABS TRIG:RFB:LEV:ABS -30 TRIG:DEL 0	Set the absolute trigger level. The default trigger type is RF Burst.

Step 3. Setup the capture parameters:

Table 1-12 *SCPI Commands for Transmit Power Measurement on Frequency Hopping Signal (4-2)*

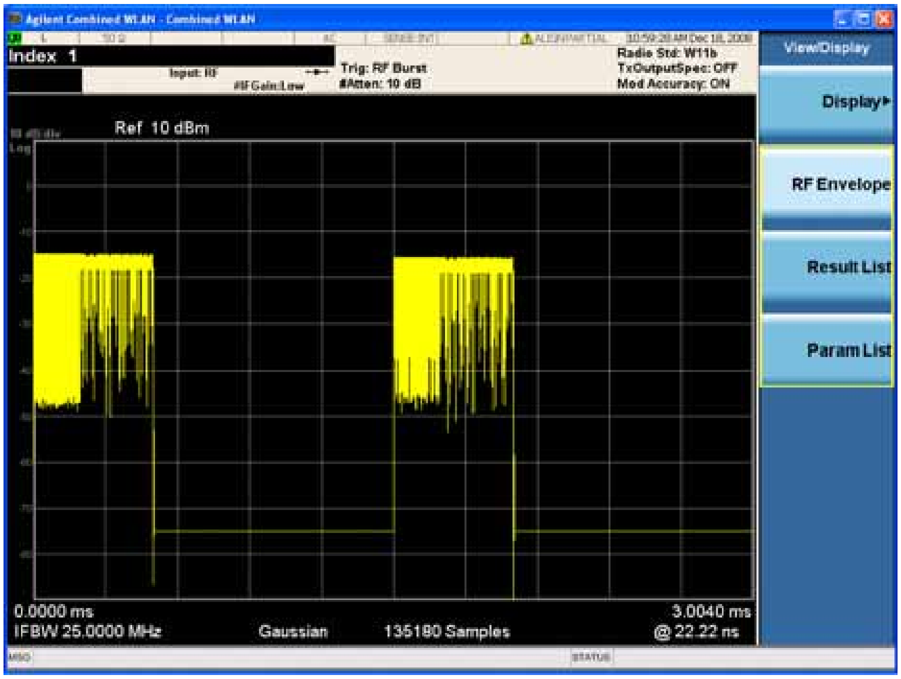
SCPI Commands	Notes
CWL:CAPT:BURS:NUMB 2	Set the measured burst number.

Table 1-12 SCPI Commands for Transmit Power Measurement on Frequency Hopping Signal (4-2)

SCPI Commands	Notes
CWL:CAPT:BURS:TYPE DYN CWL:CAPT:OFFS 0	Set the burst type to Dynamic.
CWL:CAPT:BURS:FREQ 2412MHz,2456MHz	Set the center frequency of the two bursts.
CWL:CAPT:BURS:LOAD 0.5ms,0.5ms	Set the data time of the target burst which is captured and calculated.
CWL:CAPT:BURS:PREF 2us,2us	Set the prefix of the burst.
CWL:CAPT:BURS:SUFF 1ms,1ms	Set the suffix of the burst.
INIT:IMM	Resume a sweep.
DISP:CWL:VIEW RFEN	Select the RF Envelope View to display the result of signal vs. time. You can check the signal envelope at this time.

The example of the RF Envelop View is shown below:

Figure 1-10 RF Envelope View for Transmit Power Measurement on Frequency Hopping Signal



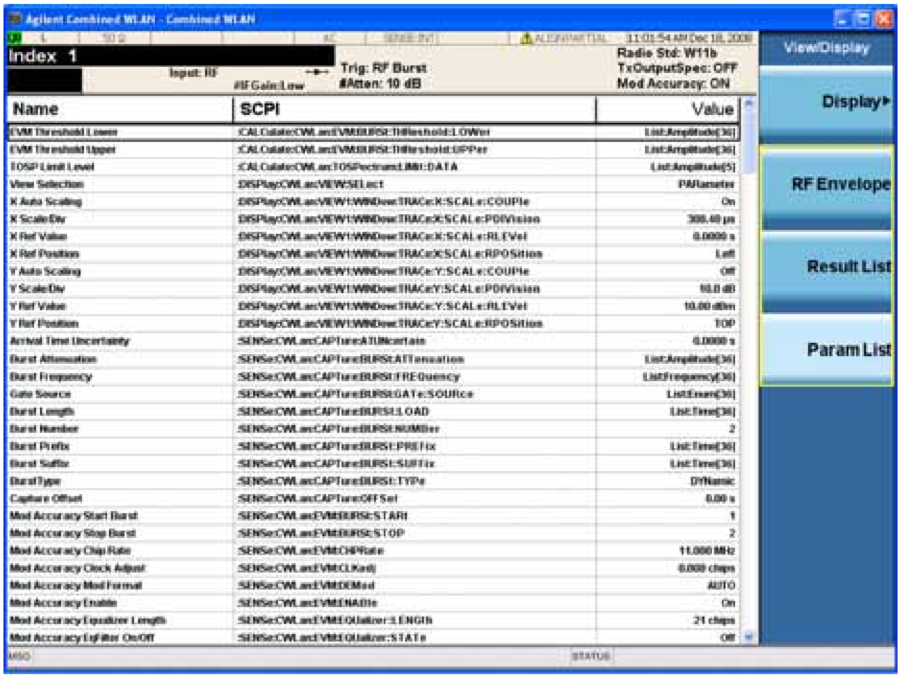
Step 4. Setup the measurements:

Table 1-13 *SCPI Commands for Transmit Power Measurement on Frequency Hopping Signal (4-3)*

SCPI Commands	Notes
CWL:TXP:BURS:STAR 1 CWL:TXP:BURS:STOP 2 CWL:EVM:BURS:STAR 1 CWL:EVM:BURS:STOP 2 CWL:EVM:TIME:RES:LENG 500 CWL:EVM:TIME:RES:MAX 2000 CWL:EVM:TIME:INT 500 CWL:EVM:TIME:OFF 0	Set the start and stop burst of transmit power measurement. Setup the result length for modulation accuracy. For 802.11a or 11g-OFDM, Data length = (2+ Max Result Length *(1+Guard Interval))/ Subcarrier Spacing For 802.11b or 11g-DSSS, Data length = Max Result Length/Chip Rate
INIT:CONT ON	Turn on Continuous Sweep.
DISP:CWL:VIEW PAR	Select the Parameter List View.

An example of Parameter List View is shown in Figure 1-11. 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. Some parameters, such as Burst Length, that may be "List:Time[36]" in the column of Value, which means this parameter has a maximum of 36 values to set. In this case, enter the index value from 1 to 36.

Figure 1-11 *Parameter List View for Transmit Power Measurement on Frequency Hopping Signal*



11:01:54 AM Dec 18, 2008

Index 1

Input: RF

#IFGain:Low

Trig: RF Burst

#Atten: 10 dB

Radio Std: W11b

TxOutputSpec: OFF

Mod Accuracy: ON

Name	SCPI	Value
EVM Threshold Lower	:CALCulate:CWLan:EVM:BURSt:THReshold:LOWer	List:Amplitude[36]
EVM Threshold Upper	:CALCulate:CWLan:EVM:BURSt:THReshold:UPPer	List:Amplitude[36]
TOSP Limit Level	:CALCulate:CWLan:TOSPectrum:LIMit:DATA	List:Amplitude[5]
View Selection	:DISPlay:CWLan:VIEW:SELect	PARameter
X Auto Scaling	:DISPlay:CWLan:VIEW1:WINDow:TRACe:X:SCALe:COUPle	On
X Scale/Div	:DISPlay:CWLan:VIEW1:WINDow:TRACe:X:SCALe:PDIVision	300.40 µs
X Ref Value	:DISPlay:CWLan:VIEW1:WINDow:TRACe:X:SCALe:RLEVel	0.0000 s
X Ref Position	:DISPlay:CWLan:VIEW1:WINDow:TRACe:X:SCALe:RPOSition	Left
Y Auto Scaling	:DISPlay:CWLan:VIEW1:WINDow:TRACe:Y:SCALe:COUPle	Off
Y Scale/Div	:DISPlay:CWLan:VIEW1:WINDow:TRACe:Y:SCALe:PDIVision	10.0 dB
Y Ref Value	:DISPlay:CWLan:VIEW1:WINDow:TRACe:Y:SCALe:RLEVel	10.00 dBm
Y Ref Position	:DISPlay:CWLan:VIEW1:WINDow:TRACe:Y:SCALe:RPOSition	TOP
Arrival Time Uncertainty	:SENSe:CWLan:CAPTure:ATUNcertain	0.0000 s
Burst Attenuation	:SENSe:CWLan:CAPTure:BURSt:ATTenuation	List:Amplitude[36]
Burst Frequency	:SENSe:CWLan:CAPTure:BURSt:FREQuency	List:Frequency[36]
Gate Source	:SENSe:CWLan:CAPTure:BURSt:GATe:SOURce	List:Enum[36]
Burst Length	:SENSe:CWLan:CAPTure:BURSt:LOAD	List:Time[36]
Burst Number	:SENSe:CWLan:CAPTure:BURSt:NUMBer	2
Burst Prefix	:SENSe:CWLan:CAPTure:BURSt:PREFix	List:Time[36]
Burst Suffix	:SENSe:CWLan:CAPTure:BURSt:SUFFix	List:Time[36]
Burst Type	:SENSe:CWLan:CAPTure:BURSt:TYPe	DYNamic
Capture Offset	:SENSe:CWLan:CAPTure:OFFSet	0.00 s
Mod Accuracy Start Burst	:SENSe:CWLan:EVM:BURSt:STARt	1
Mod Accuracy Stop Burst	:SENSe:CWLan:EVM:BURSt:STOP	2
Mod Accuracy Chip Rate	:SENSe:CWLan:EVM:CHIPrate	11.000 MHz
Mod Accuracy Clock Adjust	:SENSe:CWLan:EVM:CLKadj	0.000 chips
Mod Accuracy Mod Format	:SENSe:CWLan:EVM:DEMod	AUTO
Mod Accuracy Enable	:SENSe:CWLan:EVM:ENABle	On
Mod Accuracy Equalizer Length	:SENSe:CWLan:EVM:EQUalizer:LENGth	21 chips
Mod Accuracy EqFilter On/Off	:SENSe:CWLan:EVM:EQUalizer:STATe	Off

Step 5. Read the results:

Table 1-14 *SCPI Commands for Transmit Power Measurement on Frequency Hopping Signal (4-4)*

SCPI Commands	**Notes**
READ:CWL4?	This command is used to see the transmit power results. For more commands about reading the result, refer to N9077A-XFP Combined WLAN Measurement Application User’s and Programmer’s Reference.
DISP:CWL:VIEW RES	The measurement results are available in the Result List View.

The Result List View is shown below:

Figure 1-12 *Result List View for Transmit Power Measurement on Frequency Hopping Signal*

Index 1
Input: RF
#IFGain:Low
Trig: RF Burst
#Atten: 10 dB
Radio Std: W11b
TxOutputSpec: OFF
Mod Accuracy: ON

Measurement	Measurement Item	Result
-------------TX Power-------------		
Burst1	Total Power	-16.627 dBm/22.000 MHz
	Peak PSD	-25.319 dBm/MHz
Burst2	Total Power	-17.284 dBm/22.000 MHz
	Peak PSD	-25.966 dBm/MHz
-------------Mod Accuracy-------------		
Burst1	Frequency Error	-0.441 Hz
	Symbol Clock Error	---
	Chip Clock Error	-0.067 ppm
	Center Frequency Leakage	---
	Spectral Flatness	---
	Carrier Suppression	-67.279 dB
	RMS EVM	1.314% rms
	Peak EVM	2.881% rms
Burst2	Frequency Error	2.652 Hz
	Symbol Clock Error	---
	Chip Clock Error	-0.064 ppm
	Center Frequency Leakage	---
	Spectral Flatness	---
	Carrier Suppression	-47.556 dB
	RMS EVM	1.207% rms
	Peak EVM	2.659% rms

2 802.11 a/b/g Wireless LAN (WLAN) Concepts

This Chapter describes concepts and theory of 802.11 a/b/g WLAN signals and various measurements in the Signal Acquisition Combined WLAN measurement application. Configuration guidelines and suggestions for optimizing and troubleshooting your setup are provided when making combined WLAN measurement, along with a list of related Agilent documents that are referenced for further information.

Introduction

This chapter introduces concepts of 802.11a/b/g WLAN to better relate the features and attributes of MXA/EXA Series Spectrum Analyzer option N9077A-XFP, to measurements.

- "What Is the WLAN Communication System?" on page 25 briefly explains the WLAN system, some devices involved in the system and two topologies to build up the system.
- "What is a WLAN device?" on page 27 shows a diagram of the typical WLAN transceiver and some WLAN products.
- "Digital Modulation Format Standards" on page 29 contains a general description of the modulation format families, including basic formats and WLAN specific formats.
- "Spread Spectrum Concepts" on page 36 explains the DSSS concepts and theories.
- "Orthogonal Frequency Division Multiplexing (OFDM) Concepts" on page 38 explains the OFDM concepts and theories.
- "WLAN Standards" on page 39 introduces the popular WLAN standards, IEEE 802.11 standard family and gives a summary table of IEEE 802.11a/b/g standards.
- "Combined WLAN Measurement Concepts" on page 46 explains the Combined WLAN measurement configuration guidelines and theories.
- "Other Sources of Measurement Information" on page 53 are given along with a list of related Agilent documents for further reading.
- "References" on page 54 are given along with a list of reference documents for further reading.

What Is the WLAN Communication System?

Wireless Local Area Network (WLAN) is a high bandwidth, two-way data communications network that operates over a limited geographic area using radio as the medium of transmission, rather than optical fibre or copper cable.

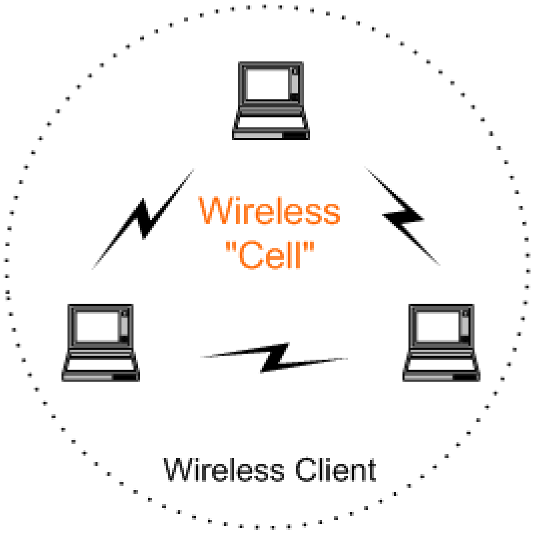
WLAN is basically an extension of the functionality of wired LAN. WLAN allows mobile computer users to connect to a network and access resources while on the move, or without being physically connected to the network.

The most widely used WLAN systems involve Network Interface Cards (NICs), also referred to as Stations (STA), and Access Points (APs). The NIC is an expansion board, like a PC (PCMCIA) card, that you can insert into a mobile terminal (MT) so the MT can be connected to the WLAN. The AP acts not only to transfer data between wired and wireless devices, but is also responsible for allocation of the radio channel to the clients it serves.

WLAN can be built with either of two topologies: peer-to-peer or access point-based.

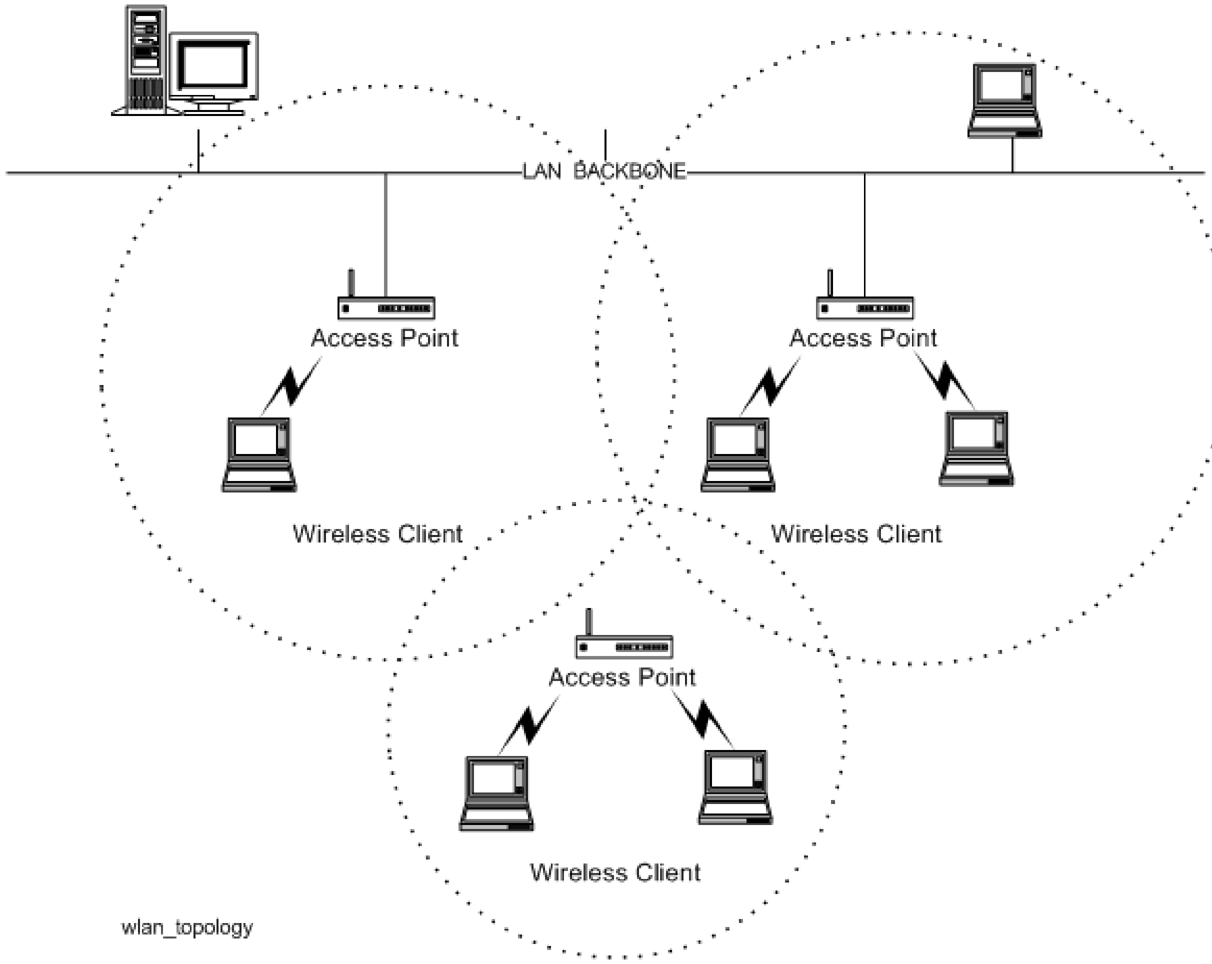
In a peer-to-peer topology, WLAN devices within the wireless “cell” communicate directly to each other as shown in Figure 2-1 on page 25.

Figure 2-1 *Peer to Peer Topology*



An access point is a bridge that connects a wireless client device to the wired network. An access point-based topology uses access points to bridge traffic onto a wired (Ethernet or Token Ring) or wireless backbone as shown in Figure 2-2 on page 26. The access point enables a wireless client device to communicate with any other wired or wireless device on the network. The access point topology is more commonly used, demonstrating that WLANs do not replace wired LANs, they extend connectivity to mobile devices.

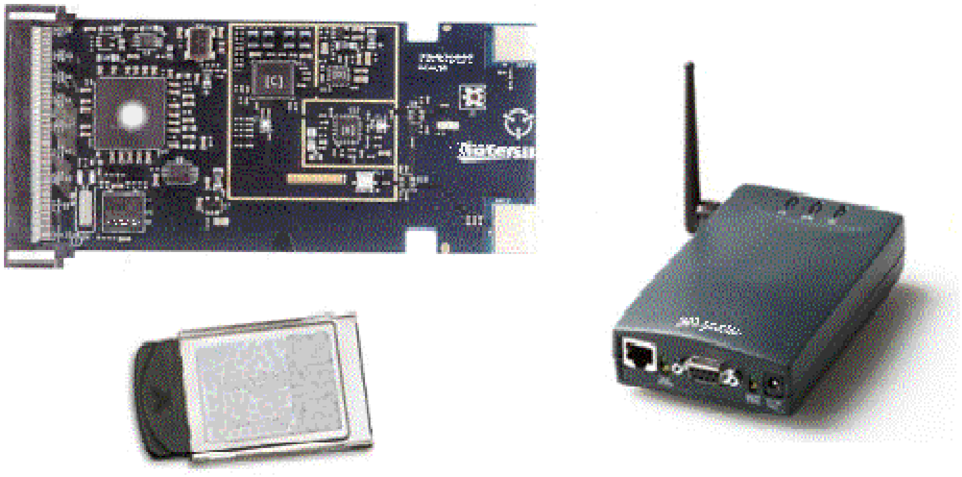
Figure 2-2 Access Point-Based Topology



What is a WLAN device?

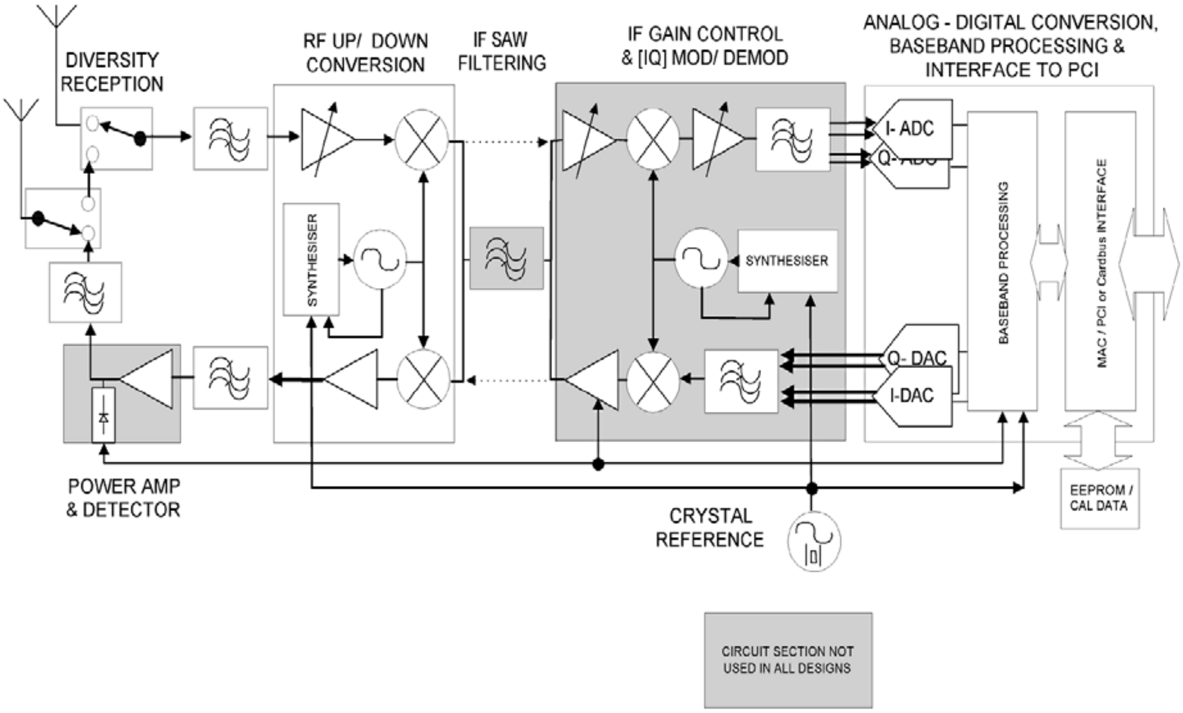
Besides stand-alone laptop PC cards WLAN chipsets are now being integrated into many other devices, for example, monitor displays, cell phones, Personal Data Assistants (PDA) devices. Follow figure shows some WLAN products.

Figure 2-3 *WLAN product examples*



The most common format of a WLAN device is a PC (PCMCIA) card suitable for direct connection to a laptop computer. Electrically, the WLAN card is split into two major sections: the analog RF (PHY layer) and the digital baseband (MAC) processing. In many cases the baseband transceiver and processing is on a separate chip from the IF and RF transceiver chain, although newer designs may have higher levels of integration. The diagram below illustrates a block diagram of a typical WLAN transceiver.

Figure 2-4 Block diagram of a typical WLAN transceiver



Digital Modulation Format Standards

Introduction

This section introduces digital modulation formats supported by WLAN standards and the concepts behind the individual formats.

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 4-1 shows modulation formats supported in N9077A - XFP, grouped by the WLAN standards.

Table 2-1 *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 Mbps
		PBCC 11 Mbps

Table 2-1 *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 Mbps
		PBCC 11 Mbps
		PBCC 22Mbps
		PBCC 33Mbps
	OFDM	BPSK
		QPSK
		16 QAM
		64 QAM

To find out more about an individual format, see:

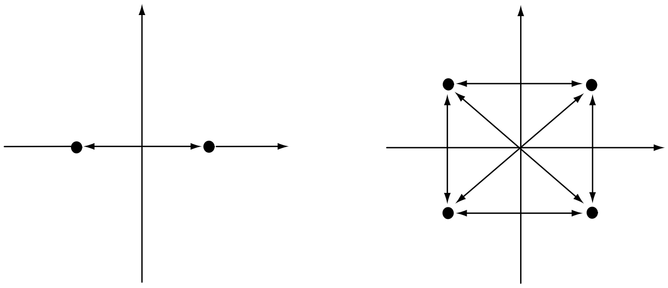
- "Phase Shift Keying (PSK) Concepts" on page 30
- "Quadrature Amplitude Modulation (QAM) Concepts" on page 33

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 2-5 *Phase Shift Keying (PSK)*



BPSK
One Bit Per Symbol

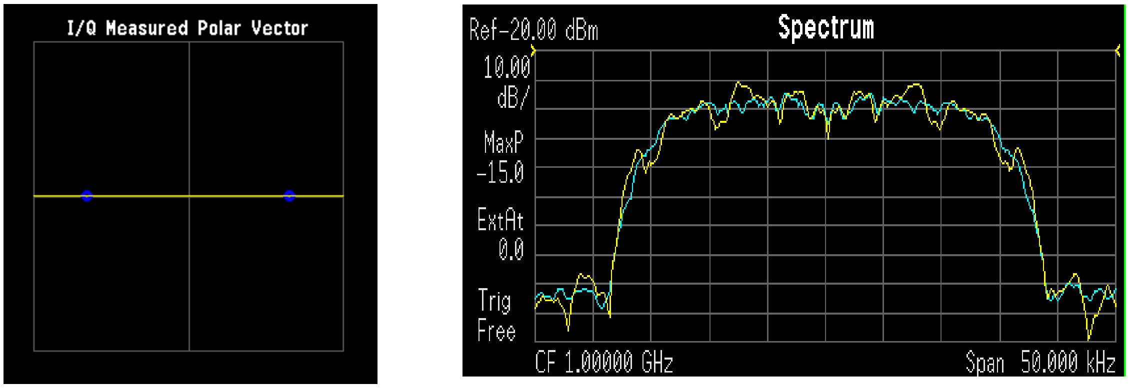
QPSK
Two Bits Per Symbol

For more information on other types of PSK, see

- “BPSK Modulation Characteristics” on page 31
- “QPSK Modulation Characteristics” on page 32
- “DQPSK Modulation Characteristics” on page 33

BPSK Modulation Characteristics

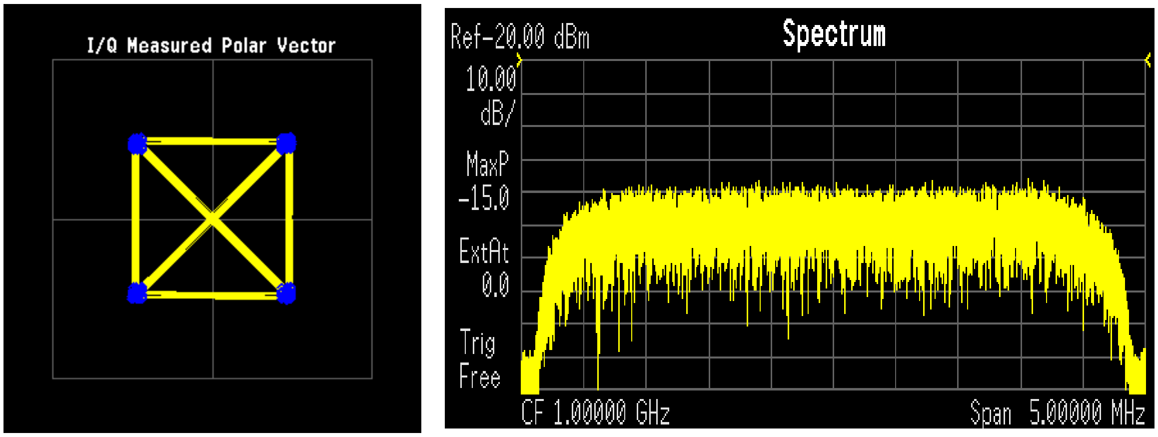
Figure 2-6 *BPSK Constellation and Spectrum View*



LEFT: BPSK constellation
RIGHT: BPSK spectrum center freq 1 GHz

QPSK Modulation Characteristics

Figure 2-7 QPSK Constellation and Spectrum View



LEFT: QPSK constellation
RIGHT: QPSK spectrum center freq 1 GHz

Differential Modulation Concepts

A variation of standard PSK is differential modulation as used in differential QPSK (DQPSK). Differential means that the information is not carried by the absolute state, it is carried by the transition between states. In some cases there are also restrictions on allowable transitions. This occurs in π /4 DQPSK where the carrier trajectory does not go through the origin. A DQPSK transmission system can transition from any symbol position to any other symbol position. The π/4 DQPSK modulation format is widely used in many applications including

CELLULAR

- NADC- IS-54 (North American digital cellular)
- PDC (Pacific Digital Cellular)

CORDLESS

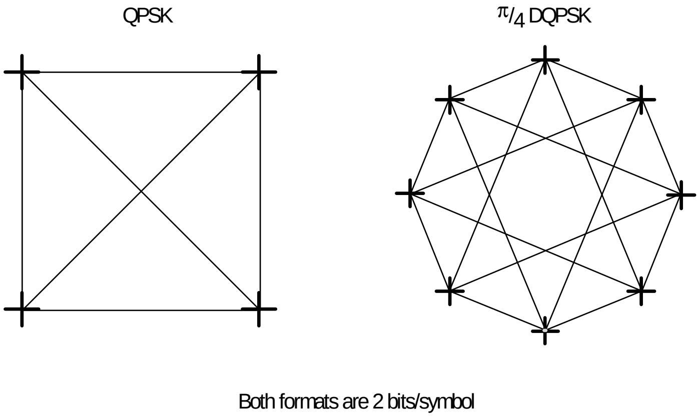
- PHS (personal handyphone system)

TRUNKED RADIO

- TETRA (Trans European Trunked Radio)

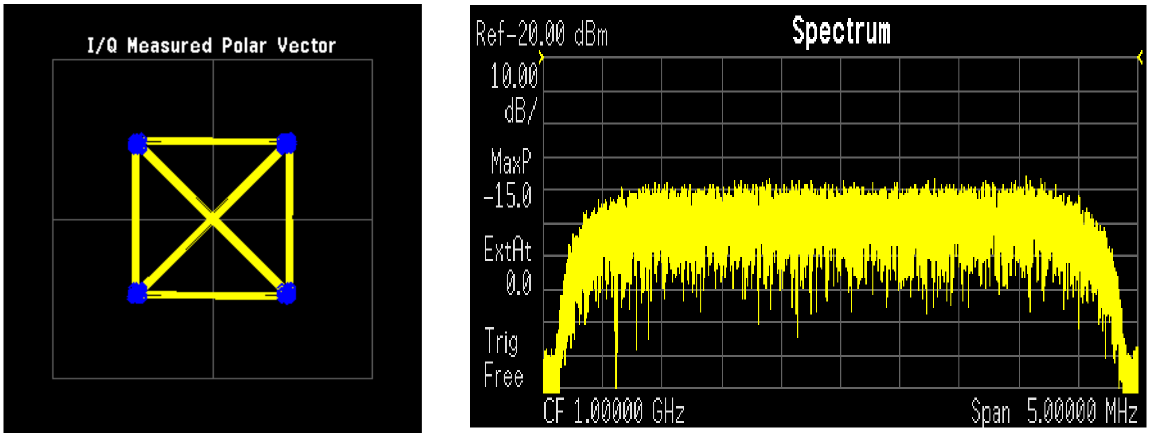
The π/4 DQPSK modulation format uses two QPSK constellations offset by 45 degrees (π/4 radians). Transitions must occur from one constellation to the other. This guarantees that there is always a change in phase at each symbol, making clock recovery easier. The data is encoded in the magnitude and direction of the phase shift, not in the absolute position on the constellation. One advantage of π/4 DQPSK is that the signal trajectory does not pass through the origin, thus simplifying transmitter design. Another is that π/4 DQPSK, with root raised cosine filtering, has better spectral efficiency than GMSK, the other common cellular modulation type.

Figure 2-8 *Differential Modulation*



DQPSK Modulation Characteristics

Figure 2-9 *DQPSK Constellation and Spectrum View*



LEFT: DQPSK constellation
RIGHT: DQPSK spectrum center freq 1 GHz

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 256QAM, 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 256QAM system uses 16 I-values and 16 Q-values, giving 256 possible states. Since $2^8 = 256$, each symbol can represent eight bits. A 256QAM 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 2-10 *Quadrature Amplitude Modulation*

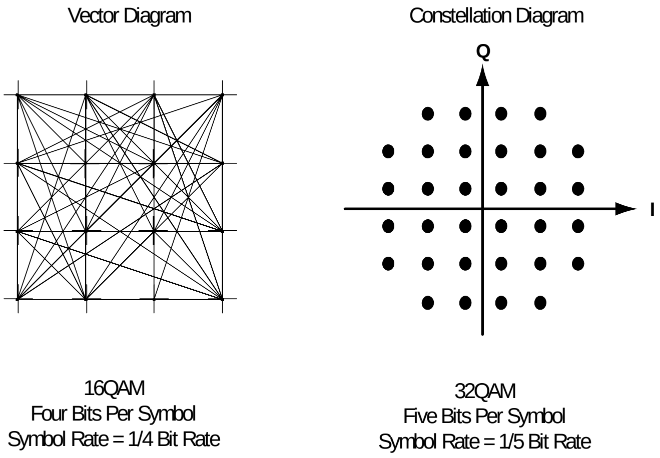


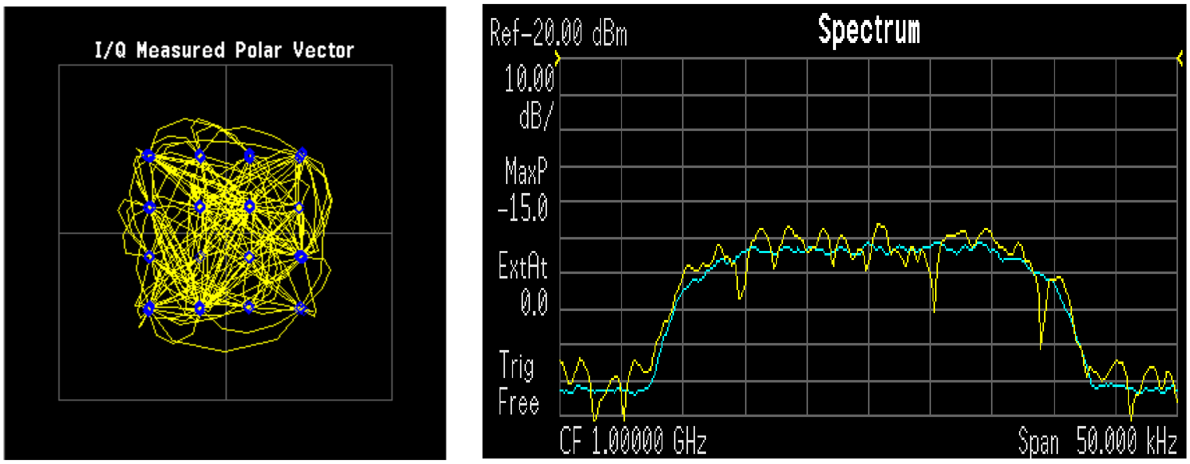
Fig. 14

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.

QAM Modulation Characteristics

Figure 2-11 *16 QAM Constellation and Spectrum View*



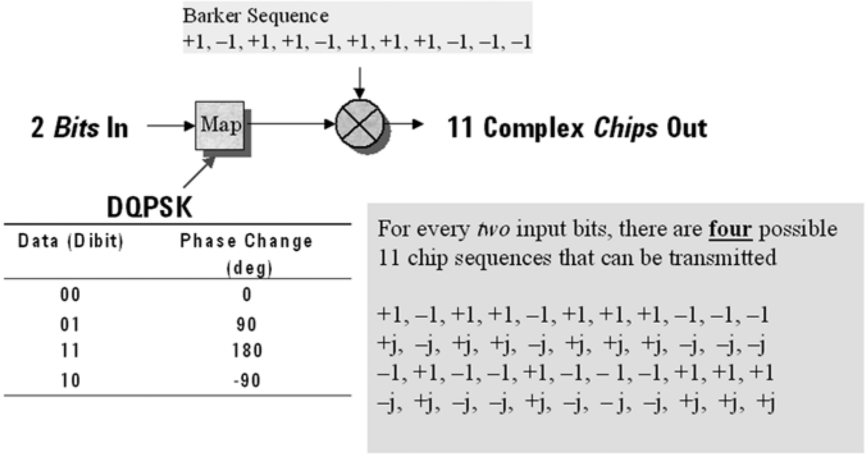
LEFT: 16 QAM constellation
RIGHT: 16 QAM spectrum center freq 1 GHz

Spread Spectrum Concepts

Direct Sequence Spread Spectrum (DSSS) Concepts

DSSS (Direct Sequence Spread Spectrum) - The energy in a single carrier is spread over a wider spectrum by multiplying data bit(s) 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 802.11 b uses an 8-bit key.
As shown in <Figure 2.1.1 from 1380-1 Page 10>, 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 2-12 *DSSS signal spreading for 2 Mbps data rate*



Data (Dibit)	Phase Change (deg)
00	0
01	90
11	180
10	-90

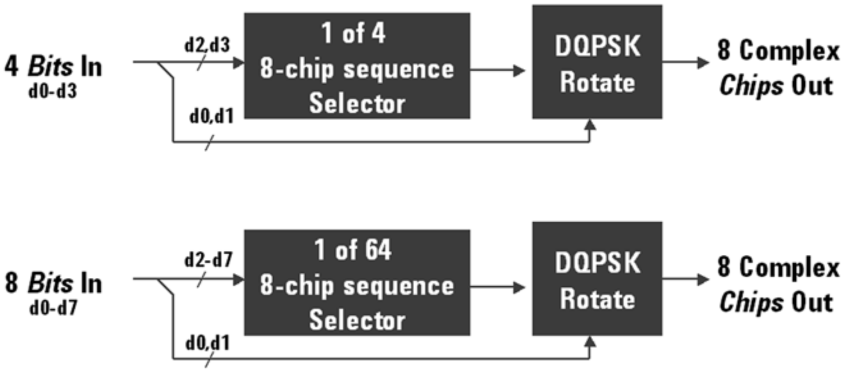
For every *two* input bits, there are **four** possible 11 chip sequences that can be transmitted

+1, –1, +1, +1, –1, +1, +1, +1, –1, –1, –1
+j, –j, +j, +j, –j, +j, +j, +j, –j, –j, –j
–1, +1, –1, –1, +1, –1, – 1, –1, +1, +1, +1
–j, +j, –j, –j, +j, –j, – j, –j, +j, +j, +j

Complementary Code Keying (CCK) Concepts

CCK (Complementary Code Keying) - Changing both the spreading factor and/or the modulation format varies the bit rate. CCK is used to increase IEEE 802.11 b'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 2-13 *CCK Modulation*



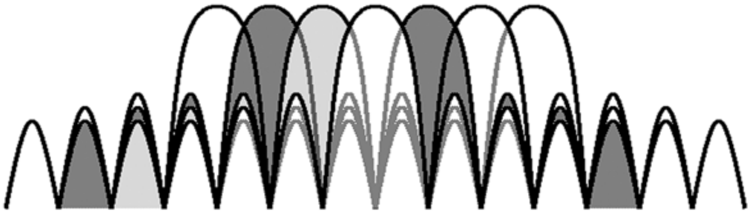
Packet Binary Convolutional Coding (PBCC) Concepts

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 2-14 *OFDM Carriers Separation*

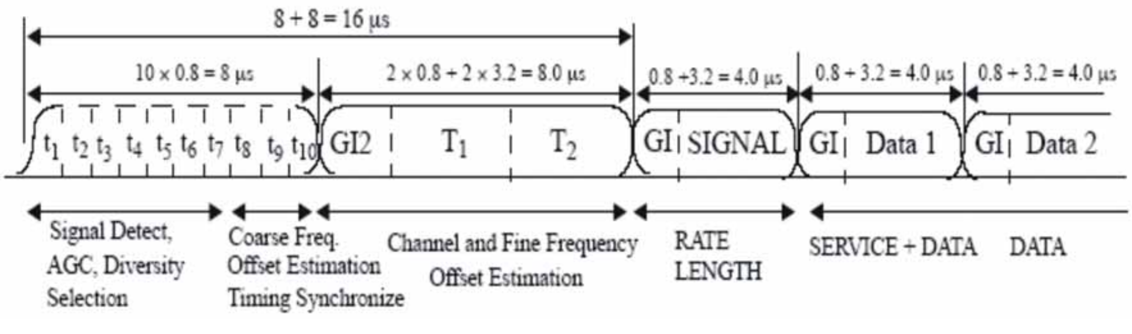


802.11a uses OFDM as its transmission scheme. For 802.11a there are 52 carriers in all, 48 of which are used to carry data and 4 which are used as pilots.

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 2-15, “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 2-15 *OFDM training structure*



WLAN Standards

Overview

Over the past few years, several different WLAN technologies and standards have been developed. This section concentrates on the IEEE 802.11 standards: 802.11b, 802.11a and 802.11g.

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 2-2 *IEEE 802.11 Standards Family*

	Wireless LAN Standards			
	802.11b	802.11a	802.11g	
Frequency band	2.4 GHz	5 GHz	2.4 GHz	
Channel separation	25 MHz	20 MHz	25 MHz	
Maximum raw data rate	11 Mbps	54 Mbps	54 Mbps	
Carrier Type	DSSS	OFDM	DSSS	OFDM
Modulation	DSSS, CCK, PBCC	BPSK, QPSK, 16 QAM, 64 QAM	DSSS, CCK, PBCC	BPSK, QPSK, 16 QAM, 64 QAM

The progression of technology in the IEEE 802.11 standard family is 802.11 to 802.11b to 802.11a, and eventually to 802.11g. These IEEE 802.11 systems use either direct sequence spread spectrum (DSSS) techniques or orthogonal frequency division multiplexing (OFDM) schemes.

802.11b

The 802.11b operates in the 2.4 GHz and uses DSSS techniques to spread the energy in a single carrier over a wider spectrum. See “Direct Sequence Spread Spectrum (DSSS) Concepts” on page 36.. 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) Concepts” on page 36.. PBCC makes use of forward error correction to improve the link performance when noise is the limitation. See “Packet Binary Convolutional Coding (PBCC) Concepts” on page 37..

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 Mpbs 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 2-3 *802.11b Rate-dependent parameters*

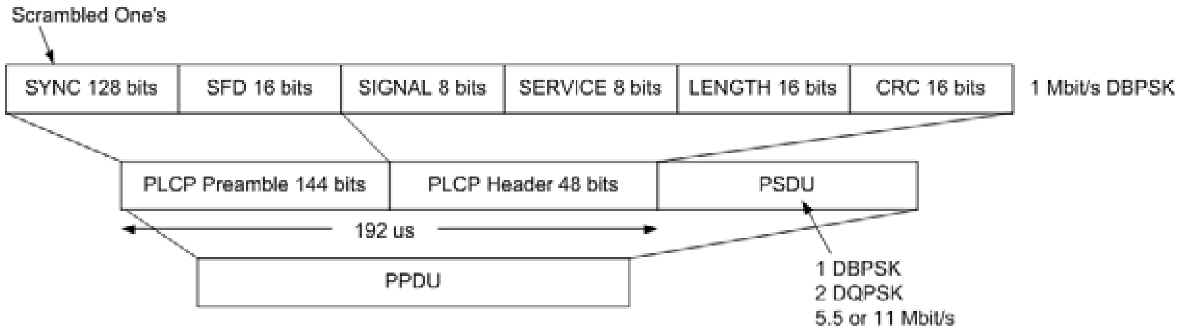
Data rate (Mbps)	Modulation	Symbol rate (MSps)
1	DBPSK	
2	DQPSK	
5.5	CCK	1.375
	PBCC	
11	CCK	1.375
	PBCC	

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 2-16, “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 usec 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 2-16 *802.11b signal*



802.11a

802.11a operates in the 5 GHz band and uses OFDM as its transmission scheme.

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 2-4 on page 41 provides a summary of the different modulation formats used in OFDM systems and their associated rate-dependent parameters.

Table 2-4 *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
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 2-17, “802.11a Signal,” shows the format for the PPDU including the OFDM preamble, header, PSDU, tail bits, and pad bits. The header contains the following fields: LENGTH, RATE, a reserved bit, an even parity bit, and the SERVICE field. In terms of modulation, the LENGTH, RATE, reserved bit, and parity bit (with 6 “zero” tail bits appended) constitute a separate single OFDM symbol, denoted SIGNAL, which is transmitted with the most robust combination of BPSK modulation and a coding rate of R = 1/2. The SERVICE field of the header and the PSDU (with 6 “zero” tail bits and pad bits appended), denoted as DATA, are transmitted at the data rate described in the RATE field and may constitute multiple OFDM symbols.

Figure 2-17 *802.11a Signal*

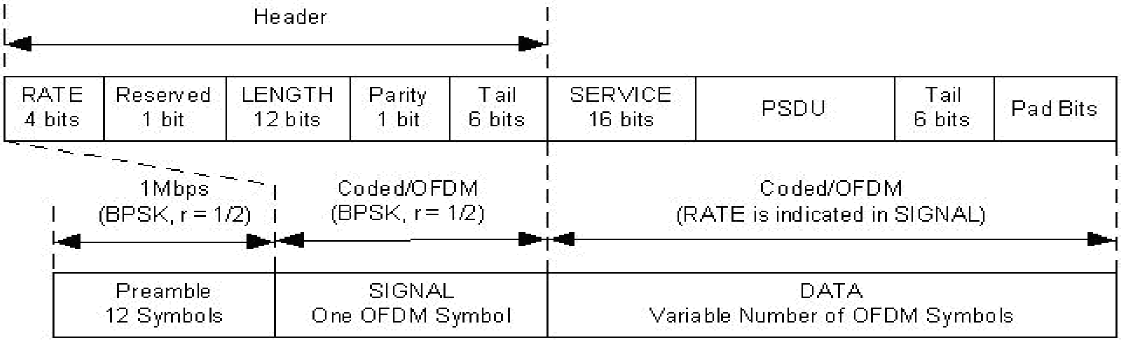
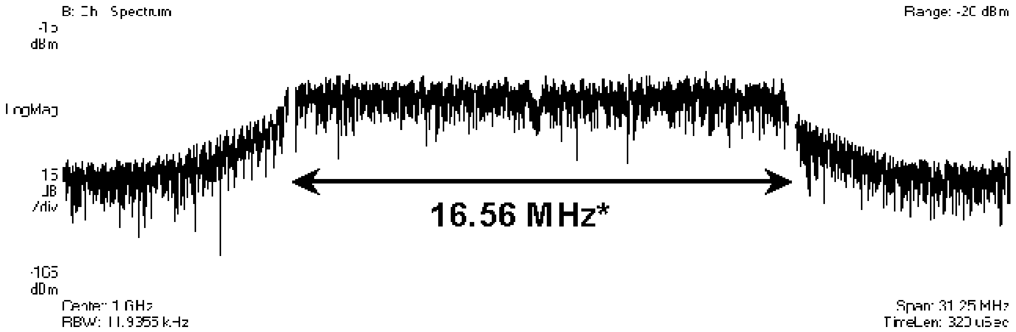
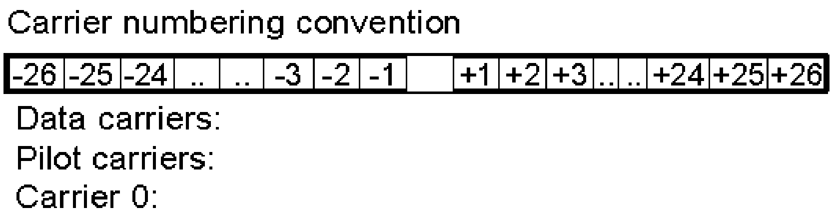


Figure 2-18, "802.11a Spectrum View," shows an 802.11 a signal burst. The spectrum is not very uniform. This is caused in part by the preambles, but mostly by the data being transmitted.

Figure 2-18 *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 2-5 *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 × nch (MHz) .... (27)

where

nch = 0,1,...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 2-6.

Table 2-6 *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

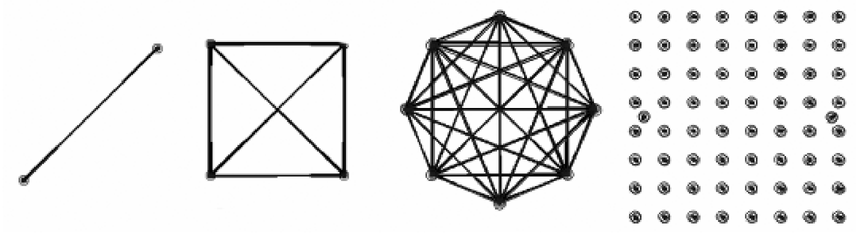
802.11g

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 Mpbs 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 2-19 *Example 802.11g (OFDM) modulation types (left to right: BPSK, QPSK, 8PSK, and 64QAM)*



802.11g Specific Modes of Carrier Operation

There are several modes of carrier operation:

- ERP (Extended Rate PHYs) - Shown as Figure 11g_Page15_F7.3.2.13, ERP information element defines the rate extension of the PHY for the Direct Sequence Spread Spectrum (DSSS) system. The ERP builds on the payload data rates of 1 and 2 Mbit/s that use DSSS modulation and builds on the payload data rates of 1, 2, 5.5 and 11 Mbit/s that use DSSS, CCK and optional PBCC modulations. The ERP draws, to provide additional payload data rates of 6, 9, 12, 18, 24, 36, 48, and 54 Mbit/s. Of these rates, transmission and reception capability for 1, 2, 5.511, 6, 12, and 24 Mbit/s data rates is mandatory.
  Two additional optional ERP-PBCC modulation modes with payload data rates of 22 and 33 Mbit/s are defined. An ERP-PBCC station may implement 22 Mbit/s alone or 22 and 33 Mbit/s. An optional modulation mode known as DSSS-OFDM is also incorporated with payload data rates of 6, 9, 12, 18, 24, 36, 48 and 54 Mbit/s.
- ERP (Extended Rate PHYs) - Shown as Figure 11g_Page15_F7.3.2.13, ERP information element defines the rate extension of the PHY for the Direct Sequence Spread Spectrum (DSSS) system. The ERP builds on the payload data rates of 1 and 2 Mbit/s that use DSSS modulation and builds on the payload data rates of 1, 2, 5.5 and 11 Mbit/s that use DSSS, CCK and optional PBCC modulations. The ERP draws, to provide additional payload data rates of 6, 9, 12, 18, 24, 36, 48, and 54 Mbit/s. Of these rates, transmission and reception capability for 1, 2, 5.511, 6, 12, and 24 Mbit/s data rates is mandatory.
  Two additional optional ERP-PBCC modulation modes with payload data rates of 22 and 33 Mbit/s are defined. An ERP-PBCC station may implement 22 Mbit/s alone or 22 and 33 Mbit/s. An optional modulation mode known as DSSS-OFDM is also incorporated with payload data rates of 6, 9, 12, 18, 24, 36, 48 and 54 Mbit/s. The ERP modulations (ERP-OFDM, ERP-PBCC, and DSSS-OFDM) have been designed to coexist with existing.
- ERP-DSSS/CCK -- The PHY uses the capabilities with the following exceptions: Support of the short PLCP PPDU header format capability is mandatory; Clear Channel Assessment has a mechanism that will detect all mandatory sync

symbols; the maximum input signal level (ref 18.4.8.2) is 20 dBm; Locking the transmit center frequency and the symbol clock frequency to the same reference oscillator is mandatory.

- ERP-OFDM -- The PHY uses the capabilities of clause 17 with the following exceptions: The frequency plan is in accordance with sub clauses 18.4.6.1 and 18.4.6.2 instead of 17.3.8.3; CCA has a mechanism that will detect all mandatory clause 19 sync symbols; The frequency accuracy (ref 17.3.9.4 and 17.3.9.5) is +/–25 PPM; The maximum input signal level (ref 17.3.10.4) is –20 dBm; The slot time is 20 µs in accordance with 18.3.3 except that an optional 9 µs slot time may be used when the BSS consists of only ERP STAs; SIFS time is 10 µs in accordance with 18.3.3. See 19.3.2.3 for more detail.
- ERP-PBCC (Optional) -- This is a single carrier modulation scheme that encodes the payload using a 256-state packet binary convolutional code. These are extensions to the PBCC modulation in clause 18. ERP-PBCC modes with payload data rates of 22 and 33 Mbit/s are defined in 19.6.
- DSSS-OFDM (Optional) -- This is a hybrid modulation combining a DSSS preamble and header with an OFDM payload transmission. DSSS-OFDM modes with payload data rates of 6, 9, 12, 18, 24, 36, 48 and 54 Mbit/s are defined in 19.7; If the optional DSSS-OFDM mode is used, the supported rates in that mode are the same as the ERP-OFDM supported rates.

Combined WLAN Measurement Concepts

This section recommends some guidelines during configuration for easy and quick measurement, it also introduces the burst structure within one acquisition and the measurements in Combined WLAN measurement application.

Configuration guidelines

The follow guidelines are recommended in order to optimize the parameter settings and make full use of the potential of the instrument.

1. This software provides freedom for a user to design and setup the test cases within its own capability. The instrument will just do what it is set to do; a user is supposed to have full knowledge of the target signals and have the full responsibility to make sure that the instrument is properly set.
2. A user can use the SCPI command ([:SENSe]:CWLan:METHod FAST|BALanced|ACCuracy) to optimize the measurement as per the need.
3. RF envelope view is very useful for the time alignment between target signal and the instrument; however, a user is encouraged to always use SCPI command ([:SENSe]:CWLan:TRACe:RF[:ENABle] OFF) to turn the trace off once the time alignment is finished. A user is not encouraged to use the RF envelope view trace for post processing, instead, the captured raw data can be obtained by SCPI commands.
4. 36 bursts could be set to be captured maximally.
5. The total captured signal time should not exceed 88.5ms, this includes the capture offset time, all the corresponding prefix time and burst time.
6. A user is always encouraged to select “static” burst type if there is no frequency change or e-atten change among different bursts.
7. When applicable, a user is encouraged to use the “trigger delay” rather than “capture offset”.
8. The first burst in the burst sequence must be the in-band signal, unless the trigger method is “event trigger”.
9. A suffix is not captured to be present in the raw data. A prefix is captured to be present in the raw data, yet not considered in the results, same with “capture offset”. A “burst” is captured, considered and calculated in the results.
10. There are no suffix (considered as 0 no matter what entered) when the burst type is “static”.
11. A user is encouraged to use suffixes to make up the empty periods between successive bursts, however, a good practice is to leave 2 ~ 4 us for the successive prefix time of the next burst, especially when the timing of the bursts can not be exacted to an us level.
12. When the burst type is “dynamic”, follow the formula below to set suffix values.

    Suffix >= | CFn – CFn+1 | * 4 (us)

CFn, the center frequency in MHz of the burst in question

CFn+1, the center frequency in MHz of the next burst

13. For TX Output Spectrum, select ”dynamic” burst type, set bursts in triple groups (Penta-groups in case farther offset is on), with the center frequency set as below:

    farther offset = off (default)

    CFn = in band center frequency

    CFn+1 = CFn + 22 MHz

    CFn+2 = CFn – 22 MHz

    farther offset = On

    CFn = in-band center frequency

    CFn+1 = CFn + 22 MHz

    CFn+2 = CFn + 44 MHz

    CFn+3 = CFn – 22 MHz

    CFn+4 = CFn – 44 MHz

14. The maximum sampling points is 4M. If (total capture time * sampling rate) > 4M point, –999.0 will be returned as invalid results.

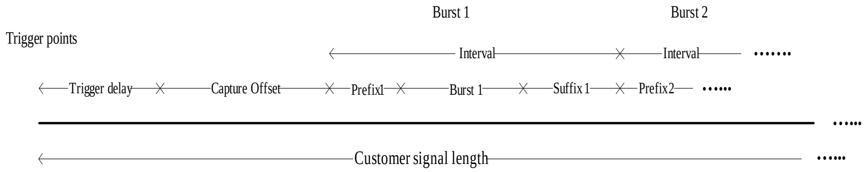
15. For each RF burst, there is no coupling and dependency applied for burst length. But if burst length < 3.769508/RBW, settings conflict (ID –221) message will be posted, and this RF burst will not be measured for power test. If burst length < EVM required length, settings conflict (ID –221) message will be posted, and this RF burst will not be measured for modulation test.

Algorithm Overview

Signal timing

As shown below, each **Burst** contains three parts: **Prefix**, **Burst** and **Suffix**.

The user is fully responsible for the exact alignment of the spectrum analyzer and the device under test in terms of these parameters.



Burst timing

Prefix If burst type is static, prefix is used to define the time spacing between this burst and the previous burst. But if burst type is dynamic, **Prefix** is used to represent the measurement start time of each burst.

Burst allows the user to specify the data time over which the measurement is made.

Suffix is used to define the hardware switching time between this burst and the next burst.

Captured Sequence

Capture starts after the trigger delay lapses. Capture Offset represents the part that somehow you do not want to measure. After Capture Offset, after the Prefix1, comes the Burst 1, which is the target part of the measurement. When Burst 1 lapses, the RF front will suspend and undertake to “hop” the frequency or “reset” the E-attenuation, which will take period of Suffix 1. When the suffix 1 lapses, the RF chain will resume capturing until Burst 2 lapses. In the captured data, prefix1 is the part that somehow you do not want to measure. Burst 1 is the target of the measurements, and so on till all the bust are captured.

It is important to note that in any case, the specified Suffixes in all bursts (equals to 0 under static burst pattern) correspond to the time the hardware (RF front end) take changing the Center frequency setting values or E-Atten setting values, so the capturing actually suspends during this time.

In any cases, the total captured length equals the capture offset plus Prefixes and Bursts of all intervals.

Transmit Power Measurement Concepts

Purpose

The Transmit 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 bandwidth). This measurement is applied to design, characterize, evaluate, and verify transmitters and their components.

Measurement Method

The Transmit Power measurement uses the FFT method to compute signal transmit power. The transmit power in Integ. BW is computed by adding up the energy of each FFT point in Integ BW around center frequency. The peak power spectral density is defined as the maximum transmit power in 1 MHz bandwidth.

The peak power spectral density is searched within channel bandwidth around center frequency for 802.11 a/b/g. The measurement acquires a number of points representing the input signal in the time domain. It transforms this information into the frequency domain using FFT and then calculates the channel power. The effective resolution bandwidth of the frequency domain trace is proportional to the number of points acquired for the FFT. The fastest FFT process is achieved using a number of acquired points that is a power of 2 (for example: 64, 128, 512).

If the user turns the Average on, it will give the average result of all the measured bursts.

Transmit Output Spectrum Measurement Concepts

Purpose

The Transmit Output Spectrum 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 transmitted spectral density of the transmitted signal shall fall within the spectral mask.

Measurement Method

The Transmit Spectrum Mask measurement measures spurious signal levels in up to five pairs of offset frequencies and relates them to the carrier power. PSD (Power Spectral Density) is used for this measurement. Transmit Spectrum 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.

The table below shows the limit line of offset A,B,C,D.

Table 2-7 *Limit Line for Offset A/B/C/D*

Radio Standard	Offset	Limit
802.11a or 802.11g-OFDM	A (9 MHz – 11 MHz)	0dB – -20dB
	B (11 MHz – 20 MHz)	-20 dB – -28 dB
	C (20 MHz – 30 MHz)	-28 dB – -40 dB
	D (30 MHz – 55 MHz)	-40 dB – -50 dB
802.11b or 802.11g-DSSS	A (11 MHz – 22 MHz)	-30dB – -30dB
	B (22 MHz – 33MHz)	-50 dB – -50 dB
	C (33 MHz – 44 MHz)	-50 dB – -50 dB
	D (44 MHz – 55 MHz)	-50 dB – -50 dB

Modulation Accuracy Measurement Concepts

Purpose

Error Vector Magnitude

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.

This measurement works in conjunction with the DSP measurement engine to complete the measurement. The hardware setup, IF path calibration, UI, measurement cycle, averaging and display are handled by the platform DLP. The interface for these systems is described in detail below.

The reference position is determined from a reference signal that is synthesized by demodulating the data bits from the received signal and then re-modulating these bits "perfectly" for a generic QPSK signal.

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. This is the error vector magnitude (EVM). EVM is a common modulation quality metric widely used in digital communication systems.

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.

Spectral Flatness

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

Measurement Method

EVM

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. This is then demodulated and the ideal phase trajectory is mathematically derived using detected bits and root-raised cosine channel filtering. Subtracting one from the other results in a phase error signal.

The modulation accuracy measurement is made to get results for a composite error vector magnitude. The error vector is defined as the ratio to the mean power of the reference waveform expressed in dB.

Spectrum Flatness

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 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 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.

When the modulation accuracy measurement is performed, the following results are provided:

- Frequency Error
- Symbol Clock Error (802.11a or 802.11g-OFDM)
- Chip Clock Error (802.11b or 802.11g-DSSS)
- Center Frequency Leakage (802.11a or 11g-OFDM)
- Spectral Flatness (802.11a or 802.11g-OFDM)
- Carrier Suppression (802.b or 802.11g-DSSS)
- RMS EVM
- Peak EVM

Other Sources of Measurement Information

Additional measurement application information is available through your local Agilent Technologies sales and service office. The following application notes treat digital communications measurements in much greater detail than discussed in this measurement guide.

- Application Note 1298

  Digital Modulation in Communications Systems - An Introduction
  Agilent part number 5965-7160E

- Application Note 1311

  Understanding CDMA Measurements for Base Stations and Their Components
  Agilent part number 5968-0953E

- Application Note 1486

  WLAN RF and Baseband Transmitter Analysis Using Agilent Infiniium Oscilloscopes and 89600 Software, literature number 5989-0327EN.

- Application Note 1380-1

  RF Testing of Wireless LAN Products, literature number 5988-3762EN.

- Application Note 1380-2

  IEEE 802.11 Wireless LAN PHY Layer (RF) Operation and Measurement, literature number 5988-5411EN.

- Application Note 1380-4

  Making 802.11G Transmitter Measurements, literature number 5988-7813EN.

- Application Note

  Characterizing Digitally Modulated Signals with CCDF Curves
  Agilent part number 5968-5858E

- Application Note

  Characterizing Digitally Modulated Signals with CCDF Curves
  Agilent part number 5968-5858E

Instrument Updates at www.agilent.com

This web location can be used to access the latest information about the instrument, including the latest firmware version.

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

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

References

1. Supplement to IEEE Standard for Information Technology, IEEE Std 802.11a-1999 (Supplement to ANSI/IEEE Std 802.11, 1999 Edition)
2. Higher Speed Physical Layer in the 2.4 GHz Band, IEEE Std 802.11b-1999 (Supplement to ANSI/IEEE Std 802.11, 1999 Edition)
3. Higher Speed Physical Layer in the 2.4 GHz Band, IEEE Std 802.11g/D8.2, Apr. 2003 (Supplement to ANSI/IEEE Std 802.11, 1999 (Reaff 2003))