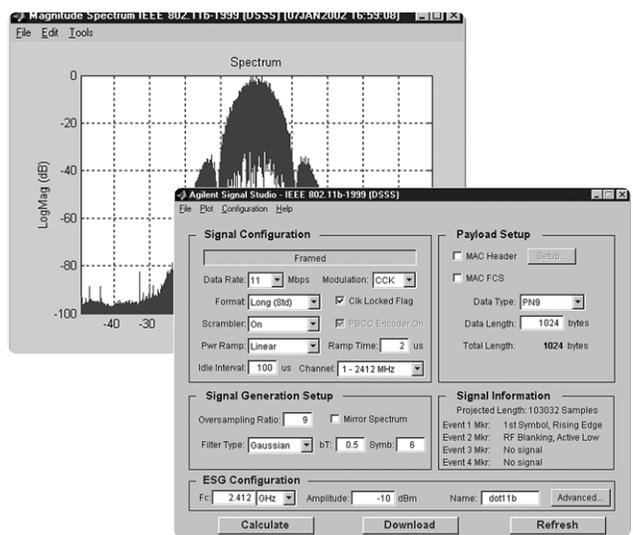


Agilent 802.11b WLAN Signal Studio Software for the E4438C ESG Vector Signal Generator

Option 405 Product Note



Use Signal Studio to create IEEE 802.11b test signals

Signal Studio 802.11b software is a powerful tool for creating 802.11b baseband I/Q waveforms for use with the Agilent E4438C ESG vector signal generator's high performance internal baseband generator.

E4438C ESG vector signal generator Main features

- 250 kHz to 6 GHz frequency range
- 80 MHz RF bandwidth
- 160 Mbytes (32 Msamples) playback memory
- 6 GB storage memory
- Hardware digital interpolation filters
- Fast microprocessor
- LAN connectivity
- Differential I/Q outputs

Key features

- Modulation: CCK, PBCC, DBPSK, DQPSK
- Choose framed or unframed signal
- Baseband filtering
- Configure payload MAC header and enable FCS
- Select long or short preamble
- Scrambling On/Off or preamble only
- Configure power ramp type and power ramp time
- Select idle time between bursts
- Enable PBCC encoder
- Remote control of basic ESG signal generator functions from software

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This Product Note is a self-guided tutorial that describes the test signals that can be created with the Signal Studio-802.11b software. This document is not meant to be an 802.11b technology tutorial. For additional information on 802.11b technology, refer to the Additional Literature and References section at the end of this document.

Introduction

Signal Studio 802.11b software is a tool for creating an 802.11b waveform in an intuitive Windows®-based environment. The software calculates a baseband I/Q waveform file based on the user-defined 802.11b frame. The waveform file can then be downloaded to the ESG's baseband generator (option 001 or 002) for playback through the I/Q modulator and upconversion to RF. The RF range is from 250 kHz to 6 GHz.

Download Signal Studio from www.agilent.com/find/signalstudio to a PC to evaluate the signal configuration and plotting capabilities of the software. A license key is required to load the signals created by the software into the ESG. The license key can be ordered through your sales engineer or your local sales office, which can be found at <http://www.agilent.com/find/assist>.

In addition to creating waveform files, the software provides basic configuration menus for signal generator settings, including frequency, amplitude, and marker polarity. The instrument settings, along with the waveform files, are passed to the ESG over the LAN or GPIB interface.

After downloading the waveform file and instrument settings, the ESG automatically begins generating the 802.11b RF signal. Local control of the instrument is then re-enabled and signal generator settings, like frequency and amplitude, can be modified from the instrument's front panel. The waveform files themselves cannot be modified once they have been downloaded to the instrument.

The Signal Studio software configuration can be recalled at any time to re-calculate and download the waveform to the signal generator. The waveform itself cannot be saved on the PC, but waveforms can be re-calculated quickly from stored settings. Once downloaded, the waveform files can be saved on the 6 GB hard drive.

The Signal Studio 802.11b signal can be used to test any portion of the receiver chain during the design process. Some software engineers may require a baseband signal to perform demodulation and decoding verification on ASIC and DSP chips, see Figure 1. RF designers may want to test components such as amplifiers or the RF chip set.

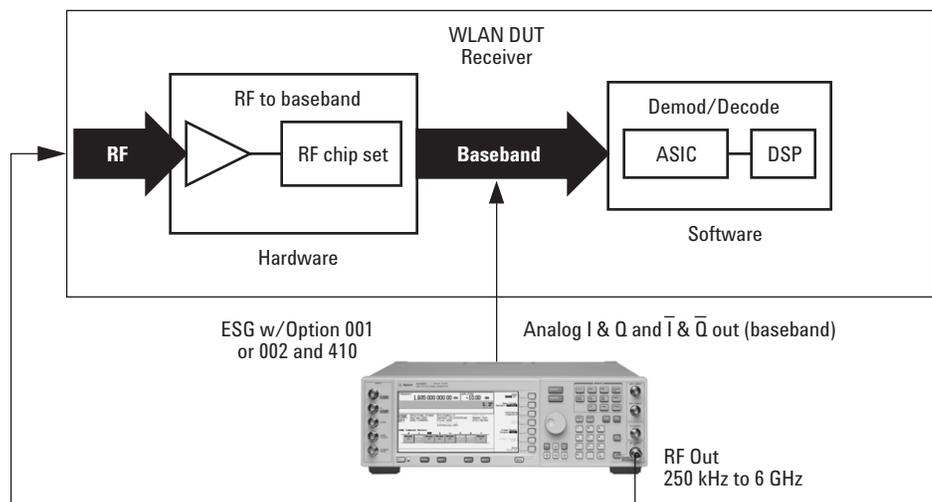


Figure 1. Test setup with ESG

Ease of use

Signal Studio 802.11b simplifies the user's role in creating 802.11b test signals for use with the ESG. Instead of wasting valuable time writing code to create a proprietary test signal, Signal Studio 802.11b provides the ability to quickly configure a standard-based test signal via an intuitive graphical user interface. Furthermore, the Signal Studio 802.11b frame configuration can easily be modified to create the desired test signal, without re-writing code.

Component test

The performance characteristics of 802.11b components - including preamplifiers, combiners, filters, and amplifiers - is determined using a stimulus that provides statistically correct signals. The Signal Studio 802.11b software meets this need. Signal parameters can be modified to provide adequate stress on the components being tested.

Receiver test

In order to thoroughly test a receiver's demodulation capabilities, a test signal with full coding is necessary. Full coding allows test engineers to determine if each functional stage of a receiver is operating correctly. This level of coding enables FER and BER testing on the signal received by the access point. The designer will be able to use this to perform standards-based tests such as receiver minimum input level sensitivity, receiver maximum input level, and receiver adjacent and non-adjacent channel rejection measurements.

Another benefit of using the Signal Studio 802.11b as a test signal is that it allows the designer to verify that the receiver correctly decodes an independently generated 802.11b test signal.

Signal structure

PMD layer

The Signal Studio 802.11b creates the physical layer PMD (physical medium dependent) test signals, which contain PLCP (physical layer convergence procedure) Preamble (long and short), PLCP Header, and the payload.

Although the signal does not provide MAC or PLCP protocol handling, it does enable testing of the PMD layer for receiver and component tests, see Figure 2.

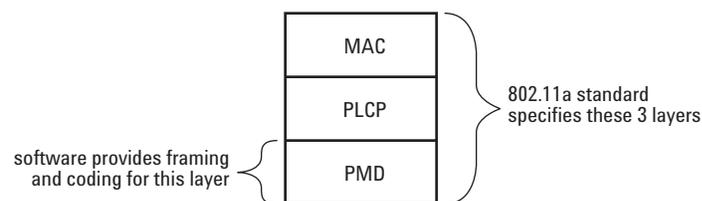


Figure 2: 802.11b standard protocol stack

The PMD sublayer is the physical layer, which provides the transmission of the signal over the air interface. The PMD layer provides the framing, scrambling, and modulation of the signal. Measurements can be made on the physical layer signal, such as spectral measurements, as well as making standards based measurements. To make these measurements, the MAC and PLCP layers are not needed.

The user has the capability to add a MAC header and FCS to the data payload. This is useful if the user needs to add addresses or other MAC fields in the MAC header, see Figures 3 and 4.

PPDU (PLCP protocol data units) frame structure

In 802.11b systems, information is transmitted in frames. The total frame length is variable. The Signal Studio-802.11b software supports framing for both the long and short preambles, as detailed below in figures 3 and 4.

PPDU frame with long PLCP preamble

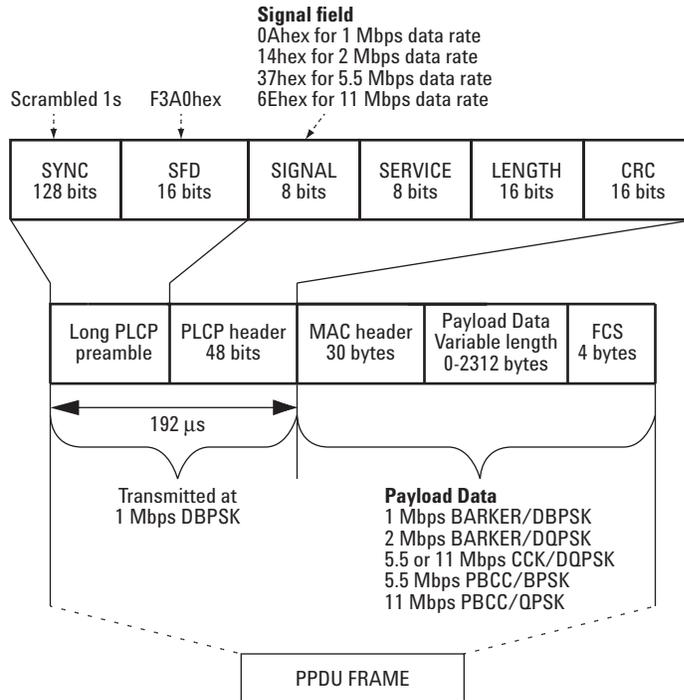


Figure 3. PPDU frame with long preamble

PLCP Preamble

Preamble:

The user can select turn scrambling On, Off, or On for the Preamble only.

SFD:

The user cannot modify the SFD field.

PLCP headers

Signal:

The user cannot modify the signal fields.

Service:

Bits 0,1,4,5,6 are reserved bits as indicated by the 802.11b standard, and cannot be modified by the user.

Bit 2 is to indicate to the receiver if the carrier and the symbol clock use the same local oscillator, user settable.

Bit 3 is set to zero if CCK is the modulation, and PBCC (Packet binary convolutional coding) is set to one if this is the modulation. This is automatically set by the software, and the user cannot modify this bit.

Bit 7 is the length extension bit. If the payload data rate is over 8 Mbps, then this bit will be set to one, by the software. The user cannot modify this bit.

Length: the user cannot modify the length fields.

CRC: automatically calculated by the software, and cannot be modified by the user.

PPDU frame with short PLCP preamble

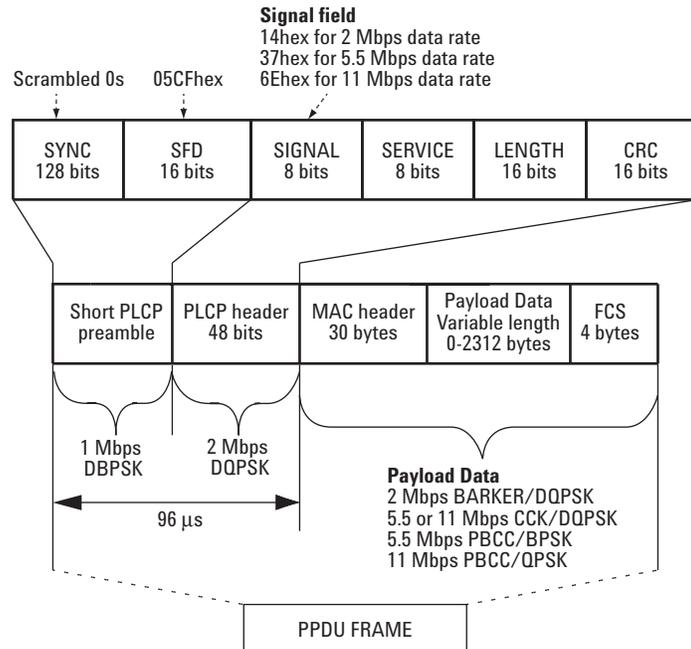


Figure 4. PPDU frame with short preamble

Payload structure

The payload field is within the PPDU frame. A MAC header and FCS can be added to the data payload. Table 1 provides a summary of the payload characteristics in 802.11b.

Data rate Mbps	Symbol rate Msps	Chip rate Mcps	Coding scheme	Modulation
1	1	11	11 Chip Barker code	DBPSK
2	1	11	11 Chip Barker code	DQPSK
5.5	1.375	11	8 chip CCK	DQPSK
11	1.375	11	8 chip CCK	DQPSK
5.5	does not apply	does not apply	PBCC	BPSK
11	does not apply	does not apply	PBCC	QPSK

Table 1. Key 802.11b payload RF characteristics supported with the Signal Studio 802.11b software

Signal configuration

This section allows the user to choose specific parameters for framing the signal.

Framed:

Toggles between framed and unframed mode. In framed mode the user can generate a test signal to make measurements according to the standard. In unframed mode, the user can perform measurements where continuous modulation of unframed data is desired.

Data rate:

Selects the data rate. Four different data rates are available: 1 Mbps, 2 Mbps, 5.5 Mbps, and 11 Mbps.

Modulation:

For the 1 Mbps and 2 Mbps data rates, the modulation formats are selected automatically and cannot be changed. For 5.5 Mbps and 11 Mbps data rates, the two different modulation formats are available: CCK and PBCC.

Format:

Selects the format of the preamble/header sections of the framed signal. This is only relevant for data rates above 1 Mbps.

Scrambler:

Selects scramble On/Off or preamble only. If parts of the design don't have scrambling set-up, the user can vary this selection for the test signal.

Clk locked flag:

Toggles the clock locked flag in the physical packet header. This is Bit 2 in the Service field of the PPDU frame. This bit is used to indicate to the receiver if the carrier and the symbol clock use the same local oscillator, and the user can set this bit. This is only relevant in framed mode.

PBCC encoder on:

Toggles the encoder on. Only relevant for PBCC modulation.

Pwr ramp:

Selects shape of the RF burst in framed mode. Selects the power up/down ramp type as none, linear, or cosine. Cosine ramp gives least amount of out of channel interference. "None" starts transmitting the signal at full power, and is the simplest power ramp to implement. The linear ramp shapes the burst in a linear fashion. The Pwr Ramp feature is only relevant in framed mode.

Ramp time:

Sets the length (in microseconds) of the power up/down ramp. This is only relevant in framed mode.

Idle interval:

Sets the length (in microseconds) of the idle time between frames. This is only relevant in framed mode.

Channel:

Sets the RF channel. This automatically sets the ESG frequency.

Payload setup

This section allows the user to configure the MAC header and choose to add an FCS added to the packet. The maximum data length of the payload is 2312 bytes. Notice that the total length of the payload is displayed.

Setup menu:

Configures the MAC header.

MAC header:

Enables/disables prepending the MAC header to the data payload. The user can fill all these individual fields with the desired data, or can disable these fields if the data is no longer desired.

MAC FCS:

Enables/disables appending the MAC FCS to the data payload. The FCS (frame check sequence) is automatically calculated by the software if this field is selected. Note: When the MAC header is not selected, then the FCS is just performed on the payload.

Data type:

Selects the payload data stream from the following types:

- PN9
- PN15
- All zeros
- All ones
- Alternating zeros and ones
- Alternating ones and zeros

Data length:

Sets the number of data bytes in a frame. This excludes MAC header and FCS.

Total length:

Displays the total number of bytes in the payload. This includes the data and MAC header and FCS.

Step 2 – Setup the signal generation options

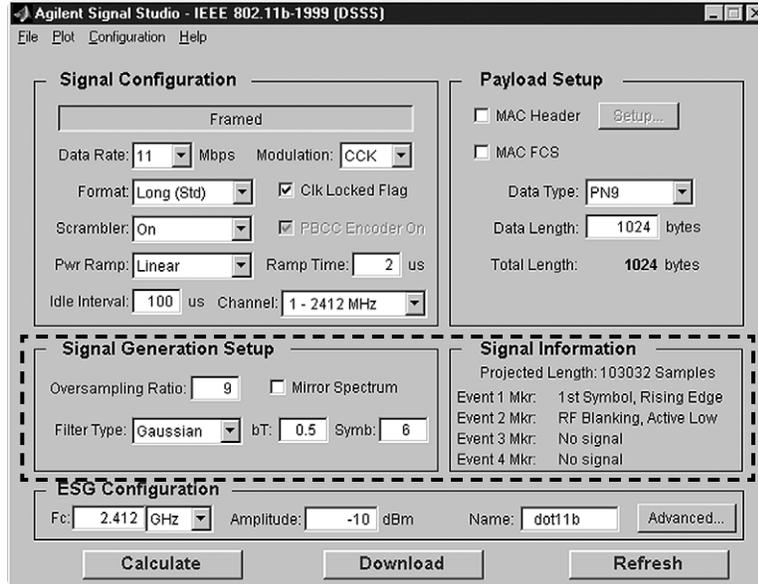


Figure 7. Signal Studio 802.11b signal generation options menu

Signal generation setup

As illustrated in Figure 7, the Signal Studio software provides a simple interface for defining the following signal generation options: Oversampling Ratio, Filter Type, and Mirror Spectrum.

Oversample ratio

The oversampling ratio (OSR) defines the number of samples calculated per I/Q symbol. Increasing the over sampling ratio of the constructed signal increases the separation between the sampling images and the desired signal. This allows for better image rejection by the baseband reconstruction filters. With the E4438C, there is no need to oversample more than 2X. Hardware resampling will separate the images by 50 MHz, where they are easily removed by the reconstruction filter.

Increasing the over sampling ratio increases the waveform calculation time and file size. Notice that the projected file length in the Signal Information section is affected by the over sampling ratio setting. The maximum sampling rate on the ESG is 100 MHz.

The software offers OSR of up to 9. When an OSR is selected, this automatically sets the Sampling Rate in the ESG Configuration section. The lower the sample rate, the less space the waveform takes up in memory, and the faster the signal can be generated and downloaded.

Filter type

A baseband filter is applied to reduce the transmitted bandwidth, increasing spectral efficiency. The standard does not specify what type of filter must be used, but the transmitted signal must meet the spectral mask requirements (see Figure 16). Gaussian filtering with a B*T of .5 was chosen for the measured example. This filter is commonly used in the 802.11b industry. Other filters may also filter the signal enough to fit within the spectral mask.

For signals generated with digital signal processing, baseband filters are often finite impulse response (FIR) filters with “taps” that represent the sampled impulse response of the desired filter. FIR filters are used to limit the bandwidth of the input to the I and Q modulators.

Three options for baseband filtering can be selected in the Filter Type menu: Rectangle, Gaussian, and Root-Cosine.

The Root-Cosine filter has an impulse response that rings at the data clock rate so nulls appear at all alphas. Alpha gives a direct measure of the occupied bandwidth of the system calculated as Occupied bandwidth = symbol rate x (1 + alpha).

Gaussian filters typically have more intersymbol interference than the Root-Cosine filter, but their adjacent channel power performance is better for constant-amplitude modes like MSK, where Root-Cosine filtering of I and Q is not possible. The bandwidth bit time (BbT) product (similar to alpha) is the Gaussian filter coefficient.

The rectangular filter is essentially no baseband filtering.

Mirror spectrum

This allows the user to invert the spectrum. If this option is selected, then the Q channel is inverted. This feature may be useful if the user plans to use a mixer to upconvert the signal.

Signal information

Projected length:

The length of the waveform is in samples. The ESG's baseband generator can playback waveforms up to 32 Msamples.

Markers:

The signal generator has four markers that can be placed on a waveform segment; markers provide timing signals that are synchronized with a waveform segment. Default settings are explained below. Markers can be set from the software, or from the ESG user interface, see users guide for more details.

Event 1 Mkr:

The Event 1 marker can be accessed from the rear panel BNC connector. The event 1 marker is set to the 1st symbol of the 802.11b waveform on the rising edge. The signal out the event 1 port can be used as a trigger signal. Default marker polarity is positive. The user can invert the polarity of marker under the Advanced button.

Event 2 Mkr:

When the 802.11b signal is framed, RF blanking increases the on/off ratio of the RF bursts. The ESG Event 2 marker is internally routed to provide the RF blanking signal. The default marker 2 polarity is set to positive. If the polarity is inverted, the desired RF signal will be blanked, resulting in no RF output from the ESG.

Event 3 Mkr:

Signal Studio-802.11b does not create a marker for Event 3. This can be done from the ESG user interface. See users guide for more details.

Event 4 Mkr:

Signal Studio-802.11b does not create a marker for Event 4. This can be done from the ESG user interface. See users guide for more details.

Step 3 – Configure the ESG

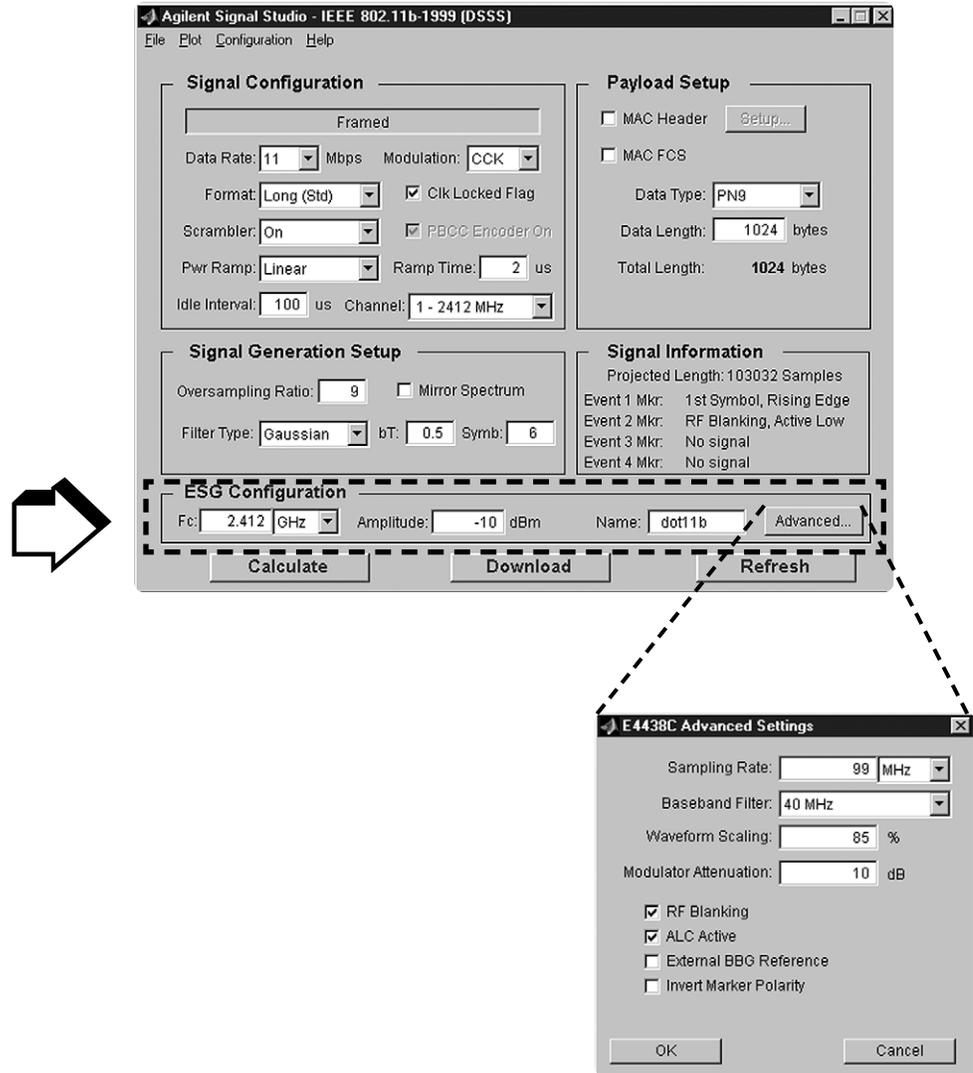


Figure 8. Signal Studio 802.11b configuration ESG menu

Along with the compiled waveform, the Signal Studio software passes instrument settings to the ESG signal generator. These are defined in the ESG Configuration menu. The following settings can be made:

ESG configuration parameters

Frequency	Defines the frequency at which the ESG will generate the signal.
Amplitude	Defines the power level at which the ESG will generate the signal.
Sampling rate	Defines the rate at which the waveform I/Q samples are read from the dual arbitrary waveform generator memory during playback.
Baseband reconstruction filter	These reconstruction filters allows the entire desired signal to pass through, while rejecting the images that occur at multiples of the OSR. The ESG provides one 50 MHz analog reconstruction filter. This filter is sufficient to eliminate any images or aliasing. The user may optionally choose the no filter option (through). These low-pass filters are intended to transmit the baseband signal while rejecting the higher frequency images.
Waveform scaling	Scaling maximizes dynamic range into the DAC, while preventing overflow errors. The waveform data is scaled as it passes through the baseband generator and the DAC interpolating filters. Scaling does not alter the original waveform data file. Scaling range is from 1 to 100%.
Modulator attenuation	Sets the attenuation level before the signal is sent through the IQ modulator.
RF blanking	When the 802.11b signal is framed, RF Blanking improves the on/off ratio of the RF bursts. The ESG Event 2 marker is internally routed to provide the RF Blanking signal. Note: When RF Blanking is enabled, the Marker Polarity is set to positive by default, otherwise the wanted RF signal will be blanked resulting in no RF output from the ESG.
ALC active	The default setting is ALC (automatic level control) on. To turn ALC off, uncheck the box. The RF output power of the signal generator is constantly monitored and controlled by the ALC circuit. Its purpose is to hold output power at its desired level in spite of drift due to temperature and time.
External BBG (baseband generator) reference	Sets reference frequency for the ESG dual arbitrary baseband generator to internal or external. If an external reference is used, should be connected to the ESG before the waveform and it instrument settings are downloaded to the instrument. The default setting is internal. Note that this is not the 10 MHz oscillator frequency reference.
Marker polarity	When RF Blanking is enabled, the Marker Polarity is set to positive by default. If this is set to negative the wanted RF signal will be blanked resulting in no RF output from the ESG.

After the waveform and instrument settings have been downloaded to the instrument, the instrument settings can be modified from the signal generator front panel. The waveform itself cannot be modified, except by re-calculating with new settings in the Signal studio software.

Step 4 – Calculate & download

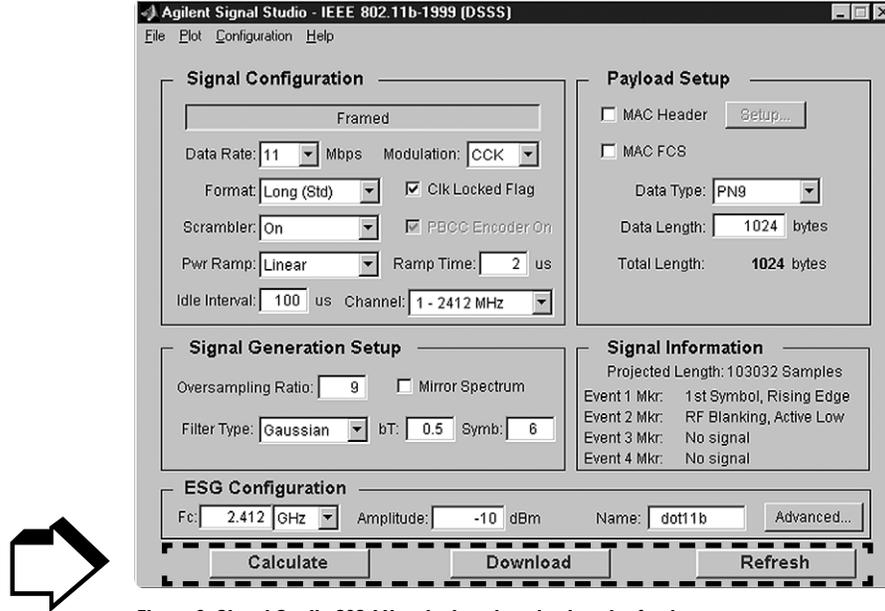


Figure 9. Signal Studio 802.11b calculate download, and refresh menu.

Once the waveform and ESG settings have been configured, the final step is to calculate the waveform and download it to the instrument.

First, name the waveform in the Waveform Title field. This is the name that will appear in the ESG dual arbitrary waveform generator user interface after the waveform is downloaded to the instrument. The ESG only recognizes waveforms that are named using the following alphanumeric characters: A thru Z, 0 thru 9, \$&_#+-[]. There is a 20-character maximum name length for waveform files. If un-supported alphanumeric characters are used to name the waveform, the ESG will generate a File Name Not Found Error (Error: -256) when the waveform is downloaded to the instrument. Valid waveform names appear in the ESG dual arbitrary waveform generator user interface after the waveform is downloaded to the instrument.

Step 4a – Calculate

Once the waveform and ESG settings have been configured, the final step is to calculate the waveform and download it to the instrument.

Name the waveform

First name the waveform in the Waveform Title field. This is the name that will appear in the ESG user interface after the waveform is downloaded to the instrument. The ESG only recognizes waveforms that are named using the following alphanumeric characters: A thru Z, 0 thru 9, \$&_#+-[]. There is a 20-character maximum name length for waveform files. If un-supported alphanumeric characters are used to name the waveform, the ESG will generate a File Name Not Found Error (Error: -256) when the waveform is downloaded to the instrument.

Select the calculate button

The software will generate an I/Q waveform file in accordance with Signal Studio settings. Waveform calculation time varies according to the selected data rate, OSR, length of the payload, and the computer's processing speed.

Generate plots

After the I/Q waveform has been calculated, the Signal Studio software is capable of generating a plot of the baseband spectrum, I/Q waveforms, and CCDF curves, see Figure 10. To plot the spectrum, choose Plot→ Spectrum from the menu keys at the top of the window. The plot can be magnified using the zoom feature in the Tools pull-down menu at the top of the plot. Simply select the zoom feature and use the mouse pointer to select the section of the plot to be affected. Plots of the I/Q and CCDF waveforms can be generated in a similar manner.

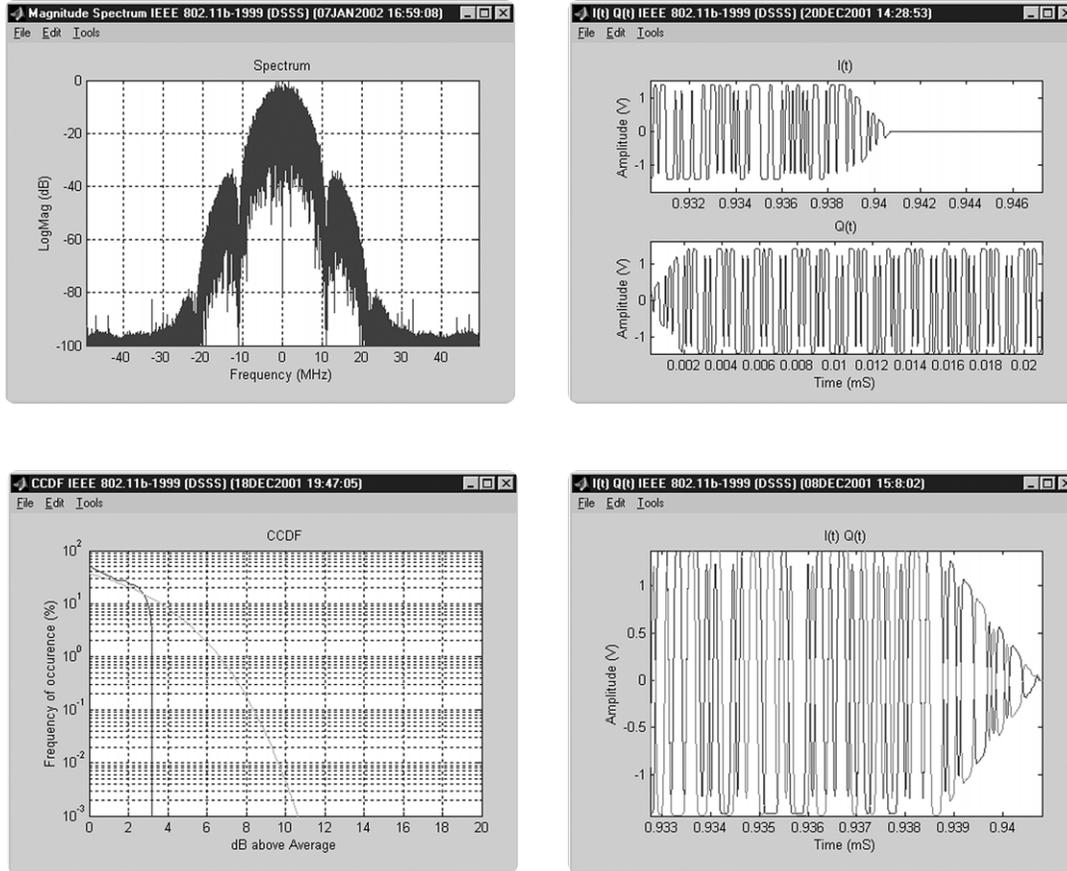


Figure 10. Spectrum plots of Signal Studio 802.11b waveform

The best way to look at power statistics is using the complementary cumulative distribution function (CCDF), see [10]. The above CCDF plot shows dB above average power on the horizontal axis, and percent probability of occurrence on vertical axis. This blue trace shows that for this one packet, the signal exceeds 2 dB above average 1% of the time. The grey curved graticule line represents the statistics for Gaussian noise.

Signal studio configuration and setup

The ESG will be connected to the PC as shown in Figure 11. See the *Signal Studio Installation Guide* [1] for more details on connecting the computer to the ESG.

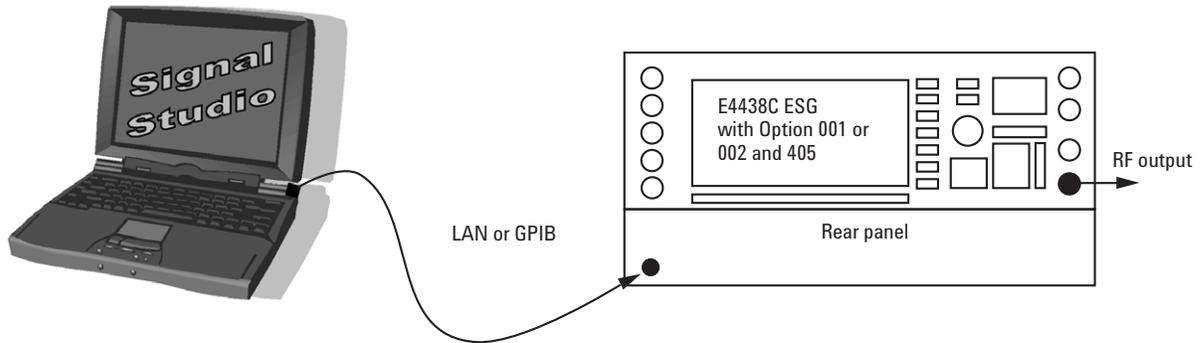


Figure 11. PC to ESG configuration

Step 4b – Download

Select download button

(See Figure 9) to send the calculated I/Q waveform file representing the 802.11b waveform and the signal generator settings to the instrument. The signal generator automatically begins producing the 802.11b RF signal. Local control of the instrument is then re-enabled, and signal generator settings can be modified from the instrument's front panel. The waveform files themselves cannot be modified once they have been downloaded to the instrument.

The Signal Studio 802.11b software configuration can be saved to the host computer's local hard drive. The configuration can then be recalled at any time to re-calculate and download the waveform to the signal generator. This is especially useful when complex configurations have been created in the software. From the menu keys at the top of the window in Figure 9, choose File → Save As, and then name the file and save it in the ESG-B/Dot11b directory. The software configuration can be recalled anytime by choosing the following menu options: File → Open, then the file name.

After the calculated I/Q waveform has been downloaded to the signal generator for playback, it can be saved in the instrument's non-volatile memory for storage and later recall. For more information on saving waveforms to the instrument. The I/Q waveform files created by the Signal Studio software cannot be stored outside the instrument.

The following window, Figure 12, appears after a successful download. This window must be closed by clicking OK to access the main menu again.

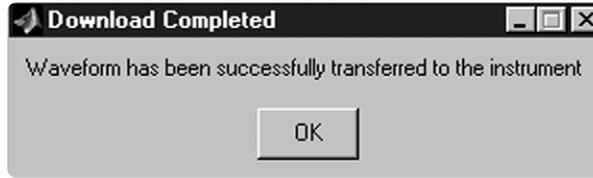


Figure 12. Window to indicate a successful waveform transfer to the ESG

Refresh button

This button refreshes the frequency and amplitude settings on the ESG. This button allows the user to modify the frequency and amplitude settings any time during operation, and then pressing the refresh button will refresh the frequency and the amplitude settings.

Verify ESG generating waveform

The signal generator is now generating the 802.11b modulated RF signal. Verify this by viewing the ESG user interface.

ESG instruction	Front panel buttons and menu selections
Verify that the 802.11b signal that was just created and named dot11b is being generated, Figure 13.	[Mode Setup]

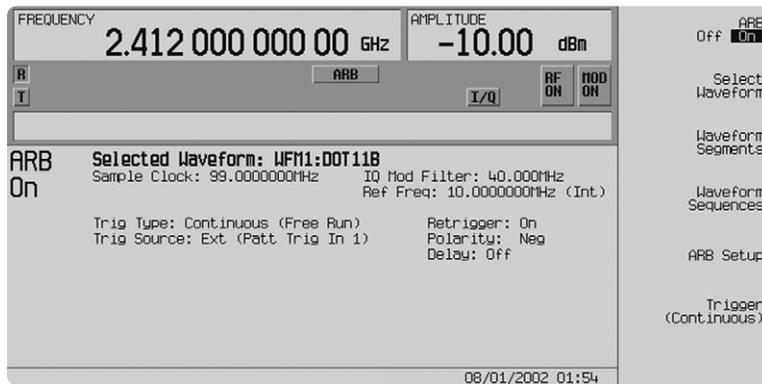


Figure 13. ESG ARB baseband generator user interface

Bit error rate tests

Bit error rate (BER) is not a specified metric in the 802.11b standard, but it is a common measure of signal quality for digital communication systems. BER is the number of corrupted bits received divided by the total number of bits received. The BER analyzer (option UN7) in the ESG can perform this measurement on the payload data. The ESG's internal BER analyzer is capable of analyzing framed and unframed continuous PN9 baseband data sequences. The BER analyzer on the ESG requires data and clock signals when performing BER on unframed data. Framed data requires three signals to the ESG's BER analyzer: data, clock, and gate.

The clock signal indicates the data rate of the incoming data sequence. The gate signal enables the BER analyzer when a valid segment of the PN9 baseband data sequence is present for analysis in a framed data structure. When performing BER measurements, the gate signal is used to strip off header information and recover the continuous PN (pseudorandom noise) sequence payload data portion of the WLAN packet. The data length of the payload must be an integer multiple of a PN9 sequence as defined by ITU V01.53. This allows the BER tester to keep track of a continuous PN9 sequence. Example: Maximum data length for Signal Studio is 2312 bytes and $PN9 = 511$ bits. An integer multiple of PN9 that would fit in the data payload would be equal to 2044 bytes ($4 * 511 = 2044$).

An example BER measurement setup for a framed 802.11b signal is illustrated in Figure 15. This example shows a RF test signal that consists of a standards compliant 802.11b modulated packet with a continuous PN9 sequence.

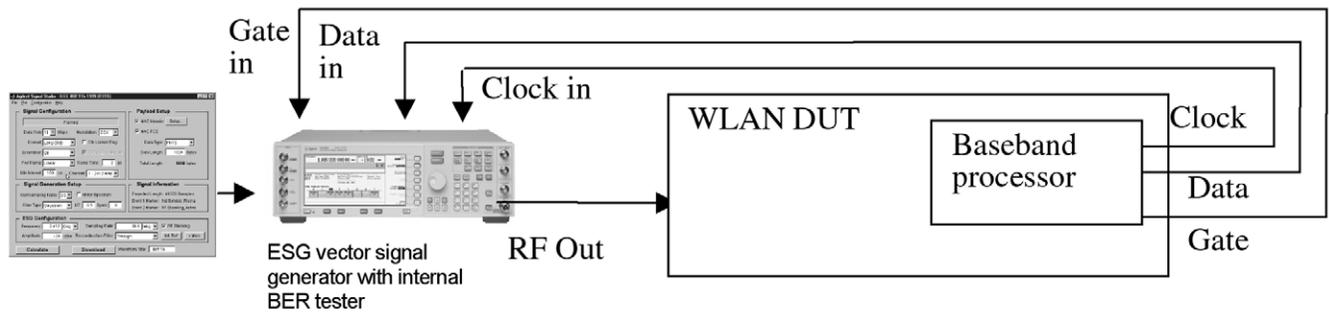


Figure 14. BER test set-up to measure a framed 802.11b signal

The WLAN receiver demodulates and decodes the signal transmitted by the ESG and provides access to the WLAN baseband signal at the baseband processor. This TTL/CMOS signal is routed to the ESG internal BER analyzer data input.

See [8] for more details on performing receiver tests using the ESG and Signal Studio.

Frame error rate tests

While the ESG doesn't have the capability to perform frame error rate (FER) tests, Signal Studio 802.11b creates standards compliant 802.11b packets. FER is the number of corrupted frames received divided by the total number of frames received. These test signals have all the framing and coding as defined in the standard, which is important to obtain FER measurements in receiver testing. The framing of the 802.11b includes a cyclic redundancy check (CRC), which can be used to determine the FER. The device under test (DUT) will need to demodulate and decode the test signal. The CRC can be used by the DUT to determine how many frames that were sent from the source were lost. The number of sent frames can then be compared to the received frames to determine the FER.

If it is desired to perform packet error rate (PER), then the MAC FCS can be used to compute the PER. When the MAC header box is selected, the FCS is performed on the MAC header and the payload. Note: When the MAC header is not selected, then the FCS is performed just on the payload.

Multipacket capability

Multiple 802.11b packets can be created using the waveform sequencer in the ARB menu in the ESG. The ARB sequencer can "play" an ordered series of individual waveforms. Waveforms can be generated using the dual arbitrary waveform generator, renamed as "waveform segments," and built into user-defined waveform sequences that are modulated to the RF output. Waveform sequencer features include waveform clipping, markers, and triggering useful for synchronizing the output of the signal generator with other devices. For more details on how to create multipacket, refer to the user's guide [9].

Transmitter measurements

- ESG Configuration
 - E4438C ESG Vector Signal Generator
 - Options 506, frequency range up to 6 GHz
 - Option UNJ, enhanced phase noise
 - 001 or 002, Baseband generator
 - Signal Studio-802.11b, Option 405 License Key
- PSA Configuration
 - E4440 PSA High Performance Spectrum Analyzer
- VSA Configuration
 - 89640A: DC to 2.7 GHz Vector Signal Analyzer
 - Option AYA, vector modulation analysis

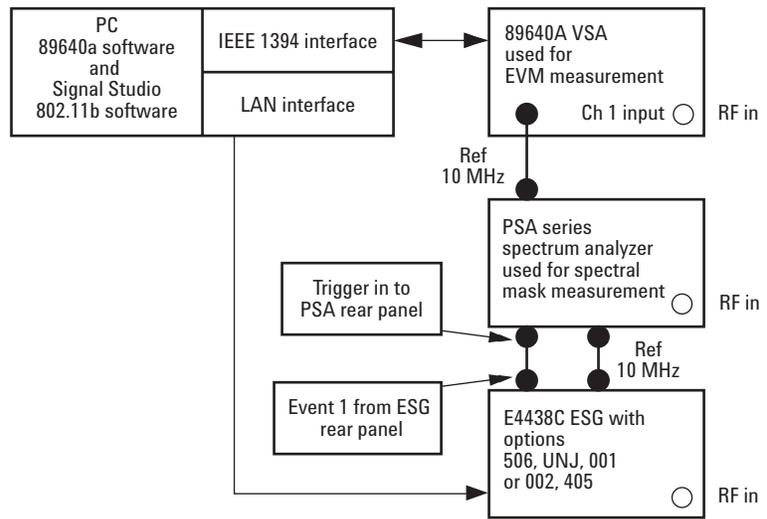


Figure 15. Test and measurement equipment set-up

Instruction	Front panel buttons and menu selections
Set the PSA to Spectrum analysis mode	[MODE] {Spectrum Analysis}
Set the PSA center frequency to match your ESG output	[Frequency Channel] {2.412} {GHz}
Set other parameters	[Span] {100 MHz}, [BW/Avg] {Res BW Man} {100 kHz} [Trig] {Ext Rear}

Transmit spectral mask

The transmitted 802.11b signal must fit in the spectral mask as defined in the standard, see Table 2. This is to help ensure that the transmitter is not interfering with adjacent and alternate channels. A red spectral mask was drawn around the transmitted 802.11b signal in the measurement shown in Figure 16. The specified spectral density levels and offsets are listed in Table 2.

dB relative to maximum spectral density of signal	Frequency offset
-30 dBr	fc $>\pm 11$ to 22 MHz
-50 dBr	fc $>\pm 22$ and greater

Table 2. IEEE 802.11b transmitted spectral requirements

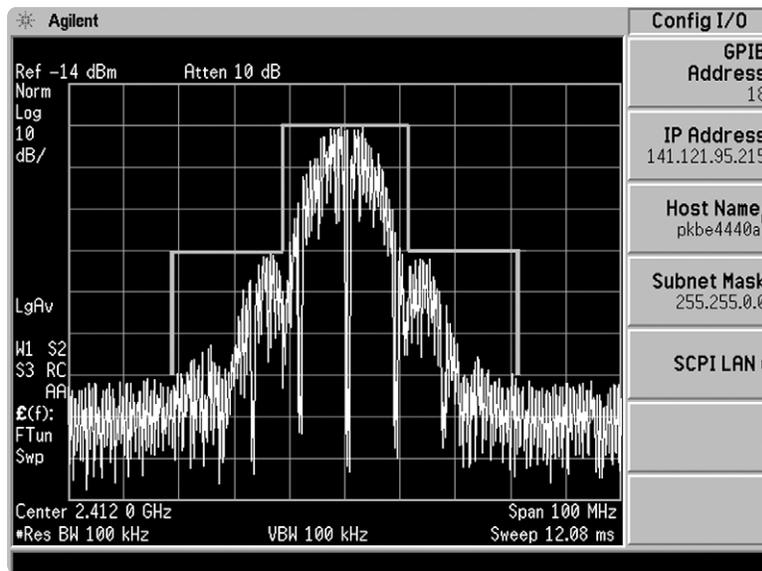


Figure 16. E4440A measured 802.11b spectrum

EVM measurement

The most widely used modulation quality metric in digital communications systems is Error Vector Magnitude. When performing EVM measurements, the analyzer samples the transmitter output to capture the actual signal trajectory. The signal is demodulated and a reference signal is mathematically derived. The error vector is the vector difference at a given time between the ideal reference signal and the measured signal. The error vector is a complex quantity that contains a magnitude and a phase component. The EVM specification for 802.11b is 35%.

Instruction	Menu selections
Set-up the VSA	Center frequency 2.412 GHz
Activate demodulator	MeasSetup/Demodulator/Digital Demo
Select 802.11b demodulation	MeasSetup/Demod Properties/Format (tab)/Standard /802.11b/Preset to Standard/IEEE 802.11b Select Search/select Pulse Search/ Search Length: 2 ms
Select four trace "quad" display layout	Display/Layout/Quad 4

NOTE: For any additional questions regarding the VSA, please see the Help menu from the 89600 software.

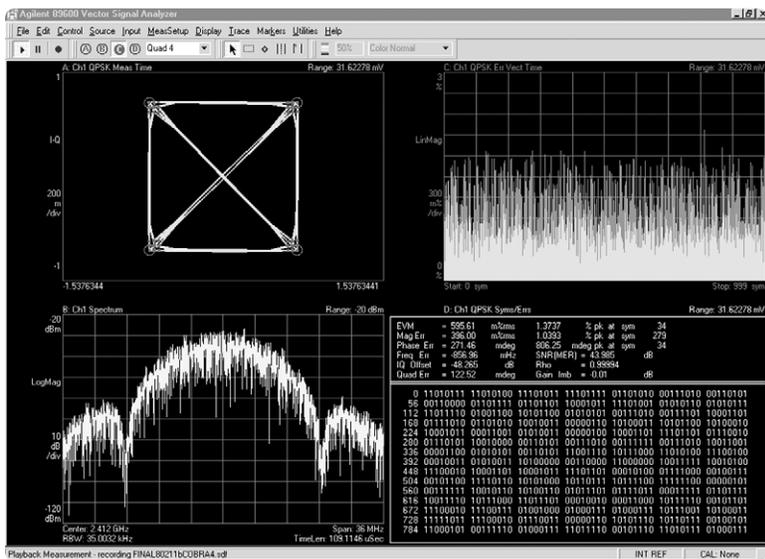


Figure 17. 89640A VSA measurement data of 11 Mbps CCK payload data: Gaussian filtered with B*T of .5

Upper left quadrant-meas time

Shows the constellation diagram.

Upper right quadrant Err Vect Time

The Error Vector Time trace shows error-vector, time-domain trace.

Lower left quadrant-Spectrum

Frequency domain representation of the signal.

Lower right quadrant-symbol/error table

The 802.11b symbol/error table provides a wealth of data on an 802.11b WLAN burst. Along with the demodulated data bits, this table provides the following information:

Ch1 QPSK syms/errs

Metric	Description
EVM	<p>EVM (error vector magnitude) is the Root Mean Square (RMS) of the error vectors computed and expressed as a percentage of the square root of the mean power of the ideal signal. The error vector is the magnitude of the vector, at the detected symbol location, which connects the I/Q reference-signal phasor to the I/Q measured-signal phasor, and is computed as follows:</p> $\text{EVM [n]} = \text{SQRT}(\text{lerr[n]}^2 + \text{Qerr[n]}^2)$ <p>Where: [n] = measurement at the symbol time lerr = I Ref - I Meas and Qerr = Q Ref - Q Meas The symbol table also shows the symbol that has the largest EVM called the Peak EVM.</p>
Mag Err	<p>Magnitude error is an indicator of the quality of the amplitude component of the modulated signal. For example: a very high magnitude error might indicate high incidental AM modulation on the signal.</p> <p>The magnitude error shown in the symbol table is computed only at the symbol times (the instant in time when symbols are detected). The computation does not include points between symbols. Therefore, the value of Points/Symbol has no effect on this parameter. The symbol table also shows the symbol that has the largest magnitude error (peak magnitude error).</p>
Phase Err	<p>This parameter is the difference, in phase, between the I/Q reference signal and the I/Q measured signal.</p> <p>The magnitude of this parameter is an indicator of the quality of the phase component of the modulated signal. For example, a very high phase error might indicate high incidental FM modulation on the signal.</p> <p>The phase error shown in the symbol table is computed only at the symbol times (the instant in time when symbols are detected). The computation does not include points between symbols. Therefore, the value of Points/Symbol has no effect on this parameter. The symbol table also shows the symbol that has the largest phase error (the peak phase error).</p>
Freq Error	<p>This parameter shows the carrier frequency-error relative to the analyzer's center frequency. This parameter is displayed in Hertz and is the amount of frequency shift, from the analyzer's center frequency, that the analyzer must perform to achieve carrier lock. SNR(MER) SNR (Digital Demodulation)</p>

SNR (MER) Signal to Noise Ratio (Message Error Rate) is reported for QAM, DVB QAM, QPSK and VSB demodulation formats. It is the signal-to-noise ratio, where signal is the average symbol power of the transmitted waveform, and noise power includes any term that causes the symbol to deviate from its ideal state position, such as additive noise, distortion, and ISI (inter-symbol-interference). The following formula shows how SNR is computed:

$$10 \log \frac{\text{sum N (amplitude at symbol locations)}^2}{\text{sum N (error amplitude at symbol locations)}^2}$$

Another way of looking at SNR is:

$$10 \log \frac{\text{sum N (Real \{IQ reference vector at symbols\})}^2}{\text{sum N (Real \{error vector at symbols\})}^2}$$

IQ Offset IQ Offset (also called I/Q origin offset) indicates the magnitude of the carrier feed through signal. When there is no carrier feed through, IQ offset is zero (-infinity dB).

RHO RHO is reported for QPSK and OQPSK formats. It is similar to error vector magnitude (EVM) and is a measure of the quality of digital modulation. RHO is computed by comparing the normalized correlated power between the measured signal and the reference signal and is designated as the waveform quality factor. The maximum value of RHO is 1.0 (which means the measured signal and reference signal are 100% identical).

A RHO value of 1.0 indicates that all of the transmitted power correlates with the ideal signal as determined by the detected sequence.

For Digital demodulation, RHO is the correlated power of a single channel (for example, the pilot channel in IS-97).

Quad Err Quadrature Skew indicates the orthogonal error between the I and Q signals. Ideally, I and Q should be orthogonal (90 degrees apart). A quadrature skew of 3 degrees means I and Q are 87 degrees (or 93 degrees) apart.

Gain Imb Q Gain Imbalance compares the gain of the I signal with the gain of the Q signal, as follows:

$$\text{IQ Gain I mb} \frac{\text{I Gain}}{\text{Q Gain}}$$

The effects of IQ gain imbalance are best viewed in constellation diagrams, where the width of the constellation diagram is different than its height.

Since gain imbalance is expressed as a logarithmic value, it may be a positive or negative value. The gain imbalance is always positive if averaging is ON and Sync Search is OFF. For non-rectangular formats (such as 8 PSK or pi/4 DQPSK), IQ Gain Imbalance may look like Quadrature Skew, and vice-versa. This occurs when the analyzer is phase locked to an orientation that is different than that of the modulator. To ensure the same phase orientation, use Sync Search. You can also use the digital demod Rotation compensate parameter to swap the IQ Gain Imbalance and Quadrature Skew data results. Figures 19 and 20 are measurements made of the Signal Studio-802.11b packet with different types of filtering applied to the packet.

Figures 18 and 19 are measurements made of the Signal Studio 802.11b packet with different types of filtering applied to the packet.

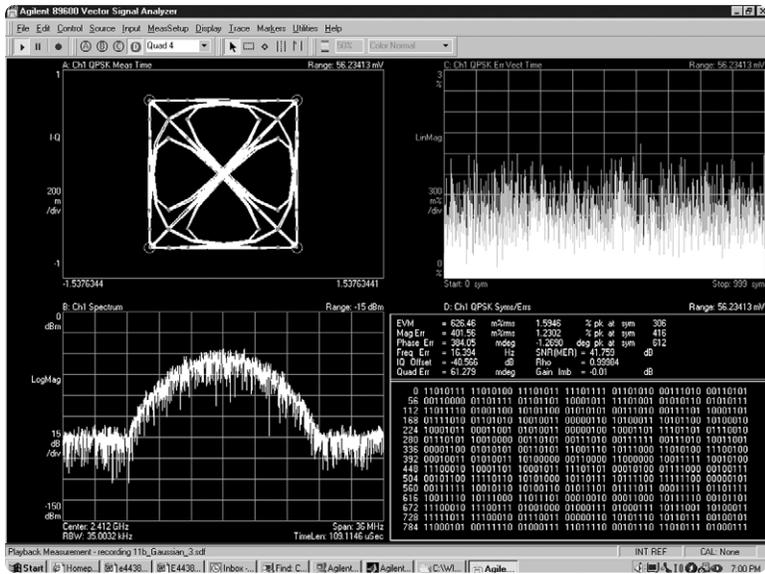


Figure 18. 89640A VSA measurement data of 11 Mbps CCK payload data: Gaussian filtered with B*T of .3

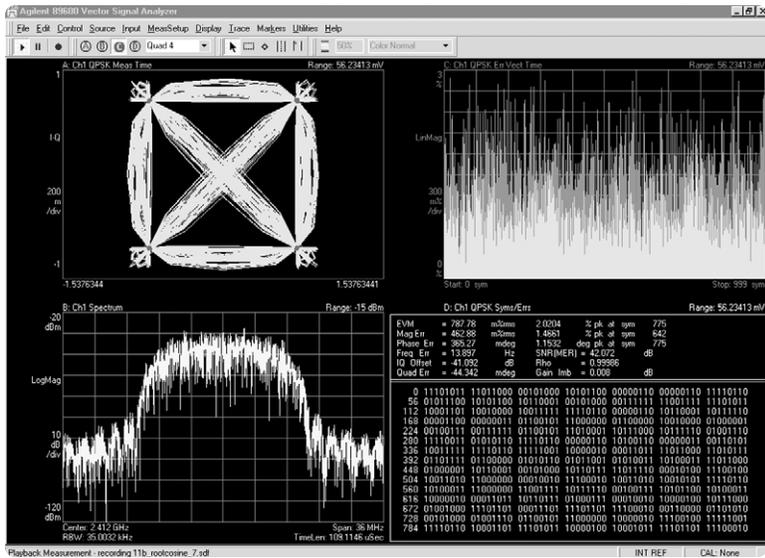


Figure 19. 89640A VSA measurement data of 11 Mbps CCK payload data: root-cosine filtered with an alpha of .7

Data sheet for Signal Studio 802.11b

Framing

- Framed: bursted packets includes a PLCP Preamble (short and long) and Header (Signal field)
- Non-framed: Continuous non-bursted payload data (no PLCP Preamble and Header added to payload)

Baseband filtering

- Rectangle
- Gaussian
 - Alpha range: 0.05-1.0 Sample length: 0-1000
- Root-cosine
 - bT range: 0.1-1.0 Sample length: 0-1000

PBCC encoder Enable/Disable

Modulation formats CCK, PBCC, DBPSK, DQPSK

Data source user file, 1s, 0s, 01s, 10s, PN9, PN15

Data rates 1, 2, 5.5, 11 Mbps

Scrambler Enable/Disable

Data length

Maximum

- 2312 Bytes

Minimum

- 0 Byte

Idle interval between frames Range: 0-1000 microseconds

Power ramping None
Linear
Cosine

Ramp time Range: 0-1000 microseconds

Oversample ratio 1-9

Acronyms and abbreviations

BPSK	binary phase shift keying
CCK	complementary code keying
DBPSK	differential binary phase shift keying
DQPSK	differential quadrature phase shift keying
DSSS	direct sequence spread spectrum
FCS	frame check sequence.
HR/DSSS	high rate direct sequence spread spectrum
I/Q	in-phase/quadrature
IEEE	Institute of Electrical and Electronics Engineers
ITU	International Telecommunication Union
MAC	medium access control
PBCC	packet binary convolutional coding
PHY	physical layer
PLCP	physical layer convergence procedure
PMD	physical medium dependent
PPDU	PLCP protocol data unit
PSDU	PLCP service data unit
RF	radio frequency
SFD	start of frame delimiter
WLAN	wireless LAN

Additional literature

E4438C Signal Studio Installation Guide, 199 kB

Available @ <http://cp.tm.agilent.com/data/downloads/eng/tmo/EP5G089090.pdf>

E4438C Data Sheet, 489 kB

Literature Number 5988-4039EN

E4438C Configuration Guide, 221 kB

Literature Number 5988-4085EN

E4438C Brochure, 5.2 MB

Literature Number 5988-3935EN

ESG Vector Signal Generator User's Guide

Part number E4400-90503

89600 Series Brochure, 1.7MB

Literature Number 5980-0723E

E4440A Data Sheet, 683KB

Literature Number 5980-1284E

RF Testing Wireless LAN Products Application Note, 6.6 MB

Literature Number 5988-3762EN

IEEE 802.11 Receiver Test Guidelines

Wireless Systems Design November 2001 Issue www.wsdmag.com

Characterizing Digitally Modulated Signals with CCDF Curves, 548 kB

Literature Number 5968-6875E

Agilent products for 802.11b WLAN web addresses

- Signal Studio Software for the ESG web site: www.agilent.com/find/signalstudio
 - E4438C ESG Vector Signal Generator web site: www.agilent.com/find/esg
 - PSA Series High-Performance Spectrum Analyzer web site:
www.agilent.com/find/psa
 - 89600 Series Vector Signal Analyzer web site: www.agilent.com/find/89600
 - Advanced Design System E8874a 5 GHz 802.11a WLAN Design Library
<http://contact.tm.agilent.com/tmo/eesof/products/e8874a-a.html>
-

References

IEEE Std 802.11b-1999 Standard

IEEE 802.11 Handbook

By Bob O'Hara and Al Petrick ISBN # -0-7381-1855-9

Ordering information

Signal Studio-802.11b is Option 405 for the Agilent E4438C ESG Vector Signal Generator.

E4438C ESG models

Option 503, 250 kHz to 3 GHz frequency range for the E4438C

The Signal Studio software requires that the ESG is equipped with the optional baseband generator (Option 001 or 002).

Download Signal Studio from www.agilent.com/find/signalstudio to a PC to evaluate the signal configuration and plotting capabilities of the software. However, to load the signal created by the software into the ESG, a license key must be purchased. The license key can be ordered through a sales engineer or local sales office. Contact information for both can be found at <http://www.agilent.com/find/assist>

Upgrade kits

If you already currently own an E4438C ESG Vector Signal Generator and are interested in obtaining an upgrade kit only (license key), order: E4438CK Option 405.

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