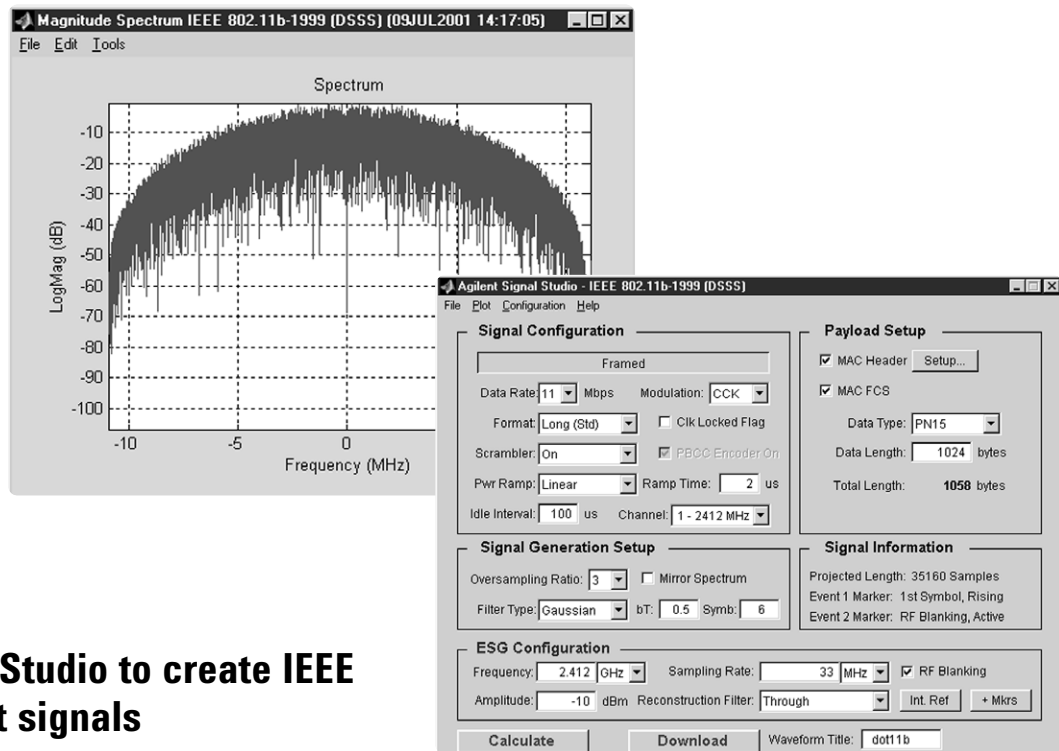


# Agilent Technologies

## Signal Studio-802.11b for the ESG

### Option 405

## Product Note



## Use Signal Studio to create IEEE 802.11b test signals

Signal Studio: 802.11b WLAN software is a powerful tool for creating IEEE 802.11b baseband I/Q waveforms for use with the Agilent ESG digital series signal generator's dual arbitrary waveform generator.

## Main 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 *References* section at the end of this document.

## Table of contents

Software overview .....	3
Benefits .....	4
Signal structure .....	5
PMD layer .....	5
PPDU frame structure .....	5
PPDU frame with long PLCP preamble .....	5
PLCP preamble .....	5
PLCP headers .....	5
PPDU frame with short PLCP preamble .....	6
Payload structure .....	6
Creating signals .....	7
Step 1 – Configure 802.11b signal and MAC header .....	7
Signal configuration .....	7
Payload setup .....	8
Step 2 - Set up the signal generation options .....	8
Signal generation setup .....	8
Oversample ratio .....	8
Filter type .....	9
Mirror spectrum .....	9
Step 3 – Configure the ESG .....	9
Step 4 - Calculate & download .....	10
Step 4a - Calculate .....	11
Step 4b - Download .....	11
Signal Studio configuration and setup .....	12
Basic measurements .....	13
Data sheet for Signal Studio-802.11b .....	14
Acronyms and Abbreviations .....	15
Additional literature .....	15
References .....	15
Ordering information .....	15
Upgrade kits .....	15

## Software overview

Signal Studio-802.11b software is a tool for defining 802.11b frame structures 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 dual arbitrary waveform generator for playback.

Try before you buy! Signal Studio software can be downloaded free of charge for evaluation. A license key is required to load the signals created by the software into the ESG digital series RF Signal Generator. The license key can be ordered through your sales engineer or your local sales office, which can be found at [www.agilent.com/find/assist](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 signal generator over the GPIB or RS-232 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 waveform files can be saved in the ESG dual arbitrary waveform generator non-volatile memory for later recall. If multiple waveforms are being created and ESG non-volatile memory capacity becomes an issue, the Signal Studio-802.11b software configuration can be saved to the host computer's local hard drive. The Signal Studio software configuration can then 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 easily re-calculated from stored settings.

# Benefits

Signal Studio-802.11b simplifies the user's role in creating 802.11b test signals for use with the ESG digital series RF signal generator. 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 by providing statistically correct signals. 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 channel coding is necessary. Full channel coding allows test engineers to determine if each functional stage of a receiver is operating correctly. This level of channel coding enables FER and BER testing on the signal received by the Access Point to verify performance.

The designer will be able to use this as a test signal 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 decodes an independently generated 802.11b test signal correctly.

# Signal structure

## PMD layer

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 1.

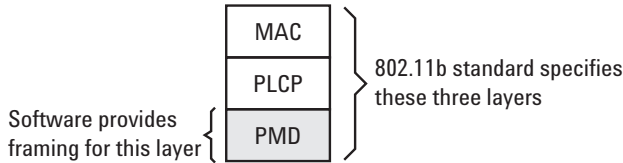


Figure 1. 802.11b standard protocol stack

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, which can be used as trouble shooting tools in design and development, as well as making standards based measurements. To make these measurements, the MAC and PLCP layers are not needed.

The user does have 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 to append to the payload data, see Figures 2 and 3.

## PPDU frame structure

In 802.11b systems, information is transmitted in frames. The total frame length is variable. Signal Studio-802.11b software supports framing for both the long and short preambles, as detailed below in figures 2 and 3.

## 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 header

**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 indicates to the receiver if the carrier and the symbol clock use the same local oscillator. The user can set this bit.

Bit 3 is set to zero if CCK is the modulation, and PBCC is set to one if this is the modulation. The software automatically sets this, 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 automatically 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.

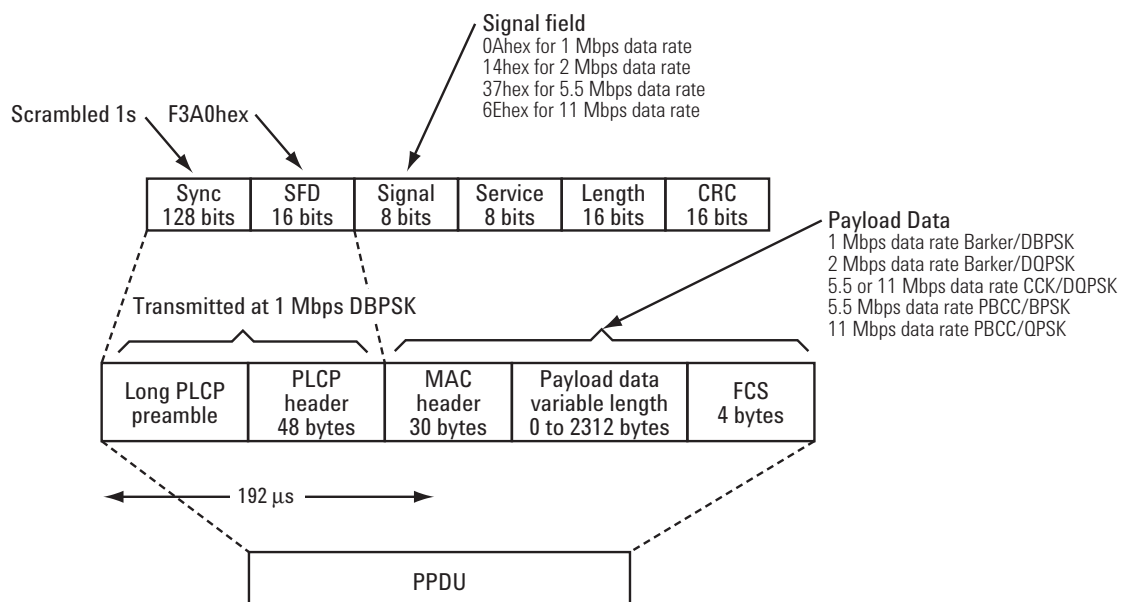


Figure 2. PPDU frame with long preamble

## PPDU frame with short PLCP preamble

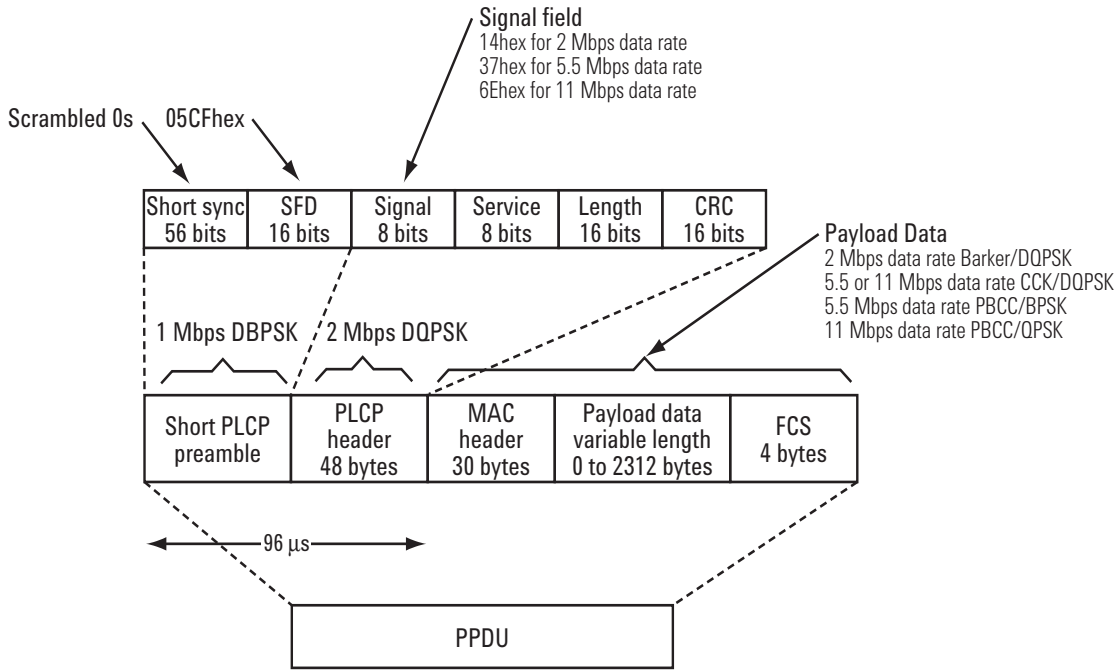


Figure 3. PPDU frame with short preamble

## 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.

Figure 4 is an illustration of the data payload structure. The description and details of each of these fields can be found in the IEEE 802.11 standard. The user has control over all these fields.

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

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

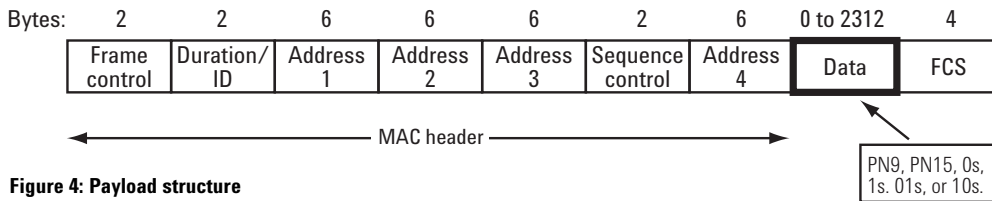


Figure 4: Payload structure

# Creating signals

An 802.11b waveform can be configured and downloaded to the ESG digital series signal generator in four easy steps:

- Step 1** - Configure the 802.11b signal
- Step 2** - Setup the signal generation options
- Step 3** - Configure the ESG
- Step 4** - Calculate & download

## Step 1 Configure 802.11b signal and MAC header

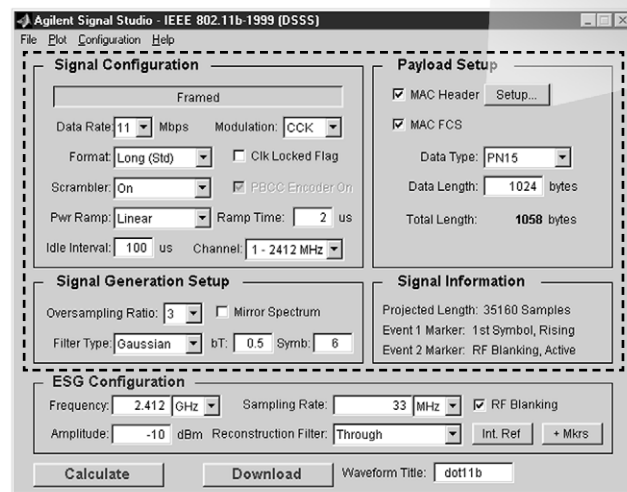


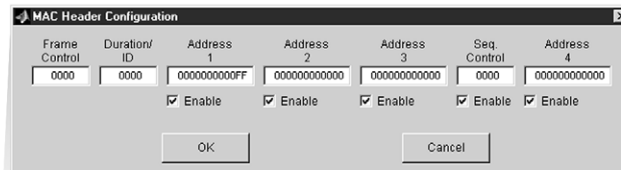
Figure 5. Signal Studio-802.11b signal configuration menu (boxed).

### Signal configuration

This section allows the user to choose specific parameters for the framing of the signal. The user can choose framing, or turn it off. A framed signal is needed in receiver tests, and an unframed signal would be useful in component tests, or other instances where continuous modulation of unframed data is desired.

**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, which are: 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 do not have scrambling set-up, the user can vary this selection for the test signal.

**Clock 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 in 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 have an FCS added to the packet. The maximum data length of the payload is 2312 bytes. Notice that the total length of the entire payload is displayed.

**Setup menu:** Configures the MAC header.

**MAC header:** Enables/disables prepending the MAC header to the data payload. The user can set all these individual fields with the desired data, and the user 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.

**Data type:** Selects the payload data stream. The “actual” user data of the frame, can contain the following data:

- 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 Set up the signal generation options

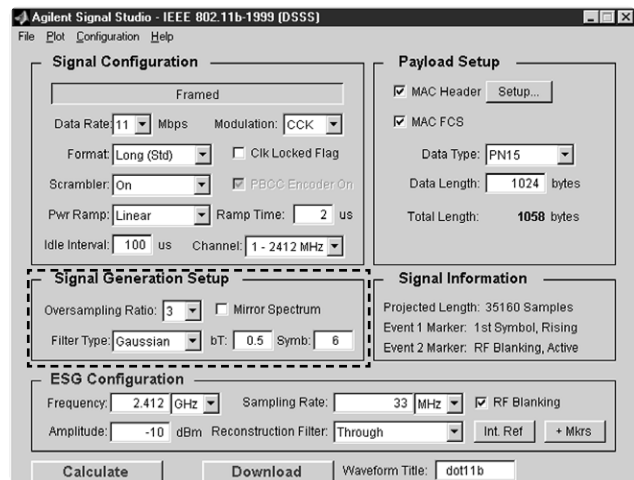


Figure 6. Signal Studio-802.11b signal generation options menu

### Signal generation setup

As illustrated in Figure 6, 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 defines the number of samples calculated per I/Q symbol. Increasing the oversampling ratio of the constructed signal increases the separation of the sampling images from the desired signal. This allows for better image rejection by the baseband reconstruction filters. However, the improved image rejection comes with a price. Increasing the oversampling 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 40 MHz.



The software offers 4 different OSR: 2, 2.5, 3, and 3.5. When an OSR is selected, this automatically sets the Sampling Rate in the ESG Configuration section. For an OSR of 2.5, the signal is up sampled to 5 and decimated every second sample. For an OSR of 3.5, the signal is up sampled to 7, and decimated every second sample. The lower the sample rate, the less space the waveform takes up in memory, and the faster the signal can be generated and downloaded. Notice that when using the reconstruction filters available on the ESG, part of the desired higher frequency components will be cut off. To prevent this from happening, an external reconstruction filter is recommended. When using an external reconstruction filter, set Reconstruction Filter in the ESG Configuration section to Through.

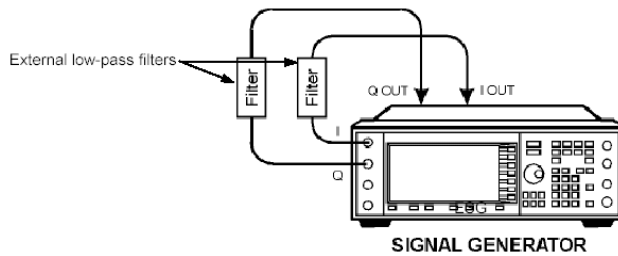


Figure 7. ESG set up with external reconstruction filters

The reconstruction filter should have at least 11 MHz bandwidth to allow the desired signal to pass through, while rejecting the images which occur at multiples of the OSR.

For more information on reconstruction filters and oversample ratios, refer to [4].

### Filter type

A baseband filter is applied to reduce the transmitted bandwidth, increasing spectral efficiency. For signals generated with digital signal processing, These 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. Several different types of FIR filters exist.

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). BbT 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.

## Step 3 Configure the ESG

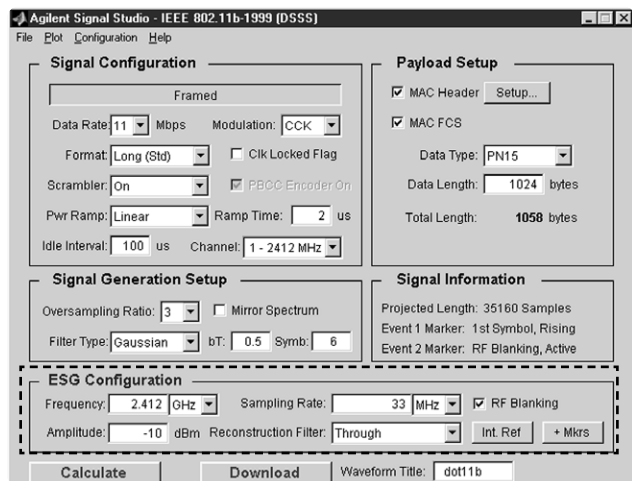


Figure 8: Signal Studio-802.11b signal generation ESG menu

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 Parameters	
Frequency	Defines the frequency at which the ESG will generate the signal.
Reconstruction	Defines the power at which the ESG will generate the signal.
Sampling Rate	This parameter is automatically set when the over sampling ratio is defined in the Signal Generation Options menu. It is the rate at which the waveform I/Q samples are read from the dual arbitrary waveform generator memory during playback.
Reconstruction Filter	The ESG provides three reconstruction filters (250kHz, 2.5MHz, 8MHz) and a no filter option (through). The bandwidth of the baseband signal dictates the minimum reconstruction filter bandwidth to be used. Depending on the over sampling ratio and where the image frequencies appear, a wider bandwidth reconstruction filter may be selected. For more information on reconstruction filters refer to [4].
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. <i>Note:</i> When RF Blanking is enabled, the Marker Polarity must be set to positive or the wanted RF signal will be blanked resulting in no RF output from the ESG.
Internal/External Reference Frequency	Toggles between INT REF/EXT REF and sets reference frequency for The dual arbitrary base band generator to internal or external. If an external reference is used, it should be connected to the ESG before the waveform and instrument settings are downloaded to the instrument.
Marker Polarity	Toggles between positive/negative and sets the polarity of the Event 1 and Event 2 markers. When RF Blanking is activated, the Event 2 marker is internally routed to provide access to the RF Blanking signal. Access to these signals is provided on the Event 1 and Event 2 ports on the rear panel of the ESG.

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

## Step 4 Calculate and download

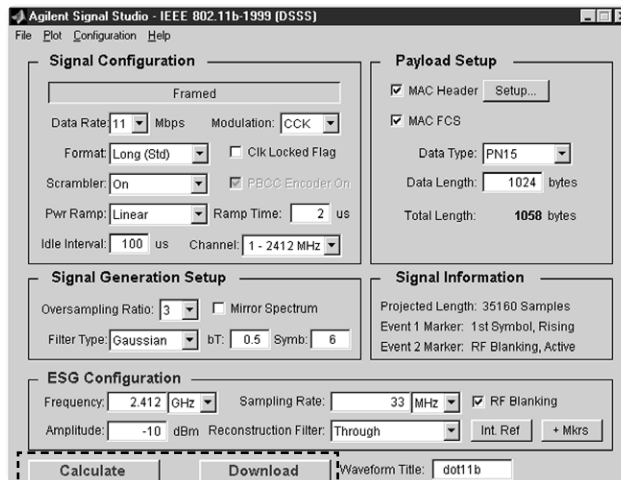


Figure 9. Signal Studio-802.11b calculate and download menu

After 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

Select the Calculate button. The software will generate an I/Q waveform file in accordance with the current channel and signal generation options configuration. Waveform calculation typically takes only a few seconds.

After the I/Q waveform has been calculated, the Signal Studio software can generate a plot of the spectrum. From the menu keys at the top of the window, choose Plot & Spectrum (Figure 10).

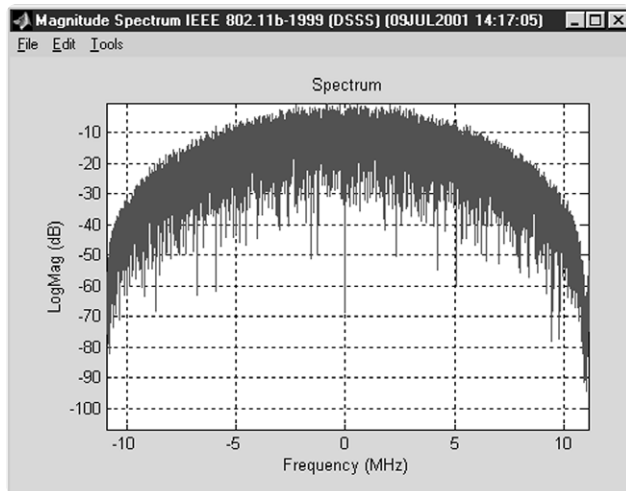


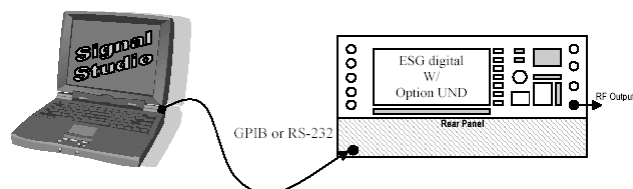
Figure 10. Signal Studio: 802.11b Plotted Spectrum

## Step 4b Download

Select Download button (Figure 9) to send the calculated I/Q waveform file representing the 802.11b and the signal generator setting 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.

## 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**

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 10, 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.

The waveform files can be saved in the ESG-D dual arbitrary waveform generator non-volatile memory for later recall.

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, refer to the *ESG Family Signal Generator Option UND Dual Arbitrary Waveform Generator Users and Programming Guide*. The I/Q waveform files created by the Signal Studio software cannot be stored outside the instrument.

# Basic measurements

## Required equipment:

E443xB ESG-D/DP Series RF Signal Generator.  
(x=0 through 7).

Arbitrary Waveform Generator, Option UND  
Signal Studio: 802.11b, Option 405 License Key  
89600 Series Vector Signal Analyzer.

The following measurements were made with the Agilent 89640A VSA.

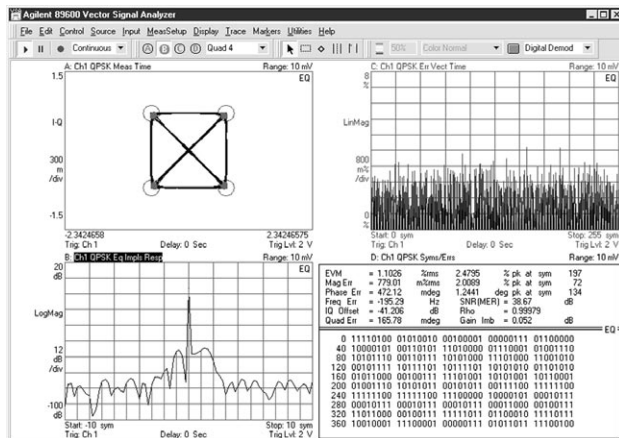


Figure 12. 89640A VSA measurement data of 11 Mbps CCK payload data with MAC header and FCS

Figure 12 is split into four quadrants. The upper left measurement shows the constellation diagram of the payload data, which is QPSK modulated. The upper right quadrant displays the EVM versus symbol time. The lower left quadrant shows the impulse response created by the adaptive equalizer. The lower right quadrant is displaying EVM (error vector magnitude), as well as other error statistics. The demodulated bits are also displayed.

**Note:** the 89640 does not calculate the EVM as defined in the 802.11b specifications. According to the 802.11b specifications, there is an attempt to properly scale the measured data and to remove carrier leakage terms before computing EVM. These parameters are not orthogonal, and therefore must be simultaneously estimated, or at least iterated for minimum EVM. The 89640A does not perform any estimation or iteration on 802.11b signals.

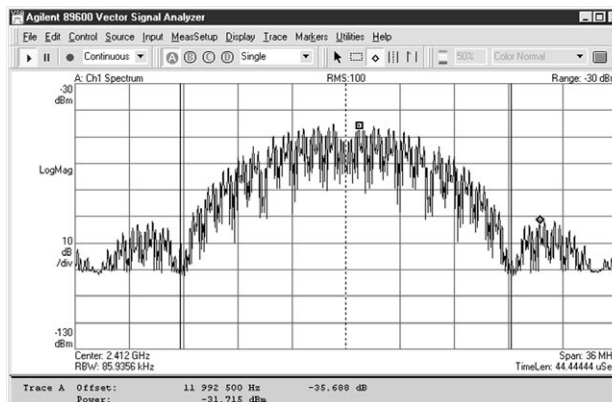


Figure 13. 89640A VSA 802.11b Spectrum

Figure 13 shows the 802.11b spectrum. To meet the IEEE 802.11b specifications, the signal must be -30 dBc at  $f_c \pm 11$  MHz. Notice that the above signal does meet these specifications.

The IEEE 802.11b specifications require that the signal must be -30 dBc at  $f_c \pm 11$  MHz and -50 dBc at  $f_c \pm 22$  MHz. When the span is changed, it is apparent that the signal does not meet the specifications of being -50 dBc at  $> \pm 22$  MHz as called out in the specification. The signal was not filtered with an external reconstruction filter. To reject the undesired higher frequency components, it is recommended to use an external reconstruction filter.

## Data sheet for Signal Studio-802.11b

Framing	<ul style="list-style-type: none"><li>• Framed: bursted packets includes a PLCP Preamble (short and long) and Header (Signal field)</li><li>• Non-framed: Continuous non-bursted payload data (no PLCP Preamble and Header added to payload)</li></ul>
Baseband	• Rectangle
Filter	<ul style="list-style-type: none"><li>• Gaussian<ul style="list-style-type: none"><li>• Alpha range: 0.05-1.0    Sample length: 0-1000</li><li>• Root-cosine</li><li>• bT range: 0.1-1.0        Sample length: 0-1000</li></ul></li></ul> Enable/Disable CCK, PBCC, DBPSK, DQPSK
Data source	1s, 0s, 01s, 10s, PN9, PN15
Data rates	1,2,5,5, 11 Mbps
Scrambler:	Enable/Disable
Data length	Maximum <ul style="list-style-type: none"><li>• 2312 Bytes</li></ul> Minimum <ul style="list-style-type: none"><li>• 0 Byte</li></ul>
Idle interval between frames	Range: 0-1000 microseconds
Power ramping	None Linear Cosine
Ramp time	Range: 0-1000 microseconds
Oversample ratio	2,2.5,3,3.5

## Acronyms and abbreviations

BPSK	binary phase shift keying
CCK	Complementary Code Keying
DA	destination address
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
MAC	medium access control
PBCC	packet binary convolutional coding
PHY	physical, physical layer
PLCP	physical layer convergence procedure
PMD	physical medium dependent
PPDU PLCP	protocol data unit
PSDU PLCP	service data unit
RF	radio frequency
SA	source address
SFD	start of frame delimiter
WLAN	wireless LAN

## Additional literature

- [1] *Signal Studio Installation Guide*  
Available at: [www.agilent.com/find/signal\\_studio](http://www.agilent.com/find/signal_studio)
- [2] *Agilent ESG Family of RF Signal Generators*,  
Data Sheet. Literature number 5965-3096E
- [3] *Agilent ESG Family/RF Signal Generators*  
Configuration Guide. Literature number 5965-4973E
- [4] *Generating Digital Modulation with the Agilent ESG-D Series Dual Arbitrary Waveform Generator*,  
Literature number 5966-4097E

## 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 (455) for the Agilent ESG Digital Series RF signal generators.

### ESG digital: standard models

E4430B	ESG digital series RF signal generator, 1 GHz
E4431B	ESG digital series RF signal generator, 2 GHz
E4432B	ESG digital series RF signal generator, 3 GHz
E4433B	ESG digital series RF signal generator, 4 GHz

### ESG digital: High spectral purity models

E4434B	ESG digital High Spectral Purity series RF signal generator, 1 GHz
E4435B	ESG digital High Spectral Purity series RF signal generator, 2 GHz
E4436B	ESG digital High Spectral Purity series RF signal generator, 3 GHz
E4437B	ESG digital High Spectral Purity series RF signal generator, 4 GHz

The Signal Studio software requires that the ESG is equipped with the optional dual arbitrary waveform generator (Option UND). Firmware Revision B.03.75 is required to activate the License Key on the ESG-signal generator.

Try before you buy! Download the software free of charge for evaluation by visiting [www.agilent.com/find/signal\\_studio](http://www.agilent.com/find/signal_studio) 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 [www.agilent.com/find/assist](http://www.agilent.com/find/assist).

## Upgrade Kits

If you currently own an ESG and are interested in obtaining an upgrade kit only (license key) for that ESG, order: E443xB Option 455 (x=0 thru 7, choose the instrument you own).

### **Agilent Technologies' Test and Measurement Support, Services, and Assistance**

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