Agilent Technologies

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WLAN Wireless Test Benches

Acknowledgments

Errata The ADS product may contain references to "HP" or "HPEESOF" such as in file names and directory names. The business entity formerly known as "HP EEsof" is now part of Agilent Technologies and is known as "Agilent EEsof". To avoid broken functionality and to maintain backward compatibility for our customers, we did not change all the names and labels that contain "HP" or "HPEESOF" references.

Measurement Results for Expressions for WLAN Wireless Test Benches

Measurement results from a wireless test bench have associated names that can be used in Expressions. Those expressions can further be used in specifying goals for Optimization and Monte Carlo/Yield analysis. For details on using expressions, see the *Measurement Expressions* (expmeas) documentation. For details on setting analysis goals using Optimization and Monte Carlo/Yield analysis, see *Tuning, Optimization, and Statistical Design* (optstat) documentation.

You can use an expression to determine the measurement result independent variable name and its minimum and maximum values. The following example expressions show how to obtain these measurement details where MeasResults is the name of the measurement result of interest:

- The *Independent Variable Name* for this measurement result is obtained by using the expression
  `indep(MeasResults)`
- The *Minimum Independent Variable Value* for this measurement result is obtained by using the expression
  `min(indep(MeasResults))`
- The *Maximum Independent Variable Value* for this measurement result is obtained by using the expression
  `max(indep(MeasResults))`

The following five tables list the measurement result names and independent variable name for each test bench measurement. Expressions defined in a MeasEqn block must use the full *Measurement Results Name* listed. Expressions used in the Data Display may omit the leading test bench name. You can also locate details on the measurement result minimum and maximum independent variable values by

- Referring to the measurement parameter descriptions when they are available (not all measurement parameter descriptions identify these minimum and maximum values).
- Observing the minimum and maximum independent variable values in the Data Display for the measurement.

WLAN_802_11a_TX Measurement Results

Measurement Results Name	Independent Variable Name
Envelope	
WLAN_802_11a_TX.RF_V	time
WLAN_802_11a_TX.Meas_V	time
Constellation	
WLAN_802_11a_TX.RF_Constellation.BPSKConstellation	Index
WLAN_802_11a_TX.RF_Constellation.Constellation	Index
WLAN_802_11a_TX.RF_Constellation.QAMConstellation	Index
WLAN_802_11a_TX.Meas_Constellation.BPSKConstellation	Index
WLAN_802_11a_TX.Meas_Constellation.Constellation	Index
WLAN_802_11a_TX.Meas_Constellation.QAMConstellation	Index
Power	
WLAN_802_11a_TX.RF_Power.AvgPower_dBm	Index
WLAN_802_11a_TX.RF_Power.CCDF	Index
WLAN_802_11a_TX.RF_Power.PeakPower_dBm	Index
WLAN_802_11a_TX.RF_Power.SignalRange_dB	Index
WLAN_802_11a_TX.Meas_Power.AvgPower_dBm	Index
WLAN_802_11a_TX.Meas_Power.CCDF	Index
WLAN_802_11a_TX.Meas_Power.PeakPower_dBm	Index
WLAN_802_11a_TX.Meas_Power.SignalRange_dB	Index
Spectrum	
WLAN_802_11a_TX.RF_Spectrum	freq
WLAN_802_11a_TX.Meas_Spectrum	freq
EVM	
WLAN_802_11a_TX.RF_EVM.CPErms_percent	Index
WLAN_802_11a_TX.RF_EVM.EVMrms_percent	Index
WLAN_802_11a_TX.RF_EVM.EVM_dB	Index
WLAN_802_11a_TX.RF_EVM.IQ_Offset_dB	Index
WLAN_802_11a_TX.RF_EVM.PilotEVM_dB	Index
WLAN_802_11a_TX.RF_EVM.SyncCorrelation	Index
WLAN_802_11a_TX.Meas_EVM.CPErms_percent	Index
WLAN_802_11a_TX.Meas_EVM.EVMrms_percent	Index
WLAN_802_11a_TX.Meas_EVM.EVM_dB	Index
WLAN_802_11a_TX.Meas_EVM.IQ_Offset_dB	Index
WLAN_802_11a_TX.Meas_EVM.PilotEVM_dB	Index
WLAN_802_11a_TX.Meas_EVM.SyncCorrelation	Index

WLAN_802_11b_TX Measurement Results

Measurement Results Name	**Independent Variable Name**
Envelope	
WLAN_802_11b_TX.RF_V	time
WLAN_802_11b_TX.Meas_V	time
Constellation	
WLAN_802_11b_TX.RF_Constellation.Header_Constellation	Index
WLAN_802_11b_TX.RF_Constellation.Preamble_Constellation	Index
WLAN_802_11b_TX.RF_Constellation.PSDU_Constellation	Index
WLAN_802_11b_TX.Meas_Constellation.Header_Constellation	Index
WLAN_802_11b_TX.Meas_Constellation.Preamble_Constellation	Index
WLAN_802_11b_TX.Meas_Constellation.PSDU_Constellation	Index
Power	
WLAN_802_11b_TX.RF_Power.AvgPower_dBm	Index
WLAN_802_11b_TX.RF_Power.CCDF	Index
WLAN_802_11b_TX.RF_Power.PeakPower_dBm	Index
WLAN_802_11b_TX.RF_Power.SignalRange_dB	Index
WLAN_802_11b_TX.Meas_Power.AvgPower_dBm	Index
WLAN_802_11b_TX.Meas_Power.CCDF	Index
WLAN_802_11b_TX.Meas_Power.PeakPower_dBm	Index
WLAN_802_11b_TX.Meas_Power.SignalRange_dB	Index
Spectrum	
WLAN_802_11b_TX.RF_Spectrum	freq
WLAN_802_11b_TX.Meas_Spectrum	freq
EVM	
WLAN_802_11b_TX.RF_EVM.Avg_EVMrms_pct	Index
WLAN_802_11b_TX.RF_EVM.Avg_FreqError_Hz	Index
WLAN_802_11b_TX.RF_EVM.Avg_IQ_Offset_dB	Index
WLAN_802_11b_TX.RF_EVM.Avg_MagErr_rms_pct	Index
WLAN_802_11b_TX.RF_EVM.Avg_PhaseErr_deg	Index
WLAN_802_11b_TX.RF_EVM.SyncCorrelation	Index
WLAN_802_11b_TX.RF_EVM.Avg_WLAN_80211b_1000_chip_Pk_EVM_pct	Index
WLAN_802_11b_TX.RF_EVM.EVMrms_pct	Index
WLAN_802_11b_TX.RF_EVM.EVM_Pk_chip_idx	Index
WLAN_802_11b_TX.RF_EVM.EVM_Pk_pct	Index
WLAN_802_11b_TX.RF_EVM.FreqError_Hz	Index
WLAN_802_11b_TX.RF_EVM.IQ_Offset_dB	Index
WLAN_802_11b_TX.RF_EVM.MagErr_Pk_chip_idx	Index
WLAN_802_11b_TX.RF_EVM.MagErr_Pk_pct	Index
WLAN_802_11b_TX.RF_EVM.MagErr_rms_pct	Index
WLAN_802_11b_TX.RF_EVM.PhaseErr_deg	Index

WLAN_802_11b_TX.RF_EVM.PhaseErr_Pk_chip_idx	Index
WLAN_802_11b_TX.RF_EVM.PhaseErr_Pk_deg	Index
WLAN_802_11b_TX.RF_EVM.SyncCorrelation	Index
WLAN_802_11b_TX.RF_EVM.WLAN_80211b_1000_chip_Pk_EVM_pct	Index
WLAN_802_11b_TX.Meas_EVM.Avg_EVMrms_pct	Index
WLAN_802_11b_TX.Meas_EVM.Avg_FreqError_Hz	Index
WLAN_802_11b_TX.Meas_EVM.Avg_IQ_Offset_dB	Index
WLAN_802_11b_TX.Meas_EVM.Avg_MagErr_rms_pct	Index
WLAN_802_11b_TX.Meas_EVM.Avg_PhaseErr_deg	Index
WLAN_802_11b_TX.Meas_EVM.SyncCorrelation	Index
WLAN_802_11b_TX.Meas_EVM.Avg_WLAN_80211b_1000_chip_Pk_EVM_pct	Index
WLAN_802_11b_TX.Meas_EVM.EVMrms_pct	Index
WLAN_802_11b_TX.Meas_EVM.EVM_Pk_chip_idx	Index
WLAN_802_11b_TX.Meas_EVM.EVM_Pk_pct	Index
WLAN_802_11b_TX.Meas_EVM.FreqError_Hz	Index
WLAN_802_11b_TX.Meas_EVM.IQ_Offset_dB	Index
WLAN_802_11b_TX.Meas_EVM.MagErr_Pk_chip_idx	Index
WLAN_802_11b_TX.Meas_EVM.MagErr_Pk_pct	Index
WLAN_802_11b_TX.Meas_EVM.MagErr_rms_pct	Index
WLAN_802_11b_TX.Meas_EVM.PhaseErr_deg	Index
WLAN_802_11b_TX.Meas_EVM.PhaseErr_Pk_chip_idx	Index
WLAN_802_11b_TX.Meas_EVM.PhaseErr_Pk_deg	Index
WLAN_802_11b_TX.Meas_EVM.SyncCorrelation	Index
WLAN_802_11b_TX.Meas_EVM.WLAN_80211b_1000_chip_Pk_EVM_pct	Index

WLAN_802_11a_RX_Sensitivity Measurement Results

Measurement Results Name	Independent Variable Name
RX Sensitivity	
WLAN_802_11a_RX_Sensitivity.Meas_BERPRER.BER	Index
WLAN_802_11a_RX_Sensitivity.Meas_BERPRER.PER	Index

WLAN_802_11b_RX_Sensitivity Measurement Results

Measurement Results Name	Independent Variable Name
RX ACR	
WLAN_802_11b_RX_Sensitivity.Meas_BERPRER.BER	Index
WLAN_802_11b_RX_Sensitivity.Meas_BERPRER.PER	Index

WLAN_802_11a_RX_ACR Measurement Results

Measurement Results Name	Independent Variable Name
RX ACR	
WLAN_802_11a_RX_ACR.Meas_BERPRER.BER	Index
WLAN_802_11a_RX_ACR.Meas_BERPRER.PER	Index

RF DUT Limitations for WLAN Wireless Test Benches

This section describes test bench use with typical RF DUTs, improving test bench performance when certain RF DUT types are used, and improving simulation fidelity. Two sections regarding special attention for Spectum and EVM transmission measurements is also included.

The RF DUT, in general, may be a circuit design with any combination and quantity of analog and RF components, transistors, resistors, capacitors, etc. suitable for simulation with the Agilent Circuit Envelope simulator. More complex RF circuits will take more time to simulate and will consume more memory.

Test bench simulation time and memory requirements can be considered to be the combination of the requirements for the baseline test bench measurement with the simplest RF circuit plus the requirements for a Circuit Envelope simulation for the RF DUT of interest.

An RF DUT connected to a wireless test bench can generally be used with the test bench to perform default measurements by setting the test bench *Required Parameters*. Default measurement parameter settings can be used (exceptions described below), for a typical RF DUT that:

- Requires an input (RF) signal with constant RF carrier frequency.
  The test bench RF signal source output does not produce an RF signal whose RF carrier frequency varies with time. However, the test bench will support an output (RF) signal that contains RF carrier phase and frequency modulation as can be represented with suitable I and Q envelope variations on a constant RF carrier frequency.
- Produces an output (Meas) signal with constant RF carrier frequency.
  The test bench input (Meas) signal must not contain a carrier frequency whose frequency varies with time. However, the test bench will support an input (Meas) signal that contains RF carrier phase noise or contains time varying Doppler shifts of the RF carrier. These signal perturbations are expected to be represented with suitable I and Q envelope variations on a constant RF carrier frequency.
- Requires an input (RF) signal from a signal generator with a 50-ohm source resistance. Otherwise, set the SourceR parameter value in the *Basic Parameters* tab.
- Requires an input (RF) signal with no additive thermal noise (TX test benches) or source resistor temperature set to 16.85^{o}C (RX test benches). Otherwise, set the SourceTemp (TX and RX test benches) and EnableSourceNoise (TX test benches) parameters in the *Basic Parameters* tab.
- Requires an input (RF) signal with no spectrum mirroring. Otherwise, set the MirrorSourceSpectrum parameter value in the *Basic Parameters* tab.
- Produces an output (Meas) signal that requires a 50-ohm external load resistance. Otherwise, set the MeasR parameter value in the *Basic Parameters* tab.
- Produces an output (Meas) signal with no spectrum mirroring. Otherwise, set the MirrorMeasSpectrum parameter value in the *Basic Parameters* tab.
- Relies on the test bench for any measurement-related bandpass signal filtering of the RF DUT output (Meas) signal.
  - When the RF DUT contains a bandpass filter with bandwidth that is on the order

of the test bench receiver system (~1 times the test bench receiver bandwidth) and the user wants a complete characterization of the RF DUT filter, the default time CE_TimeStep must be set smaller.
    - When the RF DUT bandpass filter is much wider than the test bench receiver system (>2 times the test bench receiver bandwidth), the user may not want to use the smaller CE_TimeStep time step to fully characterize it because the user knows the RF DUT bandpass filter has little or no effect in the modulation bandwidth in this case.

Improving Test Bench Performance

This section provides information regarding improving test bench performance when certain RF DUT types are used.

- Analog/RF models (TimeDelay and all transmission line models) used with Circuit Envelope simulation that perform linear interpolation on time domain waveforms for modeling time delay characteristics that are not an integer number of CE_TimeStep units. Degradation is likely in some measurements, especially EVM.
  This limitation is due to the linear interpolation between two successive simulation time points, which degrades waveform quality and adversely affects EVM measurements.
  To avoid this kind of simulator-induced waveform quality degradation: avoid use of Analog/RF models that rely on linear interpolation on time domain characteristics; or, reduce the test bench CE_TimeStep time step by a factor of 4 below the default CE_TimeStep (simulation time will be 4 times longer).
- Analog/RF lumped components (R, L, C) used to provide bandpass filtering with a bandwidth as small as the wireless signal RF information bandwidth are likely to cause degradation in some measurements, especially Spectrum. These circuit filters require much smaller CE_TimeStep values than would otherwise be required for RF DUT circuits with broader bandwidths.
  This limitation is due to the smaller Circuit Envelope simulation time steps required to resolve the differential equations for the L, C components when narrow RF bandwidths are involved. Larger time steps degrade the resolution of the simulated bandpass filtering effects and do not result in accurate frequency domain measurements, especially Spectrum and EVM measurements (when the wireless technology is sensitive to frequency domain distortions).
  To determine that your lumped component bandwidth filter requires smaller CE_TimeStep, first characterize your filter with Harmonic Balance simulations over the modulation bandwidth of interest centered at the carrier frequency of interest. Though it is difficult to identify an exact guideline on the Circuit Envelope time step required for good filter resolution, a reasonable rule is to set the CE_TimeStep to 1/(double-sided 3dB bandwidth)/32.
  To avoid this kind of simulator-induced waveform quality degradation, avoid the use of R, L, C lumped filters with bandwidths as narrow as the RF signal information bandwidth, or reduce the CE_TimeStep.
- Analog/RF data-based models (such as S-parameters and noise parameters in S2P data files) used to provide RF bandpass filtering with a bandwidth as small as 1.5 times the wireless signal RF information bandwidth are likely to cause degradation in some measurements, especially EVM.
  This limitation is due to causal S-parameter data about the signal carrier frequency

requiring a sufficient number of frequency points within the modulation bandwidth; otherwise, the simulated data may cause degraded signal waveform quality. In general, there should be more than 20 frequency points in the modulation bandwidth; more is required if the filter that the S-parameter data represents has fine-grain variations at small frequency steps.
To avoid this kind of simulator-induced waveform quality degradation, avoid the use of data-based models with bandwidths as narrow as the RF signal information bandwidth, or increase the number of frequency points in the data file within the modulation bandwidth and possibly also reduce the CE_TimeStep simulation time step.
- An additional limitation exists when noise data is included in the data file. Circuit Envelope simulation technology does not provide frequency-dependent noise within the modulation bandwidth for this specific case when noise is from a frequency domain data file. This may result in output noise power that is larger than expected; if the noise power is large enough, it may cause degraded signal waveform quality. To avoid this kind of simulator-induced waveform quality degradation avoid the use of noise data in the data-based models or use an alternate noise model.

Improving Simulation Fidelity

Some RF circuits will provide better Circuit Envelope simulation fidelity if the CE_TimeStep is reduced.

- In general, the default setting of the test bench OversamplingRatio provides adequate wireless signal definition and provides the WTB_TimeStep default value.
- Set CE_TimeStep = 1/Bandwidth/OversampingRatio/N
  where N is an integer ≥ 1
- When CE_TimeStep is less than the WTB_TimeStep (i.e., N>1), the RF signal to the RF DUT is automatically upsampled from the WTB_TimeStep and the RF DUT output signal is automatically downsampled back to the WTB_TimeStep. This sampling introduces a time delay to the RF DUT of 10×WTB_TimeStep and a time delay of the measured RF DUT output signal of 20×WTB_TimeStep relative to the measured RF signal sent to the RF DUT prior to its upsampling.

Special Attention for Spectrum Measurements

The Spectrum Measurement spectrum may have a mask against which the spectrum must be lower in order to pass the wireless specification. The Spectrum measurement itself is based on DSP algorithms that result in as much as 15 dB low-level spectrum variation at frequencies far from the carrier.

To reduce this low-level spectrum variation, a moving average can be applied to the spectrum using the moving_average(<data>, 20) measurement expression for a 20-point moving average. This will give a better indication of whether the measured signal meets the low-level spectrum mask specification at frequencies far from the carrier.

Special Attention for EVM Measurements

For the EVM measurement, the user can specify a start time. The EVM for the initial wireless segment may be unusually high (due to signal startup transient effects or other reasons) that cause a mis-detected first frame that the user does not want included in the RF DUT EVM measurement.

To remove the degraded initial burst EVM values from the RF DUT EVM measurement, set the EVM_Start to a value greater than or equal to the RF DUT time delay characteristic.

WLAN 802.11a Transmitter Test

Introduction

The WLAN_802_11a_TX transmitter test bench (user equipment to base station) provides a way for users to connect to an RF circuit device under test (RF DUT) and determine its performance by activating various test bench measurements. This test bench provides signal measurements for RF envelope, signal power (including CCDF), constellation, spectrum, and EVM.

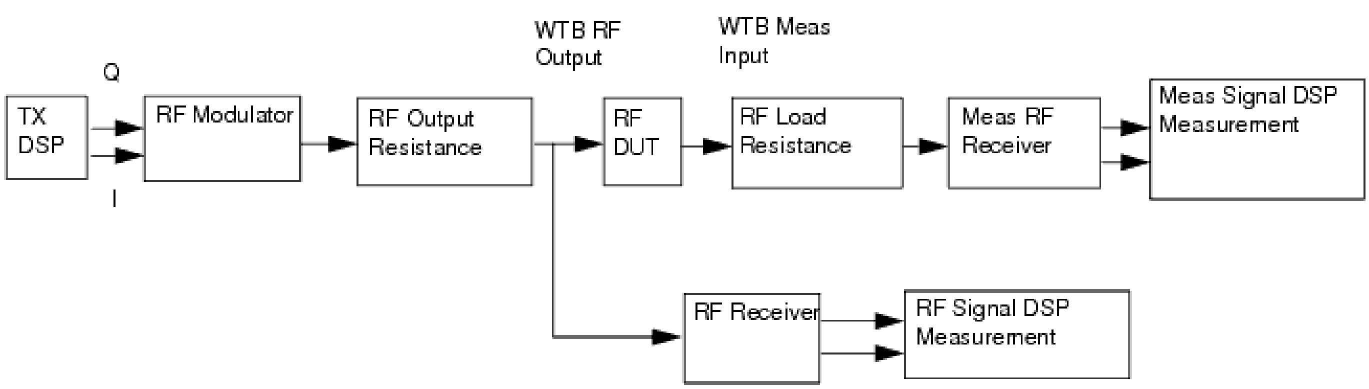
The signal and most of the measurements are designed according to IEEE Standard 802.11a-1999.

This WLAN signal source model is compatible with the Agilent Signal Studio Software option 417 for transmitter test. Details regarding Signal Studio for WLAN 802.11 are included at the website http://www.agilent.com/find/signalstudio .

The RF DUT output signal can be sent to an Agilent ESG RF signal generator.

This test bench includes a DSP section, an RF modulator, RF output source resistance, RF DUT connection, RF receivers, and DSP measurement blocks, as illustrated in the following figure. The generated test signal is sent to the DUT.

Transmitter Wireless Test Bench Block Diagram

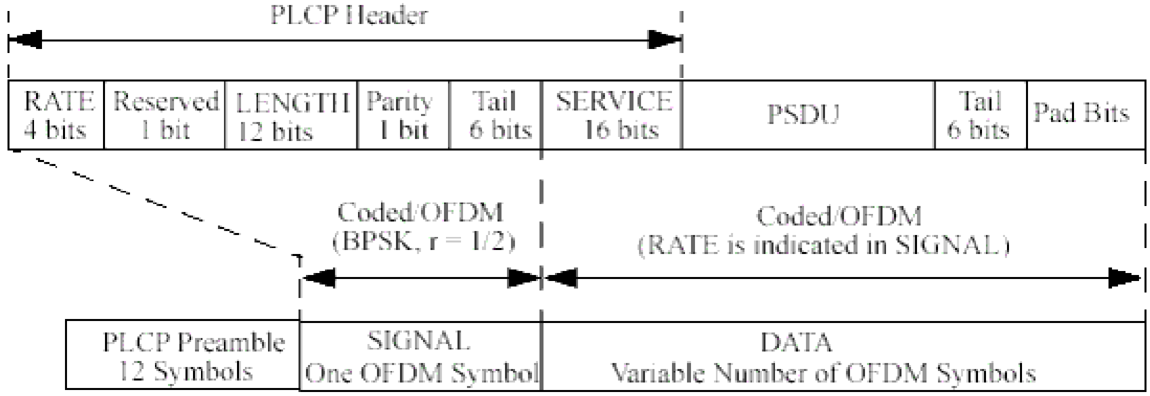


The WLAN 802.11a/g signal burst structure is illustrated in 802.11a/g Burst Structure and OFDM Training Structure. Each burst, separated by an IdleInterval, is composed of the Short Preamble, Long Preamble, SIGNAL, and DATA fields. (In 802.11a/g Burst Structure and OFDM Training Structure, PLCP means *physical layer convergence procedure* , PSDU means *PLCP service data units* , GI means *guard interval* ; GI is set to 0.25 and Bandwidth is set to 20 MHz (resulting in OFDM_SymbolTime = 4 μ).

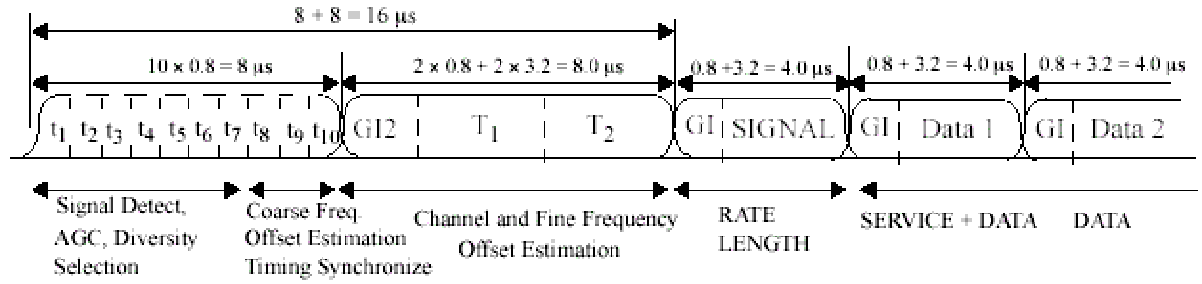
- Short Preamble consists of 10 short preambles (8 μ).
- Long Preamble consists of 2 long preambles (8 μ). The two preamble fields combined compose the PLCP Preamble that has a constant time duration (16 μ) for all source parameter settings.
- SIGNAL includes 802.11a/g bursts of information (such as data rate, payload data, and length).
- DATA contains payload data.

Channel coding, interleaving, mapping and IFFT processes are also included in SIGNAL and DATA parts generation. The SIGNAL field and each individual Data field (part of the overall DATA field) have a time duration defined as OFDM_SymbolTime and includes a GuardInterval. OFDM _SymbolTime depends on the Bandwidth (=64/Bandwidth).

802.11a/g Burst Structure

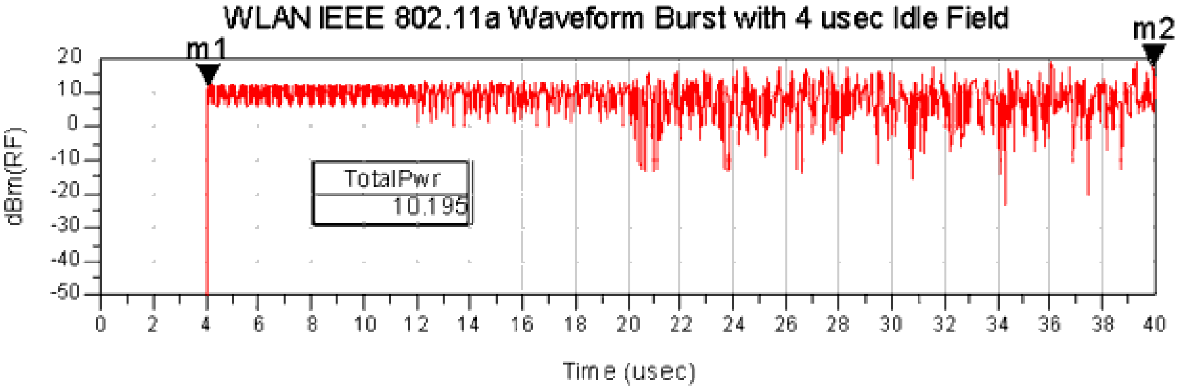


OFDM Training Structure



WLAN RF power delivered into a matched load is the average power delivered in the WLAN burst excluding the burst idle time. The following figure shows the RF envelope for an output RF signal with 10 dBm power.

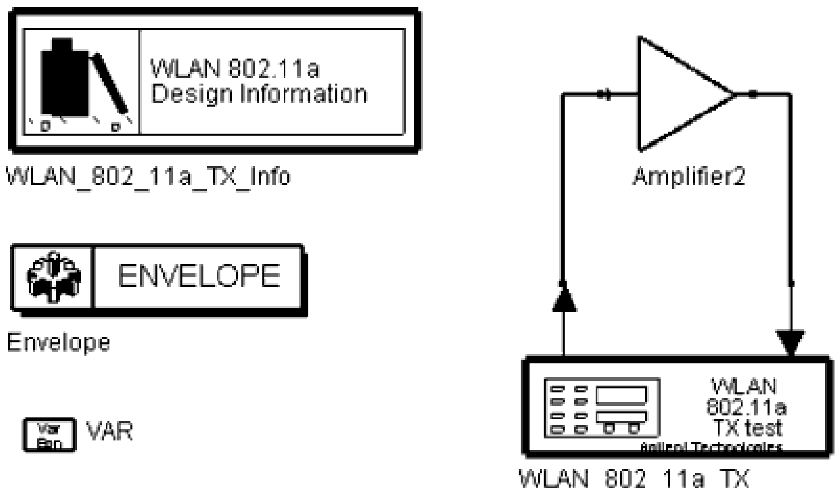
RF Signal Envelope


WLAN IEEE 802.11a Waveform Burst with 4 usec Idle Field
m1
m2
20
10
0
-10
-20
-30
-40
-50
dBm(RF)
TotalPwr
10.195
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
Time (usec)

Test Bench Basics

A template is provided for this test bench.

WLAN 802.11a Transmitter Test Bench



To access the template:

1. In an Analog/RF schematic window select *Insert* > *Template.*
2. In the *Insert* > *Template* dialog box, choose *WLAN_802_11a_TX_test* , click *OK* ; click left to place the template in the schematic window.

An example design using this template is available; from the ADS Main window click *File* > *Open* > *Example* > WLAN > WLAN_RF_Verification_wrk > *WLAN_802_11a_TX_test* .

The basics for using the test bench are:

- Replace the DUT (Amplifier2 is provided with this template) with an RF DUT that is suitable for this test bench.
- CE_TimeStep, FSource, SourcePower, and FMeasurement parameter default values are typically accepted; otherwise, set values based on your requirements.
- Activate/deactivate measurements based on your requirements.
- Run the simulation and view Data Display page(s) for your measurement(s).

For details, refer to Test Bench Details.

Test Bench Details

The following sections provide details for setting up a test bench, setting measurement parameters for more control of the test bench, simulation measurement displays, and baseline performance.

Open and use the *WLAN_802_11a_TX* template:

1. In an Analog/RF schematic window select *Insert* > *Template.*
2. In the *Insert* > *Template* dialog box, choose *WLAN_802_11a_TX_test* , click *OK* ; click left to place the template in the schematic window.

Test bench setup is detailed here.

1. Replace the DUT (Amplifier2 is provided with this template) with an RF DUT that is suitable for this test bench.
   For information regarding using certain types of DUTs, see *RF DUT Limitations for WLAN Wireless Test Benches* (adswtbwlan).

2. Set the *Required Parameters*

   > **Note**
   > Refer to *WLAN_802_11a_TX* (adswtbwlan) for a complete list of parameters for this test bench.

   Generally, default values can be accepted; otherwise, values can be changed by the user as needed.

   - Set CE_TimeStep.
     Cosimulation occurs between the test bench (using ADS Ptolemy Data Flow simulation technology) and the DUT (using Agilent Circuit Envelope simulation technology). Each technology requires its own simulation time step with time-step coordination occurring in the interface between the technologies.
     CE_TimeStep defines the Circuit Envelope simulation time step to be used with this DUT. The CE_TimeStep must be set to a value equal to or a submultiple of (less than) WTB_TimeStep; otherwise, simulation will stop and an error message will be displayed.
     Note that WTB_TimeStep is not user-settable. Its value is derived from other test bench parameter values; with default settings WTB_TimeStep=25 nsec. The value is displayed in the Data Display pages as TimeStep.

     WTB_TimeStep = 1/(Bandwidth × Ratio)

     where

     Bandwidth is the user-settable value (default 20 MHz)

     Ratio is the oversampling ratio related to OversamplingOption as Ratio = $2^{\text{OversamplingOption}}$. OversamplingOption sets the number of waveform sampling points during the signal FFT time interval. During this time interval the minimum FFT sampling size is 64 (which corresponds to an FFT order of 6; i.e 2^6) and the FFT time interval is defined as 64/Bandwidth. For example, an OversamplingOption of 2 sets the FFT sampling size to 64 × 4=256 (which corresponds to an FFT order of 8) during the signal FFT time interval.

- Set FSource, SourcePower, and FMeasurement.
  - FSource defines the RF frequency for the signal input to the RF DUT.
  - SourcePower defines the power level for FSource. SourcePower is defined as the average power during the non-idle time of the signal burst.
  - FMeasurement defines the RF frequency output from the DUT to be measured.

3. Activate/deactivate (*YES* / *NO*) test bench measurements (refer to *WLAN_802_11a_TX* (adswtbwlan)). At least one measurement must be enabled:
   - RF_EnvelopeMeasurement
   - Constellation
   - PowerMeasurement
   - SpectrumMeasurement
   - EVM_Measurement
4. More control of the test bench can be achieved by setting *Basic Parameters* , *Signal Parameters* , and parameters for each activated measurement. For details, refer to *Setting Parameters* (adswtbwlan).
5. The RF modulator (shown in the block diagram in Transmitter Wireless Test Bench Block Diagram) uses FSource, SourcePower (*Required Parameters*), MirrorSourceSpectrum (*Basic Parameters)* , GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and IQ_Rotation (*Signal Parameters*).

   The RF output resistance uses SourceR, SourceTemp, and EnableSourceNoise (*Basic Parameters*). The RF output signal source has a 50-ohm (default) output resistance defined by SourceR.

   RF output (and input to the RF DUT) is at the frequency specified (FSource), with the specified source resistance (SourceR) and with power (SourcePower) delivered into a matched load of resistance SourceR. The RF signal has additive Gaussian noise power set by resistor temperature (SourceTemp) (when EnableSourceNoise=YES).

   Note that the Meas_in point of the test bench provides a resistive load to the RF DUT set by the MeasR value (50-ohm default) (*Basic Parameters*).

   The Meas signal contains linear and nonlinear signal distortions and time delays associated with the RF DUT input to output characteristics.

   The TX DSP block (shown in the block diagram in Transmitter Wireless Test Bench Block Diagram) uses other *Signal Parameters*.

6. More control of Circuit Envelope analysis can be achieved by setting Envelope controller parameters. These settings include Enable Fast Cosim, which may speed the RF DUT simulation more than 10×. Setting these simulation options is described in *Setting Fast Cosimulation Parameters* and *Setting Circuit Envelope Analysis Parameters* in the *Wireless Test Bench Simulation* documentation.
7. To send the RF DUT output signal to an Agilent ESG RF signal generator, set *Signal to ESG Parameters* .
   For details, refer to *Signal to ESG Parameters* (adswtbwlan).

8. After running a simulation, results will appear in a Data Display window for the measurement. *Simulation Measurement Displays* (adswtbwlan) describes results for each measurement. For general WTB Data Display details refer to *Viewing WTB Analysis Results* (adswtbsim).

WLAN_802_11a_TX

This section provides parameter information for *Required Parameters, Basic Parameters, Signal Parameters,* and parameters for the various measurements.

Description: WLAN 802.11a TX test
Library: WTB
Class: TSDFWLAN_802_11a_TX
Derived From: baseWTB_TX

Parameters

Name	Description	Default	Sym	Unit	Type	Range
Required Parameters						
CE_TimeStep	Circuit envelope simulation time step	1/20 MHz/4		sec	real	(0, ∞)
WTB_TimeStep	Set CE_TimeStep<= 1/Bandwidth/ 2^OversamplingOption. Expression variables are in Signal Parameters tab/category.					
FSource	Source carrier frequency: CH1 _2412.0MHz, CH3 _2422.0MHz, CH5 _2432.0MHz, CH6 _2437.0MHz, CH7 _2442.0MHz, CH9 _2452.0MHz, CH11 _2462.0MHz, CH13 _2472.0MHz, CH36	CH1 _2412.0MHz		Hz	real enum	(0, ∞)

	_5180.0MHz, CH40 _5200.0MHz, CH44 _5220.0MHz, CH48 _5240.0MHz, CH52 _5260.0MHz, CH56 _5280.0MHz, CH60 _5300.0MHz, CH64 _5320.0MHz, CH149 _5745.0MHz, CH153 _5765.0MHz, CH157 _5785.0MHz, CH161 _5805.0MHz					
SourcePower	Source power	dbmtow(-20.0)		W	real	[0, ∞)
FMeasurement	Measurement carrier frequency: Meas_CH1 _2412.0MHz, Meas_CH3 _2422.0MHz, Meas_CH5 _2432.0MHz, Meas_CH6 _2437.0MHz, Meas_CH7 _2442.0MHz, Meas_CH9 _2452.0MHz, Meas_CH11 _2462.0MHz, Meas_CH13 _2472.0MHz, Meas_CH36 _5180.0MHz, Meas_CH40 _5200.0MHz, Meas_CH44 _5220.0MHz, Meas_CH48 _5240.0MHz, Meas_CH52 _5260.0MHz, Meas_CH56 _5280.0MHz, Meas_CH60 _5300.0MHz, Meas_CH64 _5320.0MHz, Meas_CH149 _5745.0MHz,	Meas_CH1 _2412.0MHz		Hz	real enum	(0, ∞)

	Meas_CH153 _5765.0MHz, Meas_CH157 _5785.0MHz, Meas_CH161 _5805.0MHz					
MeasurementInfo	Available Measurements Each measurement has parameters on its tab/category below.					
RF_EnvelopeMeasurement	Enable RF envelope measurement? NO, YES	YES			enum	
Constellation	Enable constellation measurement? NO, YES	NO			enum	
PowerMeasurement	Enable power measurement? NO, YES	NO			enum	
SpectrumMeasurement	Enable spectrum measurement? NO, YES	NO			enum	
EVM_Measurement	Enable EVM measurement? NO, YES	NO			enum	
Basic Parameters						
SourceR	Source resistance	50 Ohm		Ohm	real	(0, ∞)
SourceTemp	Source resistor temperature	-273.15		Celsius	real	[-273.15, ∞)
EnableSourceNoise	Enable source thermal noise? NO, YES	NO			enum	
MeasR	Measurement resistance	50 Ohm		Ohm	real	[10, 1.0e6]
MirrorSourceSpectrum	Mirror source spectrum about carrier? NO, YES	NO			enum	
MirrorMeasSpectrum	Mirror meas spectrum about carrier? NO, YES	NO			enum	
RF_MirrorFreq	Mirror source frequency for spectrum/envelope measurement? NO, YES	NO			enum	
MeasMirrorFreq	Mirror meas frequency for spectrum/envelope measurement? NO, YES	NO			enum	
TestBenchSeed	Random number generator seed	1234567			int	[0, ∞)
Signal Parameters						
GainImbalance	Gain imbalance, Q vs I	0.0		dB	real	(-∞, ∞)
PhaseImbalance	Phase imbalance, Q vs I	0.0		deg	real	(-∞, ∞)
I_OriginOffset	I origin offset (percent)	0.0			real	(-∞, ∞)
Q_OriginOffset	Q origin offset (percent)	0.0			real	(-∞, ∞)
IQ_Rotation	IQ rotation	0.0		deg	real	(-∞, ∞)
Bandwidth	Bandwidth	20 MHz	B	Hz	real	(0, ∞)
OversamplingOption	Oversampling ratio option: Option 0 for Ratio 1, Option 1 for Ratio 2, Option 2 for Ratio 4, Option 3 for	Option 2 for Ratio 4	S		enum	

	Ratio 8, Option 4 for Ratio 16, Option 5 for Ratio 32					
DataRate	Data rate (Mbps): Mbps_6, Mbps_9, Mbps_12, Mbps_18, Mbps_24, Mbps_27, Mbps_36, Mbps_48, Mbps_54	Mbps_54	R		enum	
IdleInterval	Burst idle interval	4.0 usec	I	sec	real	[0, 1000usec]
DataType	Payload data type: PN9, PN15, FIX4, _4_1_4_0, _8_1_8_0, _16_1_16_0, _32_1_32_0, _64_1_64_0	PN9			enum	
DataLength	Data length (bytes per burst)	100	L		int	[1, 4095]
GuardInterval	Guard interval (frac FFT size)	0.25			real	[0, 1]
RF_Envelope MeasurementParameters						
RF_EnvelopeDisplayPages	RF envelope measurement display pages: WLAN_802_11a_TX Envelope RF Figures WLAN_802_11a_TX Envelope Meas Figures WLAN_802_11a_TX Envelope Equations					
RF_EnvelopeStart	RF envelope measurement start	0.0		sec	real	[0, ∞)
RF_EnvelopeStop	RF envelope measurement stop	100.0 usec		sec	real	[RF_EnvelopeStart, ∞)
RF_EnvelopeBursts	RF envelope measurement bursts	3			int	[0, 100]
Constellation Parameters						
ConstellationDisplayPages	Constellation measurement display pages: WLAN_802_11a_TX Constellation Figures					
ConstellationStartBurst	Constellation measurement start burst	0			int	[0, 100]
ConstellationBursts	Constellation measurement bursts	3			int	[1, 100]
PowerMeasurement Parameters						
PowerDisplayPages	Power measurement display pages: WLAN_802_11a_TX Power Figures/Tables/Equations					
PowerBursts	Power measurement	3			int	[1, 100]

	bursts					
SpectrumMeasurement Parameters						
SpectrumDisplayPages	Spectrum measurement display pages: WLAN_802_11a_TX Spectrum Equations WLAN_802_11a_TX Spectrum Figures/Tables					
SpecMeasStart	Spectrum measurement start	0.0		sec	real	[0, ∞)
SpecMeasStop	Spectrum measurement stop	100.0 usec		sec	real	[SpecMeasStart + 16* MaxTimeStep, ∞)
SpecMeasBursts	Spectrum measurement bursts	3			int	[0, 100]
SpecMeasResBW	Spectrum resolution bandwidth	100 kHz		Hz	real	[0, ∞)
SpecMeasWindow	Window type: none, Hamming 0.54, Hanning 0.50, Gaussian 0.75, Kaiser 7.865, _8510 6.0, Blackman, Blackman-Harris	Kaiser 7.865			enum	
EVM_Measurement Parameters						
EVM_DisplayPages	EVM measurement display pages: WLAN_802_11a_TX EVM Tables					
EVM_Start	EVM measurement start	0.0		sec	real	[0, ∞)
EVM_AverageType	Average type: Off, RMS (Video)	RMS (Video)			enum	
EVM_BurstsToAverage	Bursts used for RMS averaging	10			int	[1, ∞)
EVM_DataModulationFormat	Data subcarrier modulation format: Auto Detect, BPSK, QPSK, QAM 16, QAM 64	Auto Detect			enum	
EVM_SearchLength	Search length	0.001		sec	real	(0, ∞)
EVM_ResultLengthType	Resul length type: Auto select, Manual Override	Auto select			enum	
EVM_ResultLength	Manual override result length (symbols)	60			int	[1, 1367]
EVM_MeasurementOffset	Measurement offset (symbols)	0			int	[0, ∞)
EVM_MeasurementInterval	Measurement interval (symbols)	11			int	[1, ∞)
EVM_SymbolTimingAdjust	Timing adjustment (% FFT time)	-3.125			real	[-100* GuardInterval, 0]
EVM_SyncType	Synchronization type: Short Training Seq, Channel Estimation Seq	Short Training Seq			enum	
SignalToESG						

_Parameters						
EnableESG	Enable signal to ESG? NO, YES	NO			enum	
ESG_Instrument	ESG instrument address	[GPIB0::19::INSTR] [localhost] [4790]			instrument	
ESG_Start	Signal start	0.0		sec	real	[0, ∞)
ESG_Stop	Signal stop	100.0 usec		sec	real	[(ESG_Start +60*50ns/ pow(2.0, S)), (ESG_Start +32e6*50ns/ pow(2.0,S))]
ESG_Bursts	Bursts to ESG	3			int	[0, 1000]
ESG_Power	ESG RF ouput power (dBm)	-20.0			real	(-∞, ∞)
ESG_ClkRef	Waveform clock reference: Internal, External	Internal			enum	
ESG_ExtClkRefFreq	External clock reference freq	10 MHz		Hz	real	(0, ∞)
ESG_IQFilter	IQ filter: through, filter_2100kHz, filter_40MHz	through			enum	
ESG_SampleClkRate	Sequencer sample clock rate	80 MHz		Hz	real	(0, ∞)
ESG_Filename	ESG waveform storage filename	WLAN_54			string	
ESG_AutoScaling	Activate auto scaling? NO, YES	YES			enum	
ESG_ArbOn	Select waveform and turn ArbOn after download? NO, YES	YES			enum	
ESG_RFPowOn	Turn RF ON after download? NO, YES	YES			enum	
ESG_EventMarkerType	Event marker type: Neither, Event1, Event2, Both	Event1			enum	
ESG_MarkerLength	ESG marker length	10			int	[1, 60]

Pin Input

Pin	Name	Description	Signal Type
2	Meas_In	Test bench measurement RF input from RF circuit	timed

Pin Output

Pin	Name	Description	Signal Type
1	RF_Out	Test bench RF output to RF circuit	timed

Setting Parameters

More control of the test bench can be achieved by setting parameters in the *Basic Parameters* , *Signal Parameters* , and *measurement* categories for the activated measurements.

Note For *required* parameter information, see *Set the Required Parameters* (adswtbwlan).

Basic Parameters

1. SourceR is the RF output source resistance.
2. SourceTemp is the RF output source resistance temperature (oC) and sets noise density in the RF output signal to (k(SourceTemp+273.15)) Watts/Hz, where k is Boltzmann's constant.
3. EnableSourceNoise, when set to NO disables the SourceTemp and effectively sets it to -273.15oC (0 Kelvin). When set to YES, the noise density due to SourceTemp is enabled.
4. MeasR defines the load resistance for the RF DUT output Meas signal into the test bench. This resistance loads the RF DUT output; it is also the reference resistance for Meas signal power measurements.
5. MirrorSourceSpectrum is used to invert the polarity of the Q envelope of the generated RF signal before it is sent to the RF DUT. Depending on the configuration and number of mixers in an RF transmitter, the signal at the input of the DUT may need to be mirrored. If such an RF signal is desired, set this parameter to YES.
6. MirrorMeasSpectrum is used to invert the polarity of the Q envelope in the Meas_in RF signal input to the test bench (and output from the RF DUT). Depending on the configuration and number of mixers in the RF DUT, the signal at its output may be mirrored compared to the signal generated by the signal source (before any mirroring is done because of the MirrorSourceSpectrum setting). Proper demodulation and measurement of the RF DUT output signal requires that its RF envelope is not mirrored compared to the signal generated by the signal source (before any mirroring is done because of the MirrorSourceSpectrum setting). If the Meas_in RF signal is mirrored, set this parameter to YES. Proper setting of this parameter is required for measurements on the Meas_in signal in TX test benches (EVM, Constellation, CDP, PCDE) and results in measurement on a signal with no spectrum mirroring.
7. TestBenchSeed is an integer used to seed the random number generator used with the test bench. This value is used by all test bench random number generators, except those RF DUT components that use their own specific seed parameter. TestBenchSeed initializes the random number generation. The same seed value produces the same *random* results, thereby giving you predictable simulation results. To generate repeatable *random* output from simulation to simulation, use any positive seed value. If you want the output to be truly random, enter the seed value of 0.
8. RF_MirrorFreq is used to invert the polarity of the Q envelope in the RF_out RF signal for RF envelope, ppectrum, ACLR, and occupied bandwidth measurements. RF_MirrorFreq is typically set by the user to NO when MirrorSourceSpectrum = NO; RF_MirrorFreq is typically set by the user to YES when MirrorSourceSpectrum = YES. Both settings result in viewing the RF_out signal with no spectrum mirroring. Other settings by the user result in RF_out signal for RF_Envelope and Spectrum

measurements with spectrum mirroring.

9. MeasMirrorFreq is used to invert the polarity of the Q envelope in the Meas_in RF signal for the RF envelope, spectrum, ACLR, and occupied bandwidth measurements. MeasMirrorFreq is typically set to NO by the user when the combination of the MirrorSourceSpectrum value and any signal mirroring in the users RF DUT results in no spectrum mirroring in the Meas_in signal. MeasMirrorFreq is typically set to YES by the user when the combination of the MirrorSourceSpectrum and RF DUT results in spectrum mirroring in the Meas_in signal.
   Other settings result in Meas_in signal for RF_Envelope and Spectrum measurements with spectrum mirroring. The MirrorMeasSpectrum parameter setting has no impact on the setting or use of the MeasMirrorFreq parameter.

Signal Parameters

1. GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and IQ_Rotation are used to add certain impairments to the ideal output RF signal. Impairments are added in the order described here.
   The unimpaired RF I and Q envelope voltages have gain and phase imbalance applied. The RF is given by:
   $$V_{RF}(t) = A\left(V_I(t)\cos(\omega_c t) - gV_Q(t)\sin\left(\omega_c t + \frac{\phi\pi}{180}\right)\right)$$
   where *A* is a scaling factor that depends on the SourcePower and SourceR parameters specified by the user, $V_I(t)$ is the in-phase RF envelope, $V_Q(t)$ is the quadrature phase RF envelope, *g* is the gain imbalance
   $$g = 10^{\frac{GainImbalance}{20}}$$
   and, φ (in degrees) is the phase imbalance.
   Next, the signal $V_{RF}(t)$ is rotated by IQ_Rotation degrees. The I_OriginOffset and Q_OriginOffset are then applied to the rotated signal. Note that the amounts specified are percentages with respect to the output rms voltage. The output rms voltage is given by sqrt(2 × SourceR × SourcePower).
2. Bandwidth is used to determine the actual bandwidth of WLAN systems and to calculate the sampling rate and timestep per sample. The default value is 20 MHz (defined in 802.11a/g specification); to double the rate for the 802.11a/g turbo mode, set Bandwidth to 40 MHz.
3. OversamplingOption sets the oversampling ratio of 802.11a/g RF signal source. Options from 0 to 5 result in oversampling ratio 2, 4, 8, 16, 32 where oversampling ratio = $2^{OversamplingOption}$. If OversamplingOption = 2, the oversampling ratio = 22 = 4 and the simulation RF bandwidth is larger than the signal bandwidth by a factor of 4 (e.g. for Bandwidth=20 MHz, the simulation RF bandwidth = 20 MHz × 4 = 80 MHz).
4. DataRate specifies the data rate 6, 9, 12, 18, 24, 27, 36, 48 and 54 Mbps. All data rates except 27 Mbps are defined in the 802.11a/g specification; 27 Mbps is from HIPERLAN/2. The following table lists key parameter values of 802.11a/g.

Rate-Dependent Values

Data Rate (Mbps)	Modulation	Coding Rate (R)	Coded Bits per Subcarrier (N_{BPSC})	Coded Bits per OFDM Symbol (N_{CBPS})	Data Bits per OFDM Symbol (N_{DBPS})
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
27	16-QAM	9/16	4	192	108
36	16-QAM	3/4	4	192	144
48	64-QAM	2/3	6	288	192
54	64-QAM	3/4	6	288	216

5. IdleInterval specifies the idle interval between two consecutive bursts when generating a 802.11a signal source.
6. For DataType:
   - if PN9 is selected, a 511-bit pseudo-random test pattern is generated according to CCITT Recommendation O.153.
   - if PN15 is selected, a 32767-bit pseudo-random test pattern is generated according to CCITT Recommendation O.151.
   - if FIX4 is selected, a zero-stream is generated.
   - if x_1_x_0 is selected (where x equals 4, 8, 16, 32, or 64) a periodic bit stream is generated, with the period being 2 x. In one period, the first x bits are 1s and the second x bits are 0s.
7. DataLength is used to set the number of data bytes in a burst. There are 8 bits per byte.
8. GuardInterval is used to set cyclic prefix in an OFDM symbol. The value range of GuardInterval is [0.0,1.0]. The cyclic prefix is a fractional ratio of the IFFT length. 802.11a/g defines GuardInterval=1/4 (0.8 μ) and HIPERLAN/2 defines two GuardIntervals (1/8 and 1/4).

RF Envelope Measurement Parameters

The RF Envelope measurement is not affected by the MirrorMeasSpectrum parameter. To apply spectrum mirroring to the measured RF_out signal, set RF_MirrorFreq=YES; to apply spectrum mirroring to the measured Meas_in signal, set MeasMirrorFreq=YES (*Basic Parameters*).

- RF_EnvelopeDisplayPages provides Data Display page information for this measurement. It cannot be changed by the user.
- RF_EnvelopeStart sets the start time for collecting input data.
- RF_EnvelopeStop sets the stop time for collecting input data when RF_EnvelopeBursts = 0.
- RF_EnvelopeBursts (when > 0) sets the number of bursts over which data will be collected.
  Depending on the values of RF_EnvelopeStart, RF_EnvelopeStop, and RF_EnvelopeBursts, the stop time may be adjusted.
  For RF envelope measurement for both the RF_out and Meas_in signals:
  Let:

Start = TimeStep× (int(RF_EnvelopeStart/TimeStep) + 0.5)

Stop = TimeStep × (int(RF_EnvelopeStop/TimeStep) + 0.5)

This means Start and Stop are forced to be an integer number of time-step intervals.

RF_EnvelopeBursts	Resultant Stop Time
0	Stop
> 0	Start + RF_EnvelopeBursts x BurstTime

For the RF envelope of Meas_in to contain at least one complete burst, set the Stop value to a minimum of BurstTime + (RF DUT time delay).
For information about TimeStep and SubframeTime, see Test Bench Variables for Data Displays..

Constellation Parameters

The Constellation measurement requires setting of the MirrorMeasSpectrum parameter set such that there is an even number of spectrum mirrorings from the combined test bench source and RF DUT. For example, if MirrorSourceSpectrum=NO and the RF DUT causes its output RF signal to have spectrum mirroring relative to its input signal, then set MirrorMeasSpectrum = YES.

1. ConstellationDisplayPages provides Data Display page information for this measurement. It cannot be changed by the user.
2. ConstellationStartBurst sets the start time for collecting the first burst data. The ConstellationStartBurst value can be set > 0 to avoid any start-up transient in the Constellation plots.
3. ConstellationBursts sets the number of bursts over which data will be collected.

The measurement start time is the time when ConstellationStartBurst is detected in the measured RF signal. The measurement stop time is this start time plus ConstellationBursts × BurstTime; BurstTime is defined in Test Bench Equations Derived from Test Bench Parameters and Exported to Data Display.

Power Measurement Parameters

1. PowerDisplayPages provides Data Display page information for this measurement. It cannot be changed by the user.
2. PowerBursts (when > 0) sets the number of bursts over which data will be collected.

The measurement start time is the time when the first burst is detected in the measured RF signal. The measurement stop time is this start time plus PowerBursts × BurstTime; BurstTime is defined in Test Bench Equations Derived from Test Bench Parameters and Exported to Data Display.

Spectrum Measurement Parameters

The Spectrum measurement calculates the spectrum of the input signal. Averaging the spectrum over multiple bursts can be enabled as described in this section.

This measurement is not affected by the MirrorMeasSpectrum parameter. To apply spectrum mirroring to the measured RF_out signal, set RF_MirrorFreq = YES; to apply spectrum mirroring to the measured Meas_in signal, set MeasMirrorFreq = YES.

In the following, TimeStep denotes the simulation time step, and FMeasurement denotes the measured RF signal characterization frequency.

1. The measurement outputs the complex amplitude voltage values at the frequencies of the spectral tones. It does not output the power at the frequencies of the spectral tones. However, one can calculate and display the power spectrum as well as the magnitude and phase spectrum by using the dBm, mag, and phase functions of the data display window.
   Note that the dBm function assumes a 50-ohm reference resistance; if a different measurement was used in the test bench, its value can be specified as a second argument to the dBm function, for example, dBm(SpecMeas, Meas_RefR) where SpecMeas is the instance name of the spectrum measurement and Meas_RefR is the resistive load.
   By default, the displayed spectrum extends from FMeasurement - 1/(2 × TimeStep) Hz to FMeasurement + 1/(2 × TimeStep) Hz. When FMeasurement < 1/(2 × TimeStep), the default spectrum extends to negative frequencies. The spectral content at these negative frequencies is conjugated, mirrored, and added to the spectral content of the closest positive frequency. This way, the negative frequency tones are displayed on the positive frequency axis as would happen in an RF spectrum analyzer measurement instrument. This process may introduce an error in the displayed frequency for the mirrored tones. The absolute error introduced is less than (Spectrum Frequency Step) / 2 (see Effect of Values for SpecMeasStart, SpecMeasStop, SpecMeasBursts, and SpecMeasResBW for the definition of Spectrum Frequency Step).
   The basis of the algorithm used by the spectrum measurement is the chirp-Z transform. The algorithm can use multiple bursts and average the results to achieve video averaging (see note 6).
2. SpectrumDisplayPages is not user editable. It provides information on the name of the Data Display pages in which this measurement is contained.
3. SpecMeasStart sets the start time for collecting input data.
4. SpecMeasStop sets the stop time for collecting input data when SpecMeasBursts = 0 and SpecMeasResBW = 0.
5. SpecMeasBursts sets the number of bursts over which data will be collected when SpecMeasBursts>0.
6. SpecMeasResBW sets the resolution bandwidth of the spectrum measurement when SpecMeasResBW>0.
   Depending on the values of SpecMeasStart, SpecMeasStop, SpecMeasBursts, and SpecMeasResBW, the stop time may be adjusted or spectrum video averaging may occur (or both). The different cases are described in the table *Effect of Values for SpecMeasStart, SpecMeasStop, SpecMeasBursts, and SpecMeasResBW*. Referring to the table, let

Start = TimeStep × int((SpecMeasStart/TimeStep) + 0.5)

Stop = TimeStep × int((SpecMeasStop/TimeStep) + 0.5)

(This means Start and Stop are forced to be an integer number of time step intervals.)

X = normalized equivalent noise bandwidth of the window

Equivalent noise bandwidth (ENBW) compares the window to an ideal, rectangular filter. It is the equivalent width of a rectangular filter that passes the same amount of white noise as the window. The normalized ENBW (NENBW) is ENBW multiplied by the duration of the signal being windowed. The table Window Options and Normalized Equivalent Noise Bandwidth lists the NENBW for the various window options.
The Start and Stop times are used for both the RF_out and Meas_in signal spectrum analyses. The Meas_in signal is delayed in time from the RF_out signal by the value of the RF DUT time delay. Therefore, for RF DUT time delay greater than zero, the RF_out and Meas_in signal are inherently different and some spectrum display difference in the two is expected.
TimeStep and BurstTime are defined in the *Test Bench Variables for Data Displays* section.

Effect of Values for SpecMeasStart, SpecMeasStop, SpecMeasBursts, and SpecMeasResBW

Case 1	SpecMeasBursts = 0 SpecMeasResBW = 0 Resultant stop time = Stop Resultant resolution BW = X/(Stop - Start) Resultant spectrum frequency step = 1/(Stop-Start) Video averaging status = None
Case 2	SpecMeasBursts > 0 SpecMeasResBW = 0 Resultant stop time = Start + SpecMeasBurst x BurstTime Notes: For SpecMeasBursts > 0 and SpecMeasResBW = 0 Video averaging occurs over all burst time intervals Resultant resolution BW = X /BurstTime Resultant spectrum frequency step = 1/BurstTime Video averaging status = Yes, when SpecMeasBursts > 1
Case 3	SpecMeasBursts = 0 SpecMeasResBW > 0 Resultant stop time = Start + N x BurstTimeInterval where N = int((Stop -Start)/BurstTimeInterval) + 1 For SpecMeasBursts = 0 and SpecMeasResBW > 0 Define BurstTimeInterval = TimeStep x int((X/SpecMeasResBW/TimeStep) + 0.5) This means BurstTimeInterval is forced to a value that is an integer number of time step intervals. (Stop-Start) time is forced to be an integer number (N) of BurstTimeIntervals N has a minimum value of 1 Video averaging occurs over all BurstTimeIntervals The resolution bandwidth achieved is ResBW = X / BurstTimeInterval, which is very close to SpecMeasResBW but may not be exactly the same if X/SpecMeasResBW/TimeStep is not an exact integer. Resultant resolution BW = ResBW Resultant spectrum frequency step = ResBW Video averaging status = Yes when N > 1
Case 4	SpecMeasBursts > 0 SpecMeasResBW > 0 Resultant stop time = Start + M x BurstTimeInterval where M = int((SpecMeasBursts x BurstTime)/BurstTimeInterval) + 1 For SpecMeasBursts > 0 and SpecMeasResBW > 0 Define BurstTimeInterval = TimeStep x int((X /SpecMeasResBW/TimeStep) + 0.5) This means BurstTimeInterval is forced to a value that is an integer number of time step intervals. (Stop-Start) time is forced to be an integer number (M) of the BurstTimeIntervals M has a minimum value of 1 Video averaging occurs over all BurstTimeIntervals The resolution bandwidth achieved is ResBW = X / BurstTimeInterval, which is very close to SpecMeasResBW but may not be exactly the same if X/SpecMeasResBW/TimeStep is not an exact integer. Resultant resolution BW = ResBW Resultant spectrum frequency step = ResBW Video averaging status = Yes, when M > 1

7. SpecMeasWindow specifies the window that will be applied to each burst before its spectrum is calculated. Different windows have different properties, affect the resolution bandwidth achieved, and affect the spectral shape. Windowing is often necessary in transform-based (chirp-Z, FFT) spectrum estimation in order to reduce spectral distortion due to discontinuous or non-harmonic signal over the measurement time interval. Without windowing, the estimated spectrum may suffer from spectral leakage that can cause misleading measurements or masking of weak signal spectral detail by spurious artifacts.

The windowing of a signal in time has the effect of changing its power. The spectrum measurement compensates for this and the spectrum is normalized so that the power contained in it is the same as the power of the input signal.
Window Type Definitions:

- none:

$$w(kT_s) = \begin{cases} 1.0 & 0 \le k \le N \\ 0.0 & otherwise \end{cases}$$

  where N is the window size
- Hamming 0.54:

$$w(kT_s) = \begin{cases} 0.54 - 0.46\cos\left(\frac{2\pi k}{N}\right) & 0 \le k \le N \\ 0.0 & otherwise \end{cases}$$

  where N is the window size
- Hanning 0.5:

$$w(kT_s) = \begin{cases} 0.5 - 0.5\cos\left(\frac{2\pi k}{N}\right) & 0 \le k \le N \\ 0.0 & otherwise \end{cases}$$

  where N is the window size
- Gaussian 0.75:

$$w(kT_s) = \begin{cases} exp\left(-\frac{1}{2}\left(0.75\frac{(2k-N)}{N}\right)^2\right) & 0 \le \left|k - \frac{N}{2}\right| \le \frac{N}{2} \\ 0.0 & otherwise \end{cases}$$

  where N is the window size
- Kaiser 7.865:

$$w(kT_s) = \begin{cases} \frac{I_0\left(7.865\left[1-\left(\frac{k-\alpha}{\alpha}\right)^2\right]^{1/2}\right)}{I_0(7.865)} & 0 \le k \le N \\ 0.0 & otherwise \end{cases}$$

  where N is the window size, $\alpha = N / 2$, and I_0 (.) is the 0th order modified Bessel function of the first kind
- 8510 6.0 (Kaiser 6.0):

$$w(kT_s) = \begin{cases} \frac{I_0\left(6.0\left[1-\left(\frac{k-\alpha}{\alpha}\right)^2\right]^{1/2}\right)}{I_0(6.0)} & 0 \le k \le N \\ 0.0 & otherwise \end{cases}$$

  where N is the window size, $\alpha = N / 2$, and I_0 (.) is the 0th order modified Bessel function of the first kind
- Blackman:

$$w(kT_s) = \begin{cases} 0.42 - 0.5\cos\left(\frac{2\pi k}{N}\right) + 0.08\cos\left(\frac{4\pi k}{N}\right) & 0 \le k \le N \\ 0.0 & otherwise \end{cases}$$

where N is the window size

- Blackman-Harris:

$$w(kT_s) = \begin{cases} 0.35875 - 0.48829\cos\left(\frac{2\pi k}{N}\right) + 0.14128\cos\left(\frac{4\pi k}{N}\right) - 0.01168\cos\left(\frac{6\pi k}{N}\right) & 0 \le k \le N \\ 0.0 & otherwise \end{cases}$$

where N is the window size.

Window Options and Normalized Equivalent Noise Bandwidth

Window and Default Constant	NENBW
none	1
Hamming 0.54	1.363
Hanning 0.50	1.5
Gaussian 0.75	1.883
Kaiser 7.865	1.653
8510 6.0	1.467
Blackman	1.727
Blackman-Harris	2.021

EVM Measurement Parameters

The EVM measurement requires setting the MirrorMeasSpectrum parameter such that there is an even number of spectrum mirrorings from the combined test bench source and RF DUT. For example, if MirrorSourceSpectrum = NO and the RF DUT causes its output RF signal to have spectrum mirroring relative to its input signal, then set MirrorMeasSpectrum = YES.

The EVM measurement provides results for EVMrms_percent, EVM_dB, PilotEVM_dB, CPErms_percent, IQ_Offset_dB, and SyncCorrelation. Following is a description of the algorithm and parameter information.

1. EVM_DisplayPages provides Data Display page information for this measurement. It cannot be changed by the user.
2. Starting at the time instant specified by the EVM_Start, a signal segment of length EVM_SearchLength is captured. This signal segment is searched to detect a complete burst. The burst search algorithm looks for a burst-on and a burst-off transition. In order for the burst search algorithm to detect a burst, an idle part must exist between consecutive bursts and the bursts must be at least 15 dB above the noise floor.
   The EVM_Start time is used for both the RF_out and Meas_in EVM analyses. The Meas_in signal is delayed in time from the RF_out signal by the RF DUT time delay value. Therefore, for RF DUT time delay >0, the RF_out and Meas_in signals are inherently different and some EVM difference in the two is expected even if the RF

DUT does not introduce any distortion except time delay.
If the captured signal segment does not contain a complete burst, the algorithm will not detect any burst and the analysis that follows will most likely produce the wrong results. Therefore, EVM_SearchLength must be long enough to capture at least one complete burst. Since the time instant specified by the EVM_Start parameter can be soon after the beginning of a burst, it is strongly recommended that EVM_SearchLength is set to a value approximately equal to 2 x BurstTime + 3 x Idle, where BurstTime is the duration of a burst and Idle is the duration of the idle part. If EVM_Start is known to be close to the beginning of a burst then EVM_SearchLength can be set to BurstTime + 2 x Idle. If the duration of the burst or the idle part is unknown, then the RF envelope of the signal can be plotted and these durations determined by observing the plot.
After a burst is detected, synchronization is performed based on the value of EVM_SyncType. The burst is then demodulated. The burst is then analyzed to get the EVM measurement results.

3. If EVM_AverageType is set to Off, only one burst is detected, demodulated, and analyzed.
   If EVM_AverageType is set to RMS (Video), after the first burst is analyzed the signal segment corresponding to it is discarded and new signal samples are collected to fill in the signal buffer of length EVM_SearchLength. When the buffer is full again, a new burst search is performed, and when a burst is detected, it is demodulated and analyzed. These steps repeat until EVM_BurstsToAverage bursts are processed.
   If a burst is misdetected for any reason the results from its analysis are discarded. EVM results obtained from all successfully detected, demodulated, and analyzed bursts are averaged to give the final result.
4. EVM_DataModulationFormat can be used to specify the data subcarrier modulation format. If EVM_DataModulationFormat is set to Auto Detect, the algorithm will use the information detected within the OFDM burst (SIGNAL symbol - RATE data field) to automatically determine the data subcarrier modulation format. Otherwise, the format determined from the OFDM burst will be ignored and the format specified by EVM_DataModulationFormat will be used in the demodulation for all data subcarriers. This parameter has no effect on demodulation of the pilot subcarriers and the SIGNAL symbol, whose format is always BPSK.
5. The EVM_ResultLengthType and EVM_ResultLength parameters control how much data is acquired and demodulated.
   When EVM_ResultLengthType is set to Auto select, the measurement result length is automatically determined from information in the decoded SIGNAL symbol (LENGTH data field). In this case, EVM_ResultLength defines a maximum result length for the burst in symbol times; that is, if the measurement result length that is automatically detected is larger than EVM_ResultLength it will be truncated to EVM_ResultLength.
   When EVM_ResultLengthType is set to Manual Override, the measurement result length is set to EVM_ResultLength regardless of what is detected from the SIGNAL symbol of the burst. The value specified in EVM_ResultLength includes the SIGNAL symbol but does not include any part of the burst preamble.
   The following table of summarizes the differences between how Auto Select and Manual Override modes determine the measurement result length. The table lists the measurement result lengths actually used for Auto Select and Manual Override modes for three different values of the EVM_ResultLength parameter (30, 26 and 20 symbol-times). An input burst length of 26 symbol-times is assumed.

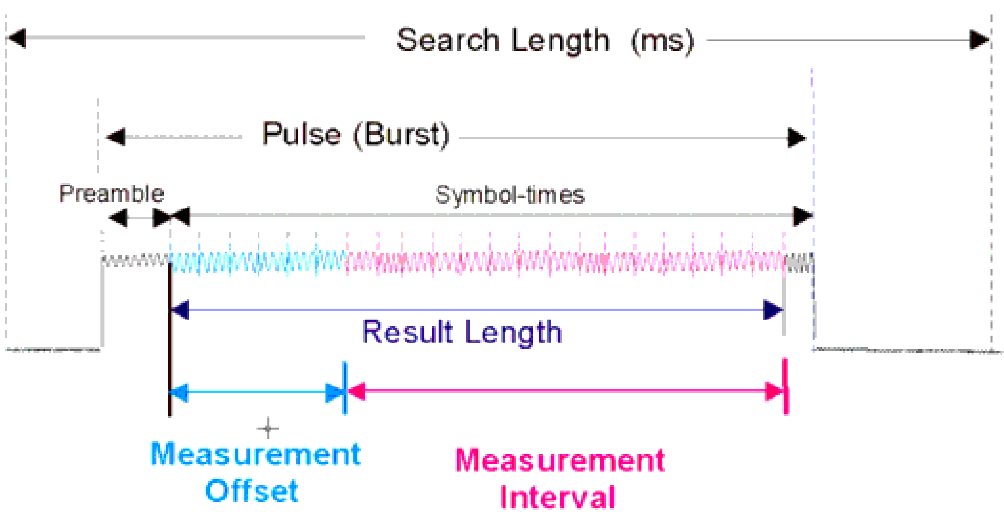
ResultLength Parameter Settings

EVM_ResultLengthType	EVM_ResultLength	Measurement Result Length Actually Used
Auto Select	20	20
Auto Select	26	26
Auto Select	30	26
Manual Override	20	20
Manual Override	26	26
Manual Override	30	30

Note that when EVM_ResultLengthType is set to Manual Override and EVM_ResultLength=30 (greater than the actual burst size) the algorithm will demodulate the full 30 symbol-times even though this is 4 symbol-times beyond the burst width.

6. The EVM_MeasurementInterval and EVM_MeasurementOffset parameters can be used to isolate a specific segment of the EVM_ResultLength symbols for analysis. Only the segment specified by these two parameters will be analyzed in order to get the EVM results. The following figure shows the interrelationship between EVM_SearchLength, EVM_ResultLength, EVM_MeasurementInterval, and EVM_MeasurementOffset.

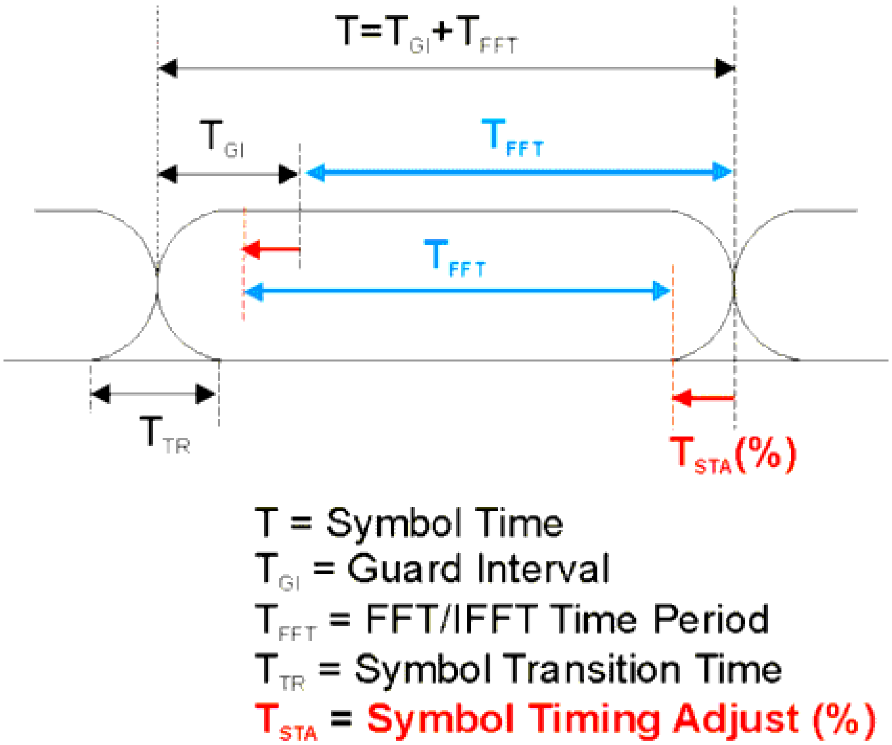
Interrelationship Between EVM_SearchLength, EVM_ResultLength, EVM_MeasurementInverval, and EVM_MeasurementOffset



7. Normally, when demodulating an OFDM symbol, the guard interval is skipped and an FFT is performed on the last portion of the symbol time. However, this means that the FFT will include the transition region between this and the following symbol. To avoid this, it is generally beneficial to back away from the end of the symbol time and use part of the guard interval.
The EVM_SymbolTimingAdjust parameter controls how far the FFT part of the symbol is adjusted away from the end of the symbol time. The value is in terms of percent of the used (FFT) part of the symbol time. Note that this parameter value is negative, because the FFT start time is moved back by this parameter. The following figure illustrates this concept. When setting this parameter, be careful to not back away from the end of the symbol time too much because this may make the FFT include corrupt data from the transition region at the beginning of the symbol time.
8. EVM_SyncType specifies whether the synchronization type will be the Short Training

Sequence or the Channel Estimation Sequence.

EVM_SymbolTimingAdjust Definition



Signal to ESG Parameters

The EVM measurement collects Meas_in signal data and downloads it to an Agilent E4438C Vector Signal Generator. Connection Manager architecture is used to communicate with the instrument; parameters specify how data is interpreted. Prerequisites for using the Signal to ESG option are:

- ESG Vector Signal Generator E4438C; for information, visit the web site http://www.agilent.com/find/esg .
- PC workstation running an instance of the connection manager server.
- Supported method of connecting the instrument to your computer through the Connection Manager architecture; for information, see *Connection Manager*.

Parameter Information

1. EnableESG specifies if the signal is downloaded to the ESG instrument. If set to NO, no attempt will be made to communicate with the instrument.
2. ESG_Instrument specifies a triplet that identifies the VSA resource of the instrument to be used in the simulation, the connection manager server hostname (defaults to *localhost*), and the port at which the connection manager server listens for incoming requests (defaults to 4790). To ensure that this field is populated correctly, click

Select Instrument , enter the server hostname and port, click *OK* to see the Remote Instrument Explorer dialog, select a VSA resource identifier, and click *OK* . For details about selecting instruments, see *Instrument Discovery* in the *Wireless Test Bench Simulation* documentation.

3. ESG_Start and ESG_Stop (when ESG_Bursts =0) specify when to start and stop data collection. The number of samples collected, ESG_Stop - ESG_Start + 1, must be in the range 60 samples to 64 Msamples, where 1 Msample = 1,048,576 samples. The ESG requires an even number of samples; the last sample will be discarded if ESG_Stop - ESG_Start + 1 is odd.
4. ESG_Bursts sets the number of bursts over which data will be collected. If ESG_Bursts is greater than zero, then ESG_Stop is forced to ESG_Start + ESG_Bursts x BurstTime where BurstTime is IdleTime + ShortPreambleTime + LongPreambleTime + SIGNAL_Time + DataTime.
5. ESG_ClkRef specifies an internal or external reference for the ESG clock generator. If set to External, the ESG_ExtClkRefFreq parameter sets the frequency of this clock.
6. ESG_IQFilter specifies the cutoff frequency for the reconstruction filter that lies between the DAC output and the Dual Arbitrary Waveform Generator output inside the ESG.
7. ESG_SampleClkRate sets the sample clock rate for the DAC output.
8. ESG_Filename sets the name of the waveform inside the ESG that will hold the downloaded data.
9. The ESG driver expects data in the range {-1, 1}. If ESG_AutoScaling is set to YES, inputs are scaled to the range {-1, 1}; if ESG_AutoScaling is set to NO, raw simulation data is downloaded to the ESG without scaling, but data outside the range {-1, 1} is clipped to -1 or 1. If set to YES, scaling is also applied to data written to the local file (ESG_Filename setting).
10. If ESG_ArbOn is set to YES, the ESG will start generating the signal immediately after simulation data is downloaded; if set to NO, waveform generation must be turned on at the ESG front panel.
11. If ESG_RFPowOn is set to YES, the ESG will turn RF power on immediately after simulation data is downloaded. If ESG_RFPowOn is set to NO (default), RF power must be turned on at the ESG front panel.
12. ESG_EventMarkerType specifies which ESG Event markers are enabled: Event1, Event2, Both, or Neither. Event markers are used for synchronizing other instruments to the ESG. When event markers are enabled, Event1 and/or Event2 is set beginning from the first sample of the downloaded Arb waveform over the range of points specified by the ESG_MarkerLength parameter. This is equivalent to setting the corresponding event from the front panel of the ESG.
13. ESG_MarkerLength specifies the range of points over which the markers must be set starting from the first point of the waveform. Depending on the setting of ESG_EventMarkerType, the length of trigger Event1 or Event2 (or both) is set to a multiple of the pulsewidth that, in turn, is determined by the sample clock rate of the DAC output.

Simulation Measurement Displays

After running the simulation, results are displayed in Data Display pages for each measurement activated.

> **Note**
> Measurement results from a wireless test bench have associated names that can be used in Data Display Expressions. For more information, refer to *Measurement Results for Expressions for WLAN Wireless Test Benches* (adswtbwlan).

RF Envelope Measurement

The RF Envelope measurement (not defined in IEEE 802.11a) shows the envelope time and spectrum of each field in the IEEE 802.11a RF signal burst (long preamble, short preamble, SIGNAL, and DATA fields). Two signals are tested, the RF source signal at the RF DUT input and the Meas signal at the RF DUT output.

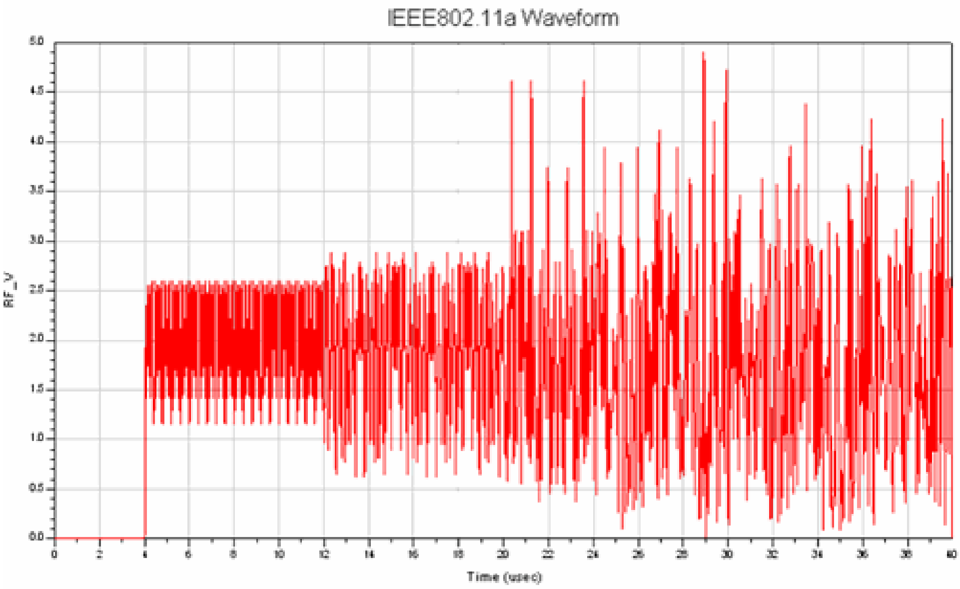
From the RF signal, the basic signal burst information is given in the following table.

Parameter	Default Setting
RF_FSource	5200.0 MHz
RF_R	50.0 Ohm
BurstTime	40.0 usec
TimeStep	12.5 nsec
IdleTime	4.0 usec
LongPreambleTime	8.0 usec
ShortPreambleTime	8.0 usec
OFDM_SymbolTime	4.0 usec
DataTime	16.0 usec
SIGNAL_Time	4.0 usec

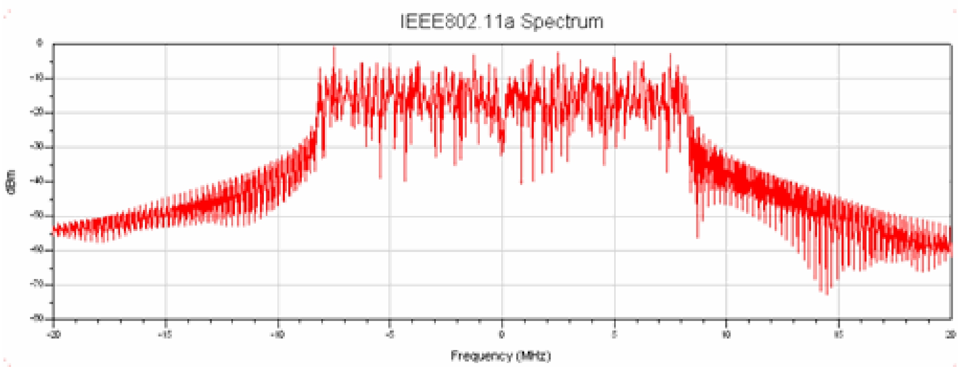
For the RF signal, the time domain envelope and envelope spectrum of one complete burst of 11a are shown, as well as burst fields for short preamble, long preamble, SIGNAL, and DATA in the following ten figures.

In Time Envelope of One Complete RF Signal Burst for Default Settings, the initial 4.0 μ interval is the idle time when the transmitter sends no signal, and follows the short preamble, long preamble, SIGNAL, and DATA fields.

Time Envelope of One Complete RF Signal Burst for Default Settings



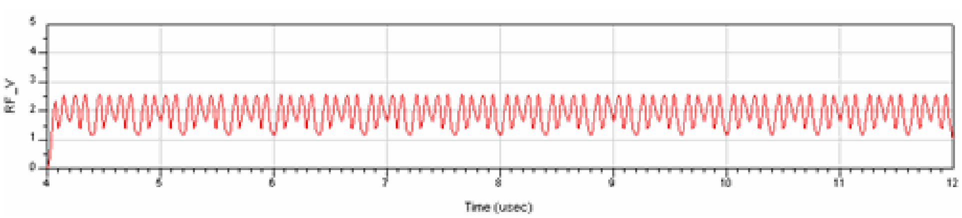
Spectrum of IEEE 802.11a RF Signal



RF Signal Short Preamble Envelope shows the Short Preamble waveform which is 8.0 μ. 12 subcarriers are clearly visible as shown in RF Signal Short Preamble Spectrum.

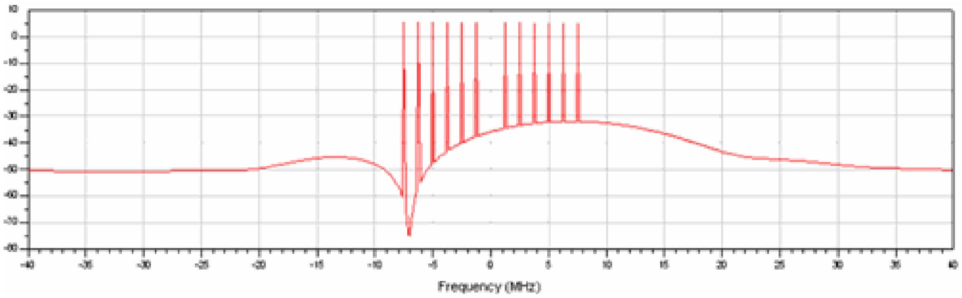
RF Signal Long Preamble Envelope shows the Long Preamble waveform, which is also 8.0 μ, lasting from 12.0 to 20.0 μ. The spectrum is shown in RF Signal Long Preamble Spectrum.

RF Signal Short Preamble Envelope

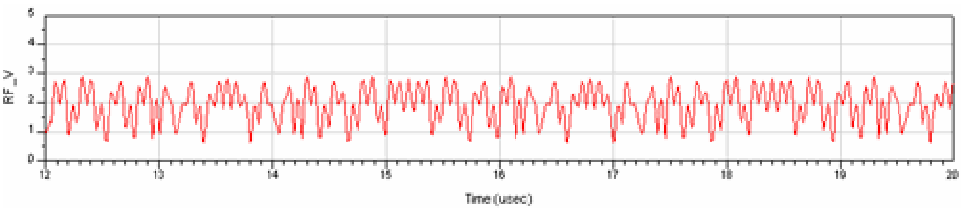


RF Signal Short Preamble Spectrum

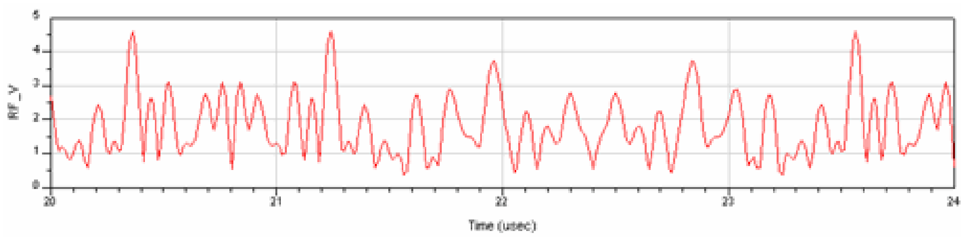
RF Signal Short Preamble Spectrum



RF Signal Long Preamble Envelope

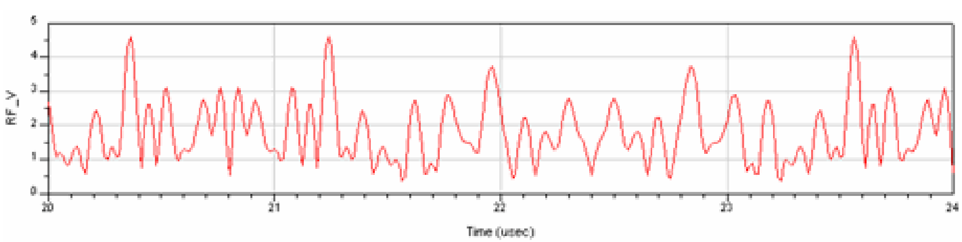


RF Signal Long Preamble Spectrum

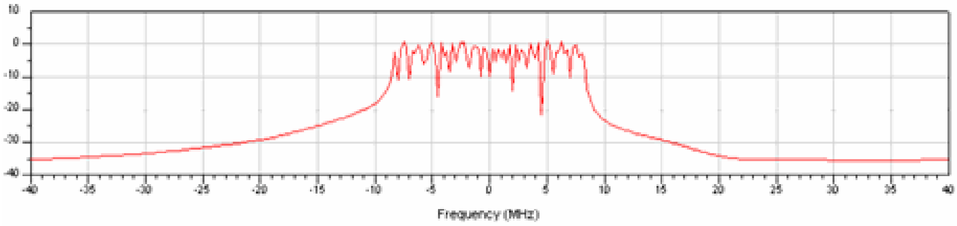


SIGNAL is 4.0 μ lasting from 20.0 to 24.0 μ (RF Signal SIGNAL Envelope). The spectrum is shown in RF Signal SIGNAL Spectrum.

RF Signal SIGNAL Envelope

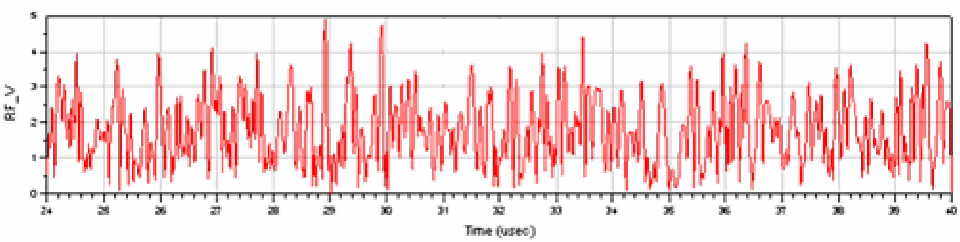


RF Signal SIGNAL Spectrum

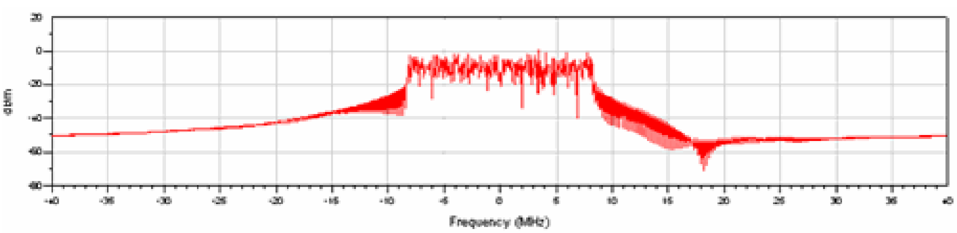


DATA is 16.0 μ lasting from 24.0 to 40.0 μ (RF Signal DATA Envelope). The spectrum is shown in RF Signal DATA Spectrum.

RF Signal DATA Envelope



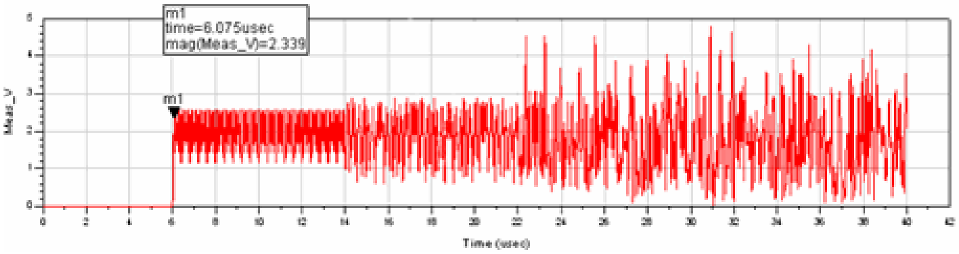
RF Signal DATA Spectrum



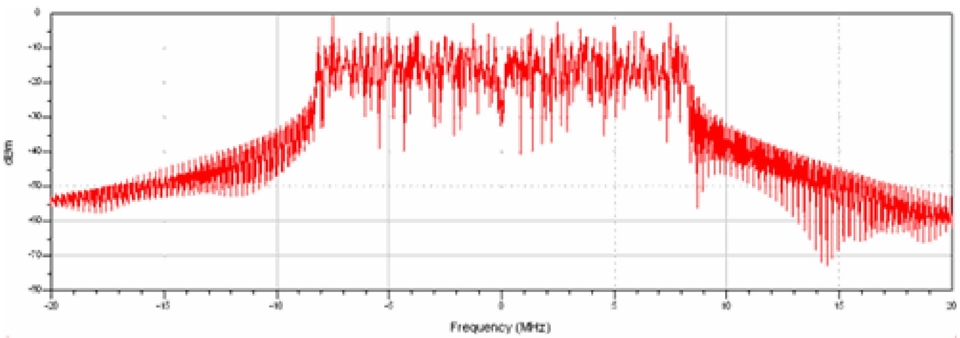
For the Meas signal test, all measurements are the same as RF signal measurements, except the Meas signal will contain any linear and nonlinear distortions, and time envelope measurements will have the RF DUT time delay. Envelope and spectrum measurements for Meas signal are shown in Meas Signal Envelope for One Entire Burst through Meas Signal DATA Spectrum.

In Meas Signal Envelope for One Entire Burst, Marker m1 must be set by the user to the start of the Short Preamble. This will determine the RF DUT time delay that identifies where each Meas burst structure begins and ends. The delay can be calculated by subtracting the idle time from the time marked by m1; for example, in Meas Signal Envelope for One Entire Burst delay=6.075μ-4.0μ=2.075μ. Because the mark may not accurately point to the start position, the calculated delay may have some error.

Meas Signal Envelope for One Entire Burst



IEEE 802.11a Meas Signal Spectrum



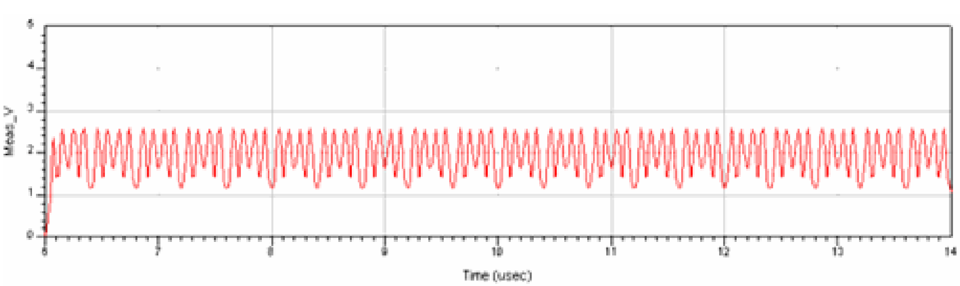
Meas Signal Short Preamble Envelope shows the Short Preamble of 8.0 µ lasting from 6.0 to 14.0 µ due to a 2.0 µ delay. 12 subcarriers of Short Preamble are shown in Meas Signal Short Preamble Spectrum.

Meas Signal Long Preamble Envelope shows the Long Preamble is also 8.0 µ lasting from 14.0 to 22.0 µ due to a 2.0 µ delay. The spectrum is shown in Meas Signal Long Preamble Spectrum.

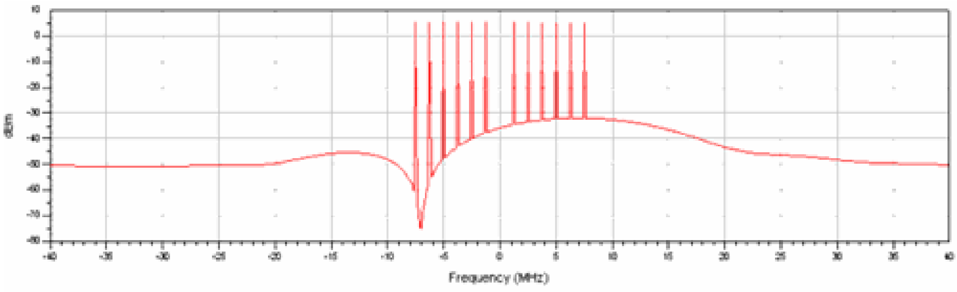
Meas Signal SIGNAL Envelope shows SIGNAL is 4.0 µ lasting from 22.0 to 26.0 µ. The spectrum is shown in Meas Signal SIGNAL Spectrum.

Meas Signal DATA Envelope shows DATA is 16.0 µ lasting from 26.0 to 42.0 µ. The spectrum is shown in Meas Signal DATA Spectrum.

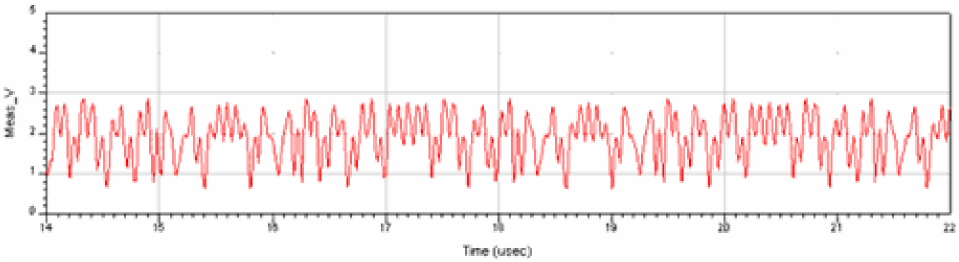
Meas Signal Short Preamble Envelope



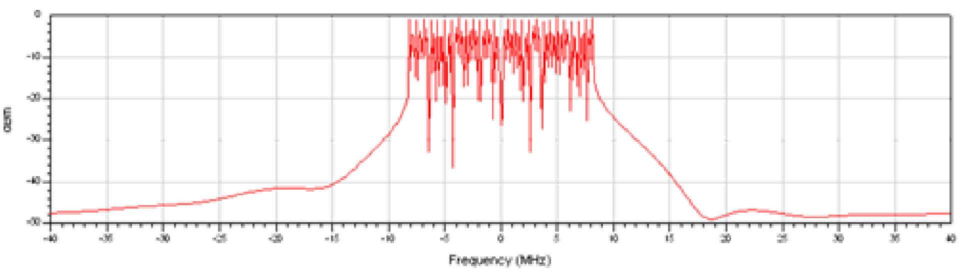
Meas Signal Short Preamble Spectrum



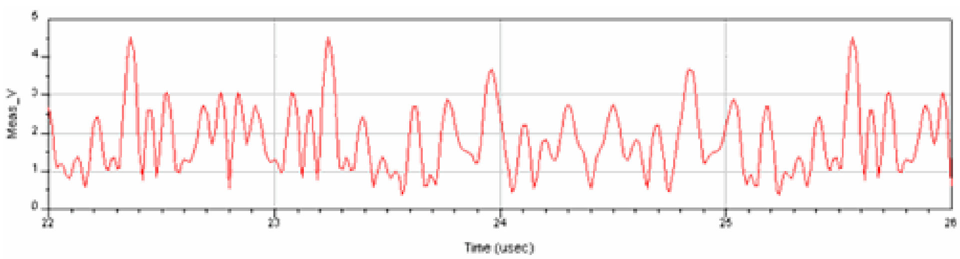
Meas Signal Long Preamble Envelope



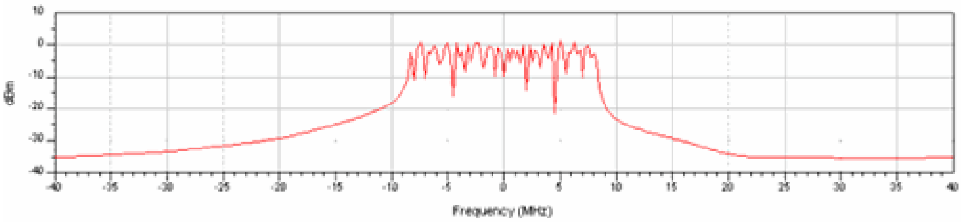
Meas Signal Long Preamble Spectrum



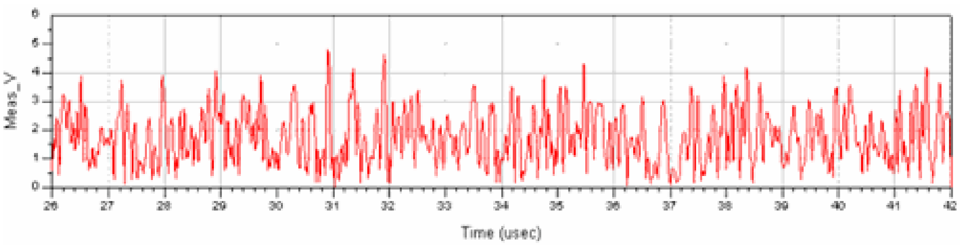
Meas Signal SIGNAL Envelope



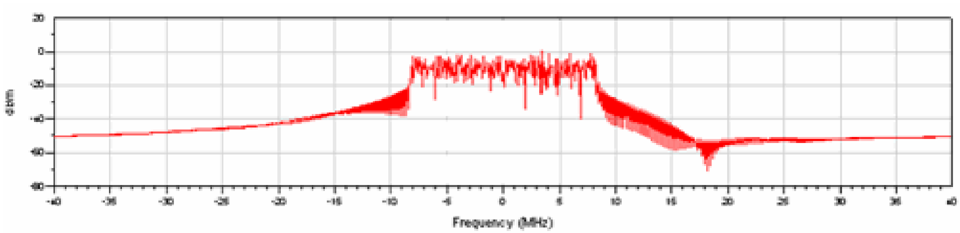
Meas Signal SIGNAL Spectrum



Meas Signal DATA Envelope



Meas Signal DATA Spectrum



Constellation Measurement

The constellation measurement (not defined in IEEE 802.11a) shows the RF and Meas signal constellations.

In IEEE 802.11a, four types of modulation are implemented. Data rates and modulation types are listed in the table Data Rates and Modulation Types. Basic signal information is listed in the table Basic Constellation Measurement Parameters.

A 54 Mbps data rate is used for this measurement; 64-QAM modulation results are shown in the figures RF Signal Constellation and Meas Signal Constellation; BPSK constellations for the SIGNAL field are also shown.

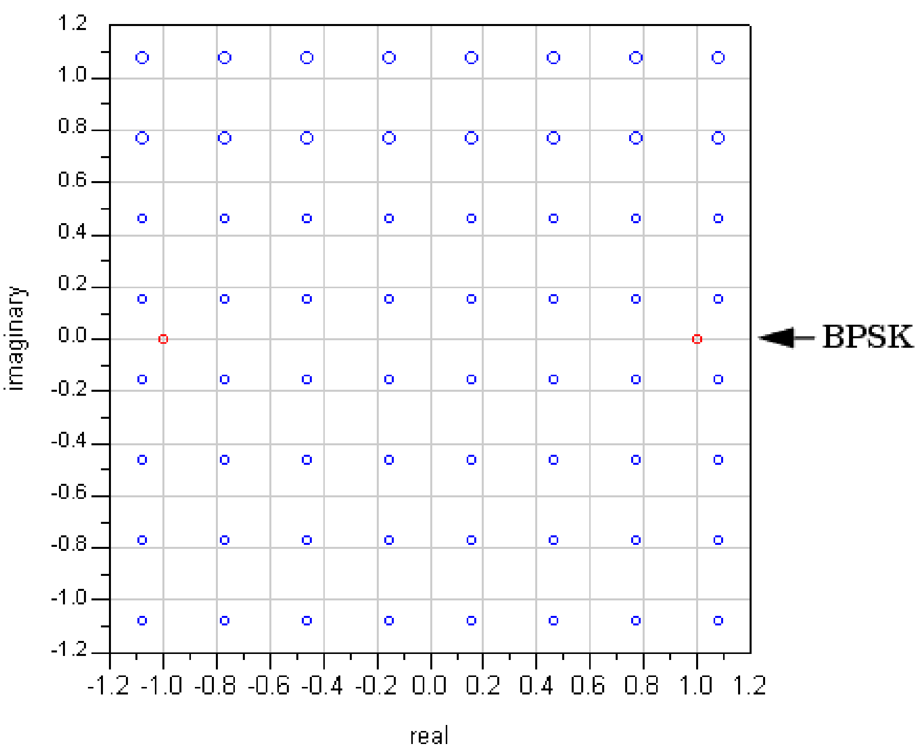
Data Rates and Modulation Types

Data Rate (Mbits/s)	Modulation
6	BPSK
9	BPSK
12	QPSK
18	QPSK
24	16-QAM
36	16-QAM
48	64-QAM
54	64-QAM

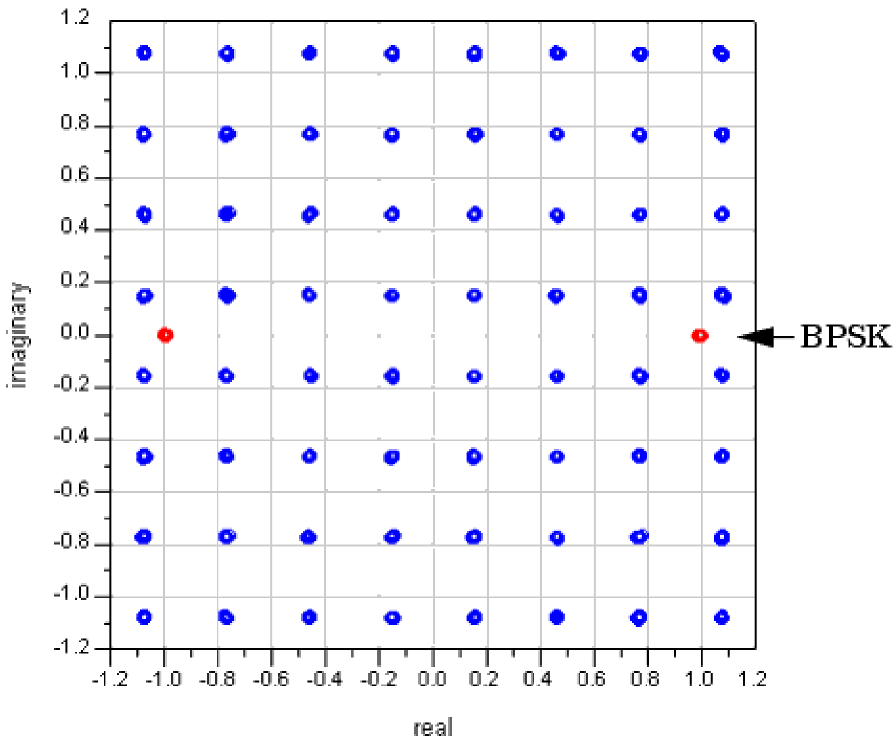
Basic Constellation Measurement Parameters

Parameter	Default Setting
RF_FSource	5200.0 MHz
RF_R	50.0 Ohm
DataTime	16.0 usec
BurstTime	40.0 usec
TimeStep	12.5 nsec
BitRate	54.0 Mbps
Meas_FMeasurement	5200.0 MHz
Meas_R	50.0 Ohm

RF Signal Constellation



Meas Signal Constellation



Power Measurement

The power measurement (not defined in IEEE 802.11a) shows the CCDF curves of the transmitter and peak-to-average ratios for the RF and Meas signals.
The basic power measurement parameters are listed in the following table.

Basic Power Measurement Parameters

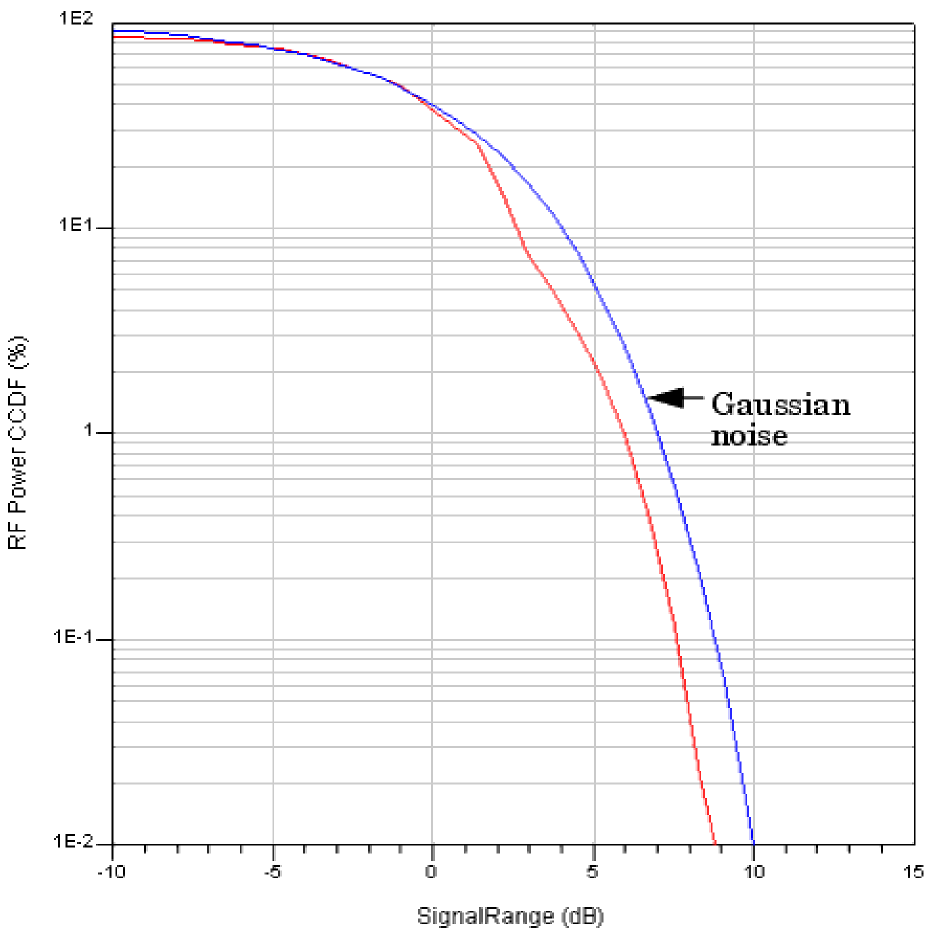
Parameter	Default Setting
RF_FSource	5200.0 MHz
RF_R	50.0 Ohm
Meas_FMeasurement	5200.0 MHz
Meas_R	50.0 Ohm
RF_Power_dBm	16.021 dBm

CCDF measurement results for RF and Meas signals are shown in the figures RF Power CCDF and Meas Power CCDF.

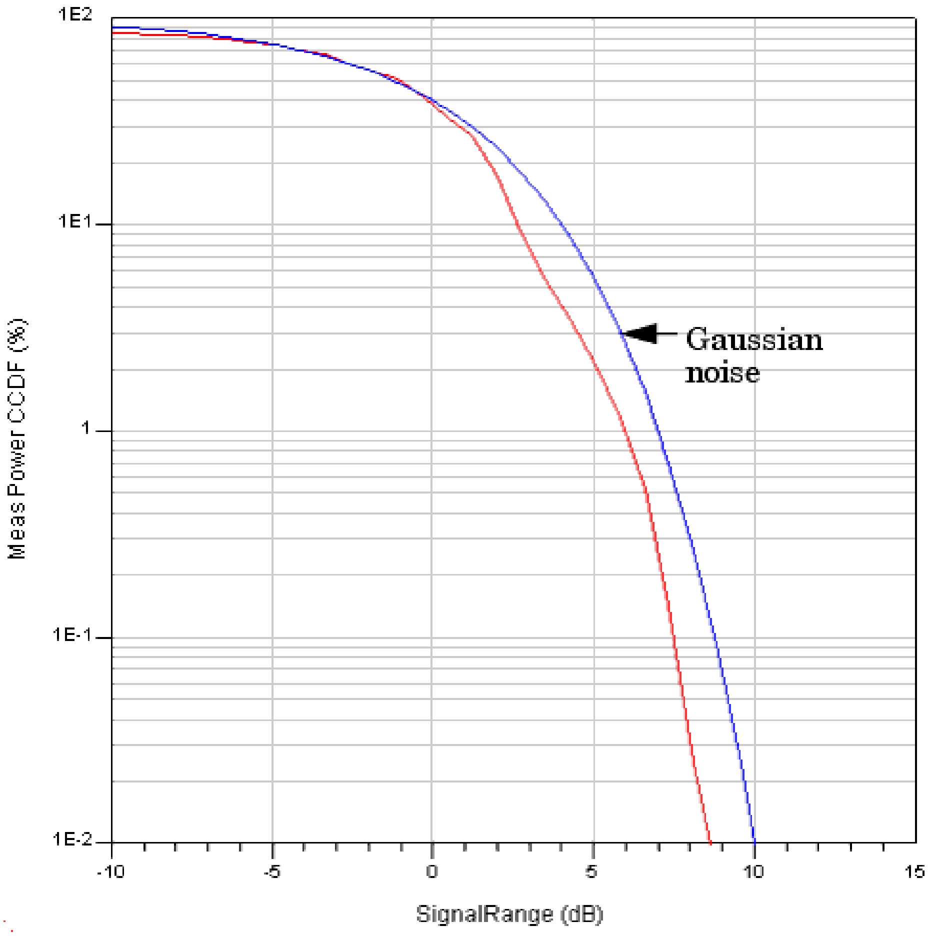
Reference CCDF measurements for Gaussian noise can be calculated by calling the *function power_ccdf_ref* () in the . *dds* files directly, as shown in Reference CCDF Calculation.

Functions for calculating peak-to-average-ratios and results are shown in RF Signal Peak-to-Average-Ratio Calculation and Results and Meas Signal Peak-to-Average-Ratio Calculation and Results.

RF Power CCDF



Meas Power CCDF



Reference CCDF Calculation

Eqn RF_CCDF_Ref=100*power_ccdf_ref(RF_Power.SignalRange_dB)

Eqn Meas_CCDF_Ref=100*power_ccdf_ref(Meas_Power.SignalRange_dB)

RF Signal Peak-to-Average-Ratio Calculation and Results

Eqn RF_Peak_to_Avg_dB = RF_Power.PeakPower_dBm - RF_Power.AvgPower_dBm

RF_Power.PeakPower_dBm	RF_Power.AvgPower_dBm	RF_Peak_to_Avg_dB
23.921	15.618	8.303

Meas Signal Peak-to-Average-Ratio Calculation and Results

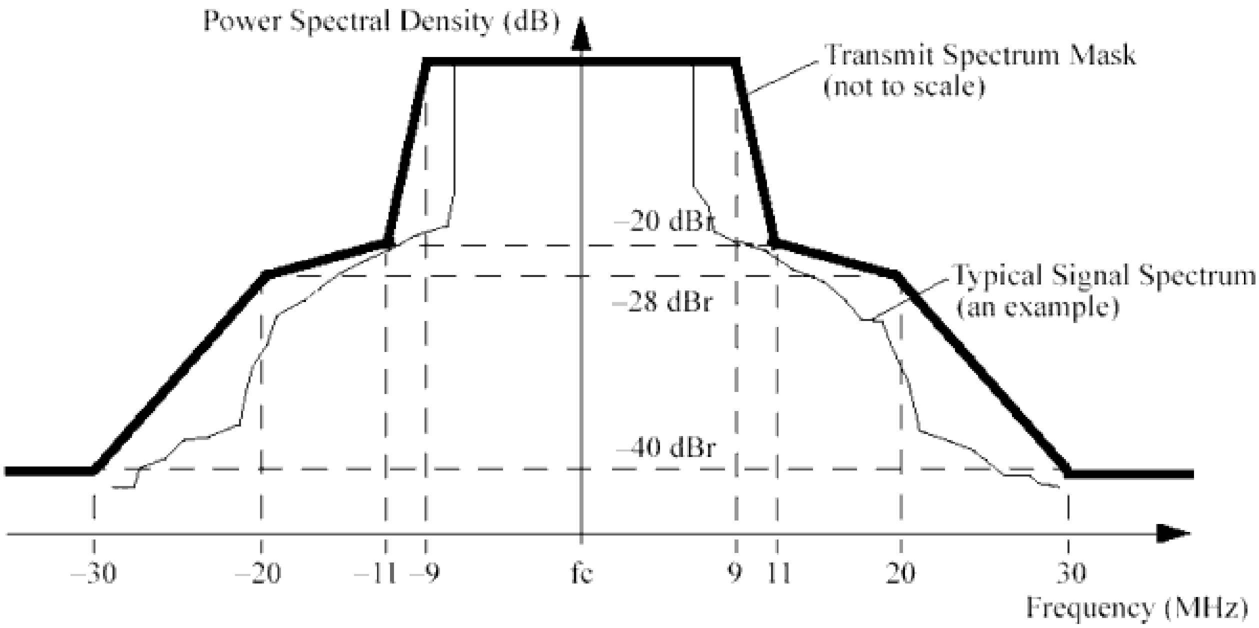
Eqn Meas_Peak_to_Avg_dB=Meas_Power.PeakPower_dBm - Meas_Power.AvgPower_dBm

Meas_Power.PeakPower_dBm	Meas_Power.AvgPower_dBm	Meas_Peak_to_Avg_dB
23.659	15.546	8.113

Spectrum Measurement

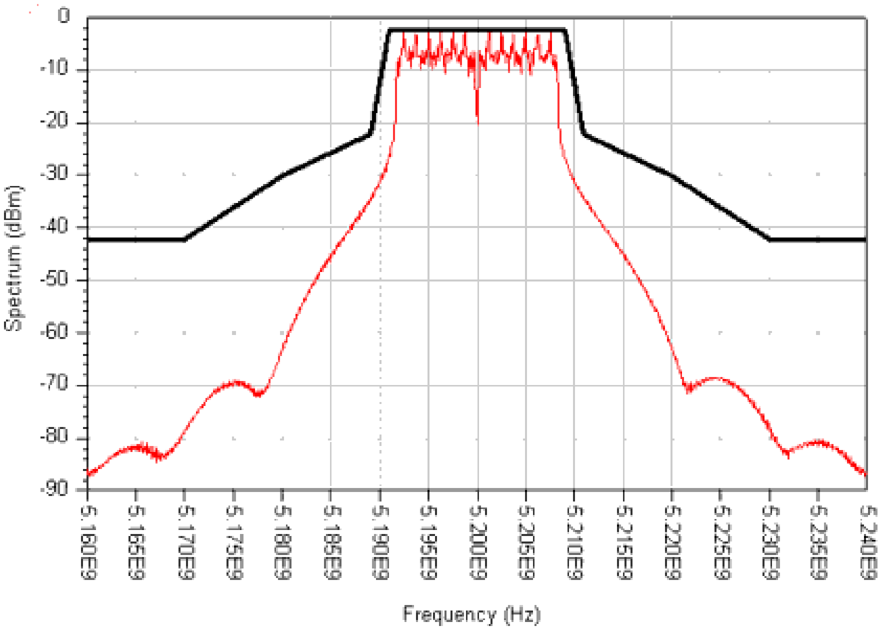
The Spectrum measurement is used to verify that the transmitted spectrum meets the spectrum mask according to IEEE 802.11a-1999, section 17.3.9.2. The transmitted spectrum must have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz (centered at the carrier frequency), -20 dBr at 11 MHz frequency offset, -28 dBr at 20 MHz frequency offset, and -40 dBr at 30 MHz frequency offset and above. The WLAN spectrum measurement has a resolution bandwidth of 100 kHz. The transmitted spectral density must fall within the spectral mask, as shown in the following figure.

Transmit Spectrum Mask

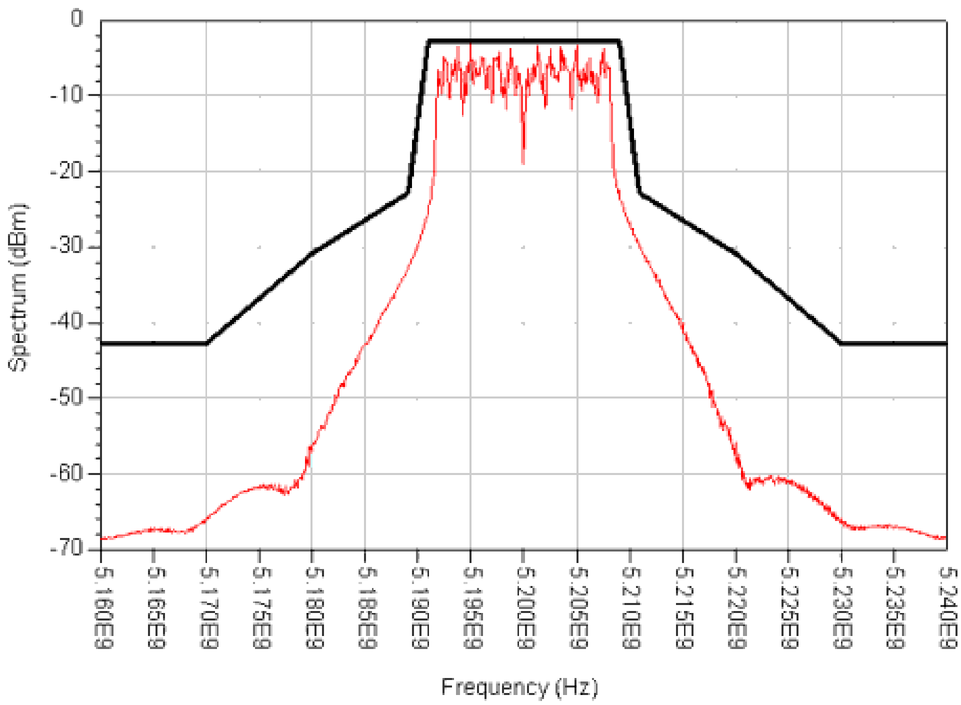


Measurement results for RF and Meas signals are shown in the figures RF Signal Spectrum and Meas Signal Spectrum. The RF and Meas signal spectrums are within the spectrum mask and therefore meet specification requirements.

RF Signal Spectrum



Meas Signal Spectrum



EVM Measurement

The EVM measurement is a modulation accuracy measurement and determines the relative constellation RMS error (EVM) according to IEEE 802.11a-1999, section 17.3.9.6.3. The RMS error is averaged over subcarriers, OFDM frames, and packets; results cannot exceed a data-rate-dependent value given in the following table.

Allowed Relative Constellation Error Values

Data Rate (Mbits/s)	Relative Constellation Error (dB)	EVM (%RMS)
6	-5	56.2
9	-8	39.8
12	-10	31.6
18	-13	22.3
24	-16	15.8
36	-19	11.2
48	-22	7.9
54	-25	5.6
Note: The 27 Mbps data rate is not defined in the 802.11a specification and is therefore not supported in this measurement.		

This measurement provides EVMrms_percent, EVM_dB, PilotEVM_dB, CPErms_percent, IQ_Offset_dB, and so on.

PilotEVM is the RMS value of EVMs (in dB) of the four pilot subcarriers for all symbols over the entire burst. For 802.11a this includes the SIGNAL symbol. Common pilot error (CPE) shows the difference between the measured and ideal pilot subcarrier symbols. SyncCorrelation is a cross correlation of the preamble synchronization of the measured signal to an ideal signal; it is a figure of merit indicating the quality of the preamble segment used for synchronization. The preamble segment used to calculate the SyncCorrelation is either the short training or the channel estimation sequence.

Basic parameters for this measurement are listed in the following table.

Basic Signal Parameters.

Parameter	Default Setting
RF_FSource	5200.0MHz
RF_R	50.0Ohm
Meas_FMeasurement	5200.0MHz
Meas_R	50.0Ohm
RF_Power_dBm	16.021dBm
BytesPerBurst	100
BitRate	54Mbps
OFDM_SymbolGuardInterval	0.25
TimeStep	12.5nsec

EVM measurement results shown in the figures RF Signal EVM and Meas Signal EVM for the 54 Mbps data rate do not exceed -25 dB; therefore the measurements meet the specification requirements.

RF Signal EVM

RF_EVM.EVM_dB	RF_EVM.EVMrms_percent
-136.730779	0.000015

RF_EVM.PilotEVM_dB	RF_EVM.CPErms_percent
-138.524406	0.000002

RF_EVM.SyncCorrelation	RF_EVM.IQ_Offset_dB
0.997451	-158.612219

Meas Signal EVM

Meas_EVM.EVM_dB	Meas_EVM.EVMrms_percent
-45.817674	0.511819

Meas_EVM.PilotEVM_dB	Meas_EVM.CPErms_percent
-47.358375	0.090730

Meas_EVM.SyncCorrelation	Meas_EVM.IQ_Offset_dB
0.997456	-67.731014

Test Bench Variables for Data Displays

Reference variables used to set up this test bench are listed in the tables Test Bench Constants for WLAN Signal Setup and Test Bench Equations Derived from Test Bench Parameters and Exported to Data Display.

DataBitsPerOFDMSymbol and BitRate values are listed in the table DataBitsPerOFDMSymbol and BitRate Values.

Test Bench Constants for WLAN Signal Setup

Constant	**Value**
MinFFT_Size	64 (= 26)
BitsPerByte	8
ServiceBits	16
TailBits	6
Ratio	Oversampling ratio related to the OversamplingOption as Ratio = 2OversamplingOption
DataBitsPerOFDMSymbol	Dependent on DataRate
OFDMSymbolsPerBurst	(int ((ServiceBits+BitsPerByte * DataLength+TailBits)/ DataBitsPerOFDMSymbol))+Tail
TailCondition	ServiceBits+BitsPerByte * DataLength+TailBits - DataBitsPerOFDMSymbol * (int ((ServiceBits+BitsPerByte * DataLength+TailBits)/ DataBitsPerOFDMSymbol))
Tail	0 if TailCondition=0, else 1

Test Bench Equations Derived from Test Bench Parameters and Exported to Data Display

Data Display Parameter	Equation with Test Bench Parameters
RF_FSource	FSource
RF_Power_dBm	10*log10(SourcePower)+30
RF_R	SourceR
TimeStep	1/(Bandwidth*Ratio) This is the test bench simulation time step.
OFDM_SymbolTime	MinFFT_Size*(1+GuardInterval)/Bandwidth This is the time duration for one OFDM symbol.
OFDM_SymbolsPerBurst	OFDMSymbolsPerBurst This is the number of OFDM symbols in the Data field of a burst.
OFDM_SymbolGuardInterval	GuardInterval This is the guard interval (as a ratio of OFDM_SymbolTime) associated with each OFDM symbol.
IdleTime	IdleInterval This is the time duration of the zero level idle field at the front of each burst.
ShortPreambleTime	8.0 usec This is the time duration of the short preamble field after the idle field in each burst.
LongPreambleTime	8.0 usec This is the time duration of the long preamble field after the short preamble field in each burst.
SIGNAL_Time	OFDM_SymbolTime This is the time duration of the SIGNAL field after the long preamble field in each burst.
DataTime	OFDM_SymbolsPerBurst*OFDM_SymbolTime This is the time duration of the Data field after the SIGNAL field in each burst.
BurstTime	IdleTime + ShortPreambleTime + LongPreambleTime + SIGNAL_Time + DataTime
BytesPerBurst	DataLength This is the number of bytes of data in the Data field in each burst.
BitRate	Dependent on DataRate This is the bit rate for the transmitted WLAN signal.
Meas_FMeasurement	FMeasurement
Meas_R	MeasR

DataBitsPerOFDMSymbol and BitRate Values

DataRate	DataBitsPerOFDMSymbol	BitRate
Mbps_6	24	6e6
Mbps_9	36	9e6
Mbps_12	48	12e6
Mbps_18	72	18e6
Mbps_24	96	24e6
Mbps_27	108	27e6
Mbps_36	144	36e6
Mbps_48	192	48e6
Mbps_54	216	54e6

Baseline Performance

- Test Computer Configuration
  - Pentium IV 2.4 GHz, 512 MB RAM, Red Hat Linux 7.3
- Conditions
  - Measurements made with default test bench settings.
  - RF DUT is an RF system behavior component.
  - Number of time points in one WLAN 802.11a burst is a function of Bandwidth, OversamplingOption, IdleInterval, GuardInterval, DataRate, and DataLength.
    Bandwidth = 20 MHz
    OversamplingOption = Option 2 for Ratio 4
    IdleInterval = 4 μ
    GuardInterval = 0.25
    DataRate = 54 Mbps
    DataLength = 100
  - Resultant WTB_TimeStep = 12.5 nsec; BurstTime = 40 μ time points per burst = 3200
- Simulation times and memory requirements:

WLAN_802_11a_TXMeasurement	Bursts Measured	Simulation Time (sec)	ADS Processes (MB)
RF_Envelope	3	10	58
Constellation	3	5	51
Power	3	4	50
Spectrum	3	4	50
EVM	10	13	53

Expected ADS Performance

Expected ADS performance is the combined performance of the baseline test bench and the RF DUT Circuit Envelope simulation with the same signal and number of time points. For example, if the RF DUT performance with Circuit Envelope simulation alone takes 2 hours and consumes 200 MB of memory (excluding the memory consumed by the core ADS product), then add these numbers to the Baseline Performance numbers to determine the expected ADS performance. This is valid only if the full memory consumed is from RAM. If RAM is less, larger simulation times may result due to increased disk access time for swap memory usage.

References

1. IEEE Std 802.11a-1999, "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High-speed Physical Layer in the 5 GHz Band," 1999.
http://standards.ieee.org/getieee802/download/802.11a-1999.pdf
2. ETSI TS 101 475 v1.2.1, "Broadband Radio Access Networks (BRAN); HIPERLAN Type 2; Physical (PHY) layer," November, 2000.
http://webapp.etsi.org/workprogram/Report_WorkItem.asp?WKI_ID=9949
3. IEEE P802.11g/D8.2, "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: Further Higher Data Rate Extension in the 2.4 GHz Band," April, 2003.
http://www.ieee.org/memberservices
4. CCITT, Recommendation O.151(10/92).
5. CCITT, Recommendation O.153(10/92).

Setting up a Wireless Test Bench Analysis in the *Wireless Test Bench Simulation* documentation explains how to use test bench windows and dialogs to perform analysis tasks.
Setting Circuit Envelope Analysis Parameters in the *Wireless Test Bench Simulation* documentation explains how to set up circuit envelope analysis parameters such as convergence criteria, solver selection, and initial guess.
Setting Automatic Behavioral Modeling Parameters in the *Wireless Test Bench Simulation* documentation explains how to improve simulation speed.

WLAN Links

European Radiocommunications Office:
http://www.ero.dk
U.S. Frequency Allocations Chart:
http://www.ntia.doc.gov/osmhome
IEEE 802.11b Compliance Organization:
http://www.wi-fi.org
IEEE 802.11 Working Group:
http://grouper.ieee.org/groups/802/11/index.html

WLAN 802.11a Receiver Adjacent Channel Rejection Test

Introduction

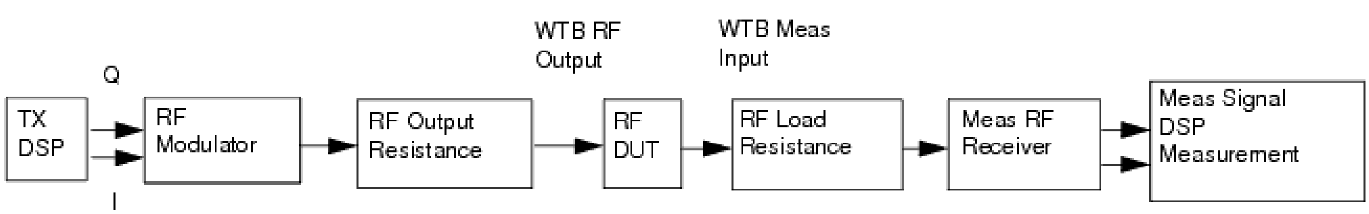
WLAN_802_11a_RX_ACR is the test bench for WLAN receiver adjacent and non-adjacent channel rejection testing. The test bench enables users to connect to an RF DUT and determine its performance.

The signal and the measurement are designed according to IEEE Standard 802.11a-1999.

This WLAN signal source model is compatible with the Agilent Signal Studio Software option 417. Details regarding Signal Studio for WLAN 802.11 are included at the website http://www.agilent.com/find/signalstudio .

This test bench includes a TX DSP section, an RF modulator, RF output source resistance, an RF DUT connection, RF receivers, and DSP measurement blocks as illustrated in Receiver Wireless Test Bench Block Diagram. The generated test signal is sent to the DUT.

Receiver Wireless Test Bench Block Diagram



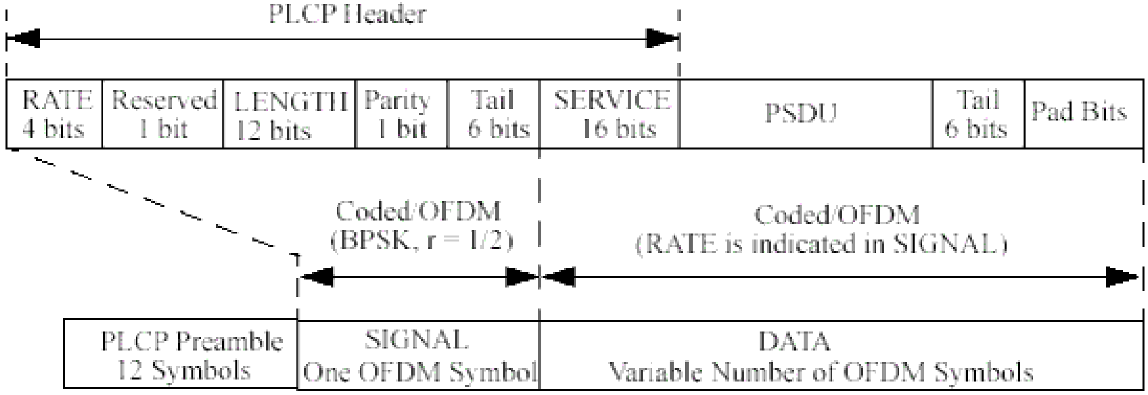
The WLAN 802.11a/g signal burst is illustrated in the figures 802.11a/g Burst Format and OFDM Training Structure. Each burst, separated by IdleInterval, consists of Short Preamble, Long Preamble, SIGNAL, and DATA fields.

- Short Preamble consists of 10 short preambles (8 μ).
- Long Preamble consists of 2 long preambles (8 μ). The two preamble fields combined compose the PLCP Preamble that has a constant duration (16 μ) for all source parameter settings.
- SIGNAL includes 802.11a/g bursts of information (such as data rate, payload data, and length).
- DATA contains payload data.

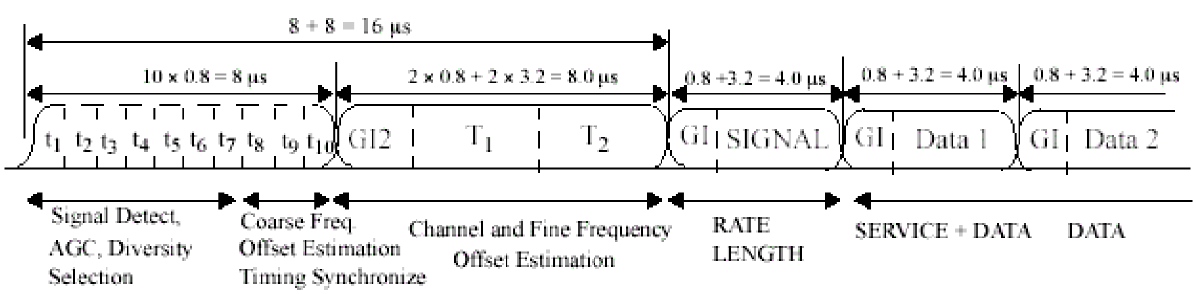
Channel coding, interleaving, mapping and IFFT processes are also included in SIGNAL and DATA parts generation. The SIGNAL field and each individual Data field (part of the overall DATA field) have a time duration defined as OFDM_SymbolTime and includes a GuardInterval. OFDM _SymbolTime depends on Bandwidth (=64/Bandwidth).

In the figures 802.11a/g Burst Format and OFDM Training Structure, PLCP means *physical layer convergence procedure* , PSDU means *PLCP service data units* , GI means *guard interval* ; GI is set to 0.25 and Bandwidth is set to 20 MHz (resulting in OFDM_SymbolTime = 4 μ).

802.11a/g Burst Format

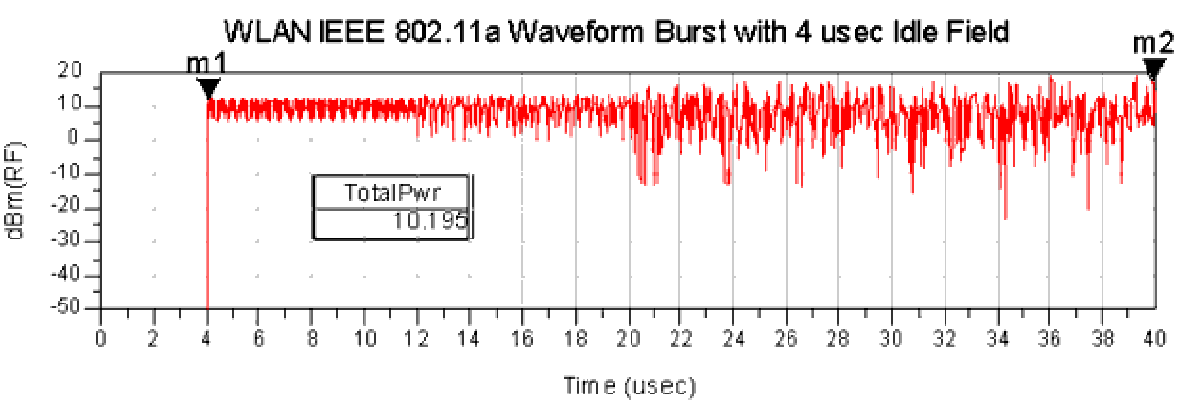


OFDM Training Structure



The WLAN RF power delivered into a matched load is the average power delivered in the WLAN burst excluding the burst idle time. The figure WLAN 802.11a RF Signal Envelope shows the RF envelope for an output RF signal with 10 dBm power.

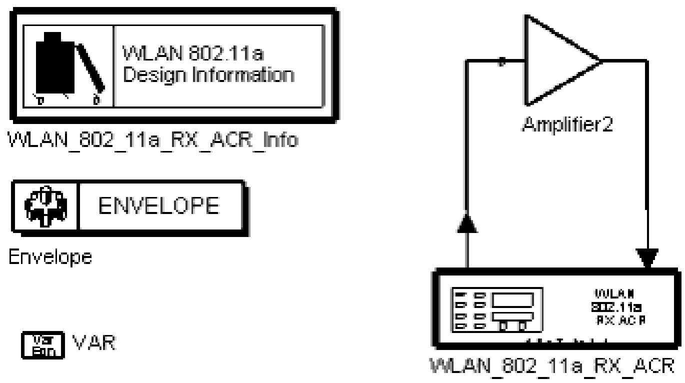
WLAN 802.11a RF Signal Envelope



Test Bench Basics

A template is provided for this test bench.

WLAN 802.11a Receiver ACR Test Bench



To access the template:

1. In an Analog/RF schematic window select *Insert* > *Template.*
2. In the *Insert* > *Template* dialog box, choose *WLAN_802_11a_RX_ACR_test* , click *OK* ; click left to place the template in the schematic window.
   An example design using this template is available; from the ADS Main window click *File* > *Open* > *Example* > WLAN > WLAN_RF_Verification_wrk > *WLAN_802_11a_RX ACR_test* .

The basics for using the test bench are:

- Replace the DUT (Amplifier2 is provided with this template) with an RF DUT that is suitable for this test bench.
- CE_TimeStep, FSource, SourcePower, and FMeasurement parameter default values are typically accepted; otherwise, set values based on your requirements.
- Activate/deactivate measurements based on your requirements.
- Run the simulation and view Data Display page(s) for your measurement(s).

For details, refer to Test Bench Details.

Test Bench Details

The following sections provide details for setting up a test bench, setting measurement parameters for more control of the test bench, simulation measurement displays, and baseline performance.

Open and use the *WLAN_802_11a_RX_ACR* template:

1. In an Analog/RF schematic window select *Insert > Template.*
2. In the *Insert > Template* dialog box, choose *WLAN_802_11a_RX_ACR_test* , click *OK* ; click left to place the template in the schematic window.

Test bench setup is detailed here.

1. Replace the DUT (Amplifier2 is provided with this template) with an RF DUT that is suitable for this test bench.
   For information regarding using certain types of DUTs, see *RF DUT Limitations for WLAN Wireless Test Benches* (adswtbwlan).

2. Set the *Required Parameters*

   > **Note**
   > Refer to *WLAN_802_11a_RX_ACR* (adswtbwlan) for a complete list of parameters for this test bench.

   Generally, default values can be accepted; otherwise, values can be changed by the user as needed.

   - Set CE_TimeStep.
     Cosimulation occurs between the test bench (using ADS Ptolemy Data Flow simulation technology) and the DUT (using Circuit Envelope simulation technology). Each technology requires its own simulation time step with time-step coordination occurring in the interface between the technologies.
     CE_TimeStep defines the Circuit Envelope simulation time step to be used with this DUT. The CE_TimeStep must be set to a value equal to or a submultiple of (less than) WTB_TimeStep; otherwise, simulation will stop and an error message will be displayed.
     Note that WTB_TimeStep is not user-settable. Its value is derived from other test bench parameter values; with default settings WTB_TimeStep=6.25 nsec. The value is displayed in the Data Display pages as TimeStep.

     WTB_TimeStep = 1/(Bandwidth × Ratio)

     where

     Bandwidth is the user-settable value (default = 20 MHz)

     Ratio is the oversampling ratio value specified by OversamplingOption (not the enum index). Ratio sets the number of waveform sampling points during the signal FFT time interval. During this time interval the minimum FFT sampling size is 64 (which corresponds to an FFT order of 6; i.e 2 {^{6}) and the FFT time interval is defined as 64/Bandwidth.

For example, a Ratio of 4 sets the FFT sampling size to 64 × 4=256 (which corresponds to an FFT order of 8) during the signal FFT time interval.

- Set FSource, SourcePower, and FMeasurement.
  - FSource defines the RF frequency for the signal input to the RF DUT. The FSource value is exported to the *Choosing Analyses* window *Fundamental Tones* field when the user clicks *OK* in the *Wireless Test Bench Setup* window.
  - SourcePower defines the power level for FSource. SourcePower is defined as the average power during the non-idle time of the signal burst.
  - FMeasurement defines the RF frequency output from the DUT to be measured.

3. More control of the test bench can be achieved by setting *Basic Parameters* , *Signal Parameters* , and measurement parameters. For details, refer to *Setting Parameters* (adswtbwlan).
4. The RF modulator (shown in the block diagram in Receiver Wireless Test Bench Block Diagram) uses FSource, SourcePower (*Required Parameters*), MirrorSourceSpectrum (*Basic Parameters)* , GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and IQ_Rotation (*Signal Parameters*).
   The RF output resistance uses SourceR and SourceTemp (*Basic Parameters*). The RF output signal source has a 50-ohm (default) output resistance defined by SourceR.
   RF output (and input to the RF DUT) is at the frequency specified (FSource), with the specified source resistance (SourceR) and with power (SourcePower) delivered into a matched load of resistance SourceR. The RF signal has additive Gaussian noise power set by resistor temperature (SourceTemp).
   Note that the Meas_in point of the test bench provides a resistive load to the RF DUT set by the MeasR value (50-ohm default) (*Basic Parameters*).
   The Meas signal contains linear and nonlinear signal distortions and time delays associated with the RF DUT input to output characteristics.
   The TX DSP block (shown in the block diagram in Receiver Wireless Test Bench Block Diagram) uses other *Signal Parameters* .
5. More control of Circuit Envelope analysis can be achieved by setting Envelope controller parameters. These settings include Enable Fast Cosim, which may speed the RF DUT simulation more than 10×. Setting these simulation options is described in *Setting Fast Cosimulation Parameters* and *Setting Circuit Envelope Analysis Parameters* in the *Wireless Test Bench Simulation* documentation.
6. After running a simulation, results will appear in a Data Display window for the measurement. *Simulation Measurement Displays* (adswtbwlan) describes results for each measurement. For general WTB Data Display details refer to *Viewing WTB Analysis Results* (adswtbsim).

WLAN_802_11a_RX_ACR

This section provides parameter information for *Required Parameters, Basic Parameters, Signal Parameters,* and parameters for the various measurements.

Description WLAN 802.11a RX ACR
Library WTB
Class TSDFWLAN_802_11a_RX_ACR
Derived From baseWTB_RX

Parameters

Name	Description	Default	Sym	Unit	Type	Range
RequiredParameters						
CE_TimeStep	Circuit envelope simulation time step	1/20 MHz/8		sec	real	(0, ∞)
WTB_TimeStep	Set CE_TimeStep< =1/Bandwidth/2^{OversamplingOption}. Expression variables are in Signal Parameters tab/category.					
FSource	Source carrier frequency: CH1 _2412.0MHz, CH3 _2422.0MHz, CH5 _2432.0MHz, CH6 _2437.0MHz, CH7 _2442.0MHz, CH9 _2452.0MHz, CH11 _2462.0MHz, CH13 _2472.0MHz, CH36 _5180.0MHz, CH40 _5200.0MHz, CH44 _5220.0MHz, CH48 _5240.0MHz,	CH1 _2412.0MHz		Hz	real enum	(0, ∞)

	CH52 _5260.0MHz, CH56 _5280.0MHz, CH60 _5300.0MHz, CH64 _5320.0MHz, CH149 _5745.0MHz, CH153 _5765.0MHz, CH157 _5785.0MHz, CH161 _5805.0MHz					
SourcePower	Source power	dbmtow(-62.0)		W	real	[0, ∞)
FMeasurement	Measurement carrier frequency: Meas_CH1 _2412.0MHz, Meas_CH3 _2422.0MHz, Meas_CH5 _2432.0MHz, Meas_CH6 _2437.0MHz, Meas_CH7 _2442.0MHz, Meas_CH9 _2452.0MHz, Meas_CH11 _2462.0MHz, Meas_CH13 _2472.0MHz, Meas_CH36 _5180.0MHz, Meas_CH40 _5200.0MHz, Meas_CH44 _5220.0MHz, Meas_CH48 _5240.0MHz, Meas_CH52 _5260.0MHz, Meas_CH56 _5280.0MHz, Meas_CH60 _5300.0MHz, Meas_CH64 _5320.0MHz, Meas_CH149 _5745.0MHz, Meas_CH153 _5765.0MHz, Meas_CH157 _5785.0MHz, Meas_CH161 _5805.0MHz	Meas_CH1 _2412.0MHz		Hz	real enum	(0, ∞)
BasicParameters						

SourceR	Source resistance	50 Ohm		Ohm	real	(0, ∞)
SourceTemp	Source resistor temperature	16.85		Celsius	real	[-273.15, ∞)
MeasR	Measurement resistance	50 Ohm		Ohm	real	[10, 1.0e6]
MirrorSourceSpectrum	Mirror source spectrum about carrier? NO, YES	NO			enum	
MirrorMeasSpectrum	Mirror meas spectrum about carrier? NO, YES	NO			enum	
TestBenchSeed	Random number generator seed	1234567			int	[0, ∞)
SignalParameters						
GainImbalance	Gain imbalance, Q vs I	0.0		dB	real	(-∞, ∞)
PhaseImbalance	Phase imbalance, Q vs I	0.0		deg	real	(-∞, ∞)
I_OriginOffset	I origin offset (percent)	0.0			real	(-∞, ∞)
Q_OriginOffset	Q origin offset (percent)	0.0			real	(-∞, ∞)
IQ_Rotation	IQ rotation	0.0		deg	real	(-∞, ∞)
Bandwidth	Bandwidth	20 MHz	B	Hz	real	(0, ∞)
OversamplingOption	Oversampling ratio option: Option 0 for Ratio 1, Option 1 for Ratio 2, Option 2 for Ratio 4, Option 3 for Ratio 8, Option 4 for Ratio 16, Option 5 for Ratio 32	Option 3 for Ratio 8	S		enum	
DataRate	Data rate (Mbps): Mbps_6, Mbps_9, Mbps_12, Mbps_18, Mbps_24, Mbps_27, Mbps_36, Mbps_48, Mbps_54	Mbps_54	R		enum	
IdleInterval	Burst idle interval	4.0 usec	I	sec	real	[0, 1000usec]
DataType	Payload data type: PN9, PN15, FIX4, _4_1_4_0, _8_1_8_0, _16_1_16_0, _32_1_32_0, _64_1_64_0	PN9			enum	
DataLength	Data length (bytes per burst)	1000	L		int	[1, 4095]
GuardInterval	Guard interval (frac FFT size)	0.25			int	[0, 1]
AdjChSignalParameters						
AdjChFSourceOffset	Adjacent channel carrier frequency offset	-20 MHz		Hz	real	(-∞, ∞)
AdjChPower	Adjacent channel power	dbmtow(-63.0)		W	real	[0, ∞)
MeasurementParameters						
DisplayPages	RX adjacent channel rejection measurement display pages: WLAN_802_11a_RX_ACR Table					
DecoderType	Decoder type: Hard, Soft, CSI	CSI			enum	
TrunLen	Path memory truncation length	60			int	[20, 200)
StartBurst	Start burst	0			int	[0, 1000]
StopBurst	Stop burst	100			int	[0, 1000]

Pin Input

Pin	Name	Description	Signal Type
2	Meas_In	Test bench measurement RF input from RF circuit	timed

Pin Output

Pin	Name	Description	Signal Type
1	RF_Out	Test bench RF output to RF circuit	timed

Setting Parameters

More control of the test bench can be achieved by setting parameters in the *Basic Parameters* , *Signal Parameters* , and *measurement* categories for the activated measurements.

> **Note**
> For *required* parameter information, see *Set the Required Parameters* (adswtbwlan).

Basic Parameters

1. SourceR is the RF output source resistance.
2. SourceTemp is the RF output source resistance temperature (oC) and sets noise density in the RF output signal to (k(SourceTemp+273.15)) Watts/Hz, where k is Boltzmann's constant.
3. MeasR defines the load resistance for the RF DUT output Meas signal into the test bench. This resistance loads the RF DUT output; it is also the reference resistance for Meas signal power measurements.
4. MirrorSourceSpectrum is used to invert the polarity of the Q envelope of the generated RF signal before it is sent to the RF DUT. Depending on the configuration and number of mixers in an RF transmitter, the signal at the input of the DUT may need to be mirrored. If such an RF signal is desired, set this parameter to YES.
5. MirrorMeasSpectrum is used to invert the polarity of the Q envelope in the Meas_in RF signal input to the test bench (and output from the RF DUT). Depending on the configuration and number of mixers in the RF DUT, the signal at its output may be mirrored compared to the signal generated by the signal source (before any mirroring is done because of the MirrorSourceSpectrum setting). Proper demodulation and measurement of the RF DUT output signal requires that its RF envelope is not mirrored compared to the signal generated by the signal source (before any mirroring is done because of the MirrorSourceSpectrum setting). If the Meas_in RF signal is mirrored, set this parameter to YES. Proper setting of this parameter is required for measurements on the Meas_in signal in RX text benches and results in measurement on a signal with no spectrum mirroring.
6. TestBenchSeed is an integer used to seed the random number generator used with the test bench. This value is used by all test bench random number generators, except those RF DUT components that use their own specific seed parameter. TestBenchSeed initializes the random number generation. The same seed value produces the same *random* results, thereby giving you predictable simulation results. To generate repeatable *random* output from simulation to simulation, use any positive seed value. If you want the output to be truly random, enter the seed value of 0.

Signal Parameters

1. GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and IQ_Rotation are used to add certain impairments to the ideal output RF signal. Impairments are

added in the order described here.
The unimpaired RF I and Q envelope voltages have gain and phase imbalance applied. The RF is given by:

$$V_{RF}(t) = A\left(V_I(t)\cos(\omega_c t) - gV_Q(t)\sin\left(\omega_c t + \frac{\phi\pi}{180}\right)\right)$$

where *A* is a scaling factor that depends on the SourcePower and SourceR parameters specified by the user, $V_I(t)$ is the in-phase RF envelope, $V_Q(t)$ is the quadrature phase RF envelope, *g* is the gain imbalance

$$g = 10^{\frac{GainImbalance}{20}}$$

and, φ (in degrees) is the phase imbalance.
Next, the signal $V_{RF}(t)$ is rotated by IQ_Rotation degrees. The I_OriginOffset and Q_OriginOffset are then applied to the rotated signal. Note that the amounts specified are percentages with respect to the output rms voltage. The output rms voltage is given by sqrt(2 × SourceR × SourcePower).

2. Bandwidth is used to determine the actual bandwidth of WLAN systems and to calculate the sampling rate and timestep per sample. The default value is 20 MHz (defined in 802.11a/g specification); to double the rate for the 802.11a/g turbo mode, set Bandwidth to 40 MHz.
3. OversamplingOption sets the oversampling ratio of 802.11a/g RF signal source. Options from 0 to 5 result in oversampling ratio 2, 4, 8, 16, 32 where oversampling ratio = $2^{OversamplingOption}$. If OversamplingOption = 2, the oversampling ratio = 22 = 4 and the simulation RF bandwidth is larger than the signal bandwidth by a factor of 4 (e.g. for Bandwidth=20 MHz, the simulation RF bandwidth = 20 MHz × 4 = 80 MHz).
4. DataRate specifies the data rate 6, 9, 12, 18, 24, 27, 36, 48 and 54 Mbps. All data rates except 27 Mbps are defined in the 802.11a/g specification; 27 Mbps is from HIPERLAN/2.
The following table lists key parameter values of 802.11a/g.

Rate-dependent parameters

Data Rate (Mbps)	Modulation	Coding Rate (R)	Coded Bits per Subcarrier (N_{BPSC})	Coded Bits per OFDM Symbol (N_{CBPS})	Data Bits per OFDM Symbol (N_{DBPS})
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
27	16-QAM	9/16	4	192	108
36	16-QAM	3/4	4	192	144
48	64-QAM	2/3	6	288	192
54	64-QAM	3/4	6	288	216

5. IdleInterval specifies the idle interval between two consecutive bursts when generating a 802.11a signal source.
6. For DataType:
   - if PN9 is selected, a 511-bit pseudo-random test pattern is generated according

to CCITT Recommendation O.153.
  - if PN15 is selected, a 32767-bit pseudo-random test pattern is generated according to CCITT Recommendation O.151.
  - if FIX4 is selected, a zero-stream is generated.
  - if x_1_x_0 is selected (where x equals 4, 8, 16, 32, or 64) a periodic bit stream is generated, with the period being 2 x. In one period, the first x bits are 1s and the second x bits are 0s.
7. DataLength is used to set the number of data bytes in a burst. There are 8 bits per byte.
8. GuardInterval is used to set cyclic prefix in an OFDM symbol. The value range of GuardInterval is [0.0,1.0]. The cyclic prefix is a fractional ratio of the IFFT length. 802.11a/g defines GuardInterval=1/4 (0.8 μsec) and HIPERLAN/2 defines two GuardIntervals (1/8 and 1/4).

Adjacent Channel Rejection Parameters

1. AdjChFSourceOffset: Adjacent channel carrier frequency offset.
2. AdjChPower: Adjacent channel power.

Measurement Parameters

This measurement requires setting of the MirrorMeasSpectrum parameter such that there is an even number of spectrum mirrorings from the combined test bench source and RF DUT. For example, if MirrorSourceSpectrum=NO and the RF DUT causes its output RF signal to have spectrum mirroring relative to its input signal, then set MirrorMeasSpectrum=YES.

1. DisplayPages provides Data Display page information for this measurement. It cannot be changed by the user.
2. DecoderType has three modes: Hard, Soft, and CSI. When DecoderType=Hard, if $b < 0$, *-1.0* is output, otherwise *1.0* is output; when DecoderType=Soft, if $b < -1.0$, *-1.0* is output; if $b > 1.0$, *1.0* is output; when DecoderType=CSI, *b* is multiplied by *CSI* $(= |H(i)|^2)$ and output. CSI means Channel Status Information and estimated channel impulse responses *(H(i))* are the CSI here.
3. TrunLen sets the most recent TrunLen information bits in each surviving sequence are stored. Once the path with the shortest distance is identified, the symbol associated with the path TrunLen periods ago is conveyed to the output as a decoded information symbol.
4. StartBurst sets the start burst. A value of 0 is the first burst.
5. StopBurst sets the stop burst. A StopBurst value of 100 results in measuring 101 bursts.

Simulation Measurement Displays

After running the simulation, results are displayed in the Data Display pages for each measurement activated.

> **Note**
> Measurement results from a wireless test bench have associated names that can be used in Data Display Expressions. For more information, refer to *Measurement Results for Expressions for WLAN Wireless Test Benches* (adswtbwlan).

Measurement

This measurement shows BER and PER results.

Adjacent or non-adjacent channel rejection is measured by setting the desired signal strength 3 dB above the rate-dependent sensitivity (as specified in Table 91 of IEEE Std. 802.11a-1999) and raising the power of the interfering signal until the 10% packet error rate (PER) is caused for a DataLength (PSDU) of 1000 bytes. The power difference between the interfering and the desired channel is the corresponding adjacent or non-adjacent channel rejection. The interfering signal in the adjacent or non-adjacent channel must be a conformant OFDM PHY signal, unsynchronized with the signal in the channel under test. For a conformant OFDM PHY the corresponding rejection must be no less than that specified in Table 91 of IEEE Std. 802.11a-1999 and listed in the following table.

Receiver Requirements

Data Rate (Mbps)	Minimum Sensitivity (dBm)	*Adjacent Channel Rejection (dB)	Alternate Adjacent Channel Rejection (dB)
6	-82	16	32
9	-81	15	31
12	-79	13	29
18	-77	11	27
24	-74	8	24
36	-70	4	20
48	-66	0	16
54	-65	-1	15

Simulation results for data rate of 54 Mbps with SourcePower at -62 dBm are shown in Simulation Results for 54 Mbps data rate and -62 dBm SourcePower.

The receiver channel rejection is defined in Table 91 of IEEE Std. 802.11a-1999. The PER shall be less than 10% when the power of the interfering signal is raised to the rate-dependent channel rejection level.

Simulation Results for 54 Mbps data rate and -62 dBm SourcePower

Defined in IEEE802.11a Specification

real(RF_FSource)/(1 MHz)	real(RF_Power_dBm)	real(RF_R)	real(Meas_FMeasurement)/(1 MHz)	real(Meas_R)
5200.000	-62.000	50.000	5200.000	50.000

real(BurstTime)/(1 usec)	real(TimeStep)/(1 nsec)	real(IdleTime)/(1 usec)	real(DataTime)/(1 usec)
176.000	6.250	4.000	152.000

real(LongPreambleTime)/(1 usec)	real(ShortPreambleTime)/(1 usec)	real(OFDM_SymbolTime)/(1 usec)	real(OFDMSymbolsPerBurst)
8.000	8.000	4.000	38.000

real(BytesPerBurst)	real(BitRate)/(1 Mbps)	real(OFDM_SymbolGuardInterval)	real(RF_SourceTemp)
1000.000	54.000	0.250	16.850

real(RF_AdjChFSourceOffset)/(1 MHz)	real(AdjChPower_dBm)
-20.000	-63.000

Meas BER PER

BER	PER
0.00003125	0.03000000

Test Bench Variables for Data Displays

The following tables identify the reference variables used to set up this test bench:

Test Bench Constants for WLAN Signal Setup

Constant	**Value**
MinFFT_Size	64 (= 2^6)
BitsPerByte	8
ServiceBits	16
TailBits	6
Ratio	Oversampling ratio related to the OversamplingOption as Ratio = $2^{OversamplingOption}$
DataBitsPerOFDMSymbol	Dependent on DataRate in the next table.
OFDMSymbolsPerBurst	(int ((ServiceBits+BitsPerByte*DataLength+TailBits)/ DataBitsPerOFDMSymbol))+Tail
TailCondition	ServiceBits+BitsPerByte*DataLength+TailBits - DataBitsPerOFDMSymbol *(int ((ServiceBits+BitsPerByte*DataLength+TailBits)/ DataBitsPerOFDMSymbol))
Tail	if (TailCondition = 0) then 0 else 1

DataRate Determines DataBitsPerOFDMSymbol and BitRate Values

DataRate	**DataBitsPerOFDMSymbol (see previous table)**	**BitRate (see next table)**
Mbps_6	24	6e6
Mbps_9	36	9e6
Mbps_12	48	12e6
Mbps_18	72	18e6
Mbps_24	96	24e6
Mbps_27	108	27e6
Mbps_36	144	36e6
Mbps_48	192	48e6
Mbps_54	216	54e6

Test Bench Equations Derived from Test Bench Parameters and Exported to the Data Display

Data Display Parameter	Equation with Test Bench Parameters
RF_FSource	FSource
RF_Power_dBm	10*log10(SourcePower)+30
RF_R	SourceR
RF_SourceTemp	SourceTemp in degrees Celsius
TimeStep	1/(Bandwidth*Ratio) This is the test bench simulation time step.
OFDM_SymbolTime	MinFFT_Size*(1+GuardInterval)/Bandwidth This is the duration for one OFDM symbol.
OFDM_SymbolsPerBurst	OFDMSymbolsPerBurst This is the number of OFDM symbols in the Data field of a burst.
OFDM_SymbolGuardInterval	GuardInterval This is the guard interval (as a ratio of the OFDM_SymbolTime) associated with each OFDM symbol.
IdleTime	IdleInterval This is the duration of the zero level idle field at the front of each burst.
ShortPreambleTime	8.0 usec This is the duration of the short preamble field after the idle field in each burst.
LongPreambleTime	8.0 usec This is the duration of the long preamble field after the short preamble field in each burst.
SIGNAL_Time	OFDM_SymbolTime This is the duration of the SIGNAL field after the long preamble field in each burst.
DataTime	OFDM_SymbolsPerBurst*OFDM_SymbolTime This is the duration of the Data field after the SIGNAL field in each burst.
BurstTime	IdleTime + ShortPreambleTime + LongPreambleTime + SIGNAL_Time + DataTime
BytesPerBurst	DataLength This is the number of bytes of data in the Data field in each burst.
BitRate	Dependent on DataRate in the previous table. This is the bit rate for transmitted WLAN signal.
Meas_FMeasurement	FMeasurement
MeasR	MeasR

Baseline Performance

- Test Computer Configuration
  - Pentium IV 2.4 GHz, 512MB RAM, Red Hat Linux 7.3
- Conditions
  - Measurements made with default test bench settings.
  - RF DUT is an RF system behavior component.
  - Number of time points in one WLAN 802.11a burst is a function of Bandwidth, OversamplingOption, IdleInterval, GuardInterval, DataRate, DataLength

    Bandwidth = 20 MHz

    OversamplingOption = Option 3 for Ratio 8

    IdleInterval = 4 μsec

    GuardInterval = 0.25

    DataRate = 54 Mbps

    DataLength = 1000
  - Resultant WTB_TimeStep = 6.25 nsec; BurstTime = 176 μsec; time points per burst = 2816
- Simulation time and memory requirements.

WLAN_802_11a_RX_ACR	Bursts Measured	Simulation Time (sec)	ADS Processes (MB)
RX ACR	100	117	71

Expected ADS Performance

Expected ADS performance is the combined performance of the baseline test bench and the RF DUT Circuit Envelope simulation with the same signal and number of time points. For example, if the RF DUT performance with Circuit Envelope simulation alone takes 2 hours and consumes 200 MB of memory (excluding the memory consumed by the core ADS product), then add these numbers to the Baseline Performance numbers to determine the expected ADS performance. This is valid only if the full memory consumed is from RAM. If RAM is less, larger simulation times may result due to increased disk access time for swap memory usage.

References

1. IEEE Standard 802.11b-1999, "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High-speed Physical Layer Extension in the 2.4 GHz Band," 1999. http://standards.ieee.org/getieee802/download/802.11b-1999.pdf
2. ETSI TS 101 475 v1.2.1, "Broadband Radio Access Networks (BRAN); HIPERLAN Type 2; Physical (PHY) layer," November, 2000. http://webapp.etsi.org/workprogram/Report_WorkItem.asp?WKI_ID=9949
3. IEEE P802.11g/D8.2, "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: Further Higher Data Rate Extension in the 2.4 GHz Band," April, 2003. http://ieeexplore.ieee.org/servlet/opac?punumber=4040922
4. CCITT, Recommendation O.151(10/92).
5. CCITT, Recommendation O.153(10/92).

Setting up a Wireless Test Bench Analysis in the *Wireless Test Bench Simulation* documentation explains how to use test bench windows and dialogs to perform analysis tasks.
Setting Circuit Envelope Analysis Parameters in the *Wireless Test Bench Simulation* documentation explains how to set up circuit envelope analysis parameters such as convergence criteria, solver selection, and initial guess.
Setting Automatic Behavioral Modeling Parameters in the *Wireless Test Bench Simulation* documentation to learn how to improve simulation speed.

WLAN Links

European Radiocommunications Office: http://www.ero.dk
U.S. Frequency Allocations Chart: http://www.ntia.doc.gov/osmhome
IEEE 802.11b Compliance Organization: http://www.wi-fi.org
IEEE 802.11 Working Group: http://grouper.ieee.org/groups/802/11/index.html

WLAN 802.11a Receiver Sensitivity Test

Introduction

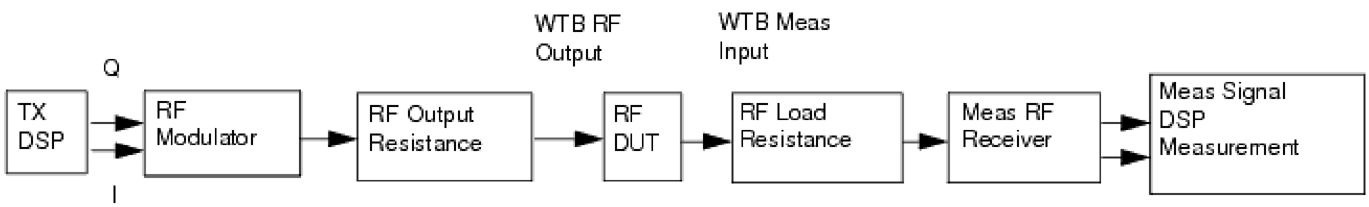
WLAN_802_11a_RX_Sensitivity is the test bench for WLAN receiver minimum and maximum input level sensitivity testing. The test bench enables users to connect to an RF DUT and determine its performance; signal measurements include BER and PER with minimum and maximum input levels.

The signal and the measurement are designed according to IEEE Standard 802.11a-1999.

This WLAN signal source model is compatible with the Agilent Signal Studio Software option 417. Details regarding Signal Studio for WLAN 802.11 are included at the website http://www.agilent.com/find/signalstudio .

This test bench includes a TX DSP section, an RF modulator, RF output source resistance, an RF DUT connection, RF receivers, and DSP measurement blocks as illustrated in Receiver Wireless Test Bench Block Diagram. The generated test signal is sent to the DUT.

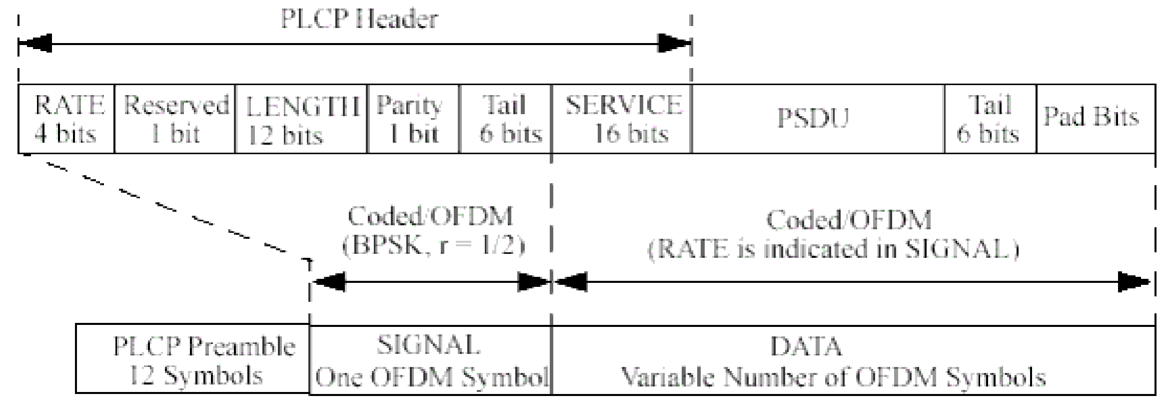
Receiver Wireless Test Bench Block Diagram



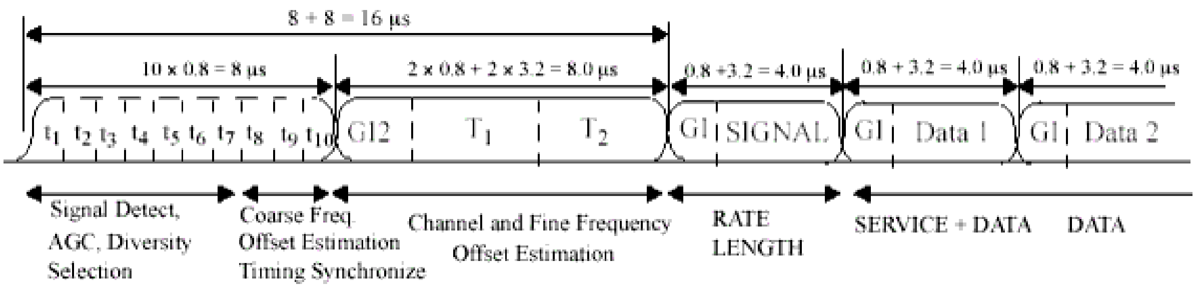
The 802.11a/g signal burst is illustrated in 802.11a/g Burst Format and OFDM Training Structure. Each burst is separated by IdleInterval and consists of Short Preamble, Long Preamble, SIGNAL, and DATA fields.

- Short Preamble field consists of 10 short preambles (8 μ).
- Long Preamble field consists of 2 long preambles (8 μ). The two preamble fields combined compose the PLCP Preamble that has a constant duration (16 μ) for all source parameter settings.
- SIGNAL field includes 802.11a/g bursts of information (data rate, payload data, and length).
- DATA field contains payload data.
  Channel coding, interleaving, mapping, and IFFT processes are also included in SIGNAL and DATA parts generation. The SIGNAL field and each individual Data field (part of the overall DATA field) have a duration defined as OFDM_SymbolTime and includes a GuardInterval. OFDM _SymbolTime depends on Bandwidth (=64/Bandwidth).
  In 802.11a/g Burst Format and OFDM Training Structure, PLCP means *physical layer convergence procedure* , PSDU means *PLCP service data units* , GI means *guard interval* ; GI is set to 0.25 and Bandwidth is set to 20 MHz (resulting in OFDM_SymbolTime = 4 μ).

802.11a/g Burst Format

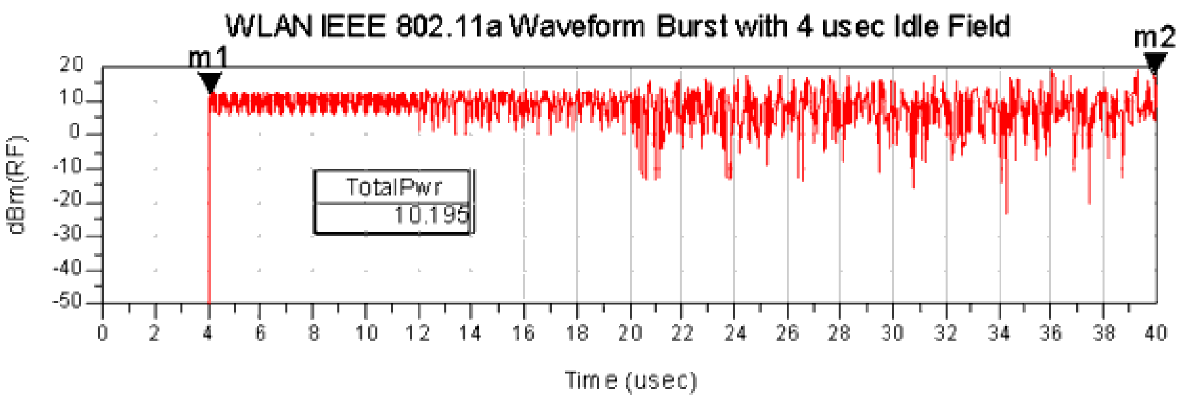


OFDM Training Structure



The WLAN RF power delivered into a matched load is the average power delivered in the WLAN burst excluding the burst idle time. WLAN 802.11a RF Signal Envelope shows the RF envelope for an output RF signal with 10 dBm power.

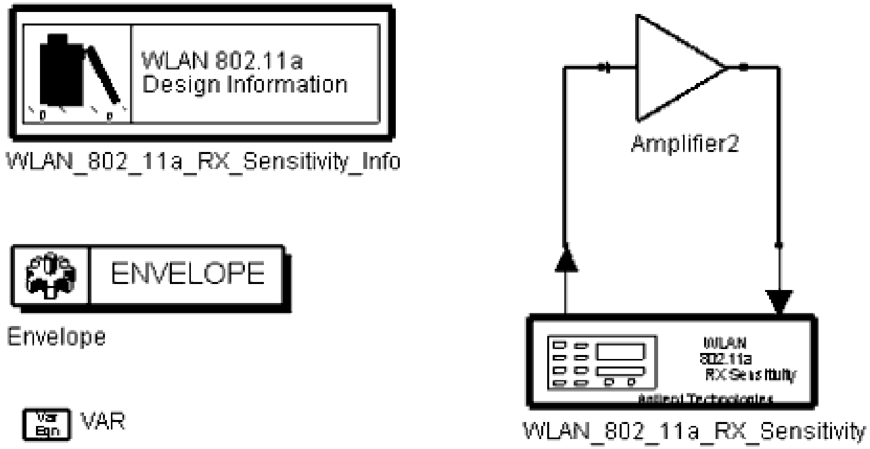
WLAN 802.11a RF Signal Envelope



Test Bench Basics

A template is provided for this test bench.

WLAN 802.11a Receiver Test Bench



To access the template:

1. In an Analog/RF schematic window select *Insert > Template.*
2. In the *Insert > Template* dialog box, choose *WLAN_802_11a_RX_Sensitivity_test* , click *OK* ; click left to place the template in the schematic window.
   An example design using this template is available; from the ADS Main window click *File > Open > Example* > WLAN > WLAN_RF_Verification_wrk > *WLAN_802_11a_RX_Sensitivity_test* .
   The basics for using the test bench are:

- Replace the DUT (Amplifier2 is provided with this template) with an RF DUT that is suitable for this test bench.
- CE_TimeStep, FSource, SourcePower, and FMeasurement parameter default values are typically accepted; otherwise, set values based on your requirements.
- Activate/deactivate measurements based on your requirements.
- Run the simulation and view Data Display page(s) for your measurement(s).
  For details, refer to Test Bench Details.

Test Bench Details

The following sections provide details for setting up a test bench, setting measurement parameters for more control of the test bench, simulation measurement displays, and baseline performance.

Open and use the *WLAN_802_11a_RX_Sensitivity* template:

1. In an Analog/RF schematic window select *Insert* > *Template.*
2. In the *Insert* > *Template* dialog box, choose *WLAN_802_11a_RX_Sensitivity_test* , click *OK* ; click left to place the template in the schematic window.

Test bench setup is detailed here.

1. Replace the DUT (Amplifier2 is provided with this template) with an RF DUT that is suitable for this test bench.
   For information regarding using certain types of DUTs, see *RF DUT Limitations for WLAN Wireless Test Benches* (adswtbwlan).

2. Set the *Required Parameters*

   > **Note**
   > Refer to *WLAN_802_11a_RX_Sensitivity* (adswtbwlan) for a complete list of parameters for this test bench.

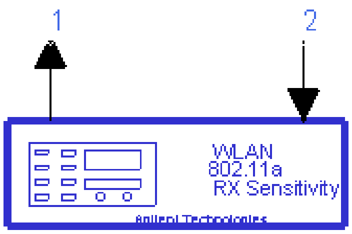
   Generally, default values can be accepted; otherwise, values can be changed by the user as needed.

   - Set CE_TimeStep.
     Cosimulation occurs between the test bench (using ADS Ptolemy Data Flow simulation technology) and the DUT (using Circuit Envelope simulation technology). Each technology requires its own simulation time step with time-step coordination occurring in the interface between the technologies.
     CE_TimeStep defines the Circuit Envelope simulation time step to be used with this DUT. The CE_TimeStep must be set to a value equal to or a submultiple of (less than) WTB_TimeStep; otherwise, simulation will stop and an error message will be displayed.
     Note that WTB_TimeStep is not user-settable. Its value is derived from other test bench parameter values; with default settings WTB_TimeStep=12.5 nsec. The value is displayed in the Data Display pages as TimeStep.
     WTB_TimeStep = 1/(Bandwidth × Ratio)
     where
     Bandwidth is the user-settable value (default = 20 MHz)
     Ratio is the oversampling ratio value specified by OversamplingOption (not the enum index). Ratio sets the number of waveform sampling points during the signal FFT time interval. During this time interval the minimum FFT sampling size is 64 (which corresponds to an FFT order of 6; i.e 2^6) and the FFT time interval is defined as 64/Bandwidth. For example, a Ratio of 4 sets the FFT sampling size to 64 × 4=256 (which corresponds to an FFT order of 8) during the signal FFT time interval.
   - Set FSource, SourcePower, and FMeasurement.
     - FSource defines the RF frequency for the signal input to the RF DUT.

  - SourcePower defines the power level for FSource. SourcePower is defined as the average power during the non-idle time of the signal burst.
  - FMeasurement defines the RF frequency output from the DUT to be measured.
3. More control of the test bench can be achieved by setting *Basic Parameters* , *Signal Parameters* , and measurement parameters. For details, refer to *Setting Parameters* (adswtbwlan).
4. The RF modulator (shown in the block diagram in Receiver Wireless Test Bench Block Diagram) uses FSource, SourcePower (*Required Parameters*), MirrorSourceSpectrum (*Basic Parameters)* , GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and IQ_Rotation (*Signal Parameters*).
   The RF output resistance uses SourceR and SourceTemp (*Basic Parameters*). The RF output signal source has a 50-ohm (default) output resistance defined by SourceR.
   RF output (and input to the RF DUT) is at the frequency specified (FSource), with the specified source resistance (SourceR) and with power (SourcePower) delivered into a matched load of resistance SourceR. The RF signal has additive Gaussian noise power set by resistor temperature (SourceTemp).
   Note that the Meas_in point of the test bench provides a resistive load to the RF DUT set by the MeasR value (50-ohm default) (*Basic Parameters*).
   The Meas signal contains linear and nonlinear signal distortions and time delays associated with the RF DUT input to output characteristics.
   The TX DSP block (shown in the block diagram in Receiver Wireless Test Bench Block Diagram) uses other *Signal Parameters*.
5. More control of Circuit Envelope analysis can be achieved by setting Envelope controller parameters. These settings include Enable AVM (Fast Cosim), which may speed the RF DUT simulation more than 10×. Setting these simulation options is described in *Setting Automatic Verification Modeling Parameters* and *Setting Circuit Envelope Analysis Parameters* in the *Wireless Test Bench Simulation* documentation.
6. After running a simulation, results will appear in a Data Display window for the measurement. *Simulation Measurement Displays* (adswtbwlan) describes results for each measurement. For general WTB Data Display details refer to *Viewing WTB Analysis Results* (adswtbsim).

WLAN_802_11a_RX_Sensitivity

This section provides parameter information for *Required Parameters, Basic Parameters, Signal Parameters,* and parameters for the various measurements.



Description WLAN 802.11a RX sensitivity
Library WTB
Class TSDFWLAN_802_11a_RX_Sensitivity
Derived From baseWTB_RX

Parameters

Name	Description	Default	Sym	Unit	Type	Range
RequiredParameters						
CE_TimeStep	Circuit envelope simulation time step	1/20 MHz/4		sec	real	(0, ∞)
WTB_TimeStep	Set CE_TimeStep <=1/Bandwidth $/2^{OversamplingOption}$.					
FSource	Source carrier frequency: CH1 _2412.0MHz, CH3 _2422.0MHz, CH5 _2432.0MHz, CH6 _2437.0MHz, CH7 _2442.0MHz, CH9 _2452.0MHz, CH11 _2462.0MHz, CH13 _2472.0MHz, CH36 _5180.0MHz, CH40 _5200.0MHz, CH44 _5220.0MHz, CH48 _5240.0MHz,	CH1 _2412.0MHz		Hz	real enum	(0, ∞)

	CH52 _5260.0MHz, CH56 _5280.0MHz, CH60 _5300.0MHz, CH64 _5320.0MHz, CH149 _5745.0MHz, CH153 _5765.0MHz, CH157 _5785.0MHz, CH161 _5805.0MHz					
SourcePower	Source power	dbmtow(-65.0)		W	real	[0, ∞)
FMeasurement	Measurement carrier frequency: Meas_CH1 _2412.0MHz, Meas_CH3 _2422.0MHz, Meas_CH5 _2432.0MHz, Meas_CH6 _2437.0MHz, Meas_CH7 _2442.0MHz, Meas_CH9 _2452.0MHz, Meas_CH11 _2462.0MHz, Meas_CH13 _2472.0MHz, Meas_CH36 _5180.0MHz, Meas_CH40 _5200.0MHz, Meas_CH44 _5220.0MHz, Meas_CH48 _5240.0MHz, Meas_CH52 _5260.0MHz, Meas_CH56 _5280.0MHz, Meas_CH60 _5300.0MHz, Meas_CH64 _5320.0MHz, Meas_CH149 _5745.0MHz, Meas_CH153 _5765.0MHz, Meas_CH157 _5785.0MHz, Meas_CH161 _5805.0MHz	Meas_CH1 _2412.0MHz		Hz	real enum	(0, ∞)
BasicParameters						

SourceR	Source resistance	50 Ohm		Ohm	real	(0, ∞)
SourceTemp	Source resistor temperature	16.85		Celsius	real	[-273.15, ∞)
MeasR	Measurement resistance	50 Ohm		Ohm	real	[10, 1.0e6]
MirrorSourceSpectrum	Mirror source spectrum about carrier? NO, YES	NO			enum	
MirrorMeasSpectrum	Mirror meas spectrum about carrier? NO, YES	NO			enum	
TestBenchSeed	Random number generator seed	1234567			int	[0, ∞)
SignalParameters						
GainImbalance	Gain imbalance, Q vs I	0.0		dB	real	(-∞, ∞)
PhaseImbalance	Phase imbalance, Q vs I	0.0		deg	real	(-∞, ∞)
I_OriginOffset	I origin offset (percent)	0.0			real	(-∞, ∞)
Q_OriginOffset	Q origin offset (percent)	0.0			real	(-∞, ∞)
IQ_Rotation	IQ rotation	0.0		deg	real	(-∞, ∞)
Bandwidth	Bandwidth	20 MHz	B	Hz	real	(0, ∞)
OversamplingOption	Oversampling ratio option: Option 0 for Ratio 1, Option 1 for Ratio 2, Option 2 for Ratio 4, Option 3 for Ratio 8, Option 4 for Ratio 16, Option 5 for Ratio 32	Option 2 for Ratio 4	S		enum	
DataRate	Data rate (Mbps): Mbps_6, Mbps_9, Mbps_12, Mbps_18, Mbps_24, Mbps_27, Mbps_36, Mbps_48, Mbps_54	Mbps_54	R		enum	
IdleInterval	Burst idle interval	4.0 usec	I	sec	real	[0, 1000usec]
DataType	Payload data type: PN9, PN15, FIX4, _4_1_4_0, _8_1_8_0, _16_1_16_0, _32_1_32_0, _64_1_64_0	PN9			enum	
DataLength	Data length (bytes per burst)	1000	L		int	[1, 4095]
GuardInterval	Guard interval (frac FFT size)	0.25			real	[0, 1]
MeasurementParameters						
DisplayPages	RX sensitivity display pages:					
DecoderType	Decoder type: Hard, Soft, CSI	CSI			enum	
TrunLen	Path memory truncation length	60			int	[20, 200)
StartBurst	Start burst	0			int	[0, 1000]
StopBurst	Stop burst	100			int	[0, 1000]

Pin Inputs

Pin	Name	Description	Signal Type
2	Meas_In	Test bench measurement RF input from RF circuit	timed

Pin Outputs

Pin	Name	Description	Signal Type
1	RF_Out	Test bench RF output to RF circuit	timed

Setting Parameters

More control of the test bench can be achieved by setting parameters in the *Basic Parameters* , *Signal Parameters* , and *measurement* categories for the activated measurements.

> **Note**
> For *required* parameter information, see *Set the Required Parameters* (adswtbwlan).

Basic Parameters

1. SourceR is the RF output source resistance.
2. SourceTemp is the RF output source resistance temperature (oC) and sets noise density in the RF output signal to (k(SourceTemp+273.15)) Watts/Hz, where k is Boltzmann's constant.
3. MeasR defines the load resistance for the RF DUT output Meas signal into the test bench. This resistance loads the RF DUT output; it is also the reference resistance for Meas signal power measurements.
4. MirrorSourceSpectrum is used to invert the polarity of the Q envelope of the generated RF signal before it is sent to the RF DUT. Depending on the configuration and number of mixers in an RF transmitter, the signal at the input of the DUT may need to be mirrored. If such an RF signal is desired, set this parameter to YES.
5. MirrorMeasSpectrum is used to invert the polarity of the Q envelope in the Meas_in RF signal input to the test bench (and output from the RF DUT). Depending on the configuration and number of mixers in the RF DUT, the signal at its output may be mirrored compared to the signal generated by the signal source (before any mirroring is done because of the MirrorSourceSpectrum setting). Proper demodulation and measurement of the RF DUT output signal requires that its RF envelope is not mirrored compared to the signal generated by the signal source (before any mirroring is done because of the MirrorSourceSpectrum setting). If the Meas_in RF signal is mirrored, set this parameter to YES. Proper setting of this parameter is required for measurements on the Meas_in signal in RX text benches and results in measurement on a signal with no spectrum mirroring.
6. TestBenchSeed is an integer used to seed the random number generator used with the test bench. This value is used by all test bench random number generators, except those RF DUT components that use their own specific seed parameter. TestBenchSeed initializes the random number generation. The same seed value produces the same *random* results, thereby giving you predictable simulation results. To generate repeatable *random* output from simulation to simulation, use any positive seed value. If you want the output to be truly random, enter the seed value of 0.

Signal Parameters

1. GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and IQ_Rotation are used to add certain impairments to the ideal output RF signal. Impairments are

added in the order described here.
The unimpaired RF I and Q envelope voltages have gain and phase imbalance applied. The RF is given by:

$$V_{RF}(t) = A\left(V_I(t)\cos(\omega_c t) - gV_Q(t)\sin\left(\omega_c t + \frac{\phi\pi}{180}\right)\right)$$

where *A* is a scaling factor that depends on the SourcePower and SourceR parameters specified by the user, $V_I(t)$ is the in-phase RF envelope, $V_Q(t)$ is the quadrature phase RF envelope, *g* is the gain imbalance

$$g = 10^{\frac{GainImbalance}{20}}$$

and, φ (in degrees) is the phase imbalance.
Next, the signal $V_{RF}(t)$ is rotated by IQ_Rotation degrees. The I_OriginOffset and Q_OriginOffset are then applied to the rotated signal. Note that the amounts specified are percentages with respect to the output rms voltage. The output rms voltage is given by sqrt(2 × SourceR × SourcePower).

2. Bandwidth is used to determine the actual bandwidth of WLAN systems and to calculate the sampling rate and timestep per sample. The default value is 20 MHz (defined in 802.11a/g specification); to double the rate for the 802.11a/g turbo mode, set Bandwidth to 40 MHz.
3. OversamplingOption sets the oversampling ratio of 802.11a/g RF signal source. Options from 0 to 5 result in oversampling ratio 2, 4, 8, 16, 32 where oversampling ratio = $2^{OversamplingOption}$. If OversamplingOption = 2, the oversampling ratio = 22 = 4 and the simulation RF bandwidth is larger than the signal bandwidth by a factor of 4 (e.g. for Bandwidth=20 MHz, the simulation RF bandwidth = 20 MHz × 4 = 80 MHz).
4. DataRate specifies the data rate 6, 9, 12, 18, 24, 27, 36, 48 and 54 Mbps. All data rates except 27 Mbps are defined in the 802.11a/g specification; 27 Mbps is from HIPERLAN/2.
The following table lists key parameter values of 802.11a/g.

Rate-Dependent Values

Data Rate (Mbps)	Modulation	Coding Rate (R)	Coded Bits per Subcarrier (N_{BPSC})	Coded Bits per OFDM Symbol (N_{CBPS})	Data Bits per OFDM Symbol (N_{DBPS})
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
27	16-QAM	9/16	4	192	108
36	16-QAM	3/4	4	192	144
48	64-QAM	2/3	6	288	192
54	64-QAM	3/4	6	288	216

5. IdleInterval specifies the idle interval between two consecutive bursts when generating a 802.11a signal source.
6. For DataType:
   - if PN9 is selected, a 511-bit pseudo-random test pattern is generated according

to CCITT Recommendation O.153.
- if PN15 is selected, a 32767-bit pseudo-random test pattern is generated according to CCITT Recommendation O.151.
- if FIX4 is selected, a zero-stream is generated.
- if x_1_x_0 is selected (where x equals 4, 8, 16, 32, or 64) a periodic bit stream is generated, with the period being 2 x. In one period, the first x bits are 1s and the second x bits are 0s.

7. DataLength is used to set the number of data bytes in a burst. There are 8 bits per byte.
8. GuardInterval is used to set cyclic prefix in an OFDM symbol. The value range of GuardInterval is [0.0,1.0]. The cyclic prefix is a fractional ratio of the IFFT length. 802.11a/g defines GuardInterval=1/4 (0.8 μsec) and HIPERLAN/2 defines two GuardIntervals (1/8 and 1/4).

Measurement Parameters

Measurement requires setting the MirrorMeasSpectrum parameter such that there is an even number of spectrum mirrorings from the combined test bench source and RF DUT. For example, if MirrorSourceSpectrum=NO and the RF DUT causes its output RF signal to have spectrum mirroring relative to its input signal, then set MirrorMeasSpectrum=YES.

1. DisplayPages provides Data Display page information for this measurement. It cannot be changed by the user.
2. DecoderType has three modes: Hard, Soft, and CSI. When DecoderType=Hard, if $b < 0$, *-1.0* is output, otherwise *1.0* is output; when DecoderType=Soft, if $b < -1.0$, *-1.0* is output; if $b > 1.0$, *1.0* is output; when DecoderType=CSI, *b* is multiplied by *CSI* $(= |H(i)|^2)$ and output. CSI means Channel Status Information and estimated channel impulse responses *(H(i))* are the CSI here.
3. TrunLen sets the most recent TrunLen information bits in each surviving sequence are stored. Once the path with the shortest distance is identified, the symbol associated with the path TrunLen periods ago is conveyed to the output as a decoded information symbol.
4. StartBurst sets the start burst. A value of 0 is the first burst.
5. StopBurst sets the stop burst. A StopBurst value of 100 results in measuring 101 bursts.

Simulation Measurement Displays

After running the simulation, results are displayed in the Data Display pages for each measurement activated.

> **Note**
> Measurement results from a wireless test bench have associated names that can be used in Data Display Expressions. For more information, refer to *Measurement Results for Expressions for WLAN Wireless Test Benches* (adswtbwlan).

Sensitivity Measurement

The sensitivity measurement shows BER and PER results.

The following table defines receiver minimum sensitivity measured at the receiver antenna connector for each data rate in the 802.11a specification. SourcePower can be set at the value in the table to perform receive minimum sensitivity tests. According to specification [1] 17.3.10.1, the packet error rate (PER) shall be less than 10% at a DataLength (PSDU length) of 1000 bytes at rate-dependent input levels listed in Table 3-2 or less. If the SourcePower is less than the value in the table when PER is less than 10%, the sensitivity measurement is passed.

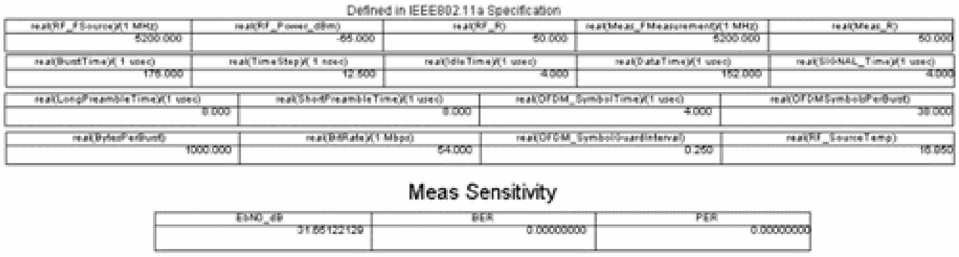
Minimum Sensitivity Performance Requirement

Data Rate (Mbps)	Minimum sensitivity (dBm)
6	-82
9	-81
12	-79
18	-77
24	-74
36	-70
48	-66
54	-65

Simulation results for data rate of 54 Mbps and SourcePower of -65 dBm are displayed in the figure Simulation Results for 54 Mbps Data Rate and -65 dBm SourcePower.

The receiver maximum input level sensitivity is defined in section 17.3.10.4, IEEE Std 802.11a-1999. The PER must be less than 10% at a DataLength (PSDU length) of 1000 bytes for a maximum input level of -30 dBm measured at the receiver antenna connector for any baseband modulation.

Simulation Results for 54 Mbps Data Rate and -65 dBm SourcePower



Defined in IEEE802.11a Specification

real(RF_FSource)/(1 MHz)	real(RF_Power_dBm)	real(RF_R)	real(Meas_FMeasurement)/(1 MHz)	real(Meas_R)
5200.000	-65.000	50.000	5200.000	50.000

real(BurstTime)/(1 usec)	real(TimeStep)/(1 nsec)	real(IdleTime)/(1 usec)	real(DataTime)/(1 usec)	real(SIGNAL_Time)/(1 usec)
176.000	12.500	4.000	152.000	4.000

real(LongPreambleTime)/(1 usec)	real(ShortPreambleTime)/(1 usec)	real(OFDM_SymbolTime)/(1 usec)	real(OFDMSymbolsPerBurst)
8.000	8.000	4.000	38.000

real(BytesPerBurst)	real(BitRate)/(1 Mbps)	real(OFDM_SymbolGuardInterval)	real(RF_SourceTemp)
1000.000	54.000	0.250	16.850

Meas Sensitivity

EbN0_dB	BER	PER
31.88122129	0.00000000	0.00000000

Parameters in the Data Display are described in the table Test Bench Equations Derived from Test Bench Parameters and Exported to Data Display. EbN0_RF_dB is the local Eb/N0 measured at the input of the RF DUT and calculated by the following equations:

T = real(RF_SourceTemp) + 273.15

k = Boltzmann's constant

N0_dBm = 10*log10(k * T) + 30

EbN0_RF_dB = real(RF_Power_dBm) - N0_dBm - 10*log10(real(BitRate))

Local Eb/No and system Eb/No are described in *Receiver Eb/No Definitions]* in *Wireless Test Bench Simulation* documentation.

Test Bench Variables for Data Displays

The following tables identify the reference variables used to set up this test bench:

Test Bench Constants for WLAN Signal Setup

Constant	**Value**
MinFFT_Size	64 (= 2^6)
BitsPerByte	8
ServiceBits	16
TailBits	6
Ratio	Oversampling ratio related to the OversamplingOption as Ratio = $2^{OversamplingOption}$
DataBitsPerOFDMSymbol	Dependent on DataRate in next table.
OFDMSymbolsPerBurst	(int ((ServiceBits+BitsPerByte*DataLength+TailBits)/ DataBitsPerOFDMSymbol))+Tail
TailCondition	ServiceBits+BitsPerByte*DataLength+TailBits - DataBitsPerOFDMSymbol *(int ((ServiceBits+BitsPerByte*DataLength+TailBits)/ DataBitsPerOFDMSymbol))
Tail	if (TailCondition = 0) then 0 else 1

DataRate Determines DataBitsPerOFDMSymbol and BitRate Values

DataRate	DataBitsPerOFDMSymbol (see previous table)	BitRate (see next table)
Mbps_6	24	6e6
Mbps_9	36	9e6
Mbps_12	48	12e6
Mbps_18	72	18e6
Mbps_24	96	24e6
Mbps_27	108	27e6
Mbps_36	144	36e6
Mbps_48	192	48e6
Mbps_54	216	54e6

Test Bench Equations Derived from Test Bench Parameters and Exported to Data Display

Data Display Parameter	Equation with Test Bench Parameters
RF_FSource	FSource
RF_Power_dBm	10*log10(SourcePower)+30
RF_R	SourceR
RF_SourceTemp	SourceTemp in degrees Celcius
TimeStep	1/(Bandwidth*Ratio) This is the test bench simulation time step.
OFDM_SymbolTime	MinFFT_Size*(1+GuardInterval)/Bandwidth This is the duration for one OFDM symbol.
OFDM_SymbolsPerBurst	OFDMSymbolsPerBurst This is the number of OFDM symbols in the Data field of a burst.
OFDM_SymbolGuardInterval	GuardInterval This is the guard interval (as a ratio of the OFDM_SymbolTime) associated with each OFDM symbol.
IdleTime	IdleInterval This is the duration of the zero level idle field at the front of each burst.
ShortPreambleTime	8.0 usec This is the duration of the short preamble field after the idle field in each burst.
LongPreambleTime	8.0 usec This is the duration of the long preamble field after the short preamble field in each burst.
SIGNAL_Time	OFDM_SymbolTime This is the duration of the SIGNAL field after the long preamble field in each burst.
DataTime	OFDM_SymbolsPerBurst*OFDM_SymbolTime This is the duration of the Data field after the SIGNAL field in each burst.
BurstTime	IdleTime + ShortPreambleTime + LongPreambleTime + SIGNAL_Time + DataTime
BytesPerBurst	DataLength This is the number of bytes of data in the Data field in each burst.
BitRate	Dependent on DataRate in previous table. This is the bit rate for transmitted WLAN signal.
Meas_FMeasurement	FMeasurement
Meas_R	MeasR

Baseline Performance

- Test Computer Configuration
  - Pentium IV 2.4 GHz, 512 MB RAM, Red Hat Linux 7.3
- Conditions
  - Measurements made with default test bench settings.
  - RF DUT is an RF system behavior component.
  - Number of time points in one WLAN 802.11a burst is a function of Bandwidth, OversamplingOption, IdleInterval, GuardInterval, DataRate, DataLength
    Bandwidth = 20 MHz
    OversamplingOption = Option 2 for Ratio 4
    IdleInterval = 4 μsec
    GuardInterval = 0.25
    DataRate = 54 Mbps
    DataLength = 1000
- Resultant WTB_TimeStep = 12.5 nsec; BurstTime = 176 μ time points per burst = 14080

WLAN_802_11a_RX_Sensitivity Measurement	Bursts Measured	Simulation Time (sec)	ADS Processes (MB)
RX Sensitivity	100	52	56

Expected ADS Performance

Expected ADS performance is the combined performance of the baseline test bench and the RF DUT Circuit Envelope simulation with the same signal and number of time points. For example, if the RF DUT performance with Circuit Envelope simulation alone takes 2 hours and consumes 200 MB of memory (excluding the memory consumed by the core ADS product), then add these numbers to the Baseline Performance numbers to determine the expected ADS performance. This is valid only if the full memory consumed is from RAM. If RAM is less, larger simulation times may result due to increased disk access time for swap memory usage.

References

1. IEEE Standard 802.11b-1999, "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High-speed Physical Layer Extension in the 2.4 GHz Band," 1999. http://standards.ieee.org/getieee802/download/802.11b-1999.pdf
2. ETSI TS 101 475 v1.2.1, "Broadband Radio Access Networks (BRAN); HIPERLAN Type 2; Physical (PHY) layer," November, 2000. http://webapp.etsi.org/workprogram/Report_WorkItem.asp?WKI_ID=9949
3. IEEE P802.11g/D8.2, "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: Further Higher Data Rate Extension in the 2.4 GHz Band," April, 2003. http://ieeexplore.ieee.org/servlet/opac?punumber=4040922
4. CCITT, Recommendation O.151(10/92).
5. CCITT, Recommendation O.153(10/92).

Setting up a Wireless Test Bench Analysis in the *Wireless Test Bench Simulation* documentation explains how to use test bench windows and dialogs to perform analysis tasks.
Setting Circuit Envelope Analysis Parameters in the *Wireless Test Bench Simulation* documentation explains how to set up circuit envelope analysis parameters such as convergence criteria, solver selection, and initial guess.
Setting Automatic Behavioral Modeling Parameters in the *Wireless Test Bench Simulation* documentation to learn how to improve simulation speed.

WLAN Links

European Radiocommunications Office: http://www.ero.dk
U.S. Frequency Allocations Chart: http://www.ntia.doc.gov/osmhome
IEEE 802.11b Compliance Organization: http://www.wi-fi.org
IEEE 802.11 Working Group: http://grouper.ieee.org/groups/802/11/index.html

WLAN 802.11b Receiver Sensitivity Test

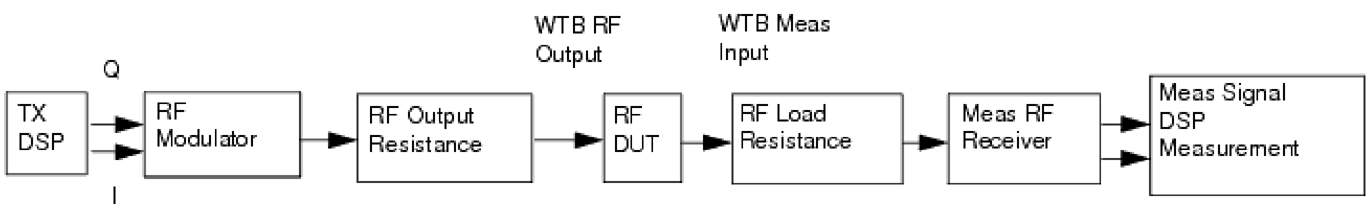
Introduction

WLAN_802_11b_RX_Sensitivity is the test bench for WLAN receiver minimum and maximum input level sensitivity testing. The test bench enables users to connect to an RF DUT and determine its performance.

The signal and the measurements are designed according to the IEEE Standard 802.11b-1999 specification.

This WLAN signal source model is compatible with the Agilent Signal Studio Software option 417. Details regarding Signal Studio for WLAN 802.11 are included at the website http://www.agilent.com/find/signalstudio .

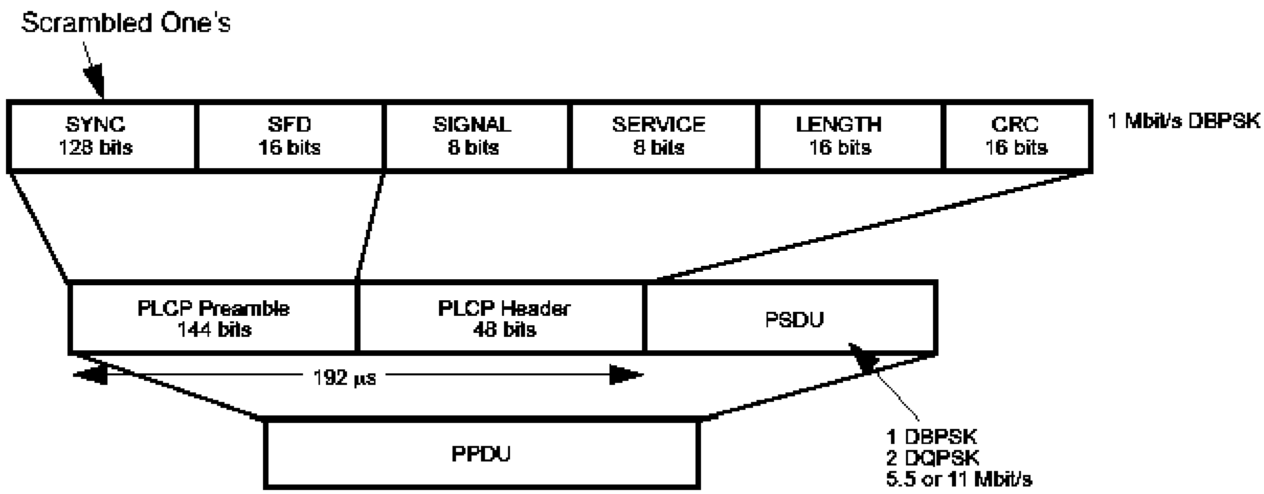
This test bench includes a TX DSP section, an RF modulator, RF output source resistance, an RF DUT connection, RF receivers, and DSP measurement blocks as illustrated in the following figure. The generated test signal is sent to the DUT.



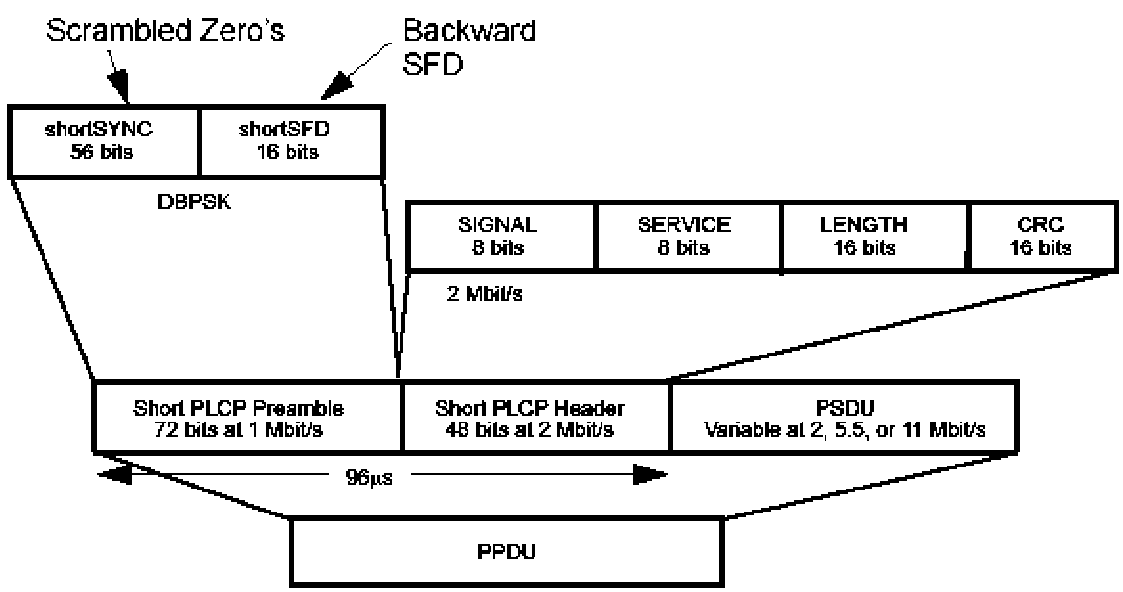
Receiver Wireless Test Bench Block Diagram

The 802.11b baseband signal source frame structure is illustrated in the figures Long PLCP Frame Format and Short PLCP Frame Format. Each frame is separated by an IdleInterval; one 802.11b frame consists of PLCP Preamble, PLCP Header and Data (PSDU) parts. (PPDU means *physical layer protocol data units* ; SFD means *start frame delimiter* ; CRC means *cyclic redundancy code* ; PLCP means *physical layer convergence procedure* ; PSDU means *PLCP service data units* .)

Long PLCP Frame Format

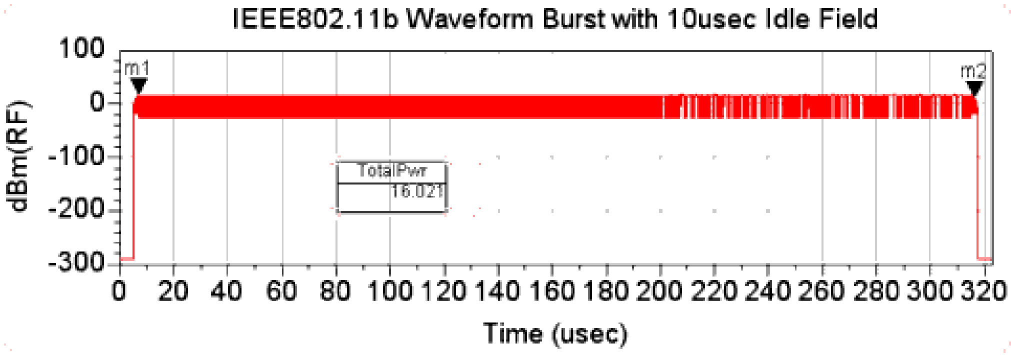


Short PLCP Frame Format



The WLAN 11b RF power delivered into a matched load is the average power delivered in the WLAN burst excluding the burst idle time. The figure WLAN 802.11b RF Signal Envelope shows the RF envelope for an output RF signal with 16 dBm power and a 10 μ idle time.

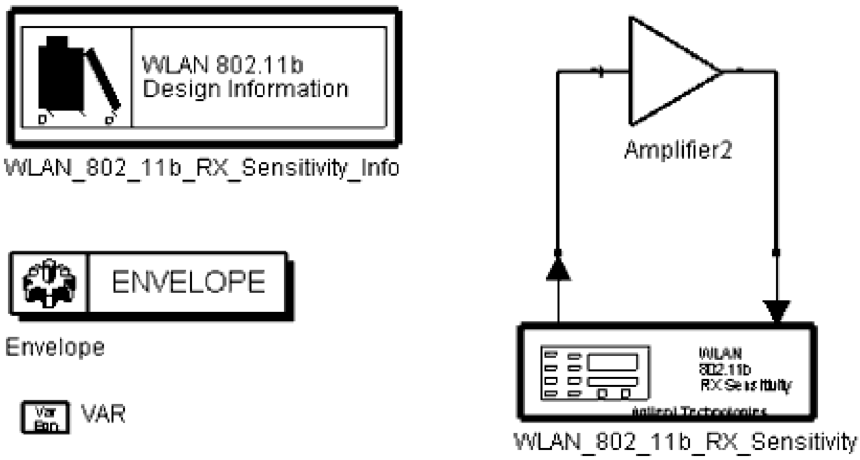
WLAN 802.11b RF Signal Envelope


IEEE802.11b Waveform Burst with 10usec Idle Field
dBm(RF)
Time (usec)
m1
m2
TotalPwr
16.021
100
0
-100
-200
-300
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320

Test Bench Basics

A template is provided for this test bench.

WLAN 802.11b Receiver Sensitivity Test Bench



To access the template:

1. In an Analog/RF schematic window select *Insert* > *Template.*
2. In the *Insert* > *Template* dialog box, choose *WLAN_802_11b_RX_Sensitivity_test* , click *OK* ; click left to place the template in the schematic window.

An example design using this template is available; from the ADS Main window click *File* > *Open* > *Example* > WLAN > WLAN_RF_Verification_wrk > *WLAN_802_11b_RX_Sensitivity_test* .

The basics for using the test bench are:

- Replace the DUT (Amplifier2 is provided with this template) with an RF DUT that is suitable for this test bench.
- CE_TimeStep, FSource, SourcePower, and FMeasurement parameter default values are typically accepted; otherwise, set values based on your requirements.
- Activate/deactivate measurements based on your requirements.
- Run the simulation and view Data Display page(s) for your measurement(s).

For details, refer to Test Bench Details.

Test Bench Details

The following sections provide details for setting up a test bench, setting measurement parameters for more control of the test bench, simulation measurement displays, and baseline performance.
Open and use the *WLAN_802_11b_RX_Sensitivity* template:

1. In an Analog/RF schematic window select *Insert > Template.*
2. In the *Insert > Template* dialog box, choose *WLAN_802_11b_RX_Sensitivity_test* , click *OK* ; click left to place the template in the schematic window.

Test bench setup is detailed here.

1. Replace the DUT (Amplifier2 is provided with this template) with an RF DUT that is suitable for this test bench.
   For information regarding using certain types of DUTs, see *RF DUT Limitations for WLAN Wireless Test Benches* (adswtbwlan).
2. Set the *Required Parameters*

   > **Note**
   > Refer to *WLAN_802_11b_RX_Sensitivity* (adswtbwlan) for a complete list of parameters for this test bench.

   Generally, default values can be accepted; otherwise, values can be changed by the user as needed.

   - Set CE_TimeStep.
     Cosimulation occurs between the test bench (using ADS Ptolemy Data Flow simulation technology) and the DUT (using Circuit Envelope simulation technology). Each technology requires its own simulation time step with time-step coordination occurring in the interface between the technologies.
     CE_TimeStep defines the Circuit Envelope simulation time step to be used with this DUT. The CE_TimeStep must be set to a value equal to or a submultiple of (less than) WTB_TimeStep; otherwise, simulation will stop and an error message will be displayed.
     Note that WTB_TimeStep is not user-settable. Its value is derived from other test bench parameter values; with default settings WTB_TimeStep=1/(11.0e6 × 4) sec. The value is displayed in the Data Display pages as TimeStep.

     WTB_TimeStep = 1/(11.0e6 × Ratio)

     where

     11.0e6 means the baseband bandwidth of 11b is 11.0MHz.

     Ratio is the OversamplingRatio value specified. OversamplingRatio sets the number of waveform sampling points during one chip time interval.
   - Set FSource, SourcePower, and FMeasurement.
     - FSource defines the RF frequency for the signal input to the RF DUT.
     - SourcePower defines the power level for FSource. SourcePower is defined

as the average power during the non-idle time of the signal burst.
    - FMeasurement defines the RF frequency output from the DUT to be measured.
3. More control of the test bench can be achieved by setting *Basic Parameters* , *Signal Parameters* , and measurement parameters. For details, refer to *Setting Parameters* (adswtbwlan).
4. The RF modulator (shown in the block diagram in Receiver Wireless Test Bench Block Diagram) uses FSource, SourcePower (*Required Parameters*), MirrorSourceSpectrum (*Basic Parameters)* , GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and IQ_Rotation (*Signal Parameters*).
   The RF output resistance uses SourceR and SourceTemp (*Basic Parameters*). The RF output signal source has a 50-ohm (default) output resistance defined by SourceR.
   RF output (and input to the RF DUT) is at the frequency specified (FSource), with the specified source resistance (SourceR) and with power (SourcePower) delivered into a matched load of resistance SourceR. The RF signal has additive Gaussian noise power set by resistor temperature (SourceTemp).
   Note that the Meas_in point of the test bench provides a resistive load to the RF DUT set by the MeasR value (50-ohm default) (*Basic Parameters*).
   The Meas signal contains linear and nonlinear signal distortions and time delays associated with the RF DUT input to output characteristics.
   The TX DSP block (shown in the block diagram in Receiver Wireless Test Bench Block Diagram) uses other *Signal Parameters*.
5. More control of Circuit Envelope analysis can be achieved by setting Envelope controller parameters. These settings include Enable Fast Cosim, which may speed the RF DUT simulation more than 10×. Setting these simulation options is described in *Setting Fast Cosimulation Parameters* and *Setting Circuit Envelope Analysis Parameters* in the *Wireless Test Bench Simulation* documentation.
6. After running a simulation, results will appear in a Data Display window for the measurement. *Simulation Measurement Displays* (adswtbwlan) describes results for each measurement. For general WTB Data Display details refer to *Viewing WTB Analysis Results* (adswtbsim).

WLAN_802_11b_RX_Sensitivity

This section provides parameter information for *Required Parameters, Basic Parameters, Signal Parameters,* and parameters for the various measurements.

Description WLAN 802.11b RX sensitivity
Library WTB
Class TSDFWLAN_802_11b_RX_Sensitivity
Derived From baseWTB_RX

Parameters

Name	Description	Default	Sym	Unit	Type	Range
RequiredParameters						
CE_TimeStep	Circuit envelope simulation time step	1/11 MHz/4		sec	real	(0, ∞)
WTB_TimeStep	Set CE_TimeStep < = 1/11e6/OversamplingRatio. OversamplingRatio is in Signal Parameters tab.					
FSource	Source carrier frequency: CH1_2412.0MHz, CH3_2422.0MHz, CH5_2432.0MHz, CH6_2437.0MHz, CH7_2442.0MHz, CH9_2452.0MHz, CH11_2462.0MHz, CH13_2472.0MHz	CH1_2412.0MHz		Hz	real enum	(0, ∞)
SourcePower	Source power	dbmtow(-76.0)		W	real	[0, ∞)
FMeasurement	Measurement carrier frequency: Meas_CH1_2412.0MHz, Meas_CH3_2422.0MHz, Meas_CH5_2432.0MHz, Meas_CH6_2437.0MHz, Meas_CH7_2442.0MHz, Meas_CH9_2452.0MHz, Meas_CH11_2462.0MHz, Meas_CH13_2472.0MHz	Meas_CH1_2412.0MHz		Hz	real enum	(0, ∞)

BasicParameters						
SourceR	Source resistance	50 Ohm		Ohm	real	(0, ∞)
SourceTemp	Source resistor temperature	16.85		Celsius	real	[-273.15, ∞)
MeasR	Measurement resistance	50 Ohm		Ohm	real	[10, 1.0e6]
MirrorSourceSpectrum	Mirror source spectrum about carrier? NO, YES	NO			enum	
MirrorMeasSpectrum	Mirror meas spectrum about carrier? NO, YES	NO			enum	
TestBenchSeed	Random number generator seed	1234567			int	[0, ∞)
SignalParameters						
GainImbalance	Gain imbalance, Q vs I	0.0		dB	real	(-∞, ∞)
PhaseImbalance	Phase imbalance, Q vs I	0.0		deg	real	(-∞, ∞)
I_OriginOffset	I origin offset (percent)	0.0			real	(-∞, ∞)
Q_OriginOffset	Q origin offset (percent)	0.0			real	(-∞, ∞)
IQ_Rotation	IQ rotation	0.0		deg	real	(-∞, ∞)
OversamplingRatio	Oversampling ratio	4	S		int	[2, 9]
DataRate	Data rate (Mbps): Mbps_5.5, Mbps_11	Mbps_11	R		enum	
PreambleFormat	Preamble format: Long, Short	Long	H		enum	
CIkLockedFlag	Lock header clock? NO, YES	YES			enum	
PwrRamp	RF power ramp shape: None, Linear, Cosine	Linear	P		enum	
IdleInterval	Burst idle interval	10.0 usec	I	sec	real	[0, 1000us]
FilterType	Shaping filter type: NoneFilter, Gaussian, Root Cosine, Ideal Lowpass	Root Cosine			enum	
RRC_Alpha	RRC roll-off factor	0.22			real	(0.0, 1.0]
GaussianFilter_bT	Gaussian filter bT coefficient	0.5			real	(0.0, 1.0]
FilterLength	Filter length (chips)	10			int	[1, 200]
DataType	Payload data type: PN9, PN15, FIX4, _4_1_4_0, _8_1_8_0, _16_1_16_0, _32_1_32_0, _64_1_64_0	PN9			enum	
DataLength	Data length (bytes per burst)	1024	L		int	[1, 2312]
MeasurementParameters						
DisplayPages	RX sensitivity measurement display pages:					
ForwardTaps	Number of equalizer forward taps	6			int	[1, 256]
FeedbackTaps	Number of equalizer feedback taps	3			int	[1, 128]
EqualizerScaleFactor	LMS algorithm scale factor	0.0006			real	(0, 1.0)

StartBurst	Start burst	0			int	[0, 1000]
StopBurst	Stop burst	125			int	[0, 1000]

Pin Inputs

Pin	Name	Description	Signal Type
2	Meas_In	Test bench measurement RF input from RF circuit	timed

Pin Outputs

Pin	Name	Description	Signal Type
1	RF_Out	Test bench RF output to RF circuit	timed

Setting Parameters

More control of the test bench can be achieved by setting parameters in the *Basic Parameters* , *Signal Parameters* , and *measurement* categories for the activated measurements.

> **Note**
> For *required* parameter information, see *Set the Required Parameters* (adswtbwlan).

Basic Parameters

1. SourceR is the RF output source resistance.
2. SourceTemp is the RF output source resistance temperature (oC) and sets noise density in the RF output signal to (k(SourceTemp+273.15)) Watts/Hz, where k is Boltzmann's constant.
3. MeasR defines the load resistance for the RF DUT output Meas signal into the test bench. This resistance loads the RF DUT output; it is also the reference resistance for Meas signal power measurements.
4. MirrorSourceSpectrum is used to invert the polarity of the Q envelope of the generated RF signal before it is sent to the RF DUT. Depending on the configuration and number of mixers in an RF transmitter, the signal at the input of the DUT may need to be mirrored. If such an RF signal is desired, set this parameter to YES.
5. MirrorMeasSpectrum is used to invert the polarity of the Q envelope in the Meas_in RF signal input to the test bench (and output from the RF DUT). Depending on the configuration and number of mixers in the RF DUT, the signal at its output may be mirrored compared to the signal generated by the signal source (before any mirroring is done because of the MirrorSourceSpectrum setting). Proper demodulation and measurement of the RF DUT output signal requires that its RF envelope is not mirrored compared to the signal generated by the signal source (before any mirroring is done because of the MirrorSourceSpectrum setting). If the Meas_in RF signal is mirrored, set this parameter to YES. Proper setting of this parameter is required for measurements on the Meas_in signal in RX text benches and results in measurement on a signal with no spectrum mirroring.
6. TestBenchSeed is an integer used to seed the random number generator used with the test bench. This value is used by all test bench random number generators, except those RF DUT components that use their own specific seed parameter. TestBenchSeed initializes the random number generation. The same seed value produces the same *random* results, thereby giving you predictable simulation results. To generate repeatable *random* output from simulation to simulation, use any positive seed value. If you want the output to be truly random, enter the seed value of 0.

Signal Parameters

1. GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and IQ_Rotation are used to add certain impairments to the ideal output RF signal. Impairments are

added in the order described here.
The unimpaired RF I and Q envelope voltages have gain and phase imbalance applied. The RF is given by:

$$V_{RF}(t) = A\left(V_I(t)\cos(\omega_c t) - gV_Q(t)\sin\left(\omega_c t + \frac{\phi\pi}{180}\right)\right)$$

where *A* is a scaling factor that depends on the SourcePower and SourceR parameters specified by the user, $V_I(t)$ is the in-phase RF envelope, $V_Q(t)$ is the quadrature phase RF envelope, *g* is the gain imbalance

$$g = 10^{\frac{GainImbalance}{20}}$$

and, φ (in degrees) is the phase imbalance.
Next, the signal $V_{RF}(t)$ is rotated by IQ_Rotation degrees. The I_OriginOffset and Q_OriginOffset are then applied to the rotated signal. Note that the amounts specified are percentages with respect to the output rms voltage. The output rms voltage is given by sqrt(2 × SourceR × SourcePower).

2. OversamplingRatio sets the oversampling ratio of 802.11b RF signal source. Eight oversampling ratios (2, 3, 4, 5, 6, 7, 8, 9) are supported. If OversamplingRatio = 4, the simulation RF bandwidth is larger than the signal bandwidth by a factor of 4 (e.g. for Bandwidth=11 MHz, the simulation RF bandwidth = 11 MHz × 4 = 44 MHz).
3. DataRate specifies the data rate 1, 2, 5.5, or 11 Mbps (data rates are defined in 802.11b).
4. PreambleFormat is used to set the format of the framed signal preamble/header sections; refer to *Long PLCP Frame Format* (adswtbwlan) and *Short PLCP Frame Format* (adswtbwlan).
5. ClkLockedFlag is used to toggle the clock locked flag in the 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. If ClkLockedFlag=YES, this bit is set to 1; if ClkLockedFlag=NO, this bit is set to 0.
6. PwrRamp is used to select the shape of the RF burst in framed mode; power up/down ramp type is 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 power up/down ramp is set to 2 μsec when PwrRamp = none.
    - Linear ramp shapes the burst in a linear fashion.
7. IdleInterval sets an idle duration time between two consecutive bursts when generating the 802.11b signal source.
8. FilterType is used to specify that a baseband filter is applied to reduce the transmitted bandwidth, thereby increasing spectral efficiency. The 802.11b specification does not indicate the type of filter to be used, but the transmitted signal must meet the spectral mask requirements. Four options for baseband filtering are available:
    - None (no filter)
    - Gaussian The Gaussian filter does not have zero ISI. Wireless system architects must determine how much of the ISI can be tolerated in a system and combine that with noise and interference. The Gaussian filter is Gaussian-shaped in time and frequency domains, and it does not ring as root cosine filters do.
    The effects of this filter in the time domain are relatively short and each symbol interacts significantly (or causes ISI) with only the preceding and succeeding symbols. This reduces the tendency for particular sequences of symbols to interact which makes amplifiers easier to build and more efficient.

- Root Cosine (also referred to as square root raised-cosine) These filters have the property that their impulse response rings at the symbol rate. Adjacent symbols do not interfere with each other at the symbol times because the response equals zero at all symbol times except the center (desired) one.
  Root cosine filters heavily filter the signal without blurring the symbols together at the symbol times. This is important for transmitting information without errors caused by ISI. Note that ISI exists at all times except at symbol (decision) times.
- Ideal Lowpass In the frequency domain, this filter appears as a lowpass, rectangular filter with very steep cut-off characteristics. The passband is set to equal the symbol rate of the signal. Due to a finite number of coefficients, the filter has a predefined length and is not truly ideal. The resulting ripple in the cut-off band is effectively minimized with a Hamming window. A symbol length of 32 or greater is recommended for this filter.

9. RRC_Alpha is used to set the sharpness of a root cosine filter when FilterType=Root Cosine.
10. GaussianFilter_bT is the Gaussian filter coefficient. B is the 3 dB bandwidth of the filter; T is the duration of the symbol period. BT determines the extent of the filtering of the signal. Common values for BT are 0.3 to 0.5.
11. FilterLength is used to set the number of symbol periods to be used in the calculation of the symbol.
12. For DataType:
    - if PN9 is selected, a 511-bit pseudo-random test pattern is generated according to CCITT Recommendation O.153
    - if PN15 is selected, a 32767-bit pseudo-random test pattern is generated according to CCITT Recommendation O.151
    - if FIX4 is selected, a zero-stream is generated
    - if x_1_x_0 is selected, where x equals 4, 8, 16, 32, or 64, a periodic bit stream is generated, with the period being 2 x. In one period, the first x bits are 1s and the second x bits are 0s.
13. DataLength is used to set the number of data bytes in a frame.
14. The signal for this test bench uses the CCK modulation format.

Measurement Parameters

This measurement requires setting the MirrorMeasSpectrum parameter such that there is an even number of spectrum mirrorings from the combined test bench source and RF DUT. For example, if MirrorSourceSpectrum = NO and the RF DUT causes its output RF signal to have spectrum mirroring relative to its input signal, then set MirrorMeasSpectrum = YES.

1. DisplayPages is not user-editable. It provides information on the name of the Data Display pages in which this measurement is contained.
2. ForwardTaps sets the number of forward taps for decision feedback equalizer (DFE) in 802.11b receiver.
3. FeedbackTaps sets the number of feedback taps for DFE in 802.11b receiver.
4. EqualizerScaleFactor sets the scale factor of DFE, which determines the convergence speed of DFE in 802.11b receiver.
5. StartBurst sets the start burst. A value of 0 is the first burst.
6. StopBurst parameter sets the stop burst. A value of 125 results in measuring 126

bursts.

Simulation Measurement Displays

After running the simulation, results are displayed in the Data Display pages for each measurement activated.

> **Note**
> Measurement results from a wireless test bench have associated names that can be used in Data Display Expressions. For more information, refer to *Measurement Results for Expressions for WLAN Wireless Test Benches* (adswtbwlan).

Measurement

The sensitivity measurement shows BER and PER results.

The receiver minimum input level sensitivity is defined in section 18.4.8.1, IEEE Std 802.11b-1999. The PER must be less than 8% at a DataLength (PSDU) of 1024 bytes (octets) for an input level of -76dBm measured at the receiver antenna connector. This PER must be specified for 11Mbit/s CCK modulation.

Simulation results are shown in the following figure.

Simulation Results for 11 Mbps Data Rate and -76 dBm SourcePower

real(RF_FSource)/(1 MHz)	real(RF_Power_dBm)	real(RF_R)	real(Meas_FMeasurement)/(1 MHz)	real(Meas_R)
2412.000	-76.000	50.000	2412.000	50.000

real(BurstTime)/(1 usec)	real(TimeStep)/(1 nsec)	real(IdleTime)/(1 usec)	real(DataTime)/(1 usec)
990.72727	22.72727	50.00000	744.72727

real(BitRate)/(1 Mbps)	real(BytesPerBurst)	real(SamplesPerBurst)	real(RF_SourceTemp)
11.000	1024.000	43592.000	16.850

Meas Sensitivity

EbN0_dB	BER	PER
27.56123203	0.00000000	0.00000000

Parameters used in the Data Display are described in the table DataRate Determines Value for BitRate. EbN0_RF_dB is the local Eb/N0 measured at the input of the RF DUT and calculated by the following equations:

T = real(RF_SourceTemp) + 273.15

k = Boltzmann's constant

N0_dBm = 10*log10(k * T) + 30

EbN0_RF = real(RF_Power_dBm) - N0_dBm - 10*log10(real(BitRate))

Local Eb/No and system Eb/No are described in *EbNo Definition* (adswtbsim) in *Wireless Test Bench Simulation* documentation.

Test Bench Variables for Data Displays

The following tables identify the reference variables used to set up this test bench:

Test Bench Constants for WLAN Signal Setup

Constant	Value
BitsPerByte	8
RampTime	if(PwrRamp==0) then 0.0 else 2*2.0 usec
LongPreambleTime	192.0 usec
ShortPreambleTime	96.0 usec
PLCPTime	if(PreambleFormat==0) then LongPreambleTime else ShortPreambleTime
PSDUTime	DataLength*BitsPerByte/BitRate Dependent on DataRate in next table.
BandWidth	11.0e6

DataRate Determines Value for BitRate

DataRate	BitRate (see the next table)
Mbps_5.5	5.5e6
Mbps_11	11e6

Test Bench Equations Derived from Test Bench Parameters and Exported to Data Display

Data Display Parameter	Equation with Test Bench Parameters
RF_FSource	FSource
RF_Power_dBm	10*log10(SourcePower)+30
RF_R	SourceR
RF_SourceTemp	SourceTemp in degrees Celsius
TimeStep	1/(Bandwidth*OversamplingRatio) This is the test bench simulation time step
IdleTime	IdleInterval This is the duration of the zero level idle field at the front of each burst
DataTime	PSDUTime This is the durtion of the PSDU field after the PLCP field in each burst
BurstTime	RampTime+PLCPTime+PSDUTime+IdleTime
SamplesPerBurst	BurstTime/TimeStep This is the numnber of Samples in the burst
BytesPerBurst	DataLength This is the number of bytes of data in the Data field in each burst
BitRate	Dependant on DataRate in previous table This is the bit rate for transmitted WLAN signal
Meas_FMeasurement	FMeasurement
Meas_R	MeasR

Baseline Performance

- Test Computer Configuration
  - Pentium IV 2.4 GHz, 512 MB RAM, Red Hat Linux 7.3
- Conditions
  - Measurements made with default test bench settings.
  - RF DUT is an RF system behavior component.
  - Number of time points in one WLAN 802.11b burst is a function of OversamplingRatio, PwrRamp, PreambleFormat, IdleInterval, DataRate, DataLength
    OversamplingRatio = 4
    PwrRamp = Linear
    PreambleFormat = Long
    IdleInterval = 50.0 μsec
    DataRate = 11 Mbps
    DataLength = 1024
  - Resultant WTB_TimeStep = 22.727 nsec; BurstTime = 990.727 μsec; time points per burst = 43592
- Simulation time and memory requirements.

Measurement	Bursts Measured	Simulation Time (sec)	ADS Processes (MB)
RX Sensitivity	125	170	74

Expected ADS Performance

Expected ADS performance is the combined performance of the baseline test bench and the RF DUT Circuit Envelope simulation with the same signal and number of time points. For example, if the RF DUT performance with Circuit Envelope simulation alone takes 2 hours and consumes 200 MB of memory (excluding the memory consumed by the core ADS product), then add these numbers to the Baseline Performance numbers to determine the expected ADS performance. This is valid only if the full memory consumed is from RAM. If RAM is less, larger simulation times may result due to increased disk access time for swap memory usage.

References

1. IEEE Standard 802.11b-1999, "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High-speed Physical Layer Extension in the 2.4 GHz Band," 1999. http://standards.ieee.org/getieee802/download/802.11b-1999.pdf
2. IEEE P802.11g/D8.2, "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: Further Higher Data Rate Extension in the 2.4 GHz Band," April, 2003. http://ieeexplore.ieee.org/servlet/opac?punumber=4040922
3. CCITT, Recommendation O.151(10/92).
4. CCITT, Recommendation O.153(10/92).

Setting up a Wireless Test Bench Analysis in the *Wireless Test Bench Simulation* documentation explains how to use test bench windows and dialogs to perform analysis tasks.
Setting Circuit Envelope Analysis Parameters in the *Wireless Test Bench Simulation* documentation explains how to set up circuit envelope analysis parameters such as convergence criteria, solver selection, and initial guess.
Setting Automatic Behavioral Modeling Parameters in the *Wireless Test Bench Simulation* documentation to learn how to improve simulation speed.

WLAN Links

European Radiocommunications Office: http://www.ero.dk
U.S. Frequency Allocations Chart: http://www.ntia.doc.gov/osmhome
IEEE 802.11b Compliance Organization: http://www.wi-fi.org
IEEE 802.11 Working Group: http://grouper.ieee.org/groups/802/11/index.html

WLAN 802.11b Transmitter Test

Introduction

WLAN_802_11b_TX is the test bench for WLAN transmitter testing. The test bench provides a way for users to connect to an RF DUT and determine its performance by activating various test bench measurements. This test bench provides signal measurements for RF envelope, signal power (including CCDF), constellation, spectrum, and EVM.

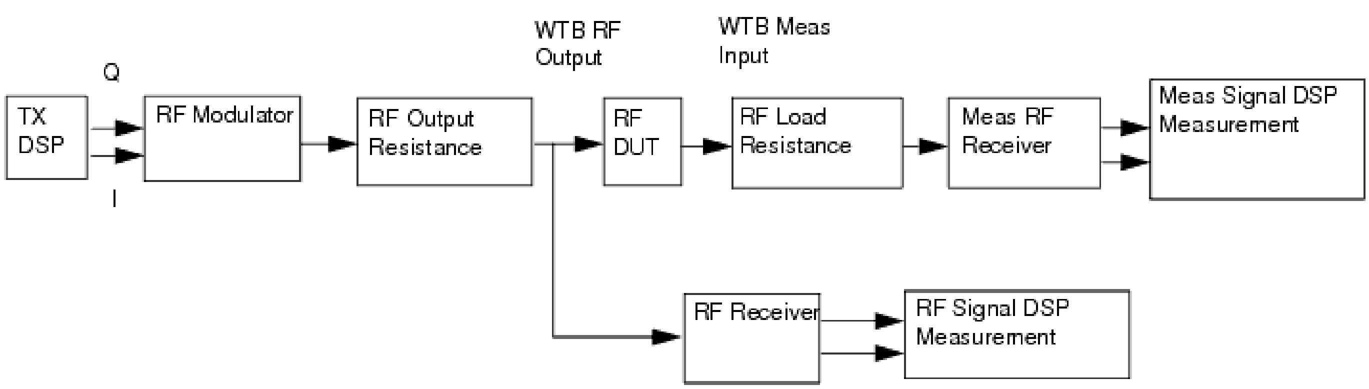
The signal and most of the measurements are designed according to the IEEE Standard 802.11b-1999.

This signal source model is compatible with the Agilent Signal Studio Software option 417 for transmitter test. Details regarding Signal Studio for WLAN 802.11 are included at the website http://www.agilent.com/find/signalstudio .

The RF DUT output signal can be sent to an Agilent ESG RF signal generator.

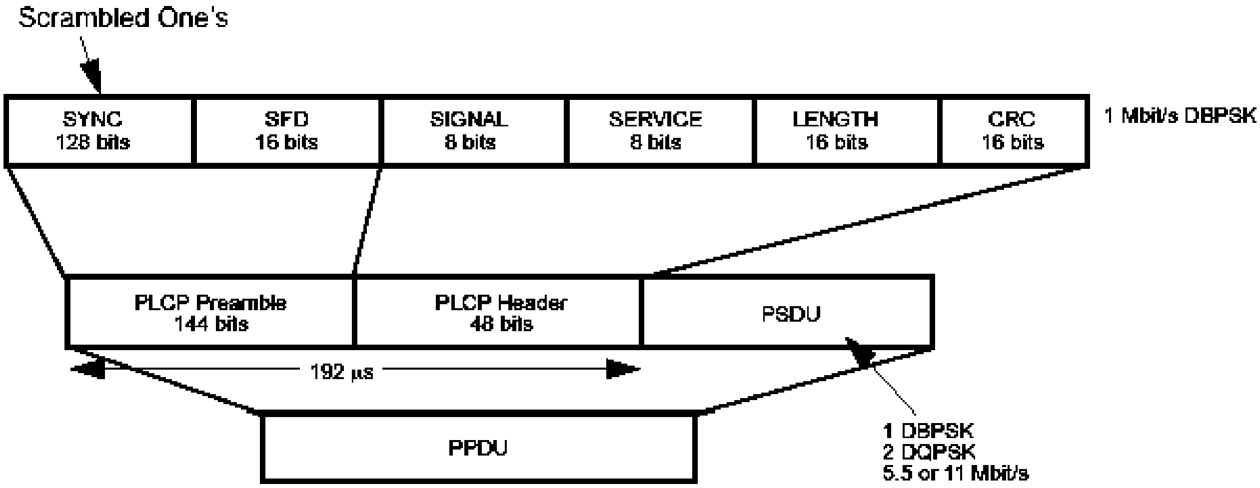
This test bench includes a DSP section, an RF modulator, RF output source resistance, RF DUT connection, RF receivers, and DSP measurement blocks, as illustrated in the following figure. The generated test signal is sent to the DUT.

Transmitter Wireless Test Bench Block Diagram

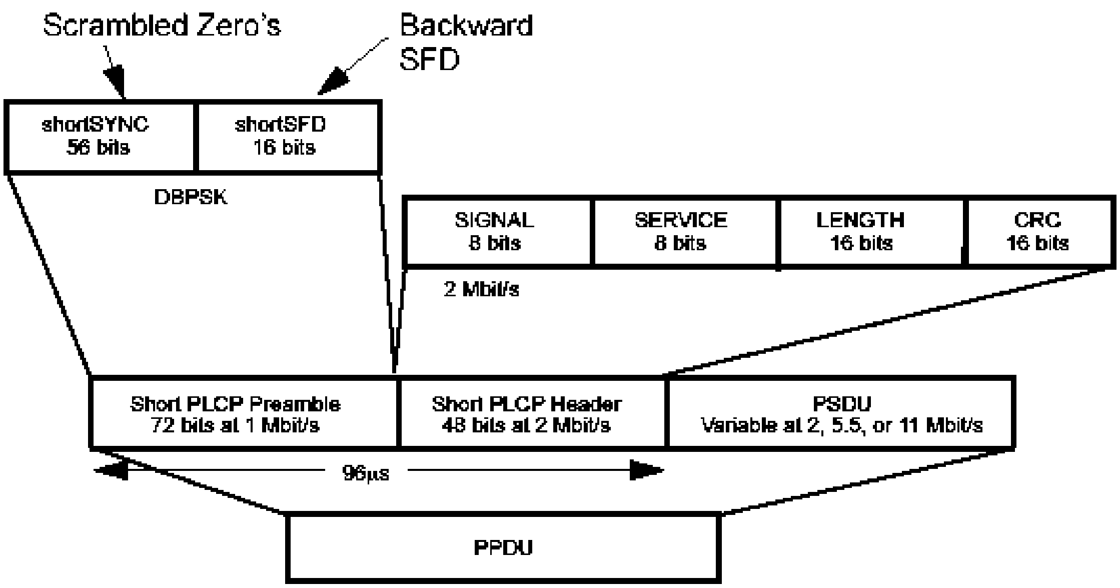


The 802.11b baseband signal source frame structure is illustrated in the figures Long PLCP Frame Format and Short PLCP Frame Format. Each frame is separated by an IdleInterval; one 802.11b frame consists of PLCP Preamble, PLCP Header and Data (PSDU) parts. (PPDU means *physical layer protocol data units* ; SFD means *start frame delimiter* ; CRC means *cyclic redundancy code* ; PLCP means *physical layer convergence procedure* ; PSDU means *PLCP service data units* .)

Long PLCP Frame Format

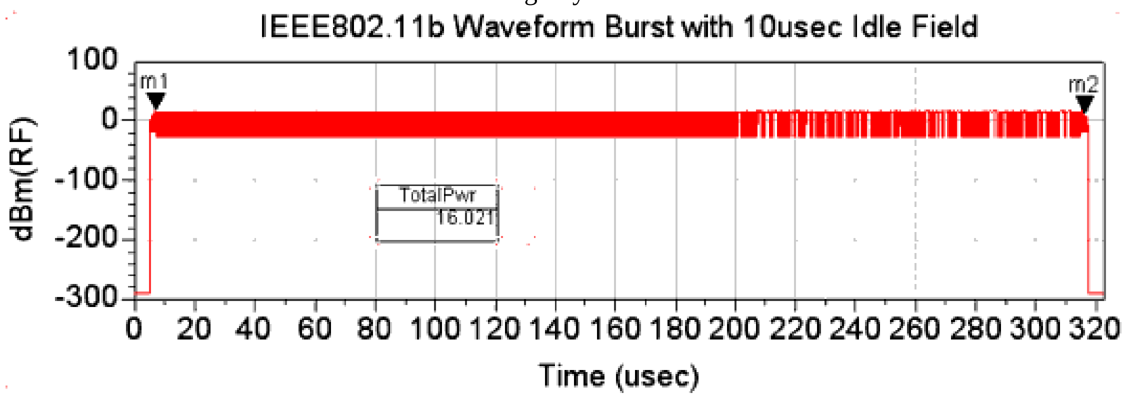


Short PLCP Frame Format



The WLAN 11b RF power delivered into a matched load is the average power delivered in the WLAN burst excluding the burst idle time. The following figure shows the RF envelope for an output RF signal with 16 dBm power and a 10 μ idle time.

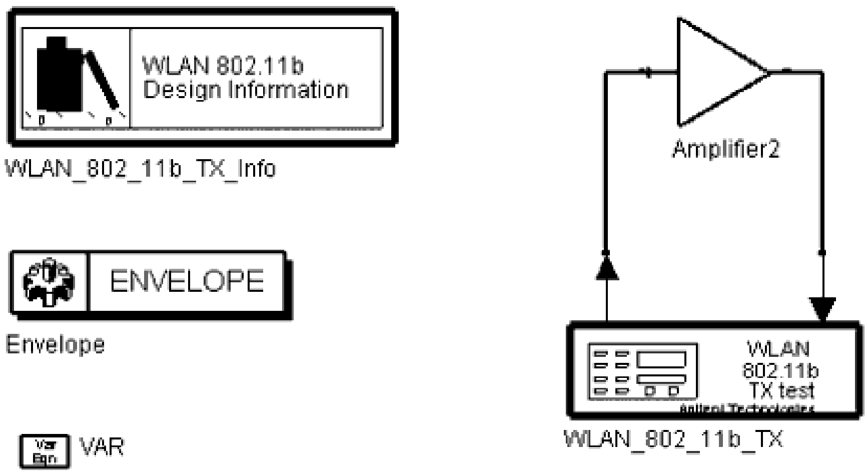
WLAN 802.11b RF Signal Envelope


IEEE802.11b Waveform Burst with 10usec Idle Field
m1
m2
TotalPwr
16.021
dBm(RF)
100
0
-100
-200
-300
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
Time (usec)

Test Bench Basics

A template is provided for this test bench.

WLAN 802.11b Transmitter Test Bench



To access the template:

1. In an Analog/RF schematic window select *Insert > Template.*
2. In the *Insert > Template* dialog box, choose *WLAN_802_11b_TX_test* , click *OK* ; click left to place the template in the schematic window.
   An example design using this template is available; from the ADS Main window click *File > Open > Example* > WLAN > WLAN_RF_Verification_wrk > *WLAN_802_11b_TX_test* .
   The basics for using the test bench are:

- Replace the DUT (Amplifier2 is provided with this template) with an RF DUT that is suitable for this test bench.
- CE_TimeStep, FSource, SourcePower, and FMeasurement parameter default values are typically accepted; otherwise, set values based on your requirements.
- Activate/deactivate measurements based on your requirements.
- Run the simulation and view Data Display page(s) for your measurement(s).
  For details, refer to Test Bench Details.

Test Bench Details

The following sections provide details for setting up a test bench, setting measurement parameters for more control of the test bench, simulation measurement displays, and baseline performance.

Open and use the *WLAN_802_11b_TX* template:

1. In an Analog/RF schematic window select *Insert* > *Template.*
2. In the *Insert* > *Template* dialog box, choose *WLAN_802_11b_TX_test* , click *OK* ; click left to place the template in the schematic window.

Test bench setup is detailed here.

1. Replace the DUT (Amplifier2 is provided with this template) with an RF DUT that is suitable for this test bench.
   For information regarding using certain types of DUTs, see *RF DUT Limitations for WLAN Wireless Test Benches* (adswtbwlan).

2. Set the *Required Parameters*

   > **Note**
   > Refer to *WLAN_802_11b_TX* (adswtbwlan) for a complete list of parameters for this test bench.

   Generally, default values can be accepted; otherwise, values can be changed by the user as needed.

   - Set CE_TimeStep.
     Cosimulation occurs between the test bench (using ADS Ptolemy Data Flow simulation technology) and the DUT (using Agilent Circuit Envelope simulation technology). Each technology requires its own simulation time step with time-step coordination occurring in the interface between the technologies.
     CE_TimeStep defines the Circuit Envelope simulation time step to be used with this DUT. The CE_TimeStep must be set to a value equal to or a submultiple of (less than) WTB_TimeStep; otherwise, simulation will stop and an error message will be displayed.
     Note that WTB_TimeStep is not user-settable. Its value is derived from other test bench parameter values; with default settings WTB_TimeStep=1/(11.0e6*6) sec. The value is displayed in the Data Display pages as TimeStep.
     WTB_TimeStep = 1/(11.0e6 × Ratio)
     where

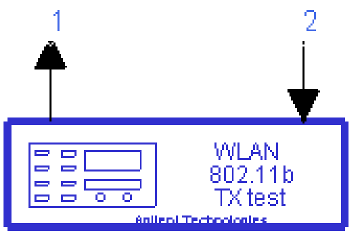
       11.0e6 means the baseband bandwidth of 11b is 11.0MHz.

     Ratio is the OversamplingRatio value specified. OversamplingRatio sets the number of waveform sampling points during one chip time interval.
   - Set FSource, SourcePower, and FMeasurement.
     - FSource defines the RF frequency for the signal input to the RF DUT. The FSource value is exported to the *Choosing Analyses* window *Fundamental Tones* field when the user clicks *OK* in the *Wireless Test Bench Setup* window.

  - SourcePower defines the power level for FSource. SourcePower is defined as the average power during the non-idle time of the signal burst.
  - FMeasurement defines the RF frequency output from the DUT to be measured.
3. Activate/deactivate (*YES* / *NO*) test bench measurements (refer to *WLAN_802_11b_TX* (adswtbwlan)). At least one measurement must be enabled:
   - RF_EnvelopeMeasurement
   - Constellation
   - PowerMeasurement
   - SpectrumMeasurement
   - EVM_Measurement
4. More control of the test bench can be achieved by setting *Basic Parameters* , *Signal Parameters* , and parameters for each activated measurement. For details, refer to *Setting Parameters* (adswtbwlan).
5. The RF modulator (shown in the block diagram in Transmitter Wireless Test Bench Block Diagram) uses FSource, SourcePower (*Required Parameters*), MirrorSourceSpectrum (*Basic Parameters)* , GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and IQ_Rotation (*Signal Parameters*).
   The RF output resistance uses SourceR, SourceTemp, and EnableSourceNoise (*Basic Parameters*). The RF output signal source has a 50-ohm (default) output resistance defined by SourceR.
   RF output (and input to the RF DUT) is at the frequency specified (FSource), with the specified source resistance (SourceR) and with power (SourcePower) delivered into a matched load of resistance SourceR. The RF signal has additive Gaussian noise power set by resistor temperature (SourceTemp) (when EnableSourceNoise=YES).
   Note that the Meas_in point of the test bench provides a resistive load to the RF DUT set by the MeasR value (50-ohm default) (*Basic Parameters*).
   The Meas signal contains linear and nonlinear signal distortions and time delays associated with the RF DUT input to output characteristics.
   The TX DSP block (shown in the block diagram in Transmitter Wireless Test Bench Block Diagram) uses other *Signal Parameters* .
6. More control of Circuit Envelope analysis can be achieved by setting Envelope controller parameters. These settings include Enable Fast Cosim, which may speed the RF DUT simulation more than 10×. Setting these simulation options is described in *Setting Fast Cosimulation Parameters* and *Setting Circuit Envelope Analysis Parameters* in the *Wireless Test Bench Simulation* documentation.
7. To send the RF DUT output signal to an Agilent ESG RF signal generator, set *Signal to ESG Parameters* .
   For details, refer to *Signal to ESG Parameters* (adswtbwlan).
8. After running a simulation, results will appear in a Data Display window for the measurement. *Simulation Measurement Displays* (adswtbwlan) describes results for each measurement. For general WTB Data Display details refer to *Viewing WTB Analysis Results* (adswtbsim).

WLAN_802_11b_TX

This section provides parameter information for *Required Parameters, Basic Parameters, Signal Parameters,* and parameters for the various measurements.



Description WLAN 802.11b TX test
Library WTB
Class TSDFWLAN_802_11b_TX
Derived From baseWTB_TX

Parameters

Name	Description	Default	Sym	Unit	Type	Range
Required Parameters						
CE_TimeStep	Circuit envelope simulation time step	1/11 MHz/6		sec	real	(0, ∞)
WTB_TimeStep	Set CE_TimeStep < = 1/11e6/ OversamplingRatio.					
FSource	Source carrier frequency: CH1 _2412.0MHz, CH3 _2422.0MHz, CH5 _2432.0MHz, CH6 _2437.0MHz, CH7 _2442.0MHz, CH9 _2452.0MHz, CH11 _2462.0MHz, CH13 _2472.0MHz	CH1 _2412.0MHz		Hz	real enum	(0, ∞)
SourcePower	Source power	dbmtow(-20.0)		W	real	[0, ∞)
FMeasurement	Measurement carrier frequency:	Meas_CH1 _2412.0MHz		Hz	real enum	(0, ∞)

	Meas_CH1 _2412.0MHz, Meas_CH3 _2422.0MHz, Meas_CH5 _2432.0MHz, Meas_CH6 _2437.0MHz, Meas_CH7 _2442.0MHz, Meas_CH9 _2452.0MHz, Meas_CH11 _2462.0MHz, Meas_CH13 _2472.0MHz					
MeasurementInfo	Available Measurements					
RF_EnvelopeMeasurement	Enable RF envelope measurement? NO, YES	YES			enum	
Constellation	Enable constellation measurement? NO, YES	NO			enum	
PowerMeasurement	Enable power measurement? NO, YES	NO			enum	
SpectrumMeasurement	Enable spectrum measurement? NO, YES	NO			enum	
EVM_Measurement	Enable EVM measurement? NO, YES	NO			enum	
Basic Parameters						
SourceR	Source resistance	50 Ohm		Ohm	real	(0, ∞)
SourceTemp	Source resistor temperature	-273.15		Celsius	real	[-273.15, ∞)
EnableSourceNoise	Enable source thermal noise? NO, YES	NO			enum	
MeasR	Measurement resistance	50 Ohm		Ohm	real	[10, 1.0e6]
MirrorSourceSpectrum	Mirror source spectrum about carrier? NO, YES	NO			enum	
MirrorMeasSpectrum	Mirror meas spectrum about carrier? NO, YES	NO			enum	
RF_MirrorFreq	Mirror source frequency for spectrum/envelope measurement? NO, YES	NO			enum	
MeasMirrorFreq	Mirror meas	NO			enum	

	frequency for spectrum/envelope measurement? NO, YES					
TestBenchSeed	Random number generator seed	1234567			int	[0, ∞)
Signal Parameters						
GainImbalance	Gain imbalance, Q vs I	0.0		dB	real	(-∞, ∞)
PhaseImbalance	Phase imbalance, Q vs I	0.0		deg	real	(-∞, ∞)
I_OriginOffset	I origin offset (percent)	0.0			real	(-∞, ∞)
Q_OriginOffset	Q origin offset (percent)	0.0			real	(-∞, ∞)
IQ_Rotation	IQ rotation	0.0		deg	real	(-∞, ∞)
OversamplingRatio	Oversampling ratio	6	S		int	[2, 9]
DataRate	Data rate (Mbps): Mpbs_1, Mbps_2, Mbps_5.5, Mbps_11	Mbps_11	R		enum	
Modulation	Modulation format: CCK, PBCC	CCK			enum	
PreambleFormat	Preamble/header format: Long, Short	Long	H		enum	
ClkLockedFlag	Lock header clock? NO, YES	YES			enum	
PwrRamp	RF power ramp shape: None, Linear, Cosine	Linear	P		enum	
IdleInterval	Burst idle interval	10.0 usec	I	sec	real	[0, 1000us]
FilterType	Shaping filter type: NoneFilter, Gaussian, Root Cosine, Ideal Lowpass	Gaussian			enum	
RRC_Alpha	RRC roll-off factor	0.22			real	(0.0, 1.0]
GaussianFilter_bT	Gaussian filter bT coefficient	0.5			real	(0.0, 1.0]
FilterLength	Filter length (chips)	10			int	[1, 200]
DataType	Payload data type: PN9, PN15, FIX4, _4_1_4_0, _8_1_8_0, _16_1_16_0, _32_1_32_0, _64_1_64_0	PN9			enum	
DataLength	Data length (bytes per burst)	160	L		int	[1, 2312]
RF_Envelope Measurement Parameters						

RF_EnvelopeDisplayPages	RF Envelope measurement display pages:					
RF_EnvelopeStart	RF envelope measurement start	0.0		sec	real	[0, ∞)
RF_EnvelopeStop	RF envelope measurement stop	100.0 usec		sec	real	[RF_EnvelopeStart, ∞)
RF_EnvelopeBursts	RF envelope measurement bursts	3			int	[0, 100]
Constellation Parameters						
ConstellationDisplayPages	Constellation measurement display pages:					
Constellation_ForwardTaps	Number of equalizer forward taps	6			int	[1, 256]
Constellation_FeedbackTaps	Number of equalizer feedback taps	3			int	[1, 128]
Constellation_EquAlpha	LMS algorithm scale factor	0.001			real	(0, 1.0)
ConstellationStartBurst	Constellation measurement start burst	0			int	[0, 100]
ConstellationBursts	Constellation measurement bursts	3			int	[1, 100]
PowerMeasurement Parameters						
PowerDisplayPages	Power measurement display pages:					
PowerBursts	Power measurement bursts	3			int	[1, 100]
SpectrumMeasurement Parameters						
SpectrumDisplayPages	Spectrum measurement display pages:					
SpecMeasStart	Spectrum measurement start	0.0		sec	real	[0, ∞)
SpecMeasStop	Spectrum measurement stop	100.0 usec		sec	real	[SpecMeasStart + 16*MaxTimeStep, ∞]
SpecMeasBursts	Spectrum measurement bursts	3			int	[0, 100]
SpecMeasResBW	Spectrum resolution bandwidth	100 kHz		Hz	real	[0, ∞)
SpecMeasWindow	Window type:	Kaiser 7.865			enum	

	none, Hamming 0.54, Hanning 0.50, Gaussian 0.75, Kaiser 7.865, _8510 6.0, Blackman, Blackman-Harris					
EVM_Measurement Parameters						
EVM_DisplayPages	EVM measurement display pages:					
EVM_Start	EVM measurement start	0.0		sec	real	[0, ∞)
EVM_AverageType	Average type: Off, RMS (Video)	RMS (Video)			enum	
EVM_BurstsToAverage	Bursts used for RMS averaging	10			int	[1, ∞)
EVM_DataModulationFormat	Data subcarrier modulation format: Auto Detect, Barker 1, Barker 2, CCK 5.5, CCK 11, PBCC 5.5, PBCC 11, PBCC 22, PBCC 33	Auto Detect			enum	
EVM_SearchLength	Search length	0.001		sec	real	(0, ∞)
EVM_ResultLengthType	Resul length type: Auto select, Manual Override	Auto select			enum	
EVM_ResultLength	Max result length (chips)	2816			int	[1, 108344]
EVM_MeasurementInterval	Measurement interval (chips)	2794			int	[1, ∞)
EVM_MeasurementOffset	Measurement offset (chips)	22			int	(0, ∞)
EVM_ClockAdjust	Clock adjustment interval (chips)	0.0			real	[-0.5, +0.5]
EVM_EqualizationFilter	Equalization filter? NO, YES	NO			enum	
EVM_FilterLength	Equalization filter length (chips)	21			int	[3, ∞)
EVM_DescrambleMode	Descramble mode: OFF, Preamble Only, Preamble&Header Only, ON	ON			enum	
SignalToESG_Parameters						
EnableESG	Enable signal to ESG? NO, YES	NO			enum	
ESG_Instrument	ESG instrument address	[GPIB0::19::INSTR][localhost][4790]			instrument	
ESG_Start	Signal start	0.0		sec	real	[0, ∞)
ESG_Stop	Signal stop	100.0 usec		sec	real	[(ESG_Start +60/

						11e6/S), (ESG_Start +32/ 11/S)]
ESG_Bursts	Bursts to ESG	3			int	[0, 1000]
ESG_Power	ESG RF ouput power (dBm)	-20.0			real	(-∞, ∞)
ESG_ClkRef	Waveform clock reference: Internal, External	Internal			enum	
ESG_ExtClkRefFreq	External clock reference freq	10 MHz		Hz	real	(0, ∞)
ESG_IQFilter	IQ filter: through, filter_2100kHz, filter_40MHz	through			enum	
ESG_SampleClkRate	Sequencer sample clock rate	80 MHz		Hz	real	(0, ∞)
ESG_Filename	ESG waveform storage filename	WLAN_11b			string	
ESG_AutoScaling	Activate auto scaling? NO, YES	YES			enum	
ESG_ArbOn	Select waveform and turn ArbOn after download? NO, YES	YES			enum	
ESG_RFPowOn	Turn RF ON after download? NO, YES	YES			enum	
ESG_EventMarkerType	Event marker type: Neither, Event1, Event2, Both	Event1			enum	
ESG_MarkerLength	ESG marker length	10			int	[1, 60]

Pin Inputs

Pin	Name	Description	Signal Type
2	Meas_In	Test bench measurement RF input from RF circuit	timed

Pin Outputs

Pin	Name	Description	Signal Type
1	RF_Out	Test bench RF output to RF circuit	timed

Setting Parameters

More control of the test bench can be achieved by setting parameters in the *Basic Parameters* , *Signal Parameters* , and *measurement* categories for the activated measurements.

> **Note**
> For *required* parameter information, see *Set the Required Parameters* (adswtbwlan).

Basic Parameter Detail

1. SourceR is the RF output source resistance.
2. SourceTemp is the RF output source resistance temperature (oC) and sets noise density in the RF output signal to (k(SourceTemp+273.15)) Watts/Hz, where k is Boltzmann's constant.
3. EnableSourceNoise, when set to NO disables the SourceTemp and effectively sets it to -273.15oC (0 Kelvin). When set to YES, the noise density due to SourceTemp is enabled.
4. MeasR defines the load resistance for the RF DUT output Meas signal into the test bench. This resistance loads the RF DUT output; it is also the reference resistance for Meas signal power measurements.
5. MirrorSourceSpectrum is used to invert the polarity of the Q envelope of the generated RF signal before it is sent to the RF DUT. Depending on the configuration and number of mixers in an RF transmitter, the signal at the input of the DUT may need to be mirrored. If such an RF signal is desired, set this parameter to YES.
6. MirrorMeasSpectrum is used to invert the polarity of the Q envelope in the Meas_in RF signal input to the test bench (and output from the RF DUT). Depending on the configuration and number of mixers in the RF DUT, the signal at its output may be mirrored compared to the signal generated by the signal source (before any mirroring is done because of the MirrorSourceSpectrum setting). Proper demodulation and measurement of the RF DUT output signal requires that its RF envelope is not mirrored compared to the signal generated by the signal source (before any mirroring is done because of the MirrorSourceSpectrum setting). If the Meas_in RF signal is mirrored, set this parameter to YES. Proper setting of this parameter is required for measurements on the Meas_in signal in TX test benches (EVM, Constellation, CDP, PCDE) and results in measurement on a signal with no spectrum mirroring.
7. TestBenchSeed is an integer used to seed the random number generator used with the test bench. This value is used by all test bench random number generators, except those RF DUT components that use their own specific seed parameter. TestBenchSeed initializes the random number generation. The same seed value produces the same *random* results, thereby giving you predictable simulation results. To generate repeatable *random* output from simulation to simulation, use any positive seed value. If you want the output to be truly random, enter the seed value of 0.
8. RF_MirrorFreq is used to invert the polarity of the Q envelope in the RF_out RF signal for RF envelope, ppectrum, ACLR, and occupied bandwidth measurements. RF_MirrorFreq is typically set by the user to NO when MirrorSourceSpectrum = NO; RF_MirrorFreq is typically set by the user to YES when MirrorSourceSpectrum = YES. Both settings result in viewing the RF_out signal with no spectrum mirroring. Other

settings by the user result in RF_out signal for RF_Envelope and Spectrum measurements with spectrum mirroring.

9. MeasMirrorFreq is used to invert the polarity of the Q envelope in the Meas_in RF signal for the RF envelope, spectrum, ACLR, and occupied bandwidth measurements. MeasMirrorFreq is typically set to NO by the user when the combination of the MirrorSourceSpectrum value and any signal mirroring in the users RF DUT results in no spectrum mirroring in the Meas_in signal. MeasMirrorFreq is typically set to YES by the user when the combination of the MirrorSourceSpectrum and RF DUT results in spectrum mirroring in the Meas_in signal.
Other settings result in Meas_in signal for RF_Envelope and Spectrum measurements with spectrum mirroring. The MirrorMeasSpectrum parameter setting has no impact on the setting or use of the MeasMirrorFreq parameter.

Signal Parameters

1. GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and IQ_Rotation are used to add certain impairments to the ideal output RF signal. Impairments are added in the order described here.
The unimpaired RF I and Q envelope voltages have gain and phase imbalance applied. The RF is given by:
$$V_{RF}(t) = A\left(V_I(t)\cos(\omega_c t) - gV_Q(t)\sin\left(\omega_c t + \frac{\phi\pi}{180}\right)\right)$$
where *A* is a scaling factor that depends on the SourcePower and SourceR parameters specified by the user, $V_I(t)$ is the in-phase RF envelope, $V_Q(t)$ is the quadrature phase RF envelope, *g* is the gain imbalance
$$g = 10^{\frac{GainImbalance}{20}}$$
and, φ (in degrees) is the phase imbalance.
Next, the signal $V_{RF}(t)$ is rotated by IQ_Rotation degrees. The I_OriginOffset and Q_OriginOffset are then applied to the rotated signal. Note that the amounts specified are percentages with respect to the output rms voltage. The output rms voltage is given by sqrt(2 × SourceR × SourcePower).
2. OversamplingRatio sets the oversampling ratio of 802.11b RF signal source. Eight oversampling ratios (2, 3, 4, 5, 6, 7, 8, 9) are supported. If OversamplingRatio=4, the simulation RF bandwidth is larger than the signal bandwidth by a factor of 4 (e.g. for Bandwidth=11 MHz, the simulation RF bandwidth=11 MHz × 4 = 44 MHz).
3. DataRate specifies the data rate 1, 2, 5.5, or 11 Mbps (data rates are defined in 802.11b).
4. Modulation specifies modulation format CCK or PBCC (802.11b formats) for 5.5 Mbps and 11 Mbps data rates.
5. PreambleFormat is used to set the format of the framed signal preamble/header sections; refer to *Long PLCP Frame Format* (adswtbwlan) and *Short PLCP Frame Format* (adswtbwlan).
6. ClkLockedFlag is used to toggle the clock locked flag in the 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. If ClkLockedFlag=YES, this bit is set to 1; if ClkLockedFlag=NO, this bit is set to 0.
7. PwrRamp is used to select the shape of the RF burst in framed mode; power up/down

ramp type is 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 power up/down ramp is set to 2 μ when PwrRamp = none.
- Linear ramp shapes the burst in a linear fashion.

8. IdleInterval sets an idle time between two consecutive bursts when generating the 802.11b signal source.
9. FilterType is used to specify that a baseband filter is applied to reduce the transmitted bandwidth, thereby increasing spectral efficiency. The 802.11b specification does not indicate the type of filter to be used, but the transmitted signal must meet the spectral mask requirements. Four options for baseband filtering are available:
    - None (no filter)
    - Gaussian The Gaussian filter does not have zero ISI. Wireless system architects must determine how much of the ISI can be tolerated in a system and combine that with noise and interference. The Gaussian filter is Gaussian-shaped in time and frequency domains, and it does not ring as root cosine filters do.
      The effects of this filter in the time domain are relatively short and each symbol interacts significantly (or causes ISI) with only the preceding and succeeding symbols. This reduces the tendency for particular sequences of symbols to interact which makes amplifiers easier to build and more efficient.
    - Root Cosine (also referred to as square root raised-cosine) These filters have the property that their impulse response rings at the symbol rate. Adjacent symbols do not interfere with each other at the symbol times because the response equals zero at all symbol times except the center (desired) one.
      Root cosine filters heavily filter the signal without blurring the symbols together at the symbol times. This is important for transmitting information without errors caused by ISI. Note that ISI exists at all times except at symbol (decision) times.
    - Ideal Lowpass In the frequency domain, this filter appears as a lowpass, rectangular filter with very steep cut-off characteristics. The passband is set to equal the symbol rate of the signal. Due to a finite number of coefficients, the filter has a predefined length and is not truly *ideal* . The resulting ripple in the cut-off band is effectively minimized with a Hamming window. A symbol length of 32 or greater is recommended for this filter.
10. RRC_Alpha is used to set the sharpness of a root cosine filter when FilterType=Root Cosine.
11. GaussianFilter_bT is the Gaussian filter coefficient. B is the 3 dB bandwidth of the filter; T is the duration of the symbol period. BT determines the extent of the filtering of the signal. Common values for BT are 0.3 to 0.5.
12. FilterLength is used to set the number of symbol periods to be used in the calculation of the symbol.
13. For DataType:
    - if PN9 is selected, a 511-bit pseudo-random test pattern is generated according to CCITT Recommendation O.153
    - if PN15 is selected, a 32767-bit pseudo-random test pattern is generated according to CCITT Recommendation O.151
    - if FIX4 is selected, a zero-stream is generated
    - if x_1_x_0 is selected, where x equals 4, 8, 16, 32, or 64, a periodic bit stream is generated, with the period being 2 x. In one period, the first x bits are 1s and the second x bits are 0s.
14. DataLength is used to set the number of data bytes in a frame.

RF Envelope Measurement Parameters

The RF Envelope measurement is not affected by the MirrorMeasSpectrum parameter. To apply spectrum mirroring to the measured RF_out signal, set RF_MirrorFreq=YES; to apply spectrum mirroring to the measured Meas_in signal, set MeasMirrorFreq=YES (*Basic Parameters*).

- RF_EnvelopeDisplayPages provides Data Display page information for this measurement. It cannot be changed by the user.
- RF_EnvelopeStart sets the start time for collecting input data.
- RF_EnvelopeStop sets the stop time for collecting input data when RF_EnvelopeBursts = 0.
- RF_EnvelopeBursts (when > 0) sets the number of bursts over which data will be collected.

Depending on the values of RF_EnvelopeStart, RF_EnvelopeStop, and RF_EnvelopeBursts, the stop time may be adjusted.

For RF envelope measurement for both the RF_out and Meas_in signals:
Let:

Start = TimeStep× (int(RF_EnvelopeStart/TimeStep) + 0.5)

Stop = TimeStep × (int(RF_EnvelopeStop/TimeStep) + 0.5)

This means Start and Stop are forced to be an integer number of time-step intervals.

RF_EnvelopeBursts	Resultant Stop Time
0	Stop
> 0	Start + RF_EnvelopeBursts x BurstTime

For the RF envelope of Meas_in to contain at least one complete burst, set the Stop value to a minimum of BurstTime + (RF DUT time delay).

For the RF envelope of Meas_in to contain at least one complete burst, the Stop value should be set to a minimum of BurstTime + (RF DUT time delay).

For information about TimeStep and BurstTime, see Test Bench Equations Derived from Test Bench Parameters and Exported to the Data Display.

Constellation Parameters

The Constellation measurement requires setting of the MirrorMeasSpectrum parameter set such that there is an even number of spectrum mirrorings from the combined test bench source and RF DUT. For example, if MirrorSourceSpectrum=NO and the RF DUT causes its output RF signal to have spectrum mirroring relative to its input signal, then set

MirrorMeasSpectrum = YES.

1. ConstellationDisplayPages provides Data Display page information for this measurement. It cannot be changed by the user.
2. Constellation_ForwardTaps sets the number of forward taps for the decision feedback equalizer in 802.11b.
3. Constellation_FeedbackTaps sets the number of feedback taps for the decision feedback equalizer in 802.11b.
4. Constellation_EquAlpha sets the feedback taps scale factor for the decision feedback equalizer, which determines the convergence speed of the DFE in the 802.11b receiver.
5. ConstellationStartBurst sets the start time for collecting the first burst data. The ConstellationStartBurst value can be set > 0 to avoid any start-up transient in the Constellation plots.
6. ConstellationBursts sets the number of bursts over which data will be collected.

The measurement start time is the time when ConstellationStartBurst is detected in the measured RF signal. The measurement stop time is this start time plus ConstellationBursts × BurstTime; BurstTime is defined in Test Bench Equations Derived from Test Bench Parameters and Exported to the Data Display.

Power Measurement Parameters

1. PowerDisplayPages provides Data Display page information for this measurement. It cannot be changed by the user.
2. PowerBursts (when > 0) sets the number of bursts over which data will be collected.

The measurement start time is the time when the first burst is detected in the measured RF signal. The measurement stop time is this start time plus PowerBursts × BurstTime; BurstTime is defined in Test Bench Equations Derived from Test Bench Parameters and Exported to the Data Display.

Spectrum Measurement Parameters

The Spectrum measurement calculates the spectrum of the input signal. Averaging the spectrum over multiple bursts can be enabled as described in this section.

This measurement is not affected by the MirrorMeasSpectrum parameter. To apply spectrum mirroring to the measured RF_out signal, set RF_MirrorFreq = YES; to apply spectrum mirroring to the measured Meas_in signal, set MeasMirrorFreq = YES.

In the following, TimeStep denotes the simulation time step, and FMeasurement denotes the measured RF signal characterization frequency.

1. The measurement outputs the complex amplitude voltage values at the frequencies of the spectral tones. It does not output the power at the frequencies of the spectral tones. However, one can calculate and display the power spectrum as well as the magnitude and phase spectrum by using the dBm, mag, and phase functions of the

data display window.
Note that the dBm function assumes a 50-ohm reference resistance; if a different measurement was used in the test bench, its value can be specified as a second argument to the dBm function, for example, dBm(SpecMeas, Meas_RefR) where SpecMeas is the instance name of the spectrum measurement and Meas_RefR is the resistive load.
By default, the displayed spectrum extends from FMeasurement - 1/(2 × TimeStep) Hz to FMeasurement + 1/(2 × TimeStep) Hz. When FMeasurement < 1/(2 × TimeStep), the default spectrum extends to negative frequencies. The spectral content at these negative frequencies is conjugated, mirrored, and added to the spectral content of the closest positive frequency. This way, the negative frequency tones are displayed on the positive frequency axis as would happen in an RF spectrum analyzer measurement instrument. This process may introduce an error in the displayed frequency for the mirrored tones. The absolute error introduced is less than (Spectrum Frequency Step) / 2 (see Effect of Values for SpecMeasStart, SpecMeasStop, SpecMeasBursts, and SpecMeasResBW for the definition of Spectrum Frequency Step).
The basis of the algorithm used by the spectrum measurement is the chirp-Z transform. The algorithm can use multiple bursts and average the results to achieve video averaging (see note 6).

2. SpectrumDisplayPages is not user editable. It provides information on the name of the Data Display pages in which this measurement is contained.
3. SpecMeasStart sets the start time for collecting input data.
4. SpecMeasStop sets the stop time for collecting input data when SpecMeasBursts = 0 and SpecMeasResBW = 0.
5. SpecMeasBursts sets the number of bursts over which data will be collected when SpecMeasBursts>0.
6. SpecMeasResBW sets the resolution bandwidth of the spectrum measurement when SpecMeasResBW>0.
   Depending on the values of SpecMeasStart, SpecMeasStop, SpecMeasBursts, and SpecMeasResBW, the stop time may be adjusted or spectrum video averaging may occur (or both). The different cases are described in Effect of Values for SpecMeasStart, SpecMeasStop, SpecMeasBursts, and SpecMeasResBW.
   Referring to Effect of Values for SpecMeasStart, SpecMeasStop, SpecMeasBursts, and SpecMeasResBW let

   Start = TimeStep × int((SpecMeasStart/TimeStep) + 0.5)

   Stop = TimeStep × int((SpecMeasStop/TimeStep) + 0.5)

   (This means Start and Stop are forced to be an integer number of time step intervals.)

   X = normalized equivalent noise bandwidth of the window

   Equivalent noise bandwidth (ENBW) compares the window to an ideal, rectangular filter. It is the equivalent width of a rectangular filter that passes the same amount of white noise as the window. The normalized ENBW (NENBW) is ENBW multiplied by the duration of the signal being windowed. Window Options and Normalized Equivalent Noise Bandwidth lists the NENBW for the various window options.
   The Start and Stop times are used for both the RF_out and Meas_in signal spectrum analyses. The Meas_in signal is delayed in time from the RF_out signal by the value

of the RF DUT time delay. Therefore, for RF DUT time delay greater than zero, the RF_out and Meas_in signal are inherently different and some spectrum display difference in the two is expected.
TimeStep and BurstTime are defined in the *Test Bench Variables for Data Displays* section.

Effect of Values for SpecMeasStart, SpecMeasStop, SpecMeasBursts, and SpecMeasResBW

Case 1	SpecMeasBursts = 0 SpecMeasResBW = 0 Resultant stop time = Stop Resultant resolution BW = X/(Stop - Start) Resultant spectrum frequency step = 1/(Stop-Start) Video averaging status = None
Case 2	SpecMeasBursts > 0 SpecMeasResBW = 0 Resultant stop time = Start + SpecMeasBurst x BurstTime Notes: For SpecMeasBursts > 0 and SpecMeasResBW = 0 Video averaging occurs over all burst time intervals Resultant resolution BW = X /BurstTime Resultant spectrum frequency step = 1/BurstTime Video averaging status = Yes, when SpecMeasBursts > 1
Case 3	SpecMeasBursts = 0 SpecMeasResBW > 0 Resultant stop time = Start + N x BurstTimeInterval where N = int((Stop -Start)/BurstTimeInterval) + 1 For SpecMeasBursts = 0 and SpecMeasResBW > 0 Define BurstTimeInterval = TimeStep x int((X/SpecMeasResBW/TimeStep) + 0.5) This means BurstTimeInterval is forced to a value that is an integer number of time step intervals. (Stop-Start) time is forced to be an integer number (N) of BurstTimeIntervals N has a minimum value of 1 Video averaging occurs over all BurstTimeIntervals The resolution bandwidth achieved is ResBW = X / BurstTimeInterval, which is very close to SpecMeasResBW but may not be exactly the same if X/SpecMeasResBW/TimeStep is not an exact integer. Resultant resolution BW = ResBW Resultant spectrum frequency step = ResBW Video averaging status = Yes when N > 1
Case 4	SpecMeasBursts > 0 SpecMeasResBW > 0 Resultant stop time = Start + M x BurstTimeInterval where M = int((SpecMeasBursts x BurstTime)/BurstTimeInterval) + 1 For SpecMeasBursts > 0 and SpecMeasResBW > 0 Define BurstTimeInterval = TimeStep x int((X /SpecMeasResBW/TimeStep) + 0.5) This means BurstTimeInterval is forced to a value that is an integer number of time step intervals. (Stop-Start) time is forced to be an integer number (M) of the BurstTimeIntervals M has a minimum value of 1 Video averaging occurs over all BurstTimeIntervals The resolution bandwidth achieved is ResBW = X / BurstTimeInterval, which is very close to SpecMeasResBW but may not be exactly the same if X/SpecMeasResBW/TimeStep is not an exact integer. Resultant resolution BW = ResBW Resultant spectrum frequency step = ResBW Video averaging status = Yes, when M > 1

7. SpecMeasWindow specifies the window that will be applied to each burst before its spectrum is calculated. Different windows have different properties, affect the resolution bandwidth achieved, and affect the spectral shape. Windowing is often necessary in transform-based (chirp-Z, FFT) spectrum estimation in order to reduce spectral distortion due to discontinuous or non-harmonic signal over the measurement time interval. Without windowing, the estimated spectrum may suffer from spectral leakage that can cause misleading measurements or masking of weak signal spectral detail by spurious artifacts.
   The windowing of a signal in time has the effect of changing its power. The spectrum measurement compensates for this and the spectrum is normalized so that the power contained in it is the same as the power of the input signal.
   Window Type Definitions:
   - none:

     $$w(kT_s) = \begin{cases} 1.0 & 0 \le k \le N \\ 0.0 & otherwise \end{cases}$$

     where N is the window size
   - Hamming 0.54:

     $$w(kT_s) = \begin{cases} 0.54 - 0.46\cos\left(\frac{2\pi k}{N}\right) & 0 \le k \le N \\ 0.0 & otherwise \end{cases}$$

     where N is the window size
   - Hanning 0.5:

     $$w(kT_s) = \begin{cases} 0.5 - 0.5\cos\left(\frac{2\pi k}{N}\right) & 0 \le k \le N \\ 0.0 & otherwise \end{cases}$$

     where N is the window size
   - Gaussian 0.75:

     $$w(kT_s) = \begin{cases} exp\left(-\frac{1}{2}\left(0.75\frac{(2k-N)}{N}\right)^2\right) & 0 \le \left|k - \frac{N}{2}\right| \le \frac{N}{2} \\ 0.0 & otherwise \end{cases}$$

     where N is the window size
   - Kaiser 7.865:

     $$w(kT_s) = \begin{cases} \dfrac{I_0\left(7.865\left[1-\left(\frac{k-\alpha}{\alpha}\right)^2\right]^{1/2}\right)}{I_0(7.865)} & 0 \le k \le N \\ 0.0 & otherwise \end{cases}$$

     where N is the window size, $\alpha = N / 2$, and $I_0(.)$ is the 0th order modified Bessel function of the first kind
   - 8510 6.0 (Kaiser 6.0):

$$w(kT_s) = \begin{cases} \dfrac{I_0\left(6.0\left[1-\left(\frac{k-\alpha}{\alpha}\right)^2\right]^{1/2}\right)}{I_0(6.0)} & 0 \le k \le N \\ 0.0 & otherwise \end{cases}$$

where N is the window size, α = N / 2, and $I_0(.)$ is the 0th order modified Bessel function of the first kind

- Blackman:

$$w(kT_s) = \begin{cases} 0.42 - 0.5\cos\left(\frac{2\pi k}{N}\right) + 0.08\cos\left(\frac{4\pi k}{N}\right) & 0 \le k \le N \\ 0.0 & otherwise \end{cases}$$

where N is the window size

- Blackman-Harris:

$$w(kT_s) = \begin{cases} 0.35875 - 0.48829\cos\left(\frac{2\pi k}{N}\right) + 0.14128\cos\left(\frac{4\pi k}{N}\right) - 0.01168\cos\left(\frac{6\pi k}{N}\right) & 0 \le k \le N \\ 0.0 & otherwise \end{cases}$$

where N is the window size.

Window Options and Normalized Equivalent Noise Bandwidth

Window and Default Constant	NENBW
none	1
Hamming 0.54	1.363
Hanning 0.50	1.5
Gaussian 0.75	1.883
Kaiser 7.865	1.653
8510 6.0	1.467
Blackman	1.727
Blackman-Harris	2.021

EVM Measurement Parameters

This measurement requires setting of the MirrorMeasSpectrum parameter such that there is an even number of spectrum mirrorings from the combined test bench source and RF DUT. For example, if MirrorSourceSpectrum = NO and the RF DUT causes its output RF signal to have spectrum mirroring relative to its input signal, then set MirrorMeasSpectrum = YES.

This measurement provides results for:

- Avg_WLAN_80211b_1000_chip_Pk_EVM_pct: average EVM in percentage as specified by the standard (section 18.4.7.8 Transmit modulation accuracy in 802.11b specification; pages 55-57) except that the EVM value is normalized
- WLAN_80211b_1000_chip_Pk_EVM_pct: EVM in percentage as specified by the standard (section 18.4.7.8 Transmit modulation accuracy in 802.11b specification;

pages 55-57) with the exception that the EVM value is normalized versus burst
- Avg_EVMrms_pct: average EVM rms in percentage as defined in the Agilent 89600 VSA
- EVMrms_pct: EVM rms in percentage as defined in the Agilent 89600 VSA versus burst
- EVM_Pk_pct: peak EVM in percentage versus burst
- EVM_Pk_chip_idx: peak EVM chip index versus burst
- Avg_MagErr_rms_pct: average magnitude error rms in percentage
- MagErr_rms_pct: magnitude error rms in percentage versus burst
- MagErr_Pk_pct: peak magnitude error in percentage versus burst
- MagErr_Pk_chip_idx: peak magnitude error chip index versus burst
- Avg_PhaseErr_deg: average phase error in degrees
- PhaseErr_deg: phase error in degrees versus burst
- PhaseErr_Pk_deg: peak phase error in degrees versus burst
- PhaseErr_Pk_chip_idx: peak phase error chip index versus burst
- Avg_FreqError_Hz: average frequency error in Hz
- FreqError_Hz: frequency error in Hz versus burst
- Avg_IQ_Offset_dB: average IQ offset in dB
- IQ_Offset_dB: IQ offset in dB versus burst
- Avg_SyncCorrelation: average sync correlation
- SyncCorrelation: sync correlation versus burst

Results named Avg_ are averaged over the number of bursts specified by the user (if AverageType is set to RMS (Video)). Results that are not named Avg_ are results versus burst.

Algorithm and Parameter Information

1. EVM_DisplayPages provides Data Display page information. It is not user editable.
2. Starting at the time instant specified by EVM_Start, a signal segment of length EVM_SearchLength is captured. This signal segment is searched in order for a complete burst to be detected. The burst search algorithm looks for both a burst on and a burst off transition. In order for the burst search algorithm to detect a burst, an idle part must exist between consecutive bursts and the bursts must be at least 15 dB above the noise floor.
   EVM_Start time is used for both the RF_out and Meas_in EVM analyses. The Meas_in signal is delayed in time from the RF_out signal by the value of the RF DUT time delay. Thus for RF DUT time delay greater than zero, the RF_out and Meas_in signal are inherently different and some EVM difference in the two is expected even if the RF DUT does not introduce any distortion except for time delay.
   If the captured signal segment does not contain a complete burst, the algorithm will not detect any burst and the analysis that follows will most likely produce the wrong results. Therefore, EVM_SearchLength must be long enough to capture at least one complete burst. Since the time instant specified by the EVM_Start parameter can be a little after the beginning of a burst, it is strongly recommended that EVM_SearchLength is set to a value approximately equal to 2 x BurstTime + 3 x Idle, where BurstTime is the duration of a burst and Idle is the duration of the idle part. If it is known that EVM_Start is close to the beginning of a burst then EVM_SearchLength can be set to BurstTime + 2 x Idle. If the duration of the burst or the idle part is unknown, then the RF envelope of the signal can be plotted and these

durations determined by observing the plot.
After a burst is detected, the I and Q envelopes of the input signal are extracted. In the RF_out (Meas_in) EVM analysis, the FSource (FMeasurement) parameter sets the frequency of the internal local oscillator signal for the I and Q envelope extraction. Then synchronization is performed based on the preamble. Finally, the burst is demodulated and analyzed to get the EVM measurement results.

3. If EVM_AverageType is set to Off, only one pulse is detected, demodulated, and analyzed.
   If EVM_AverageType is set to RMS (Video), after the first pulse is analyzed the signal segment corresponding to it is discarded and new signal samples are collected from the input to fill in the signal buffer of length EVM_SearchLength. When the buffer is full again a new pulse search is performed and when a pulse is detected it is demodulated and analyzed. These steps are repeated until EVM_BurstsToAverage pulses are processed.
   If for any reason a pulse is misdetected the results from its analysis are discarded. The EVM results obtained from all the successfully detected, demodulated, and analyzed pulses are averaged to give the final averaged results. The EVM results from each successfully analyzed pulse are also recorded (in the variables without the "Avg_" prefix in their name).
4. EVM_DataModulationFormat allows the user to specify the modulation format used in the PSDU part of the burst. If EVM_DataModulationFormat is set to Auto Detect, the algorithm will use the information detected in the PLCP header part of the burst to automatically determine the modulation format. Otherwise, the modulation format determined from the PLCP header is ignored and the modulation format specified by the EVM_DataModulationFormat parameter is used in the demodulation of the PSDU part of the burst.
5. EVM_ResultLengthType and EVM_ResultLength control how much data is acquired and demodulated.
   - When EVM_ResultLengthType is set to Auto Select, the measurement result length is automatically determined from the information in the PLCP header part of the burst. In this case, the EVM_ResultLength defines a maximum result length for the burst in chips; that is, if the measurement result length that is automatically detected is larger than EVM_ResultLength it will be truncated to EVM_ResultLength. The maximum result length specified by EVM_ResultLength includes the PLCP preamble and PLCP header.
   - When EVM_ResultLengthType is set to Manual Override, the measurement result length is set to EVM_ResultLength regardless of what is detected in the PLCP header part of the burst. The result length specified by EVM_ResultLength includes the PLCP preamble and PLCP header.
     The following table lists measurement result lengths actually used based on Auto Select and Manual Override modes for different EVM_ResultLength values; an input burst of 2816 chips is assumed.
     Note that when EVM_ResultLengthType=Manual Override and EVM_ResultLength=3300 (greater than the actual burst size) the algorithm will demodulate the full 3300 chips even though this is 484 chips beyond the pulse width.

EVM_ResultLengthType	EVM_ResultLength	Measurement Result Length Actually Used
Auto Select	2200	2200
Auto Select	2816	2816
Auto Select	3300	2816
Manual Override	2200	2200
Manual Override	2816	2816
Manual Override	3300	3300

6. With the EVM_MeasurementInterval and EVM_MeasurementOffset parameters the user can isolate a specific segment of the EVM_ResultLength for analysis. Only the segment specified by these two parameters will be analyzed in order to determine the EVM results. The values of EVM_MeasurementInterval and EVM_MeasurementOffset are in number of chips and are relative to the ideal starting point of the PLCP preamble portion of the burst. For a signal that uses the long PLCP format, the ideal starting point of the PLCP preamble is exactly 128 symbol times (128×11 chips) before the start of the SFD sync pattern. For a signal that uses the short PLCP format, the ideal starting point of the PLCP preamble is exactly 56 symbol times (56×11 chips) before the start of the SFD sync pattern.
7. Although the algorithm synchronizes to the chip timing of the signal, it is possible for the synchronization to be slightly off. EVM_ClockAdjust allows the user to specify a timing offset which is added to the chip timing detected by the algorithm; EVM_ClockAdjust should be used only when trying to debug unusual signals.
8. EVM_EqualizationFilter and EVM_FilterLength define whether an equalization filter will be used or not and what the filter length (in number of chips) should be. An equalization filter can dramatically improve EVM results because the equalizer can compensate for ISI caused by the transmit filter. An equalization filter can also compensate for distortion introduced by the DUT. If the filter used in the transmitter is Gaussian, then a Gaussian filter with the same BT is automatically used as a reference filter for EVM analysis. In this case, turning the equalizer off will give a more accurate measure of distortion caused by the DUT.

Signal to ESG Parameters

The EVM measurement collects Meas_in signal data and downloads it to an Agilent E4438C Vector Signal Generator. Connection Manager architecture isused to communicate with the instrument; parameters specify how data is interpreted.
Prerequisites for using the Signal to ESG option are:

- ESG Vector Signal Generator E4438C; for information, visit the web site http://www.agilent.com/find/esg .
- PC workstation running an instance of the connection manager server.
- Supported method of connecting the instrument to your computer through the Connection Manager architecture; for information, see *Connection Manager* .

Parameter Information

1. EnableESG specifies if the signal is downloaded to the ESG instrument. If set to NO,

no attempt will be made to communicate with the instrument.

2. ESG_Instrument specifies a triplet that identifies the VSA resource of the instrument to be used in the simulation, the connection manager server hostname (defaults to *localhost*), and the port at which the connection manager server listens for incoming requests (defaults to 4790). To ensure that this field is populated correctly, click *Select Instrument* , enter the server hostname and port, click *OK* to see the Remote Instrument Explorer dialog, select a VSA resource identifier, and click *OK* . For details about selecting instruments, see *Instrument Discovery* in the *Wireless Test Bench Simulation* documentation.
3. ESG_Start and ESG_Stop (when ESG_Bursts =0) specify when to start and stop data collection. The number of samples collected, ESG_Stop - ESG_Start + 1, must be in the range 60 samples to 64 Msamples, where 1 Msample = 1,048,576 samples. The ESG requires an even number of samples; the last sample will be discarded if ESG_Stop - ESG_Start + 1 is odd.
4. ESG_Bursts sets the number of bursts over which data will be collected. If ESG_Bursts is greater than zero, then ESG_Stop is forced to ESG_Start + ESG_Bursts x BurstTime where BurstTime is IdleTime + ShortPreambleTime + LongPreambleTime + SIGNAL_Time + DataTime.
5. ESG_ClkRef specifies an internal or external reference for the ESG clock generator. If set to External, the ESG_ExtClkRefFreq parameter sets the frequency of this clock.
6. ESG_IQFilter specifies the cutoff frequency for the reconstruction filter that lies between the DAC output and the Dual Arbitrary Waveform Generator output inside the ESG.
7. ESG_SampleClkRate sets the sample clock rate for the DAC output.
8. ESG_Filename sets the name of the waveform inside the ESG that will hold the downloaded data.
9. The ESG driver expects data in the range {-1, 1}. If ESG_AutoScaling is set to YES, inputs are scaled to the range {-1, 1}; if ESG_AutoScaling is set to NO, raw simulation data is downloaded to the ESG without scaling, but data outside the range {-1, 1} is clipped to -1 or 1. If set to YES, scaling is also applied to data written to the local file (ESG_Filename setting).
10. If ESG_ArbOn is set to YES, the ESG will start generating the signal immediately after simulation data is downloaded; if set to NO, waveform generation must be turned on at the ESG front panel.
11. If ESG_RFPowOn is set to YES, the ESG will turn RF power on immediately after simulation data is downloaded. If ESG_RFPowOn is set to NO (default), RF power must be turned on at the ESG front panel.
12. ESG_EventMarkerType specifies which ESG Event markers are enabled: Event1, Event2, Both, or Neither. Event markers are used for synchronizing other instruments to the ESG. When event markers are enabled, Event1 and/or Event2 is set beginning from the first sample of the downloaded Arb waveform over the range of points specified by the ESG_MarkerLength parameter. This is equivalent to setting the corresponding event from the front panel of the ESG.
13. ESG_MarkerLength specifies the range of points over which the markers must be set starting from the first point of the waveform. Depending on the setting of ESG_EventMarkerType, the length of trigger Event1 or Event2 (or both) is set to a multiple of the pulsewidth that, in turn, is determined by the sample clock rate of the DAC output.

Simulation Measurement Displays

After running the test bench simulation and opening the Data Display pages, the simulation results will be displayed for each measurement selected.

> **Note**
> Measurement results from a wireless test bench have associated names that can be used in Data Display Expressions. For more information, refer to *Measurement Results for Expressions for WLAN Wireless Test Benches* (adswtbwlan).

RF Envelope Measurement

The RF envelope measurement (not defined in IEEE 802.11b) is used to show the time envelope of each field in IEEE 802.11b RF signal burst, such as ramp, preamble and header, and PSDU. Two signals are tested: the RF signal at the input of the RF DUT and the Meas signal at the output of the RF DUT.

From the RF signal, the basic signal burst information (long preamble time, short preamble time, data time) are listed in the following table.

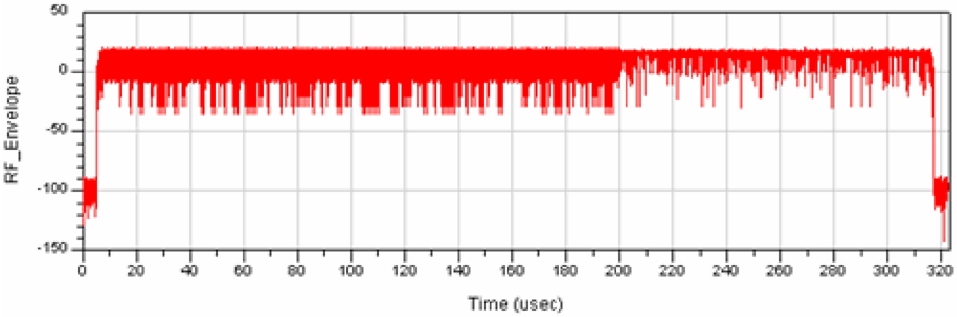
RF Signal Burst Information

Parameter	Test Bench Default Value
RF_FSource	2412.0 MHz
RF_R	50.0 Ohm
Meas_FMeasurement	2412.0 MHz
Meas_R	50.0 Ohm
BurstTime	322.364 usec
IdleTime	10.0 usec
BitRate	11.0 Mbps
RF_Power_dBm	16.021 dBm
BytesPerBurst	160
DataTime	116.364 usec

For the RF signal, the time envelope of one complete burst of 11b are shown, as well as the time envelope of ramp, Preamble and Header, PSDU in the following four figures

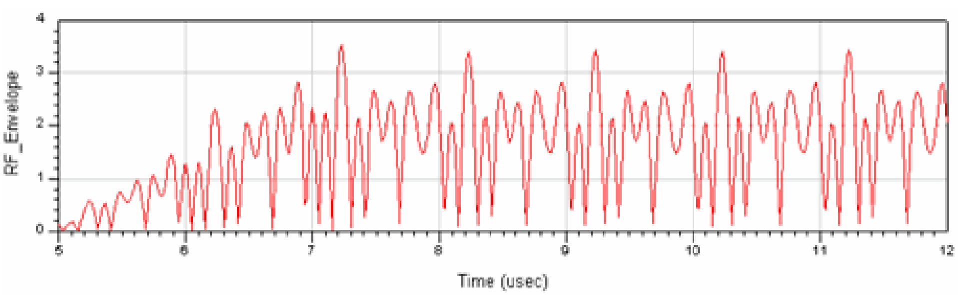
The figure RF Signal Time Envelope of One Complete Burst shows an entire 11b burst with a long preamble setting. The initial time interval of 5.0 μ is the idle time when the transmitter sends no signal. The second time interval of 2.0 μ is the ramp which simulates the transmitter switching power-on or power-off. The third interval of 192 μ is the Preamble and Header; if short preamble setting is selected, this part is 96 μ. The next interval of 160 octets is where the PSDU is attached which carries the data payload.

RF Signal Time Envelope of One Complete Burst



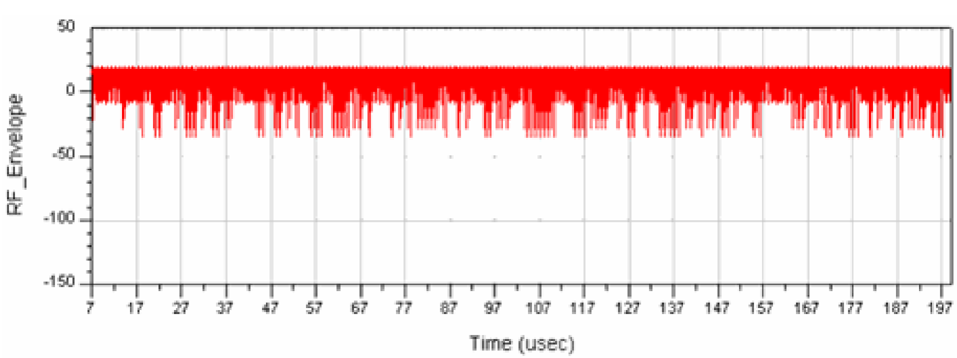
In the figure RF Signal Time Envelope of Ramp Time, you can see the ramp from 5.0 μ to 7.0 μ, indicating the transmitter is power-on, and the ramp attached PSDU indicates the transmitter is power-off.

RF Signal Time Envelope of Ramp Time



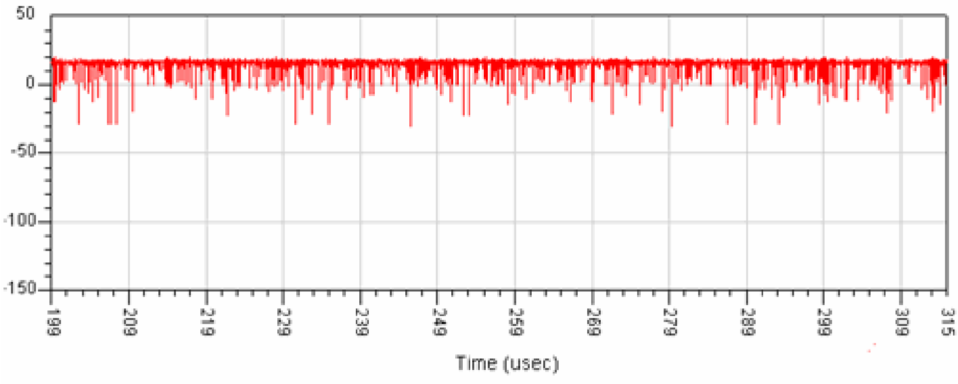
The figure Time Envelope of Long Preamble and Header for RF Signal shows the time envelope of the Long Preamble and header. Long Preamble and header lasts from 7.0 μ to 199.0 μ. The initial 144 μ interval is the Long Preamble. The next 48 μ interval is the header. If Short Preamble is set, the Long Preamble interval is 72 μ, and the header interval is 24 μ.

Time Envelope of Long Preamble and Header for RF Signal



In the figure Time Envelope of DATA for RF Signal, DATA is approximately 116 μ and lasts from 199.0 μ to 315.0 μ.

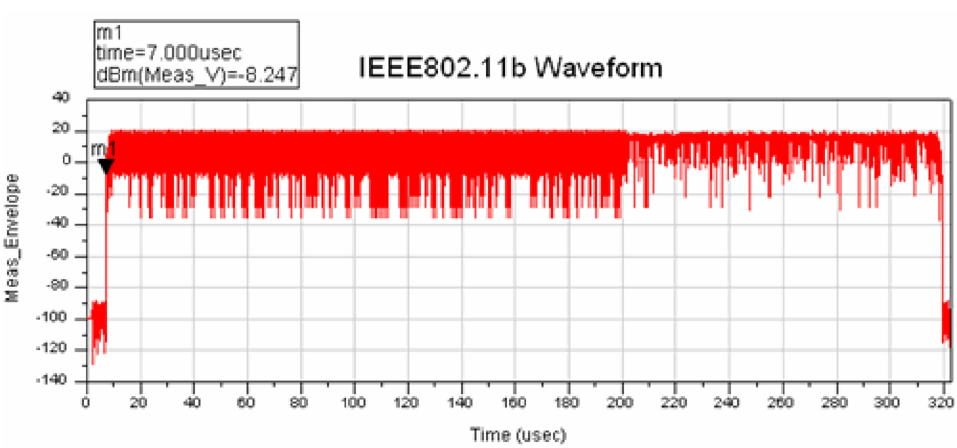
Time Envelope of DATA for RF Signal



In Meas signal testing, all measurements are similar to that for the RF signal, the difference is that Meas signal contains any linear and nonlinear distortions and time delay from RF DUT. All time envelope measurements for the Meas signal have the RF DUT time delay. The envelope measurements for Meas signal are shown in the following four figures

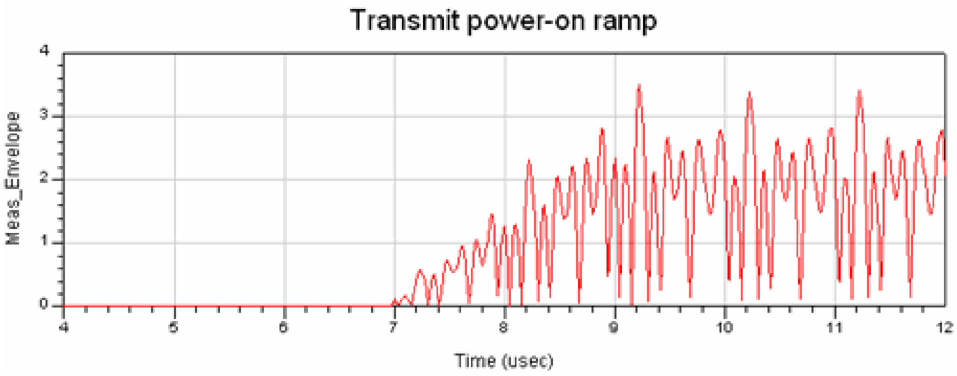
In the figure Time Envelope of One Entire Burst for Meas Signal, Marker m1 must be set manually by the user to the start of the Short Preamble; this is used to determine the RF DUT time delay. This RF DUT delay is used to identify where each Meas burst structure begins and ends. The delay can be calculated by subtracting half idle time from the time marked m1; for example, in this figure, the delay=7.0μ-5.0μ=2.0μ. If the marker does not point to the accurate position, the calculated delay will not be accurate.

Time Envelope of One Entire Burst for Meas Signal

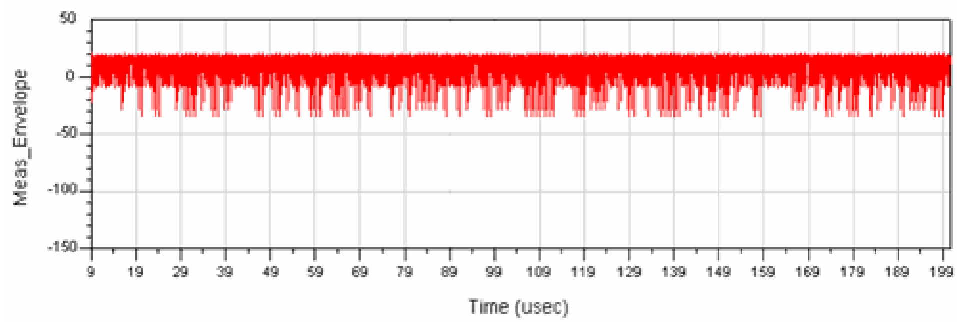


In the figureTime Envelope of Short Preamble for Meas Signal, you can see the ramp from 7.0 to 9.0 μ. Meas Signal Long Preamble and Header Time Envelope shows the Long Preamble and Header is 192.0 μ and lasts 9.0 to 201.0 μ. Meas Signal Data Time Envelope shows the DATA is approximately 116.0 μ and lasts 201.0 to 317.0 μ.

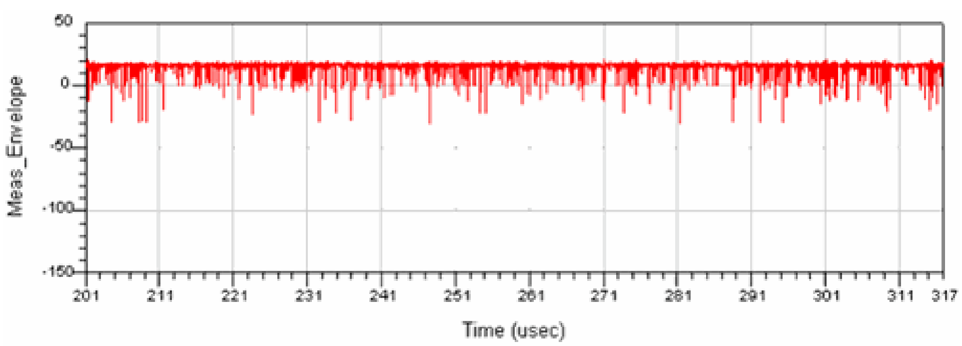
Time Envelope of Short Preamble for Meas Signal



Meas Signal Long Preamble and Header Time Envelope



Meas Signal Data Time Envelope



Constellation Measurement

The constellation measurement (not defined in IEEE 802.11b) measures the constellation of PSDU.

In IEEE 802.11b: 1, 2, 5.5, and 11 Mbps data rates for long preamble are supported in PSDU; 2, 5.5, and 11 data rates for short preamble are supported. DBPSK, DQPSK, CCK, or PBCC modulations correspond to each data rate; modulation types based on data rates are given in the table Data Rates and Modulation Types.

The basic parameters for this measurement are given in the table Basic Constellation Measurement Parameters.

Data Rates and Modulation Types

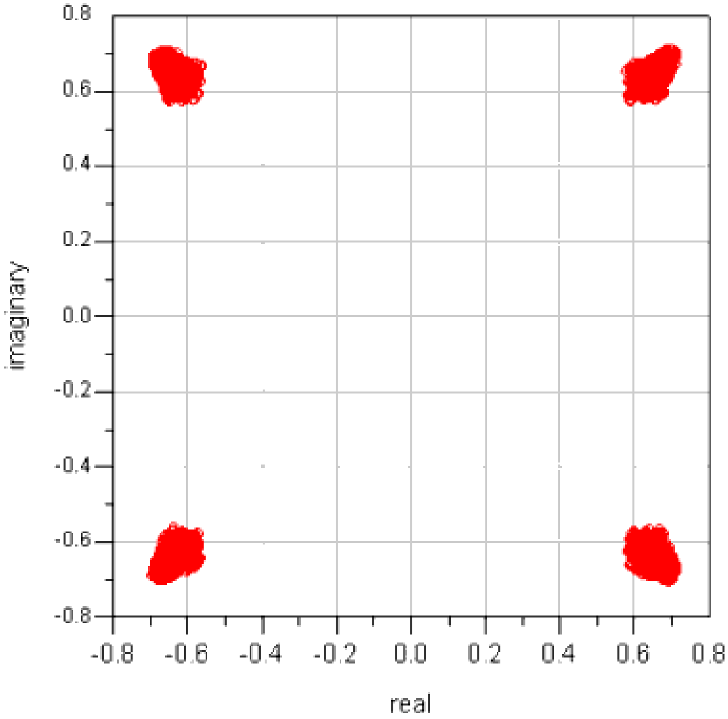
Data Rate (Mbits/s)	Modulation
1	DBPSK
2	DQPSK
5.5	CCK, PBCC
11	CCK, PBCC

Basic Constellation Measurement Parameters

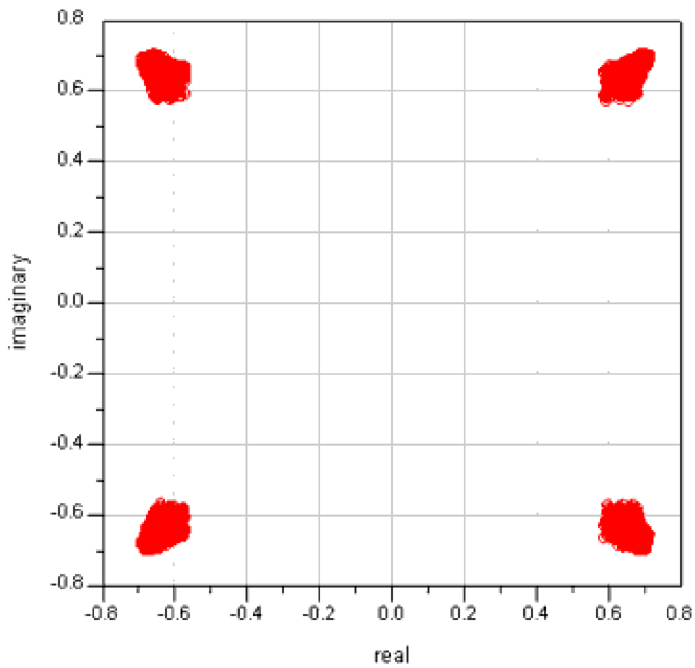
Parameter	Default
RF_FSource	2412.0 MHz
RF_R	50.0 Ohm
DataTime	116.36 usec
BurstTime	322.364.0 usec
TimeStep	15.151515 nsec
BitRate	11.0 Mbps
Meas_FMeasurement	2412.0.0 MHz
Meas_R	50.0 Ohm

For the 11Mbps data rate selected in this measurement, CCK modulation is used; the constellations for RF and Meas signals are shown in the figures RF Signal Constellation and Meas Signal Constellation.

RF Signal Constellation



Meas Signal Constellation



Power Measurement

The power measurement (not defined in IEEE 802.11b) shows the CCDF (complementary cumulative distribution function) transmission curves and peak-to-average ratio for the RF and Meas signals.

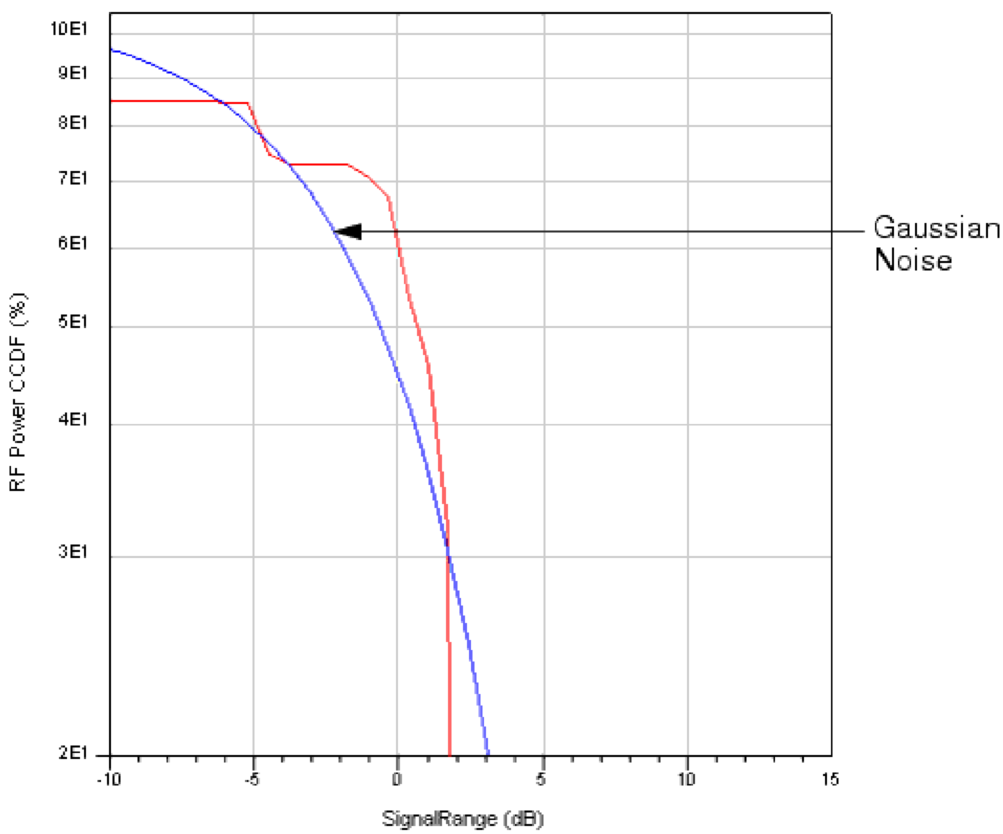
The basic parameters for this measurement are listed in the table Basic Power Measurement Parameters.

Measurement results are shown in the figures RF Power CCDF and Meas Power CCDF.

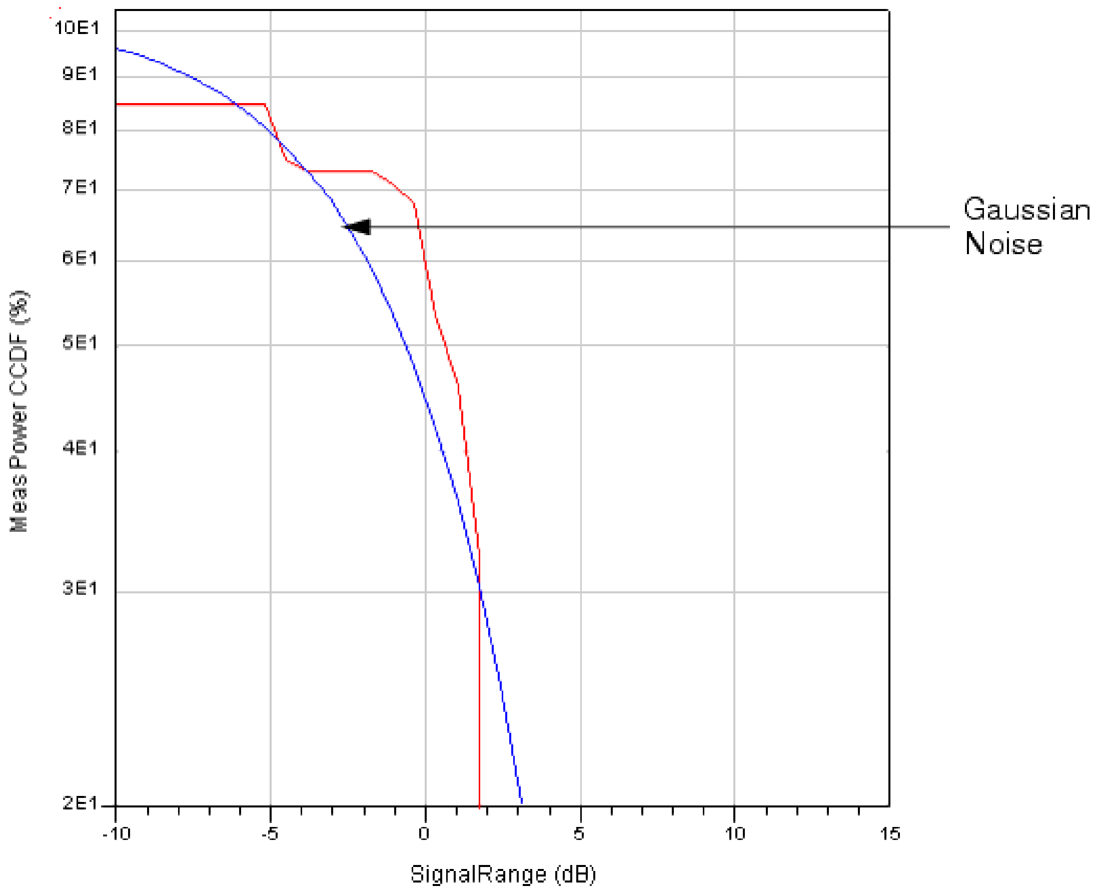
Basic Power Measurement Parameters

Parameter	Default
RF_FSource	2412.0MHz
RF_R	50.0Ohm
Meas_FMeasurement	2412.0MHz
Meas_R	50.0Ohm
RF_Power_dBm	16.021dBm

RF Power CCDF



Meas Power CCDF



In these figures, the blue curves are the reference CCDF for Gaussian noise. They can be calculated by calling the function *power_ccdf_ref*() in the . *dds* files directly, as shown in Reference CCDF Calculation.

Reference CCDF Calculation

Eqn RF_CCDF_Ref=100*power_ccdf_ref(RF_Power.SignalRange_dB)

Eqn Meas_CCDF_Ref=100*power_ccdf_ref(Meas_Power.SignalRange_dB)

The function for calculating the peak-average-ratio for as well as the results are shown in the figures RF Signal Peak-Average-Ratio Calculation and Results and Meas Signal Peak-Average-Ratio Calculation and Results.

RF Signal Peak-Average-Ratio Calculation and Results

Eqn RF_Peak_to_Avg_dB = RF_Power.PeakPower_dBm - RF_Power.AvgPower_dBm

RF_Power.PeakPower_dBm	RF_Power.AvgPower_dBm	RF_Peak_to_Avg_dB
21.078	15.846	5.233

Meas Signal Peak-Average-Ratio Calculation and Results

Eqn RF_Peak_to_Avg_dB = RF_Power.PeakPower_dBm - RF_Power.AvgPower_dBm

RF_Power.PeakPower_dBm	RF_Power.AvgPower_dBm	RF_Peak_to_Avg_dB
21.078	15.846	5.233

Spectrum Measurement

The Spectrum measurement is used to verify whether the transmitted spectrum meets the spectrum mask according to IEEE Std 802.11b-1999, section 18.4.7.3 requirements. The transmitted spectrum must be less -30 dBr (dB relative to the SINx/x peak) for

fc-22MHz<f<fc-11MHz

and

fc+11MHz<f<fc+22MHz;

and must be less than -50 dBr for

f<fc-22MHz

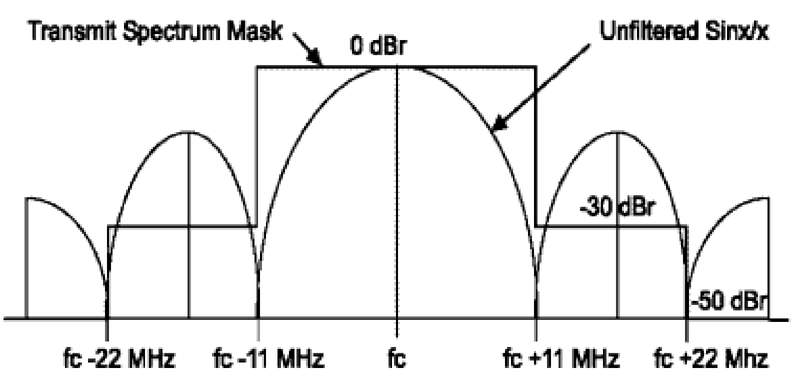
and

f>fc+22MHz

where fc is the channel center frequency.

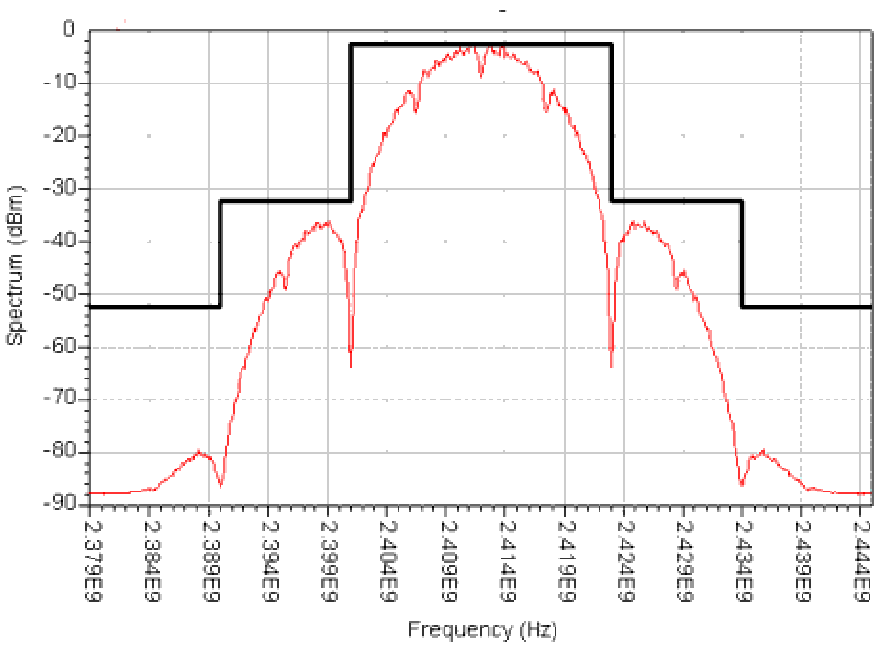
The transmitted spectral density of the transmitted signal must fall within the spectral mask illustrated in Transmit Spectrum Mask; measurements must be made using a 100 kHz resolution bandwidth and a 100 kHz video bandwidth.

Transmit Spectrum Mask

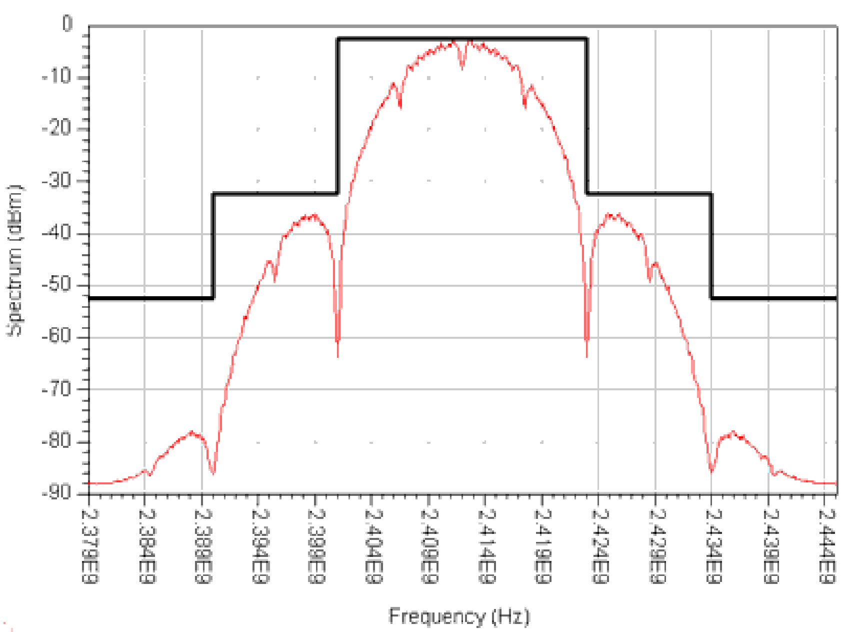


Measurement results are shown in the figures RF Signal Spectrum and Meas Signal Spectrum. From these figures, you can see that the spectrums are within the spectrum mask; therefore, the transmitted spectrum meets the specification requirement. Please note, the shapes of spectrums are dependent on the shape of transmitter filter, filter length, and roll factor. The spectrums of these figures are generated by a Gaussian filter with filter length of 10 and roll factor of 0.5.

RF Signal Spectrum



Meas Signal Spectrum



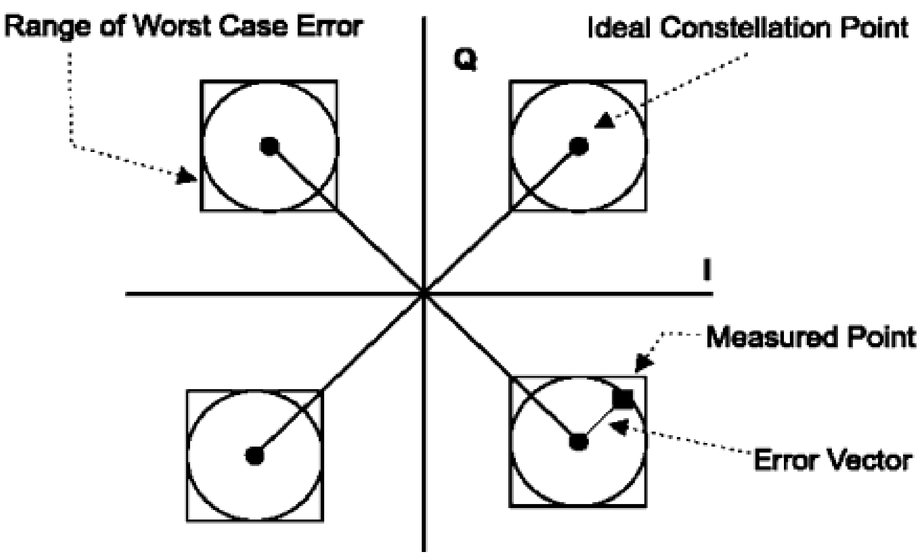
EVM Measurement

The EVM measurement tests the transmit modulation accuracy (EVM) according to IEEE Std 802.11b-1999, section 18.4.7.8. The transmit modulation accuracy requirement for the high rate PHY is based on the difference between the actual and the ideal signal waveform. Modulation accuracy is determined by measuring the peak vector error magnitude during each chip period. Worst-case vector error magnitude cannot exceed 0.35 for the normalized sampled chip data. The ideal complex I and Q constellation points associated with DQPSK modulation, (0.707,0.707), (0.707, -0.707), (-0.707, 0.707), (-0.707, -0.707), are used as the reference.

Measurements are from baseband I and Q sampled data after recovery through a reference receiver system. The figure Modulation Accuracy Measurement Example illustrates the ideal DQPSK constellation point and range of worst-case error specified for modulation accuracy.

This measurement provides averaged EVM rms specified by percent and the transient EVM varied with burst.

Modulation Accuracy Measurement Example



The basic parameters used for this measurement are given in the table Basic EVM Measurement Parameters.

Basic EVM Measurement Parameters

Parameter	Default Value
RF_FSource	2412.0 MHz
RF_R	50.0 Ohm
Meas_FMeasurement	2412.0 MHz
Meas_R	50.0 Ohm
RF_Power_dBm	16.021 dBm
BytesPerBurst	160
BitRate	11 Mbps
BurstTime	322.364 usec
DataTime	116.364 nsec

Averaged results are shown in the figuresRF Signal Averaged EVM and Meas Signal Averaged EVM.

RF Signal Averaged EVM

RF_EVM.Avg_WLAN_80211b_1000_chip_Pk_EVM_pct
4.554

RF_EVM.Avg_EVMrms_pct	..._EVM.Avg_MagErr_rms_pct	RF_EVM.Avg_PhaseErr_deg
4.290	3.985	0.911

RF_EVM.Avg_FreqError_Hz	RF_EVM.Avg_IQ_Offset_dB	RF_EVM.Avg_SyncCorrelation
-0.079	-38.174	0.999

Meas Signal Averaged EVM

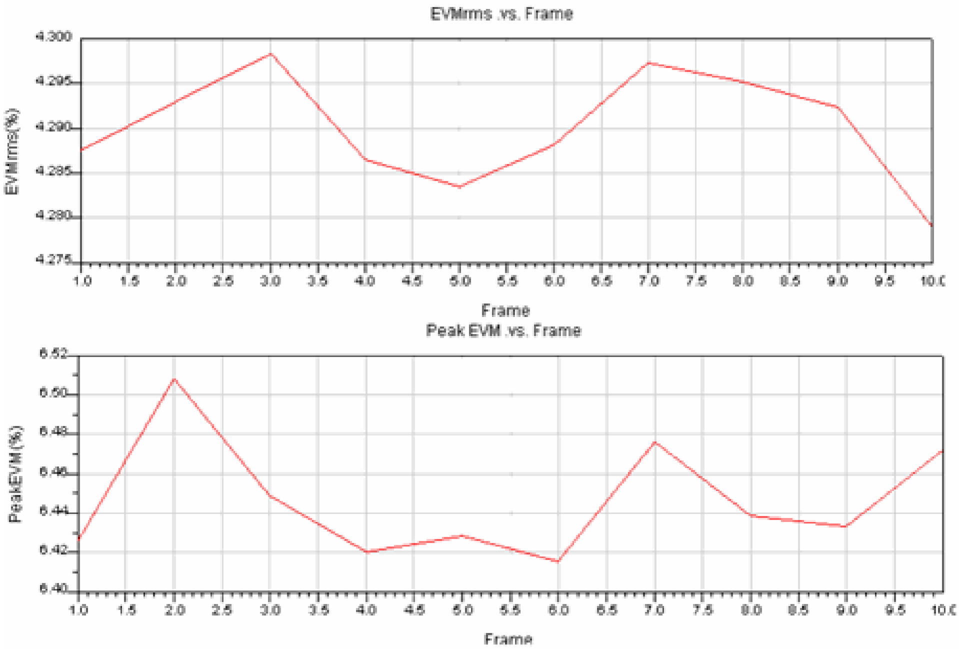
RF_EVM.Avg_WLAN_80211b_1000_chip_Pk_EVM_pct
4.554

RF_EVM.Avg_EVMrms_pct	..._EVM.Avg_MagErr_rms_pct	RF_EVM.Avg_PhaseErr_deg
4.290	3.985	0.911

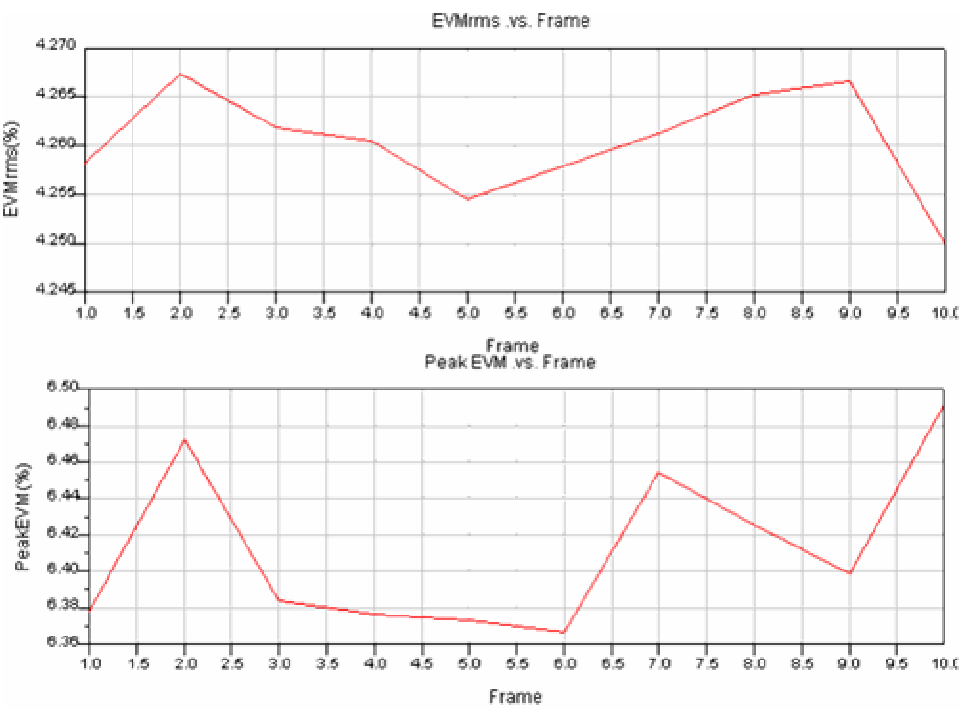
RF_EVM.Avg_FreqError_Hz	RF_EVM.Avg_IQ_Offset_dB	RF_EVM.Avg_SyncCorrelation
-0.079	-38.174	0.999

The variation of EVM rms and peak EVM with bursts are shown in the figures RF Signal Variation of EVM rms and Peak EVM with Bursts and Meas Signal Variation of EVM rms and Peak EVM with Bursts. The RF EVM or Meas EVM do not exceed the 35% value required by specification and therefore meet specification requirements.

RF Signal Variation of EVM rms and Peak EVM with Bursts



Meas Signal Variation of EVM rms and Peak EVM with Bursts



Test Bench Variables for Data Displays

The following tables identify the reference variables used to set up this test bench:

Test Bench Constants for WLAN 11b Signal Setup

Constant	Value
BitsPerByte	8
RampTime	if(PwrRamp==0) then 0.0 else 2*2.0usec endif
LongPreambleTime	192.0usec
ShortPreambleTime	96.0usec
PLCPTime	if(PreambleFormat==0) then LongPreambleTime else ShortPreambleTime endif
PSDUTime	DataLength*BitsPerByte/BitRate Dependent on DataRate in the next table
BandWidth	11.0MHz

DataRate Determines BitRate Value

DataRate	BitRate (see the next table)
Mbps_1	1e6
Mbps_2	2e6
Mbps_5.5	5.5e6
Mbps_11	11e6

Test Bench Equations Derived from Test Bench Parameters and Exported to the Data Display

Data Display Parameter	Equation with Test Bench Parameters
RF_FSource	FSource
RF_Power_dBm	10*log10(SourcePower)+30
RF_R	SourceR
RF_SourceTemp	SourceTemp
TimeStep	1/(Bandwidth*OversamplingRatio)
IdleTime	IdleInterval
DataTime	PSDUTime
BurstTime	RampTime+PLCPTime+PSDUTime+IdleTime
SamplesPerBurst	BurstTime/TimeStep
BytesPerBurst	DataLength
BitRate	Dependant on DataRate in the previous table. This is the bit rate for transmitted WLAN signal.
Meas_FMeasurement	FMeasurement
Meas_R	MeasR

Baseline Performance

- Test Computer Configuration
  - Pentium IV 2.4 GHz, 512 MB RAM, Red Hat Linux 7.3
- Conditions
  - Measurements made with default test bench settings.
  - RF DUT is an RF system behavior component.
  - The number of time points in one WLAN 802.11b burst is a function of OversamplingRatio, PwrRamp, PreambleFormat, IdleInterval, DataRate, DataLength.
    OversamplingRatio = 6
    PwrRamp = Linear
    PreambleFormat = Long
    IdleInterval = 10.0 μ
    DataRate = 11 Mb/s
    DataLength = 160
  - Resultant WTB_TimeStep = 15.152 nsec; BurstTime = 322.364 μ time points per burst = 21276
- Simulation times and memory requirements:

WLAN_802_11b_TX Measurement	Bursts Measured	Simulation Time (sec)	ADS Processes (MB)
RF_Envelope	3	23	110
Constellation	3	9	72
Power	3	6	60
Spectrum	3	7	57
EVM	10	23	63

Expected ADS Performance

Expected ADS performance is the combined performance of the baseline test bench and the RF DUT Circuit Envelope simulation with the same signal and number of time points. For example, if the RF DUT performance with Circuit Envelope simulation alone takes 2 hours and consumes 200 MB of memory (excluding the memory consumed by the core ADS product), then add these numbers to the Baseline Performance numbers to determine the expected ADS performance. This is valid only if the full memory consumed is from RAM. If RAM is less, larger simulation times may result due to increased disk access time for swap memory usage.

References

1. IEEE Standard 802.11b-1999, "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High-speed Physical Layer Extension in the 2.4 GHz Band," 1999.
http://standards.ieee.org/getieee802/download/802.11b-1999.pdf
2. IEEE P802.11g/D8.2, "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: Further Higher Data Rate Extension in the 2.4 GHz Band," April, 2003.
http://ieeexplore.ieee.org/servlet/opac?punumber=4040922
3. CCITT, Recommendation O.151(10/92).
4. CCITT, Recommendation O.153(10/92).
Setting up a Wireless Test Bench Analysis in the *Wireless Test Bench Simulation* documentation explains how to use test bench windows and dialogs to perform analysis tasks.
Setting Circuit Envelope Analysis Parameters in the *Wireless Test Bench Simulation* documentation explains how to set up circuit envelope analysis parameters such as convergence criteria, solver selection, and initial guess.
Setting Automatic Behavioral Modeling Parameters in the *Wireless Test Bench Simulation* documentation to learn how to improve simulation speed.

WLAN Links

European Radiocommunications Office: http://www.ero.dk
U.S. Frequency Allocations Chart: http://www.ntia.doc.gov/osmhome
IEEE 802.11b Compliance Organization: http://www.wi-fi.org
IEEE 802.11 Working Group: http://grouper.ieee.org/groups/802/11/index.html