Agilent Technologies

Advanced Design System 2011.01

Feburary 2011
UWB 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 UWB 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 the *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 three 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.

UWB_TX Measurement Results

Measurement Results Name	Independent Variable Name
Envelope	
UWB_TX.RF_V	time
UWB_TX.Meas_V	time
Constellation	
UWB_TX.RF_EVM.RxConstellation	Index
UWB_TX.RF_EVM.TxConstellation	Index
UWB_TX.Meas_EVM.RxConstellation	Index
UWB_TX.Meas_EVM.TxConstellation	Index
Power	
UWB_TX.RF_Power.MeanPower_dBm	Index
UWB_TX.RF_Power.CCDF	Index
UWB_TX.RF_Power.PeakPower_dBm	Index
UWB_TX.RF_Power.SignalRange_dB	Index
UWB_TX.Meas_Power.MeanPower_dBm	Index
UWB_TX.Meas_Power.CCDF	Index
UWB_TX.Meas_Power.PeakPower_dBm	Index
UWB_TX.Meas_Power.SignalRange_dB	Index
Spectrum	
UWB_TX.RF_Spectrum	freq
UWB_TX.Meas_Spectrum	freq
UWB_TX.RF_Spectrum3960	freq
UWB_TX.Meas_Spectrum3960	freq
EVM	
UWB_TX.RF_EVM.EVM	Index
UWB_TX.Meas_EVM.EVM	Index

UWB_Rx_Sensitivity Measurement Results

Measurement Results Name	Independent Variable Name
RX Sensitivity	
UWB_Rx_Sensitivity.B1.BER	Index
UWB_Rx_Sensitivity.B1.FER	Index

UWB_Rx_Performance_11a_Interference Measurement Results

Measurement Results Name	Independent Variable Name
RX Sensitivity	
UWB_Rx_Sensitivity.B1.BER	Index
UWB_Rx_Sensitivity.B1.FER	Index

RF DUT Limitations for UWB 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.

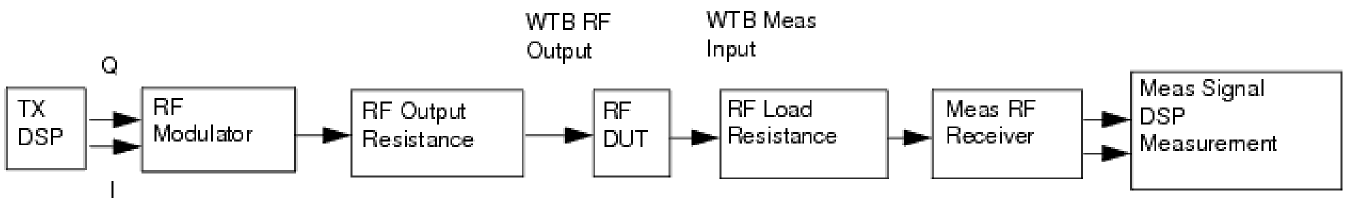
UWB Receiver Performance Test with WLAN 11a Interference

Introduction

UWB_RX_with_WLAN_11a_Interferer_test is the test bench for UWB receiver performance with WLAN 11a interferer. The test bench enables users to connect to an RF DUT and determine its performance; signal measurements include signal spectrum, BER and PER.

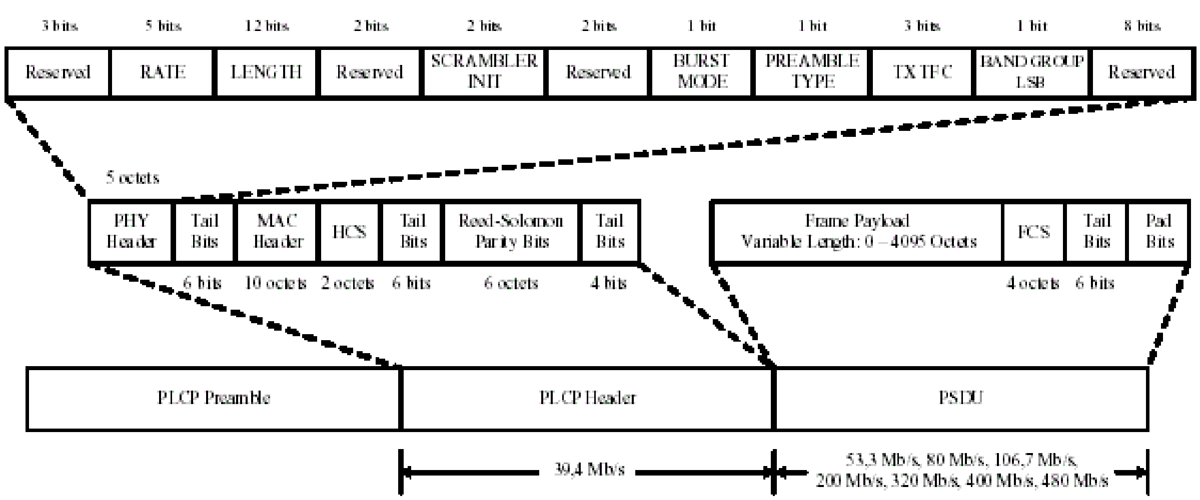
The signal and the measurement are designed according to *Reference 1* (adswtbuwb).

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 UWB PLCP frame format is shown in the following figure. Each frame is separated by IdleInterval and consists of three parts: the PLCP preamble, PLCP header (PHY header, MAC header, header check sequence, tail bits, and pad bits), MAC frame body (frame payload plus FCS, tail bits, and pad bits).



PLCP Frame Format

The standard PLCP preamble consists of two portions: the time domain packet and frame synchronization sequence; and the frequency domain channel estimation sequence. The basic sequence for time domain packet and frame synchronization sequence is implemented by model UWB_TimeDomainSeq. The frequency domain channel estimation sequence is implemented by a model WaveFormCx. The basic sequence of timed domain packet and frame synchronization is repeated and combined with FFT'd frequency domain channel estimation sequence and FFT'd frame body in model UWB_MuxFrame.

According to the specification, the frame body shall be encoded in the following manner. The PLCP header (consisting of the PHY header and associated tail bits, the MAC header plus HCS, and the associated tail bits, followed by the pad bits as in Section 1.3.8[1]) shall be encoded with a rate R = 1/3. The encoder shall be reset to the all-zero state following this. Next, the MAC frame body, tail bits and pad bits appended shall be encoded with a rate R = 1/3, 11/32, 1/2, 5/8, or 3/4, corresponding to the desired data rate. The algorithm to reset the encoder after encoding PLCP header is as follows:

- Append 6 extra tail bits after PLCP header
- Convolutionally encode the PLCP header and extra tail bits. with a rate R = 1/3. The encoder is reset to the all-zero state following this.
- Remove 18 symbols generated from the 6 tail bits.

Although there is no requirement for the encoder to be reset after encoding the MAC frame body, tail bits and pad bits appended, it is a requirement of the simulation. So the same algorithm is implemented.

The number of OFDM symbols per UWB-OFDM frame also consists of three parts.

There are 30 or 18 OFDM symbols for Standard preamble or Shortened preamble, respectively.

$$Nsym_{preamble} = \begin{cases} 30 & Standard \\ 18 & Shortened \end{cases}$$

The preceding illutration of the frame format shows the PLCP Header, whose data rate is 53.3 Mb/s. It includes PHY Header (40 bits), first Tail Bits (6 bits), MAC Header (80 bits), HCS (header check sequence, 16 bits) second Tail Bits (6 bits), and pad bits. The total bits of PLCP Header is 148 bits. The OFDM symbols of PLCP Header before time-domain spreading is computed as follows:

$$Nsym_{Header} = \frac{6}{TSF} \times \left\lceil \frac{\left\lceil \frac{148}{R} \right\rceil}{\frac{6}{TSF} \times N_{CBPS}} \right\rceil = 6$$

Where TSF=2, NCBPS=100 and R=1/3 from the table of *Rate-dependent parameters* (adswtbuwb) because PLCP Header is always 53.3 Mb/s. The number pad bits is 52 (!adswtbuwb-4-1-05.gif!).

So the OFDM symbols of PLCP Header after time-domain spreading is as follows:

$$Nsym_{Header-TSF} = TSF \times \frac{6}{TSF} \times \left\lceil \frac{\left\lceil \frac{148}{R} \right\rceil}{\frac{6}{TSF} \times N_{CBPS}} \right\rceil = 12$$

MAC frame body consists of frame payload, FCS, tail bits, and pad bits. The OFDM symbols of PSDU before time-domain spreading is computed as follows:

$$Nsym_{PSDU} = \frac{6}{TSF} \times \left\lceil \frac{\left\lceil \frac{8 \times DataLength + 32 + 6}{R} \right\rceil}{\frac{6}{TSF} \times N_{CBPS}} \right\rceil$$

Where R is the data rate of PSDU, TSF and NCBPS are determined by the data rate and DataLength is the number of data bytes in the frame payload part of each PLCP frame. Please refer to the table of *Rate-dependent parameters* (adswtbuwb) for detail.

The number of pad bits is:

$$Nsym_{PSDU} \times N_{CBPS} - \left\lceil \frac{8 \times DataLength + 32 + 6}{R} \right\rceil$$

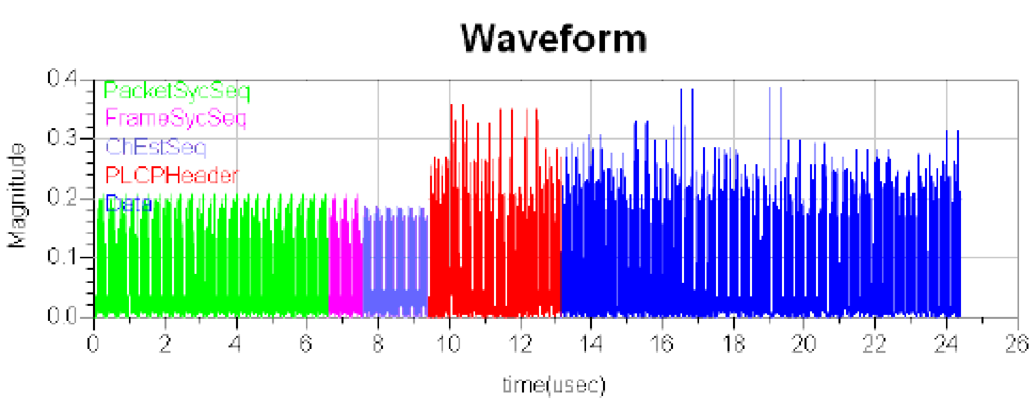
The OFDM symbols of PSDU before time-domain spreading is computed as follows:

$$Nsym_{PSDU-TSF} = TSF \times \frac{6}{TSF} \times \left\lceil \frac{\left\lceil \frac{8 \times DataLength + 32 + 6}{R} \right\rceil}{\frac{6}{TSF} \times N_{CBPS}} \right\rceil$$

So, the total number of OFDM symbols N_{SYM} per UWB-OFDM frame is

$$N_{SYM} = Nsym_{preamble} + Nsym_{Header-TSF} + Nsym_{PSDU-TSF}$$

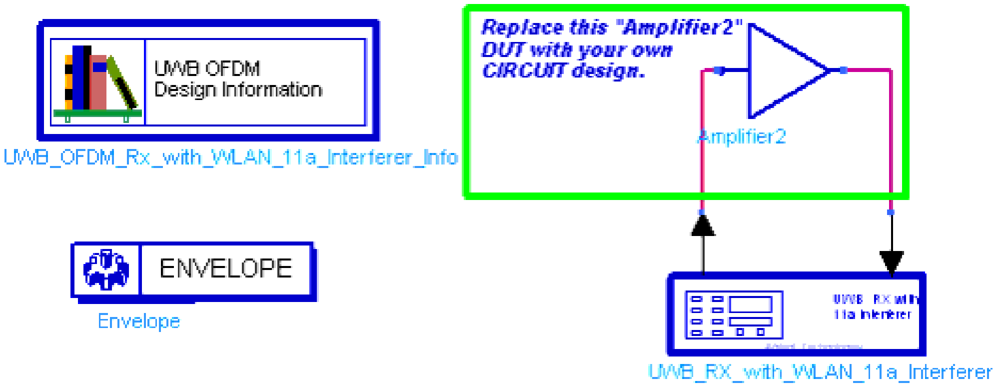
The UWB RF power delivered into a matched load is the average power delivered in the UWB frame excluding the idle time. The following figure shows the RF envelope for an output RF signal with -9.9 dBm power.



UWB RF Signal Envelope

Test Bench Basics

A template is provided for this test bench.



UWB 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 *UWB_RX_with_WLAN_11a_Interferer_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* > UWB> UWB_RF_Verification_wrk > *UWB_RX_with_WLAN_11a_Interferer_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, 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 *UWB_RX_with_WLAN_11a_Interferer_test* template:

1. In an Analog/RF schematic window select *Insert > Template.*
2. In the *Insert > Template* dialog box, choose *UWB_RX_with_WLAN_11a_Interferer_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 UWB Wireless Test Benches* (adswtbuwb).

2. Set the *Required Parameters*

   > **Note** Refer to *UWB_RX_with_WLAN_11a_Interferer* (adswtbuwb) for a complete list of parameters for this test bench.

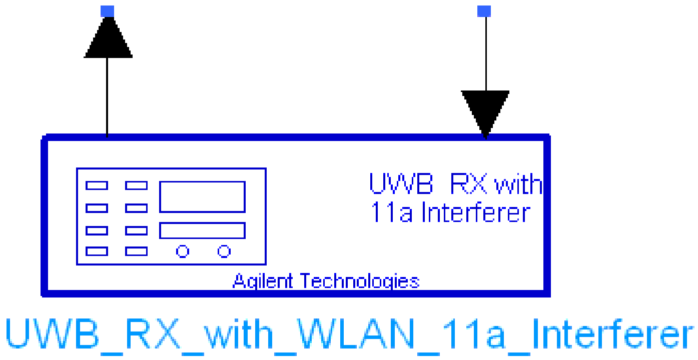
   Generally, default values can be accepted; otherwise, values can be changed by the user as needed.

   - 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=0.9470 nsec. The value is displayed in the Data Display pages as TimeStep.
     WTB_TimeStep = 1/528 MHz/($2^{OversamplingOption}$)
     where:
     528 MHz is the bandwidth of UWB OFDM signal
     $2^{OversamplingOption}$ is the oversampling ratio value. Oversampling ratio sets the number of waveform sampling points during the signal FFT time interval. During this time interval the minimum FFT sampling size is 128 (which corresponds to an FFT order of 7; i.e 2^7) and the FFT time interval is defined as 128/528 MHz. For example, a Ratio of 4 sets the FFT sampling size to 128 × 4=512 (which corresponds to an FFT order of 9) during the signal FFT time interval.
   - Set SourcePower, and FMeasurement.
     - SourcePower defines the power level of the source. 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* (adswtbuwb).
4. The RF modulator (shown in the Receiver Wireless Test Bench Block Diagram) uses SourcePower (*Required Parameters*), GainImbalance, PhaseImbalance(*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 delivered into a matched load of resistance SourceR, with frequency hopping, with the specified source resistance (SourceR) and with power (SourcePower) . 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 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* (adswtbuwb) describes results for each measurement. For general WTB Data Display details refer to *Viewing WTB Analysis Results* (adswtbsim).

UWB_RX_with_WLAN_11a_Interferer

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



Parameters

Name	Description	Default	Sym	Unit	Type	Range
RequiredParameters						
CE_TimeStep	Circuit envelope simulation time step	1/528 MHz/2		sec	real	(0, ∞)
WTB_TimeStep	Set CE_TimeStep< =1/528 MHz/2^OversamplingOption. Expression variables are in Signal Parameters tab/category.					
SourcePower	Source power	dbmtow(-9.9)		W	real	[0, ∞)
FMeasurement	Measurement carrier frequency	4224 MHz		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]
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	(-∞, ∞)
DataPattern	Data pattern: 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	
BandGroup	Band group: BandGroup1 BandGroup2 BandGroup3 BandGroup4 BandGroup5	BandGroup1			enum	

	BandGroup6					
DataRate	Data rate: _53.3Mbps, _55Mbps, _80Mbps, _106.67Mbps, _110Mbps, _160Mbps, _200Mbps, _320Mbps, _400Mbps,_480Mbps	_53.3Mbps			enum	[1,4095]
DataLength	Octet number of PSDU	1024			int	
PreambleFormat	PLCP preamble format: Standard Format, Shortened Format	Standard Format			enum	
TFC_Number	Time-frequency code number: TFC1, TFC2, TFC3, TFC4, TFC5, TFC6	TFC1			enum	
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32, Ratio 64	Ratio 2			enum	
ScramblerSeed	Scrambler seed selection: Seed 00, Seed 01, Seed 10, Seed 11	Seed 00			enum	
MeasurementParameters						
DisplayPages	RX sensitivity display pages: UWB_RX_with_WLAN_11a_Interferer Tables					
Delay	Frequency synthesizer delay	1.8939 nsec			real	
StartBurst	Start block	1			int	[0, 1000]
StopBurst	Stop block	50			int	[1, 1000]
DataSet	dataSet file to construct Expression from					[0, 1000]
Expression	variable/sink name from dataset					[1, 1000]
WLAN11aPower	WLAN 11a interferer power	1-17		W	real	(0, ∞)
FWLAN11a	WLAN 11a carrier frequency	5.1GHz		Hz	real	(0, ∞)
WLAN11aSampleRate	WLAN 11a source sampling rate	$20e6*2^{5}$		Hz	real	(0, ∞)

Pin Input

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

Pin Output

Pin	Name	Description
1	RF_Out	Test bench RF output to RF circuit

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 the *Set the Required Parameters* (adswtbuwb) step in the test bench setup procedure.

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. 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 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.
2. For DataPattern:
   - 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.

3. DataRate, DataLength, ScramblerSeed are used to set the multi-band OFDM PHY specific service parameter. These parameters will be transmitted in the PHY header and also be used to frame the packets. When the DataRate is set, the data rate-dependent parameters such as modulation, coding rate, conjugate symmetric Input to IFFT, time spreading factor, overall spreading gain and coded bits per OFDM symbol (N_{CBPS}) will be set according to the specification. Please refer to the following table of rate-dependent parameters for detail. Although there are 10 choices for parameter DataRate, only 8 of them are supported. The data rate 55 Mbps and 106.7 Mbps are kept for future extension.

Rate-dependent parameters

Data Rate (Mb/s)	Modulation	Coding rate (R)	Conjugate Symmetric Input to IFFT	Time Spreading Factor (TSF)	Overall Spreading Gain	Coded bits per OFDM symbol (N_{CBPS})
53.3	QPSK	1/3	Yes	2	4	100
80	QPSK	1/2	Yes	2	4	100
110	QPSK	11/32	No	2	2	200
160	QPSK	1/2	No	2	2	200
200	QPSK	5/8	No	2	2	200
320	DCM	1/2	No	1 (No spreading)	1	200
400	DCM	5/8	No	1 (No spreading)	1	200
480	DCM	3/4	No	1 (No spreading)	1	200

4. DataLength is used to set the number of data bytes in the frame payload part of each PLCP frame. There are 8 bits per byte.
5. PreambleFormat indicates which type of preamble is used.
6. TFC_Number indicates which time frequency code is used.
7. OversamplingOption sets the oversampling ratio of UWB RF signal source, where oversampling ratio = $2^{OversamplingOption}$. If OversamplingOption = 2, and the simulation RF bandwidth is larger than the signal bandwidth by a factor of $2^{OversamplingOption}$.

Measurement Parameters

1. DisplayPages provides Data Display page information for this measurement. It cannot be changed by the user.
2. Delay indicates the delay introduced for UWB_Freq_Hopping in UWB_Receiver_FH_RF in order to compensate the delay introduced by DUT to make the local carrier synchronized with the carrier in received signal approximately.
3. StartBlock sets the start frame.
4. StopBurst sets the stop frame.
5. WLAN11aPowr sets the WLAN 11a interferer power

6. DataSet and Expression set the interferer data file and interferer variable
7. FWLAN11a set the WLAN 11a interferer carrier frequency
8. WLAN11aSampleRate set the WLAN 11a interferer sample rate

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* (adswtbuwb).

Interference Measurement

The interference measurement shows BER and PER results.

In this testbench, the UWB signal works on BandGroup 1 occupying the spectrum from 3168 MHz to 4752 MHz, while the WLAN 11a is at 5.19 GHz with a bandwidth of 20 MHz as an out-of-band interferer.

To display and analyze the combined signals, the parameter OversamplingOption of UWB source should be set to 3 or larger. The WLAN 11a interference signal is loaded from dataset file, with 20MHz bandwidth and the 20*32 MHz sample rate. The data rate is 54 Mbps and the data length is 1024 bytes. The 11a signal will be interpolated and decimated to the same sampling rate as the UWB signal in the testbench.

Test Bench Variables for Data Displays

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

Test Bench Constants for UWB Signal Setup

Constant	Value
DR	DataRate+1
N_CBPS	{100, 100, 100, 200, 200, 200, 200, 200, 200, 200}
CodingRate	{1/3, 11/32, 1/2, 1/3, 11/32, 1/2, 5/8, 1/2, 5/8, 3/4}
TSF	{2, 2, 2, 2, 2, 2, 2, 1, 1, 1}
UsefulBits	DataLength*8+32+6
N_Sym_Data	6/TSF[DR]*ceil(ceil(UsefulBits/CodingRate[DR])/(6/TSF[DR]*N_CBPS[DR]))
N_Sym_Preamble	if(PreambleFormat==0) then 30 else 18 endif
N_Sym_Header	12
SymbolsPerFrame	N_Sym_Data*TSF[DR]+N_Sym_Header+N_Sym_Preamble
SamplesPerSymbol	2^(7+OversamplingOption)+int((70.08e-9)/TimeStep+0.5)
SamplesPerFrame	SamplesPerSymbol*SymbolsPerFrame
FrameTime	312.5e-9*SymbolsPerFrame
TimeStep	1/528MHz/2^OversamplingOption
ScramblerSeed_Receiver	if(ScramblerSeed==0) then 3 elseif(ScramblerSeed==1) then 0 elseif(ScramblerSeed==2) then 1 else 2 endif

DataRate Determines BitRate Values

DataRate	BitRate (See following table)
_53.3Mbps	53.3e6
_55Mbps	55e6
_80Mbps	80e6
_106.67Mbps	106.67e6
_110Mbps	110e6
_160Mbps	160e6
_200Mbps	200e6
_320Mbps	320e6
_400Mbps	400e6
_480Mbps	480e6

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

Data Display Parameter	Equation with Test Bench Parameters
RF_SourcePower_dBm	10*log10(SourcePower)+30
RF_SourceR	SourceR
RF_SourceTemp	SourceTemp in degrees Celcius
Meas_FMeasurement	FMeasurement
Meas_R	MeasR
DataLen	DataLength Octet number of PSDU
OversamplingRatio	2^OversamplingOption
TStep	TimeStep
BitRate	Dependent on DataRate in previous table This is the bit rate for transmitted UWB signal.
SymbolData	N_Sym_Data*TSF[DR] Number of OFDM symbols within PSDU
SymbolHeader	12 Number of OFDM symbols within PLCP Header
SymbolPreamble	N_Sym_Preamble Number of OFDM symbols within Preamble
SymbolPerFrame	SymbolsPerFrame Number of OFDM symbols within each frame
FramePeriod	FrameTime Time duration of each frame
SamplePerFrame	SamplesPerFrame Number of samples within each frame
FrameMeasured	StopBlock-StartBlock+1 Number of frames measured

Baseline Performance

- Test Computer Configuration
  - Pentium-M 2GHz, 1.5G RAM, Windows XP
- Conditions
  - Measurements made with default test bench settings.
  - RF DUT is an RF system behavior component.
  - SignalPower = -76.8 dBm
  - DataRate = 53.3 Mbps
  - DataLength=100 bytes
  - OversamplingOption = Ratio_8
  - WTB_TimeStep = 1/528 MHz/8
  - FMeasurement = 3960 MHz

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 1 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. "Multiband OFDM Physical Layer Specification", WiMedia Alliance document, Release 1.1, July 14, 2005.

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.

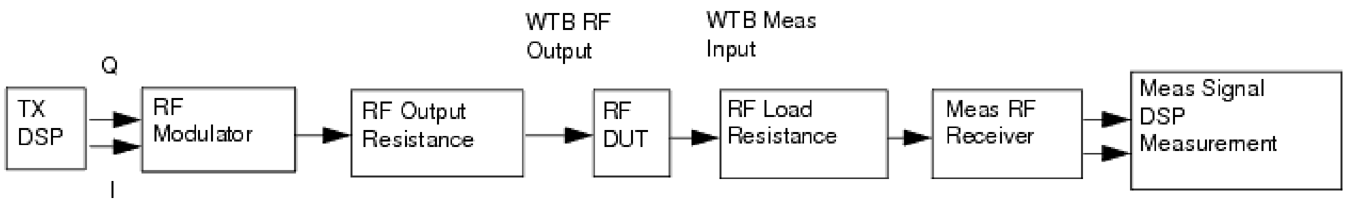
UWB Receiver Sensitivity Test

Introduction

UWB_RX_Sensitivity_test is the test bench for UWB receiver minimum 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 input level.

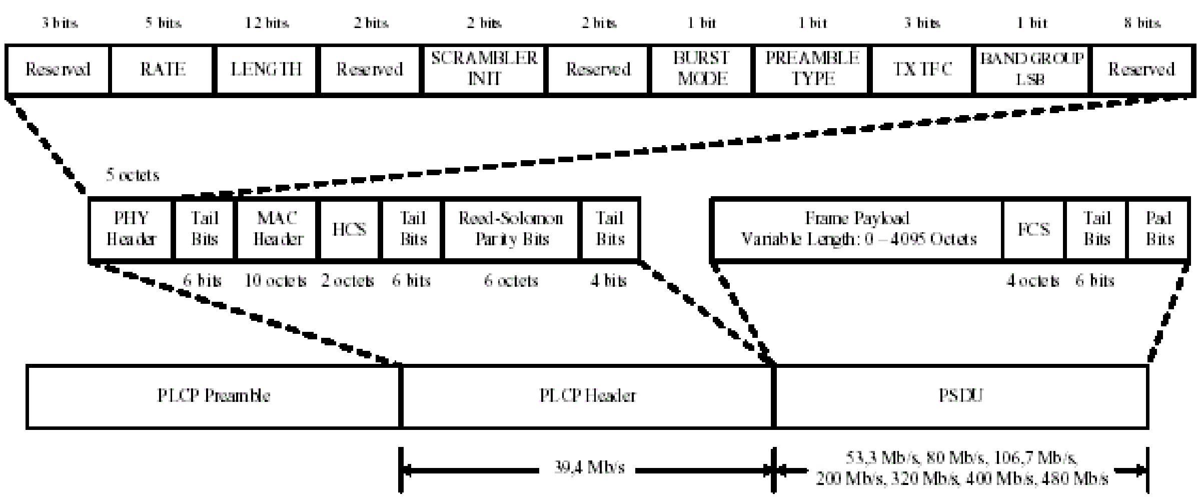
The signal and the measurement are designed according to *Reference 1* (adswtbuwb).

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 block diagram. The generated test signal is sent to the DUT.



Receiver Wireless Test Bench Block Diagram

The UWB PLCP frame format is shown in PLCP Frame Format. Each frame is separated by IdleInterval and consists of three parts: the PLCP preamble, PLCP header (PHY header, MAC header, header check sequence, tail bits, and pad bits), MAC frame body (frame payload plus FCS, tail bits, and pad bits).



PLCP Frame Format

The standard PLCP preamble consists of two portions: the time domain packet and frame synchronization sequence; and the frequency domain channel estimation sequence. The basic sequence for time domain packet and frame synchronization sequence is implemented by model UWB_TimeDomainSeq. The frequency domain channel estimation sequence is implemented by a model WaveFormCx. The basic sequence of timed domain packet and frame synchronization is repeated and combined with FFT'd frequency domain channel estimation sequence and FFT'd frame body in model UWB_MuxFrame.

According to the specification, the frame body shall be encoded in the following manner. The PLCP header (consisting of the PHY header and associated tail bits, the MAC header plus HCS, and the associated tail bits, followed by the pad bits as in Section 1.3.8[1]) shall be encoded with a rate R = 1/3. The encoder shall be reset to the all-zero state following this. Next, the MAC frame body, tail bits and pad bits appended shall be encoded with a rate R = 1/3, 11/32, 1/2, 5/8, or 3/4, corresponding to the desired data rate. The algorithm to reset the encoder after encoding PLCP header is as follows:

- Append 6 extra tail bits after PLCP header
- Convolutionally encode the PLCP header and extra tail bits. with a rate R = 1/3. The encoder is reset to the all-zero state following this.
- Remove 18 symbols generated from the 6 tail bits.

Although there is no requirement for the encoder to be reset after encoding the MAC frame body, tail bits and pad bits appended, it is a requirement of the simulation. So the same algorithm is implemented.

The number of OFDM symbols per UWB-OFDM frame also consists of three parts.

There is 30 or 18 OFDM symbols for Standard preamble or Shortened preamble, respectively.

$$Nsym_{preamble} = \begin{cases} 30 & Standard \\ 18 & Shortened \end{cases}$$

The preceding figure shows the PLCP Header, whose data rate is 53.3 Mb/s. It includes PHY Header (40 bits), first Tail Bits (6 bits), MAC Header (80 bits), HCS (header check sequence, 16 bits) second Tail Bits (6 bits), and pad bits. The total bits of PLCP Header is 148 bits. The OFDM symbols of PLCP Header before time-domain spreading is computed as follows:

$$Nsym_{Header} = \frac{6}{TSF} \times \left\lceil \frac{\left\lceil \frac{148}{R} \right\rceil}{\frac{6}{TSF} \times N_{CBPS}} \right\rceil = 6$$

Where TSF=2, NCBPS=100 and R=1/3 from the table of *Rate-dependent parameters* (adswtbuwb) because PLCP Header is always 53.3 Mb/s. The number pad bits is 52 ($= 6 \times N_{CBPS} - 148/R$).
So the OFDM symbols of PLCP Header after time-domain spreading is as follows:

$$Nsym_{Header-TSF} = TSF \times \frac{6}{TSF} \times \left\lceil \frac{\left\lceil \frac{148}{R} \right\rceil}{\frac{6}{TSF} \times N_{CBPS}} \right\rceil = 12$$

MAC frame body consists of frame payload, FCS, tail bits, and pad bits. The OFDM symbols of PSDU before time-domain spreading is computed as follows:

$$Nsym_{PSDU} = \frac{6}{TSF} \times \left\lceil \frac{\left\lceil \frac{8 \times DataLength + 32 + 6}{R} \right\rceil}{\frac{6}{TSF} \times N_{CBPS}} \right\rceil$$

Where R is the data rate of PSDU, TSF and NCBPS are determined by the data rate and DataLength is the number of data bytes in the frame payload part of each PLCP frame. Please refer to the table of *Rate-dependent parameters* (adswtbuwb) for detail.

The number of pad bits is:

$$Nsym_{PSDU} \times N_{CBPS} - \left\lceil \frac{8 \times DataLength + 32 + 6}{R} \right\rceil$$

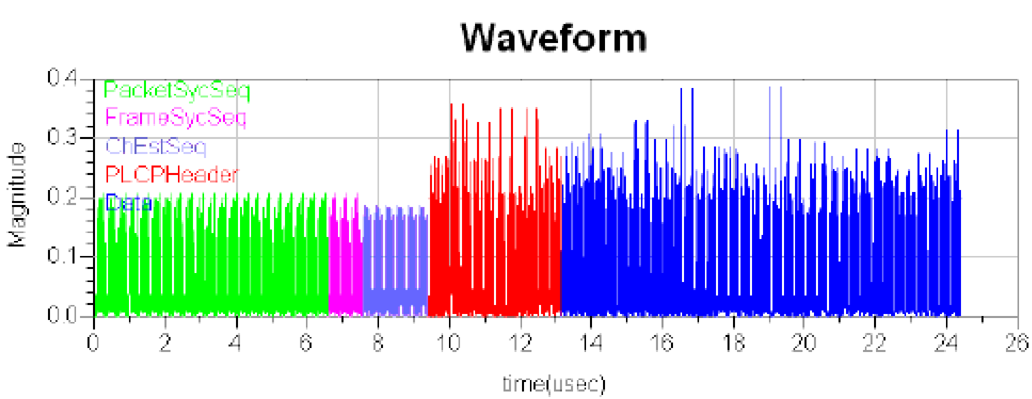
The OFDM symbols of PSDU before time-domain spreading is computed as follows:

$$Nsym_{PSDU-TSF} = TSF \times \frac{6}{TSF} \times \left\lceil \frac{\left\lceil \frac{8 \times DataLength + 32 + 6}{R} \right\rceil}{\frac{6}{TSF} \times N_{CBPS}} \right\rceil$$

So, the total number of OFDM symbols N_{SYM} per UWB-OFDM frame is

$$N_{SYM} = Nsym_{preamble} + Nsym_{Header-TSF} + Nsym_{PSDU-TSF}$$

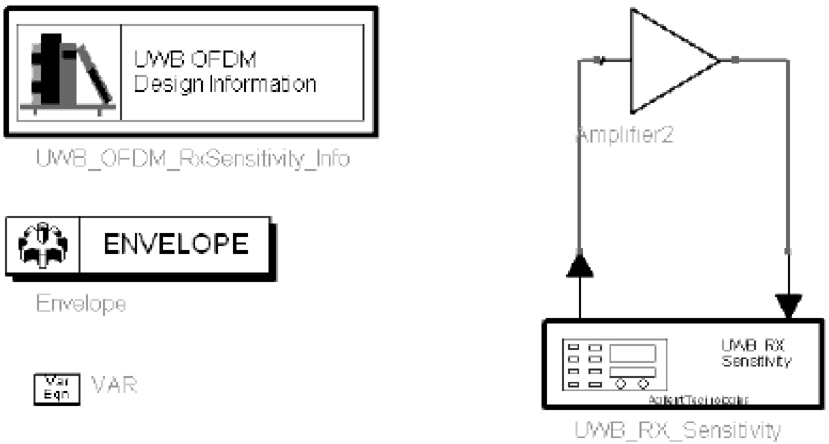
The UWB RF power delivered into a matched load is the average power delivered in the UWB frame excluding the idle time. The following figure shows the RF envelope for an output RF signal with -9.9 dBm power.



UWB RF Signal Envelope

Test Bench Basics

A template is provided for this test bench.



UWB 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 *UWB_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* > UWB> UWB_RF_Verification_wrk > *UWB_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, 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 *UWB_RX_Sensitivity_test* template:

1. In an Analog/RF schematic window select *Insert > Template.*
2. In the *Insert > Template* dialog box, choose *UWB_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 UWB Wireless Test Benches* (adswtbuwb).
2. Set the *Required Parameters*

    Note
    Refer to *UWB_RX_Sensitivity* (adswtbuwb) 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=0.9470 nsec. The value is displayed in the Data Display pages as TimeStep.

      WTB_TimeStep = 1/528 MHz/($2^{OversamplingOption}$)

      where

      528 MHz is the bandwidth of UWB OFDM signal

      2^OversamplingOption is the oversampling ratio value. Oversampling ratio sets the number of waveform sampling points during the signal FFT time interval. During this time interval the minimum FFT sampling size is 128 (which corresponds to an FFT order of 7; i.e 2^{7}) and the FFT time interval is defined as

128/528 MHz. For example, a Ratio of 4 sets the FFT sampling size to 128 × 4=512 (which corresponds to an FFT order of 9) during the signal FFT time interval.

- Set SourcePower, and FMeasurement.
  - SourcePower defines the power level of the source. 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* (adswtbuwb).
4. The RF modulator (shown in the block diagram in Receiver Wireless Test Bench Block Diagram) uses SourcePower (*Required Parameters*), GainImbalance, PhaseImbalance(*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 delivered into a matched load of resistance SourceR, with frequency hopping, with the specified source resistance (SourceR) and with power (SourcePower) . The RF signal has additive Gaussian noise power set by resistor temperature (SourceTemp).

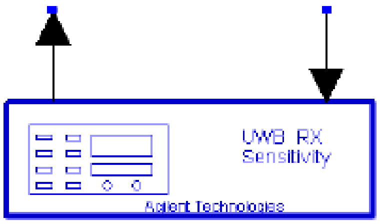
   Note that the Meas_in point of the test bench provides a resistive load to the RF DUT set by the MeasR value (50-ohm default) (*Basic Parameters*).

   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* (adswtbuwb) describes results for each measurement. For general WTB Data Display details refer to *Viewing WTB Analysis Results* (adswtbsim).

UWB_RX_Sensitivity

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



Parameters

Name	Description	Default	Sym	Unit	Type	Range
RequiredParameters						
CE_TimeStep	Circuit envelope simulation time step	1/528 MHz/2		sec	real	(0, ∞)
WTB_TimeStep	Set CE_TimeStep< =1/528 MHz/2^OversamplingOption. Expression variables are in Signal Parameters tab/category.					
SourcePower	Source power	dbmtow(-9.9)		W	real	[0, ∞)
FMeasurement	Measurement carrier frequency	4224 MHz		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]
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	(-∞, ∞)
DataPattern	Data pattern: 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	
BandGroup	Band group:	BandGroup1			enum	
DataRate	Data rate: _53.3Mbps, _55Mbps, _80Mbps, _106.67Mbps, _110Mbps, _160Mbps, _200Mbps, _320Mbps, _400Mbps,_480Mbps	_53.3Mbps			enum	[1,4095]
DataLength	Octet number of PSDU	1024			int	
PreambleFormat	PLCP preamble format: Standard Format, Shortened Format	Standard Format			enum	
TFC_Number	Time-frequency code number: TFC1, TFC2, TFC3, TFC4, TFC5, TFC6	TFC1			enum	
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32, Ratio 64	Ratio 2			enum	
ScramblerSeed	Scrambler seed selection: Seed 00, Seed 01, Seed 10, Seed 11	Seed 00			enum	
MeasurementParameters						
DisplayPages	RX sensitivity display pages:					
Delay	Frequency synthesizer delay	1.8939 nsec			real	
StartBurst	Start block	1			int	[0, 1000]
StopBurst	Stop block	50			int	[1, 1000]

Pin Inputs

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

Pin Outputs

Pin	Name	Description
1	RF_Out	Test bench RF output to RF circuit

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 the *Set the required parameters* (adswtbuwb) step under *Test Bench Details*.

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. 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 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.
2. For DataPattern:
   - 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.

3. DataRate, DataLength, ScramblerSeed are used to set the multi-band OFDM PHY specific service parameter. These parameters will be transmitted in the PHY header and also be used to frame the packets. When the DataRate is set, the data rate-dependent parameters such as modulation, coding rate, conjugate symmetric Input to IFFT, time spreading factor, overall spreading gain and coded bits per OFDM symbol (N_{CBPS}) will be set according to the specification. Please refer to the table of rate-dependent parameters below for detail. Although there are 10 choices for parameter DataRate, only 8 of them are supported. The data rate 55 Mbps and 106.7 Mbps are kept for future extension.

Rate-dependent parameters

Data Rate (Mb/s)	Modulation	Coding rate	Conjugate	Time	Overall	Coded bits per OFDM symbol (N_{CBPS})
53.3	QPSK	1/3	Yes	2	4	100
80	QPSK	1/2	Yes	2	4	100
110	QPSK	11/32	No	2	2	200
160	QPSK	1/2	No	2	2	200
200	QPSK	5/8	No	2	2	200
320	DCM	1/2	No	1 (No spreading)	1	200
400	DCM	5/8	No	1 (No spreading)	1	200
480	DCM	3/4	No	1 (No spreading)	1	200

4. DataLength is used to set the number of data bytes in the frame payload part of each PLCP frame. There are 8 bits per byte.
5. PreambleFormat indicates which type of preamble is used.
6. TFC_Number indicates which time frequency code is used.
7. OversamplingOption sets the oversampling ratio of UWB RF signal source, where oversampling ratio = $2^{OversamplingOption}$. If OversamplingOption = 2, and the simulation RF bandwidth is larger than the signal bandwidth by a factor of $2^{OversamplingOption}$.

Measurement Parameters

1. DisplayPages provides Data Display page information for this measurement. It cannot be changed by the user.
2. Delay indicates the delay introduced for UWB_Freq_Hopping in UWB_Receiver_FH_RF in order to compensate the delay introduced by DUT to make the local carrier synchronized with the carrier in received signal approximately.
3. StartBlock sets the start frame.
4. StopBurst sets the stop frame.

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 UWB Wireless Test Benches* (adswtbuwb).

Sensitivity Measurement

The sensitivity measurement shows BER and PER results.

The table of minimum sensitivity performance requirements defines receiver minimum sensitivity measured at the receiver antenna connector for each data rate in UWB specification. SourcePower can be set at the value in the table to perform receive minimum sensitivity tests. According to specification [1] 1.6.1, the packet error rate (PER) shall be less than 10% with a PSDU of 1024 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.

Data Rate (Mbps)	Minimum sensitivity (dBm)
53.3	-80.8
80	-78.9
106.7	-77.8
160	-75.9
200	-74.5
320	-72.8
400	-71.5
480	-70.4

Simulation results for data rate of 200 Mbps and SourcePower of -76.8 dBm are displayed in the following figure.

real(RF_SourcePower_dBm)	real(RF_SourceR)	real(Meas_fMeasurement) / (1 MHz)	real(Meas_R)
-76.800	50.000	4224.000	50.000

real(BitRate)	real(DataLen)	real(OversamplingRatio)	real(TStep)
2.000E8	1024.000	2.000	9.470E-10

real(SymbolHeader)	real(SymbolPreamble)	real(SymbolData)	real(SymbolPerFrame)	real(SamplePerFrame)	real(FramePeriod)
12.000	30.000	132.000	174.000	57420.000	5.438E-5

Meas Sensitivity

real(FrameMeasured)	BER	FER
2.00000000	0.00356166	1.00000000

Simulation Results for 200 Mbps Data Rate and -76.8 dBm SourcePower

Parameters in the Data Display are described in Test Bench Equations Derived from Test Bench Parameters or variables 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_SourcePower_dBm) - N0_dBm - 10*log10(real(BitRate))

Local Eb/No and system Eb/No are described in *Wireless Measurement Definitions (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 UWB Signal Setup

Constant	**Value**
DR	DataRate+1
N_CBPS	{100, 100, 100, 200, 200, 200, 200, 200, 200, 200}
CodingRate	{1/3, 11/32, 1/2, 1/3, 11/32, 1/2, 5/8, 1/2, 5/8, 3/4}
TSF	{2, 2, 2, 2, 2, 2, 2, 1, 1, 1}
UsefulBits	DataLength*8+32+6
N_Sym_Data	6/TSF[DR]*ceil(ceil(UsefulBits/CodingRate[DR])/(6/TSF[DR]*N_CBPS[DR]))
N_Sym_Preamble	if(PreambleFormat==0) then 30 else 18 endif
N_Sym_Header	12
SymbolsPerFrame	N_Sym_Data*TSF[DR]+N_Sym_Header+N_Sym_Preamble
SamplesPerSymbol	2^(7+OversamplingOption)+int((70.08e-9)/TimeStep+0.5)
SamplesPerFrame	SamplesPerSymbol*SymbolsPerFrame
FrameTime	312.5e-9*SymbolsPerFrame
TimeStep	1/528MHz/2^OversamplingOption
ScramblerSeed_Receiver	if(ScramblerSeed==0) then 3 elseif(ScramblerSeed==1) then 0 elseif(ScramblerSeed==2) then 1 else 2 endif

DataRate Determines BitRate Values

DataRate	BitRate (see the following table)
_53.3Mbps	53.3e6
_55Mbps	55e6
_80Mbps	80e6
_106.67Mbps	106.67e6
_110Mbps	110e6
_160Mbps	160e6
_200Mbps	200e6
_320Mbps	320e6
_400Mbps	400e6
_480Mbps	480e6

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

Data Display Parameter	Equation with Test Bench Parameters
RF_SourcePower_dBm	10*log10(SourcePower)+30
RF_SourceR	SourceR
RF_SourceTemp	SourceTemp in degrees Celcius
Meas_FMeasurement	FMeasurement
Meas_R	MeasR
DataLen	DataLength
OversamplingRatio	2^OversamplingOption
TStep	TimeStep
BitRate	Dependent on DataRate (see previous table)
SymbolData	N_Sym_Data*TSF[DR]
SymbolHeader	12
SymbolPreamble	N_Sym_Preamble
SymbolPerFrame	SymbolsPerFrame
FramePeriod	FrameTime
SamplePerFrame	SamplesPerFrame
FrameMeasured	StopBlock-StartBlock+1

Baseline Performance

- Test Computer Configuration
  - Pentium IV 2.4 GHz, 512 MB RAM, Windows 2000
- Conditions
  - Measurements made with default test bench settings.
  - RF DUT is an RF system behavior component.
  - SignalPower = -76.8 dBm
  - DataRate = 200 Mbps
  - DataLength=1024 bytes
  - OversamplingOption = Ratio_2
  - WTB_TimeStep = 1/528 MHz/2
  - FMeasurement = 3960 MHz
- Simulation time and memory requirements:

UWB_RX_Sensitivity_test Measurement	Frames Measured	Simulation Time (hour)	ADS Processes (MB)
RX Sensitivity	50	3	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. "Multiband OFDM Physical Layer Specification", WiMedia Alliance document, Release 1.1, July 14, 2005.
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.

UWB Transmitter Test

Introduction

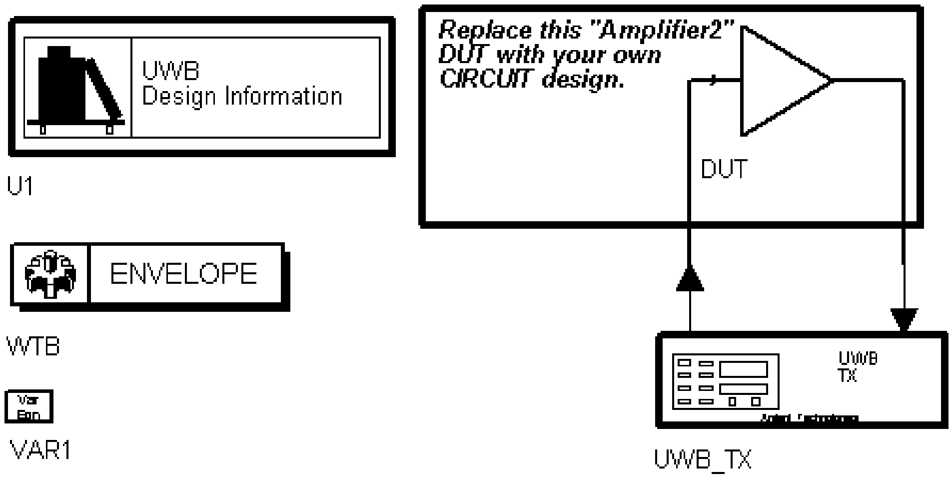
The UWB_TX transmitter test bench provides a way for users to connect to an RF circuit device under test (RF DUT) and determine its performance by activating various test bench measurements. This test bench provides signal measurements for RF envelope, signal power (including CCDF), constellation, spectrum,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

The signal and most of the measurements are designed according to WiMedia Multiband OFDM Physical Layer Specification, Release 1.1.

The UWB frame structure is illustrated in the following figure. Each frame is composed of the PLCP preamble, PLCP header and MAC frame body, tail bits and pad bits. (PLCP means *physical layer convergence procedure* , PSDU means *PLCP service data units*)!adswtbuwb-2-1-01.gif!

UWB frame Structure

Test Bench Basics



UWB Transmitter Test Bench

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, 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).

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 *UWB_TX* template:

1. In an Analog/RF schematic window select *Insert > Template.*
2. In the *Insert > Template* dialog box, choose *UWB_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 UWB Wireless Test Benches* (adswtbuwb).
2. Set the *Required Parameters*

   > **Note**
   > Refer to *UWB_TX* (adswtbuwb) 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. The value is displayed in the Data Display pages as TimeStep.

     WTB_TimeStep = 1/(Bandwidth × Ratio)

     where

     Bandwidth is the user-settable value (default 528 MHz)

     Ratio is the oversampling ratio related to OversamplingOption as Ratio = $2^{OversamplingOption}$. OversamplingOption sets the number of waveform sampling points during the signal FFT time interval. During this time interval the minimum FFT sampling size is 128 (which corresponds to an FFT order of 7; i.e 2^7) and the FFT time interval is defined as 128/Bandwidth. For example, an OversamplingOption of 2 sets the bq. FFT sampling size to 128 × 4=512 (which corresponds to an FFT order of 9) during the signal FFT time interval.

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

3. Activate/deactivate (*YES* / *NO*) test bench measurements (refer to *UWB_TX* (adswtbuwb)). 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* (adswtbuwb).
5. The RF modulator of UWB_TX(shown in the preceding block diagram) uses SourcePower (*Required Parameters*), GainImbalance, PhaseImbalance(*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 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).

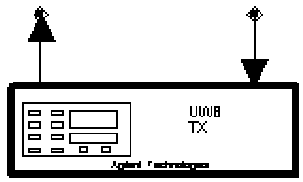
   Note that the Meas point of the test bench provides a resistive load to the RF DUT set by the MeasR value (50-ohm default) (*Basic Parameters*).

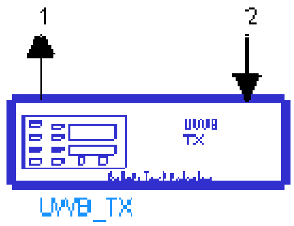
   The Meas signal contains linear and nonlinear signal distortions and time delays associated with the RF DUT input to output characteristics.

   The DSP block of UWB_TX(shown in the preceding 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. After running a simulation, results will appear in a Data Display window for the measurement. *Simulation Measurement Displays* (adswtbuwb) describes results for each measurement. For general WTB Data Display details refer to *Viewing WTB Analysis Results* (adswtbsim).

UWB_TX

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





Description: UWB TX test
Library: WTB
Class: TSDFUWB_TX
Derived From: baseWTB_TX

Parameters

Name	Description	Default	Unit	Type	Range
RequiredParameters					
CE_TimeStep	Circuit envelope simulation time step	1/528 MHz/2	sec	real	(0, ∞)
WTB_TimeStep	Set CE_TimeStep< =1/Bandwidth/2^OversamplingOption.				
SourcePower	Source power	dbmtow(-9.9)	W	real	[0, ∞)
FMeasurement	Measurement carrier frequency	4224 MHz	Hz	real	(0, ∞)
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	
BasicParameters					
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]
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	(-∞, ∞)
OversamplingOption	Oversampling ratio: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 2		enum	
DataPattern	Data pattern: 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	
BandGroup	BandGroup: BandGroup1, BandGroup2, BandGroup3, BandGroup4, BandGroup5, BandGroup6	BandGroup1		enum	
DataRate	Data rate: _53.3 Mbps, _55 Mbps, _80 Mbps, _106.67 Mbps, _110 Mbps, _160 Mbps, _200 Mbps, _320 Mbps, _400 Mbps, _480 Mbps	_53.3 Mbps		enum	
DataLength	Octet number of PSDU	100		int	[1, 4095]
PreambleFormat	PLCP preamble format: Standard Format, Burst Format	Standard Format		enum	
TFC_Number	Time frequency code: TFC1, TFC2, TFC3, TFC4, TFC5, TFC6, TFC7	TFC1		enum	
ScramblerSeed	Scrambler seed selection: Seed 00, Seed 01, Seed 10, Seed 11	Seed 00		enum	
RF_EnvelopeMeasurementParameters					
RF_EnvelopeDisplayPages	RF envelope measurement display pages:				
RF_EnvelopeStart	RF envelope measurement start	0.0	sec	real	[0, ∞)
RF_EnvelopeStop	RF envelope measurement stop	0.5 µ	sec	real	[0, ∞)
RF_EnvelopeSymbols	RF envelope measurement OFDM symbols	1		int	[0, 1000]
ConstellationParameters					
ConstellationDisplayPages	Constellation measurement display pages:				
ConstellationFrames	Constellation measurement OFDM frames	1		int	[1,)
PowerMeasurementParameters					
PowerDisplayPages	Power measurement display pages:				
PowerSymbolsMeasured	OFDM symbols measured	3		int	[1, ∞)
PowerOutputPoint	Indicate output precision	100		int	[1, ∞)
SpectrumMeasurementParameters					
SpecMeasDisplayPages	Spectrum measurement display pages:				
SpecMeasStart	Spectrum measurement start	0.0	sec	real	[0, ∞)
SpecMeasStop	Spectrum measurement stop	0.5 µ	sec	real	[0, ∞)

SpecMeasSymbols	Spectrum measurement OFDM symbols	3		int	[0, 100]
SpecMeasResBW	Spectrum resolution bandwidth	0	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	none		enum	
EVM_MeasurementParameters					
EVM_DisplayPages	EVM measurement display pages:				
EVM_Delay	EVM measurement delay	10 nsec	sec	real	(0, ∞)
EVM_StartFrame	EVM measurement start frame	1		int	[1, ∞)
EVM_FramesToAverage	Frames used for RMS averaging	1		int	[1, ∞)

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 the instruction *Set the Required Parameters* (adswtbuwb) under *UWB Transmitter Test*.

Basic Parameters

1. SourceR is the RF output source resistance.
2. SourceTemp is the RF output source resistance temperature (°C) 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 -273.15°C (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. 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 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:
   $$V_{RF}(t) = A\left(V_I(t)\cos(\omega_c t) - g V_Q(t)\sin\left(\omega_c t + \frac{\phi\pi}{180}\right)\right)$$
   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.
2. OversamplingOption sets the oversampling ratio of UWB RF signal source. Options from 0 to 6 result in oversampling ratio 2, 4, 8, 16, 32, 64 where oversampling ratio

= 2 ^{OversamplingOption} . If OversamplingOption = 2, the oversampling ratio = 2 ^{2} = 4 and the simulation RF bandwidth is larger than the signal bandwidth by a factor of 4 (e.g. for Bandwidth=528 MHz, the simulation RF bandwidth = 528 MHz × 4 = 2112 MHz).

3. For DataPattern:
   - 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.
4. DataRate specifies the data rate 53.3, 55, 80, 106.67, 110, 160, 200, 320, 400 and 480 Mbps. When the DataRate is set, the data rate-dependent parameters such as modulation, coding rate, conjugate symmetric Input to IFFT, time spreading factor, overall spreading gain and coded bits per OFDM symbol (N^{CBPS}) will be set according to the specification. Please refer to the following table for details. Although there are 10 choices for parameter DataRate, only 8 of them are supported. The data rate 55M bps and 106.7M bps are kept for future extension.

Data Rate (Mb/s)	**Modulation**	**Coding rate (R)**	**Conjugate Symmetric Input to IFFT**	**Time Spreading Factor (TSF)**	**Overall Spreading Gain**	**Coded bits per OFDM symbol (N^{CBPS})**
53.3	QPSK	1/3	Yes	2	4	100
80	QPSK	1/2	Yes	2	4	100
110	QPSK	11/32	No	2	2	200
160	QPSK	1/2	No	2	2	200
200	QPSK	5/8	No	2	2	200
320	DCM	1/2	No	1 (No spreading)	1	200
400	DCM	5/8	No	1 (No spreading)	1	200
480	DCM	3/4	No	1 (No spreading)	1	200

5. DataLength represents the bytes of PSDU (MAC frame body). Its value range is for 1 to 4095 bytes.
6. PreambleFormat is used to select Standard PLCP or Shortened PLCP preamble format defined in UWB-OFDM.
7. TFC_Number is for Time-frequency codes number, which controls the frequency hopping sequence.
8. ScramblerSeed is to select the seed identifier. And the seed identifier controls 15 bit initialization vector. Please note, the receiver has a fixed one frame delay. So, the values of ScramblerSeed in UWB-OFDM signal source (UWB_SignalSource, UWB_SignalSource_RF and UWB_Source_FH_RF) and receiver (UWB_Receiver, UWB_Receiver_RF and UWB_Receiver_FH_RF) should be the two consecutive values. Only above setting can get right BER (Bit Error Rate). For examples, ScramblerSeed =Seed 00 in UWB-OFDM signal source; ScramblerSeed = Seed 11 in UWB-OFDM receiver.

RF Envelope Measurement Parameters

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

- 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_EnvelopeSymbols = 0.
- RF_EnvelopeSymbols (when > 0) sets the number of symbols over which data will be collected.

For RF envelope measurement for both the RF and Meas 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_EnvelopeSymbols	Resultant Stop Time
0	Stop
> 0	Start + RF_EnvelopeSymbols x SymbolTime

For information about TimeStep, see Test Bench Variables for Data Displays.

Constellation Parameters

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

The measurement start time is the time when ConstellationStartframe is detected in the measured RF signal. The measurement stop time is this start time plus Constellationframes × frameTime; frameTime is defined in Test Bench Variables for Data Displays.

Power Measurement Parameters

1. PowerDisplayPages provides Data Display page information for this measurement. It cannot be changed by the user.

2. PowerSymbolsMeasured (when > 0) sets the number of symbols over which data will be collected.
3. PowerOutputPoint indicates the output precision.

The measurement start time is the time when the first frame is detected in the measured RF signal. The measurement stop time is this start time plus PowerSymbolsMeasured × 312.5 nsec.

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.

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 (refer to the "Effect of Values" table 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.
2. SpecMeasDisplayPages 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 SpecMeasSymbols = 0 and SpecMeasResBW = 0.
5. SpecMeasSymbols sets the number of symbols over which data will be collected when SpecMeasSymbols>0.
6. SpecMeasResBW sets the resolution bandwidth of the spectrum measurement when SpecMeasResBW>0.
   Depending on the values of SpecMeasStart, SpecMeasStop, SpecMeasSymbols, and SpecMeasResBW, the stop time may be adjusted or spectrum video averaging may

occur (or both). The different cases are described in the table below.

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

Case 1	SpecMeasSymbols = 0 SpecMeasResBW = 0 Resultant stop time = Stop Resultant resolution BW = NENBW/(Stop - Start) Resultant spectrum frequency step = 1/(Stop-Start) Video averaging status = None
Case 2	SpecMeasSymbols > 0 SpecMeasResBW = 0 Resultant stop time = Start + SpecMeasSymbols x SymbolTime (Notes: For SpecMeasSymbols > 0 and SpecMeasResBW = 0. Video averaging occurs over all symbol time intervals.) Resultant resolution BW = NENBW /SymbolTime Resultant spectrum frequency step = 1/SymbolTime Video averaging status = Yes, when SpecMeasSymbols > 1
Case 3	SpecMeasSymbols = 0 SpecMeasResBW > 0 Resultant stop time = Start + N x SymbolTimeInterval where N = int((Stop -Start)/SymbolTimeInterval) + 1 For SpecMeasSymbols = 0 and SpecMeasResBW > 0 Define SymbolTimeInterval = TimeStep x int((X/SpecMeasResBW/TimeStep) + 0.5) This means SymbolTimeInterval 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 SymbolTimeIntervals N has a minimum value of 1 Video averaging occurs over all SymbolTimeIntervals The resolution bandwidth achieved is ResBW = NENBW / SymbolTimeInterval, which is very close to SpecMeasResBW but may not be exactly the same if NENBW/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	SpecMeasSymbols > 0 SpecMeasResBW > 0 Resultant stop time = Start + M x SymbolTimeInterval where M = int((SpecMeasSymbols x SymbolTime)/SymbolTimeInterval) + 1 For SpecMeasSymbols > 0 and SpecMeasResBW > 0 Define SymbolTimeInterval = TimeStep x int((NENBW /SpecMeasResBW/TimeStep) + 0.5) This means SymbolTimeInterval 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 SymbolTimeIntervals M has a minimum value of 1 Video averaging occurs over all SymbolTimeIntervals The resolution bandwidth achieved is ResBW = NENBW / SymbolTimeInterval, 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

Referring to the table, let

$$\text{Start} = \text{TimeStep} \times \text{int}((\text{SpecMeasStart}/\text{TimeStep}) + 0.5)$$

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

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

NENBW = 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 "Window Options" table lists the NENBW for the various window options.
The Start and Stop times are used for both the RF and Meas signal spectrum analyses. The Meas signal is delayed in time from the RF signal by the value of the RF DUT time delay. Therefore, for RF DUT time delay greater than zero, the RF and Meas signal are inherently different and some spectrum display difference in the two is expected.
TimeStep is defined under Test Bench Variables for Data Displays.

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, α = 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	Normalized Equivalent Noise Bandwidth (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 is used to measure the EVM of UWB RF signal source with frequency hopping used, and needs no reference signal provided by the source.

1. EVM_DisplayPages provides Data Display page information for this measurement. It cannot be changed by the user.
2. EVM_StartFrame sets the start frame for collecting input data.
3. EVM_FramesToAverage sets the frame number used for averaging.
4. EVM_Delay sets EVM measurement delay.

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 UWB Wireless Test Benches* (adswtbuwb).

Envelope Measurement

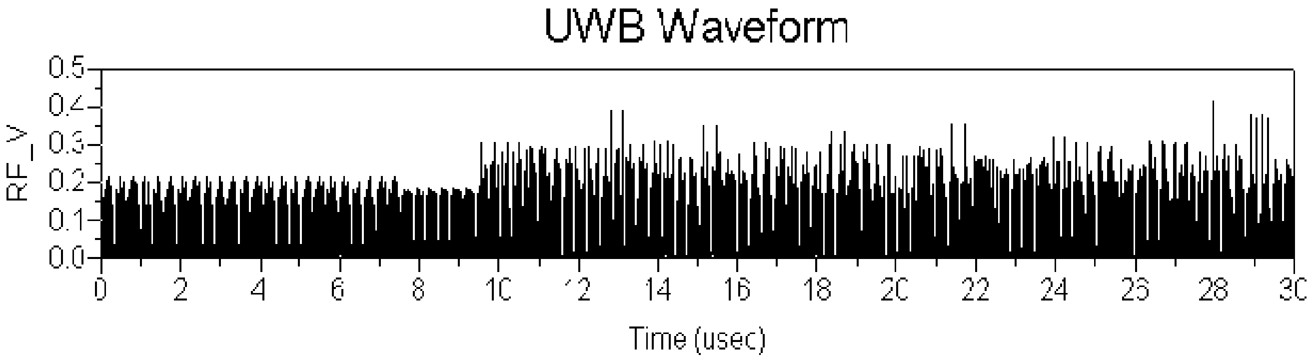
The Envelope measurement shows the envelope and spectrum of each field in the UWB frame (PLCP preamble, PLCP header, and DATA fields). Two signals are tested, the RF source signal at the RF DUT input and the Meas signal at the RF DUT output.

For envelope measurement, the default parameter setting is given in the following table.

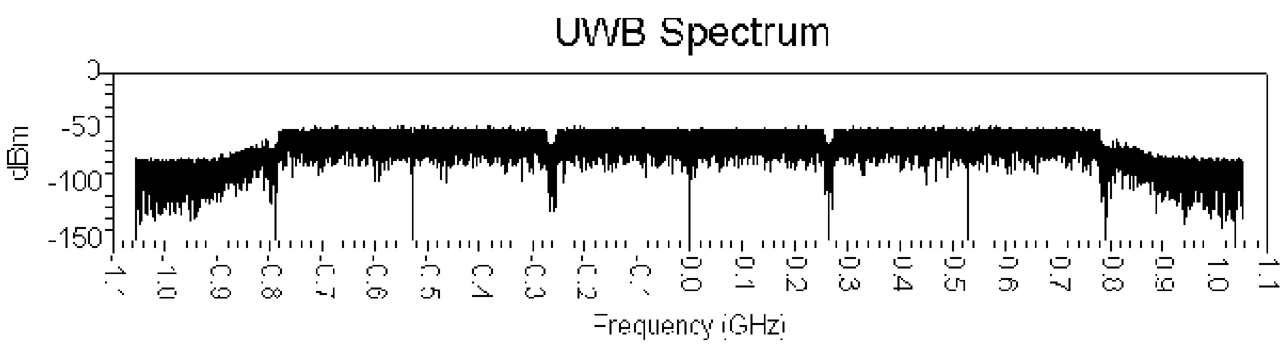
Parameter	Default Setting
RF_FSource	3960.0 MHz
RF_R	50.0 Ohm
PreambleTime	9.375 usec (standard format)
HeaderTime	3.75 usec
OFDM_SymbolTime	312.5 nsec
frameTime	30.0 usec
TimeStep	0.473 nsec
BitRate	53.3 Mbps
Meas_FMeasurement	3960.0 MHz
Meas_R	50.0 Ohm

For the RF signal, the time domain envelope and spectrum of one complete UWB frame, as well as preamble, header, and DATA fields are shown in the following eight figures.

Time Envelope of UWB RF Signal for Default Settings (one frame)

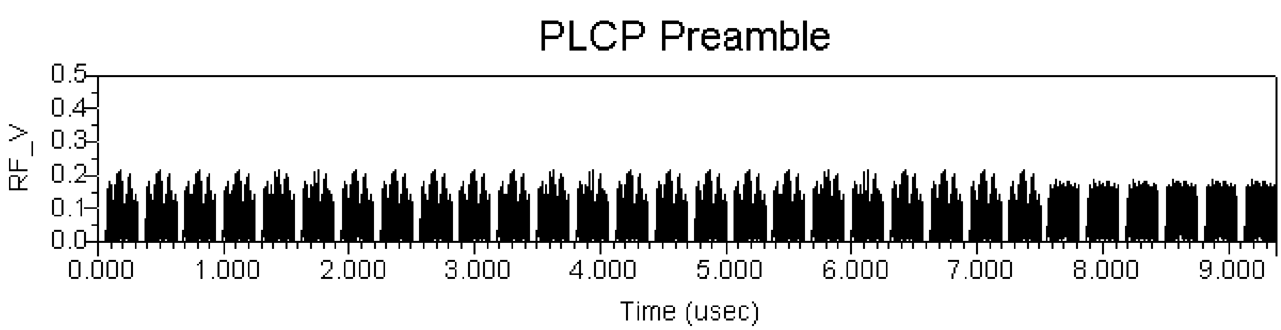


Spectrum of UWB RF Signal

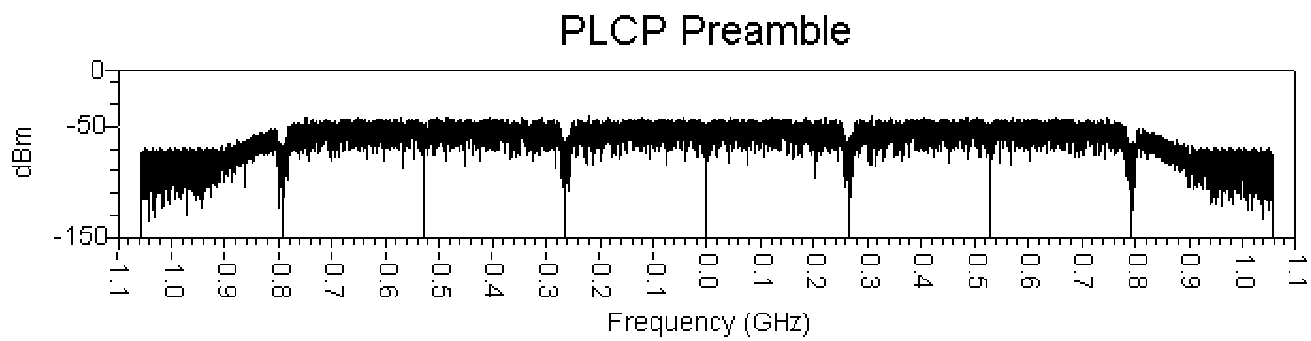


RF Signal PLCP preamble Envelope shows the Preamble is 9.375 μ lasting from 0 to 9.375 μ. The spectrum is shown in RF Signal PLCP preamble Spectrum.

RF Signal PLCP preamble Envelope

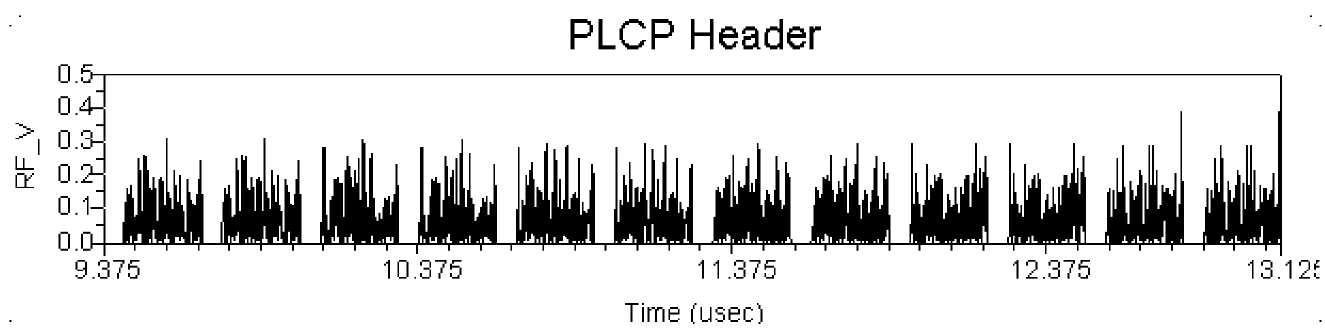


RF Signal PLCP preamble Spectrum

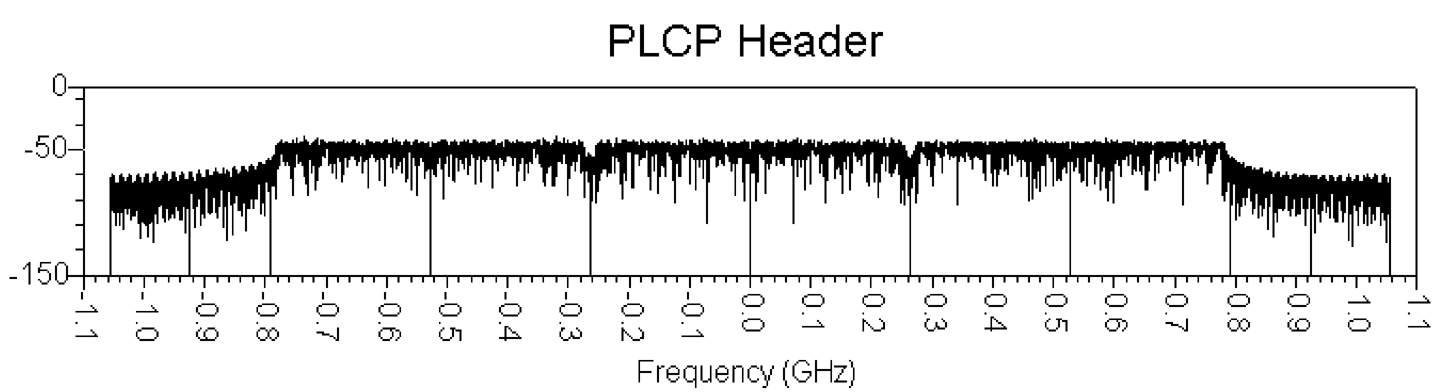


RF Signal PLCP Header Envelope shows Header is 3.75 μ lasting from 9.375 to 13.125 μ. The spectrum is shown in RF Signal PLCP Header Spectrum.

RF Signal PLCP Header Envelope

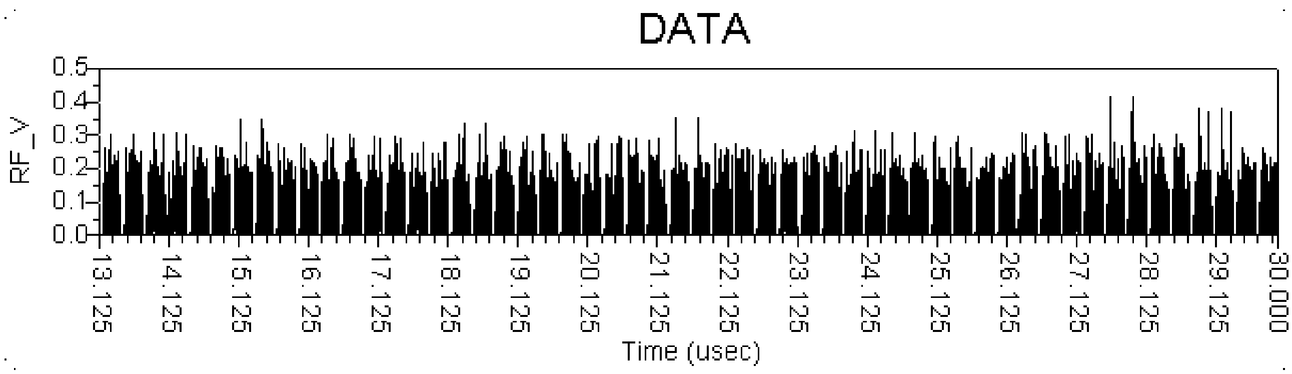


RF Signal PLCP Header Spectrum

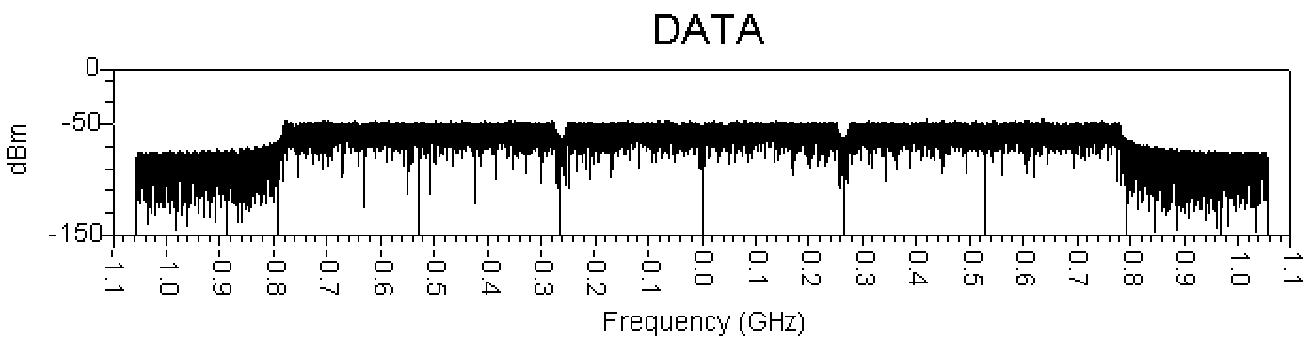


RF Signal DATA Envelope shows Data is 16.875 μ lasting from 13.125 to 30.0 μ. The spectrum is shown in RF Signal DATA Spectrum.

RF Signal DATA Envelope

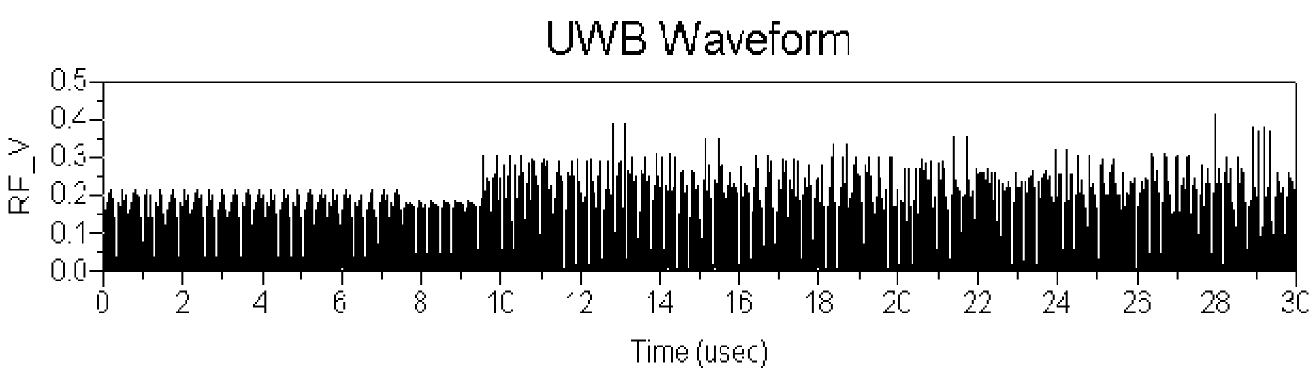


RF Signal DATA Spectrum

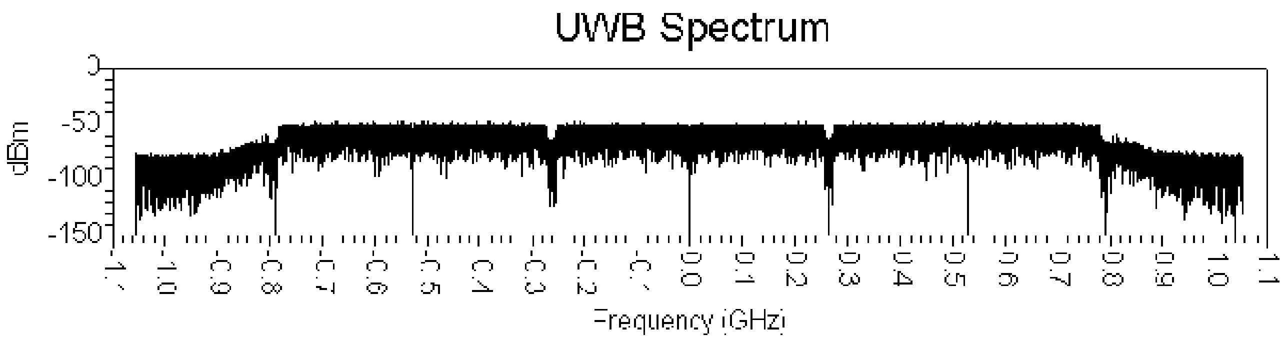


For the Meas signal test, all measurements are the same as RF signal measurements, except the Meas signal will contain any linear and nonlinear distortions. Envelope and spectrum measurements for Meas signal are shown in the following eight figures.

Time Envelope of UWB Meas Signal for Default Settings (one frame)

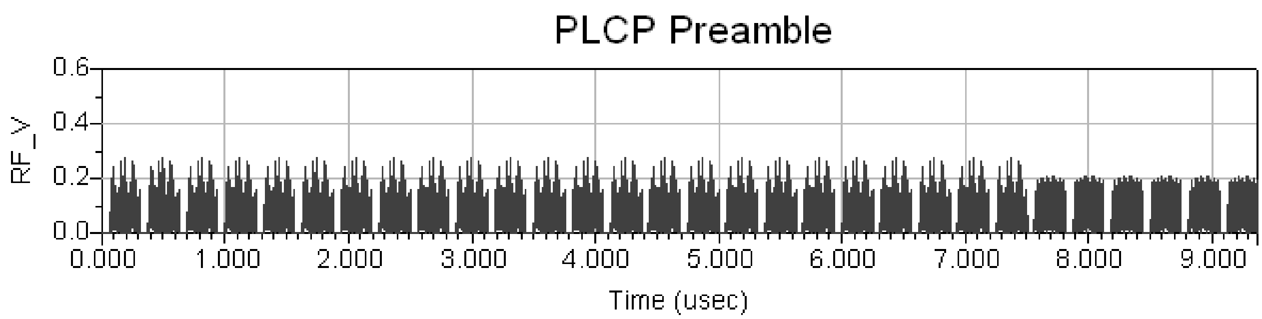


Spectrum of UWB Meas Signal

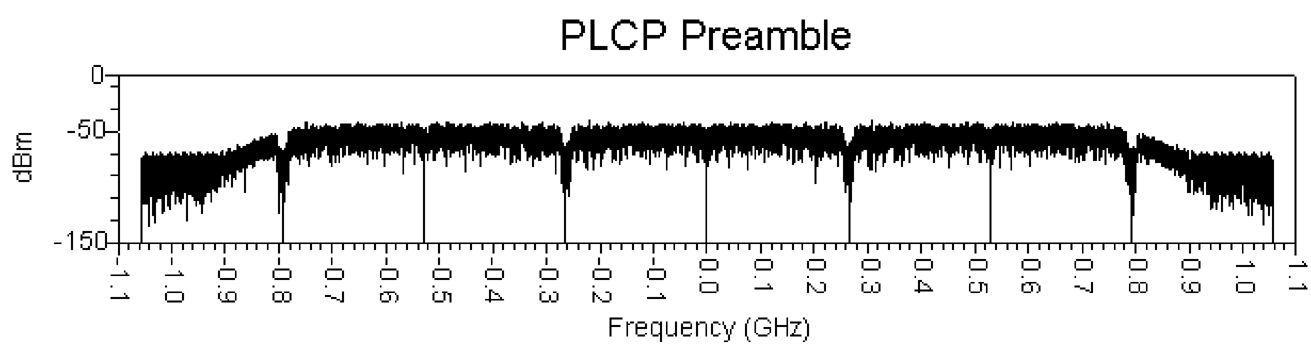


Meas Signal PLCP preamble Envelope shows the Preamble is 9.375 μ lasting from 0 to 9.375 μ. The spectrum is shown in Meas Signal PLCP preamble Spectrum.

Meas Signal PLCP preamble Envelope

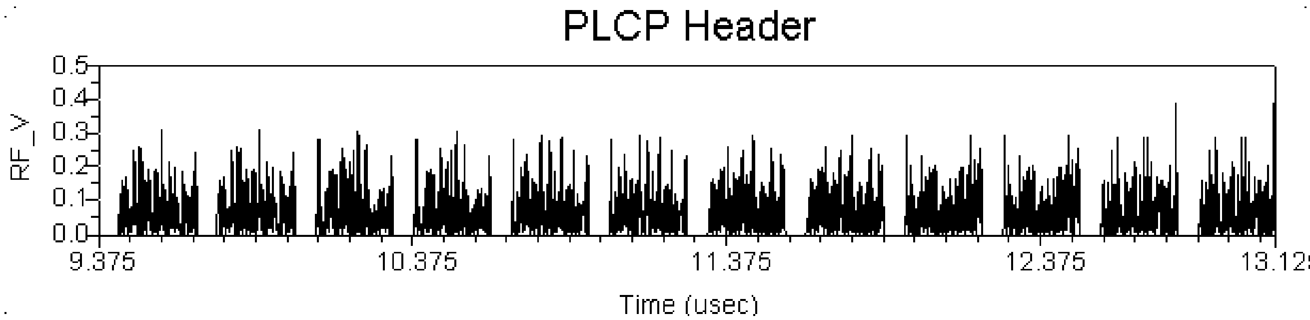


Meas Signal PLCP preamble Spectrum

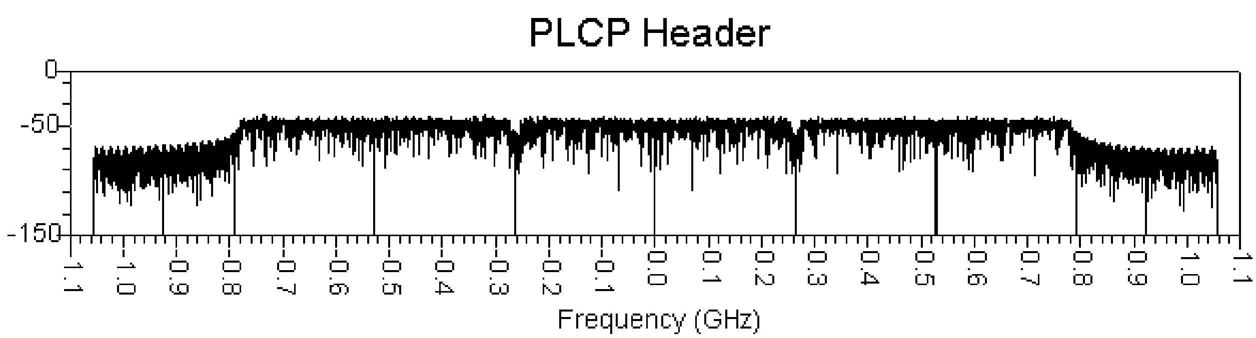


Meas Signal PLCP Header Envelope shows Header is 3.75 μ lasting from 9.375 to 13.125 μ. The spectrum is shown in Meas Signal PLCP Header Spectrum.

Meas Signal PLCP Header Envelope

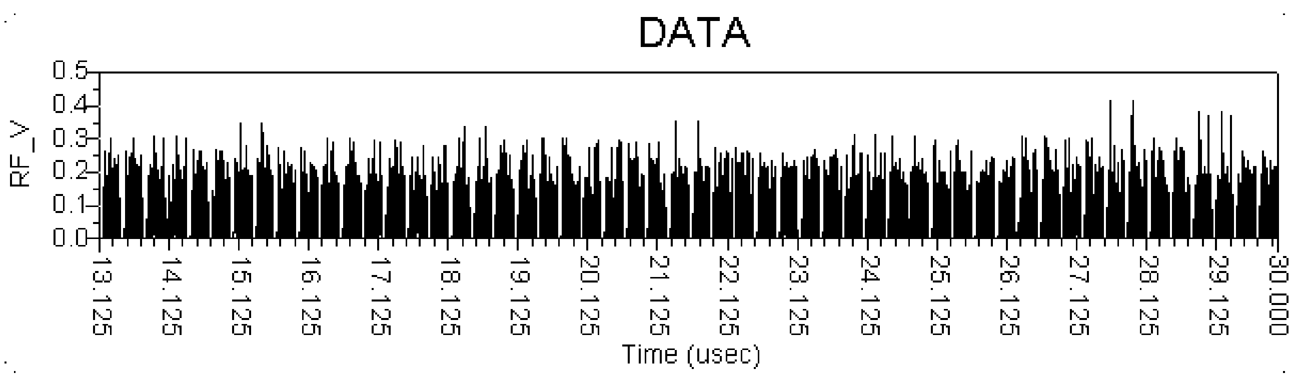


Meas Signal PLCP Header Spectrum

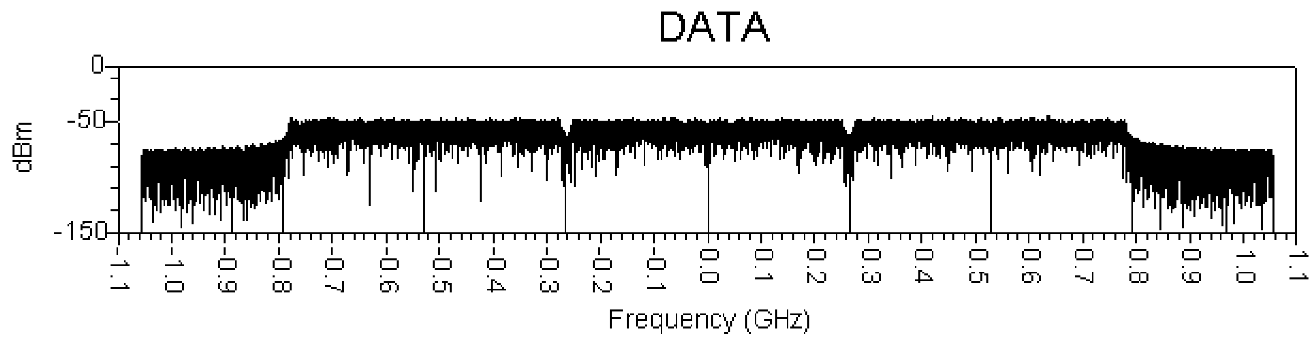


Meas Signal DATA Envelope shows Data is 16.875 µ lasting from 13.125 to 30.0 µ. The spectrum is shown in Meas Signal DATA Spectrum.

Meas Signal DATA Envelope



Meas Signal DATA Spectrum



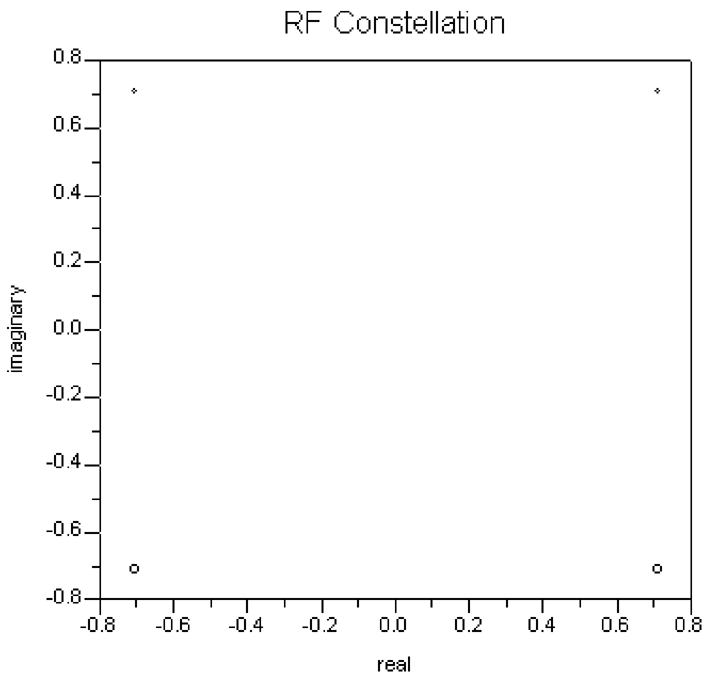
Constellation Measurement

The constellation measurement shows the RF and Meas signal constellations.

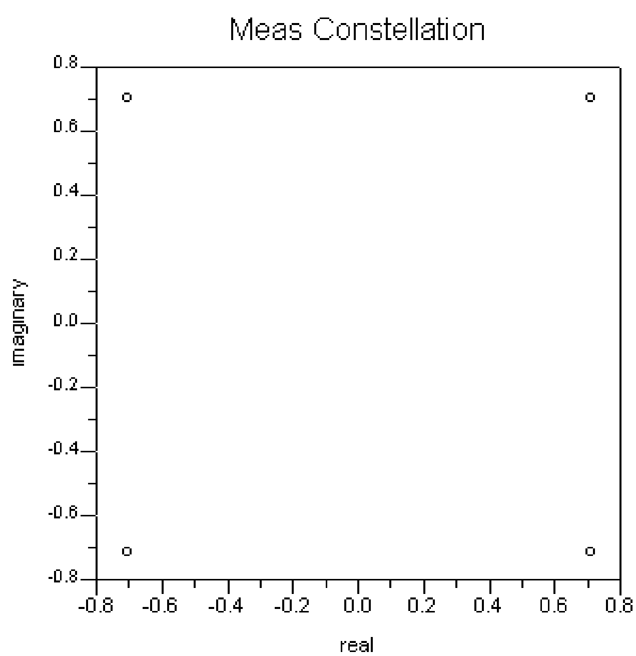
According to Reference 1, only QPSK modulation is implemented. The default data rate of 53.3 Mbps is used for this measurement.

Default Constellation Measurement Parameters

Parameter	Default Setting
RF_FSource	3960.0 MHz
RF_R	50.0 Ohm
frameTime	30.0 usec
TimeStep	0.473 nsec
BitRate	53.3 Mbps
Meas_FMeasurement	3960.0 MHz
Meas_R	50.0 Ohm



RF Signal Constellation



Meas Signal Constellation

Power Measurement

The power measurement shows the CCDF curves of the transmitter and peak-to-average ratios for the RF and Meas signals.

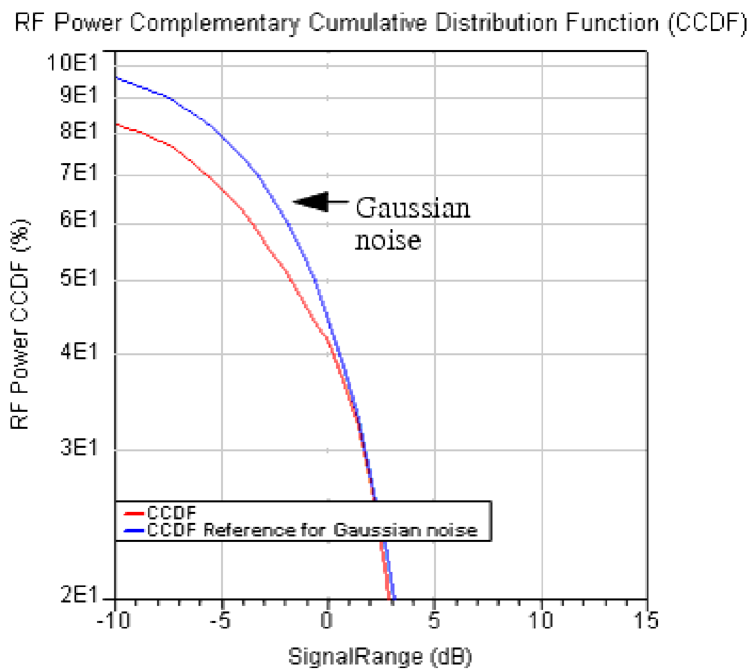
The basic power measurement parameters are listed in the following table.

Parameter	Default Setting
RF_FSource	3960.0 MHz
RF_R	50.0 Ohm
Meas_FMeasurement	3960.0 MHz
Meas_R	50.0 Ohm
RF_Power_dBm	-9.9 dBm

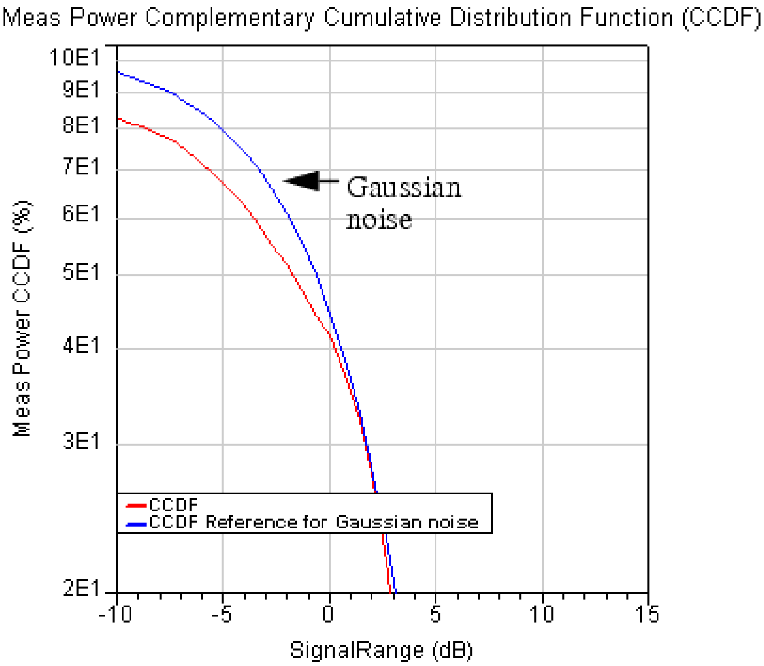
CCDF measurement results for RF and Meas signals are shown in RF Power CCDF and Meas Power CCDF.

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

RF Power CCDF



Meas Power CCDF



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

RF Signal Peak-to-Average-Ratio and Results

RF_Power.PeakPower_dBm	RF_Power.MeanPower_dBm	RF_Peak_to_Avg_dB
-0.222	-9.806	9.584

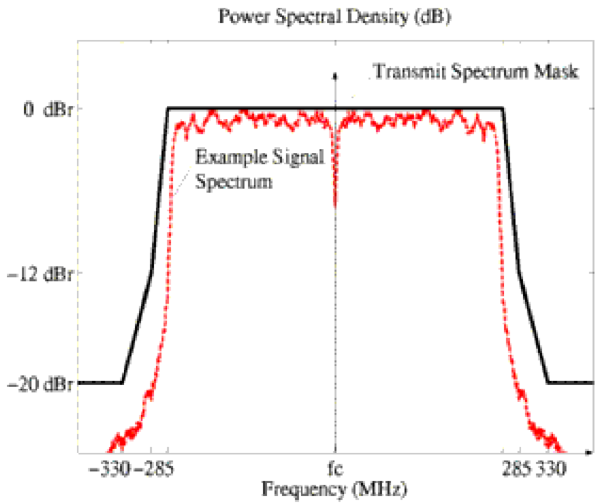
Meas Signal Peak-to-Average-Ratio Results

Meas_Power.PeakPower_dBm	Meas_Power.MeanPower_dBm	Meas_Peak_to_Avg_dB
-0.222	-9.806	9.584

Spectrum Measurement

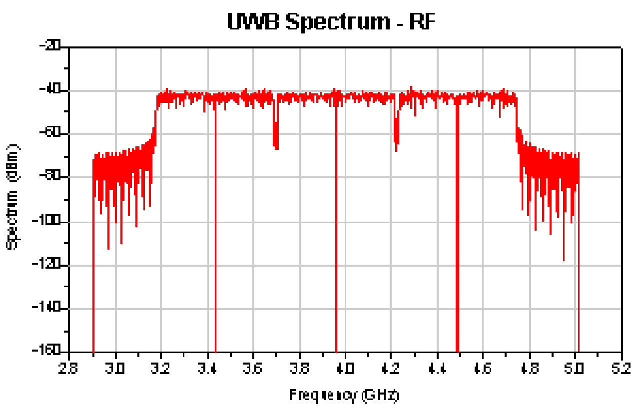
The Spectrum measurement is used to verify that the transmitted spectrum meets the spectrum mask according to Reference 1. The transmitted spectrum shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth not exceeding 260 MHz, -12 dBr at 285 MHz frequency offset, -20 dBr at 330 MHz frequency offset and above. The transmitted spectral density must fall within the spectral mask, as shown in Transmit Spectrum Mask.

Transmit Spectrum Mask

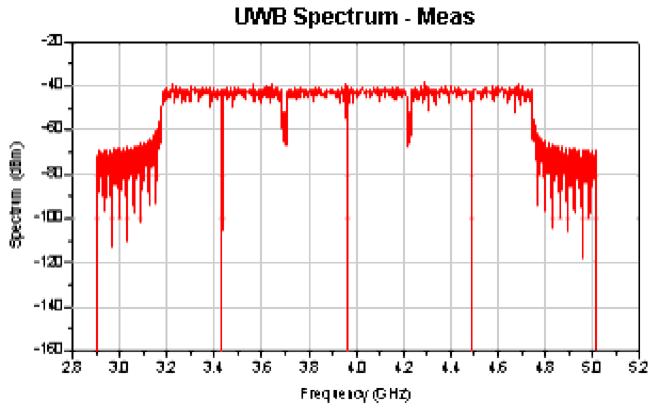


[RF Signal Spectrum](#) and [Meas Signal Spectrum](#) show the power spectrum density of the UWB multi-band signals. Measurement results for RF and Meas signals at Band 2, together with the FCC mask, are shown in [RF Signal Spectrum for Band 2](#) and [Meas Signal Spectrum for Band 2](#). The RF and Meas signal spectrums are within the spectrum mask and therefore meet specification requirements.

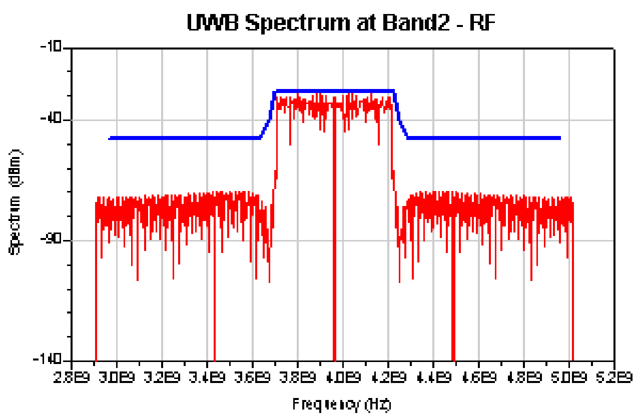
RF Signal Spectrum



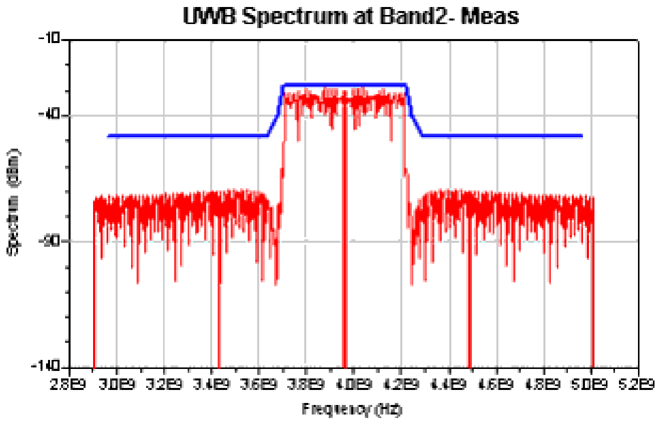
Meas Signal Spectrum



RF Signal Spectrum for Band 2



Meas Signal Spectrum for Band 2



EVM Measurement

The EVM measurement is a modulation accuracy measurement. Basic parameters for this measurement are listed in the following table.

Parameter	Default Setting
RF_FSource	3960.0 MHz
RF_R	50.0 Ohm
frameTime	30.0 usec
TimeStep	0.473 nsec
BitRate	53.3 Mbps
Meas_FMeasurement	3960.0 MHz
Meas_R	50.0 Ohm

EVM measurement results shown in 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_dB	RF_EVM_Percentage
-226.149178	4.926530E-10

Meas Signal EVM

Meas_EVM_dB	Meas_EVM_Percentage
-226.149167	4.926536E-10

Test Bench Variables for Data Displays

Variables listed in the following table are used to set up this test bench and data displays.

Data Display Parameter	Equation with Test Bench Parameters
RF_FSource	FSource
RF_Power_dBm	10*log10(SourcePower)+30
RF_R	SourceR
TimeStep	1/Bandwidth/(2^OversamplintOption)
N_Sym_Preamble	Number of OFDM symbols in preamble. Standard preamble: 30; Shortened preamble: 18
N_Sym_Header	Number of OFDM symbols in header after time-domain spreading. N_Sym_Header=12
UsefulBits	DataLength*8+32+6
N_Sym_Data	Number of OFDM symbols in PSDU before time-domain spreading. N_Sym_Data=6/TSF*ceil(ceil(UsefulBits/CodingRate)/(6/TSF*N_CBPS))
SymbolsPerFrame	N_Sym_Data*TSF+N_Sym_Header+N_Sym_Preamble
DataTime	OFDM_SymbolsPerframe*OFDM_SymbolTime
FrameTime	T_Sym*SymbolsPerFrame
BitRate	Dependent on DataRate
Meas_FMeasurement	FMeasurement
Meas_R	MeasR

Baseline Performance

- Test Computer Configuration
  - Pentium IV 2.26 GHz, 1024 MB RAM, Windows 2000
- Conditions
  - Measurements made with default test bench settings.
  - RF DUT is an RF system behavior component.
  - Length of one UWB frame is a function of Bandwidth, OversamplingOption, IdleInterval, GuardInterval, DataRate, and DataLength.
    Bandwidth = 528 MHz
    OversamplingOption = 2 for Ratio 4
    IdleInterval=0 μ
    T_Sym=312.5 nsec
    CyclicPrefix=70.08 nsec
    GuardInterval = 0.0 nsec
    DataRate = 53.3 Mbps
    DataLength = 100
  - Resultant WTB_TimeStep = 0.473 nsec; frameTime = 30 μ
- Simulation times:

UWB_TX Measurement	Simulation Time (sec)	ADS Processes(MB)
RF_Envelope	681	122
Constellation	676	122
Power	1300	165
Spectrum	689	122
EVM	676	122

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. "Multiband OFDM Physical Layer Specification", WiMedia Alliance document, Release 1.1, July 14, 2005.

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.