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HSUPA Wireless Test Benches

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HSUPA User Equipment Transmitter Test

Introduction

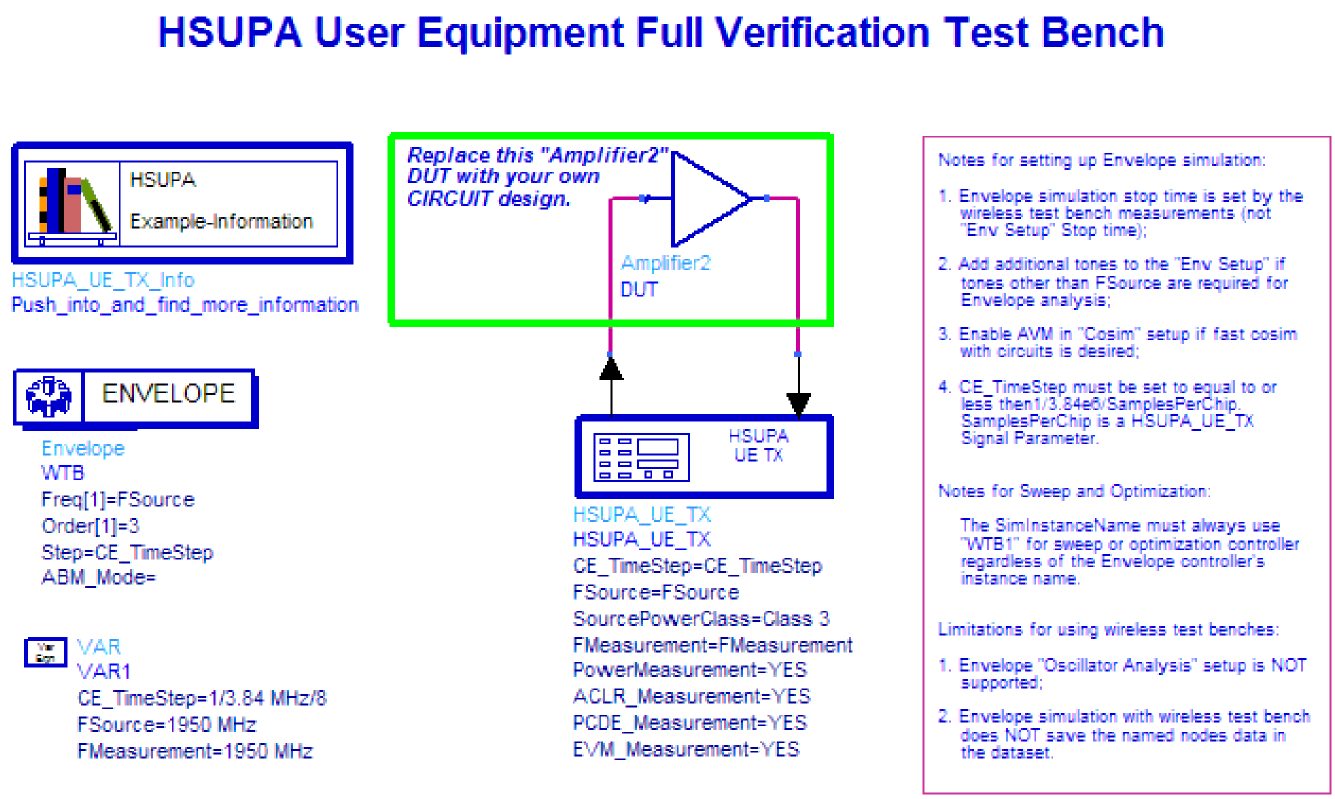
The HSUPA_RF_Verification_wrk workspace shows how to build an application that can be used as a Wireless Test Bench (WTB) and includes a special *Summary* data display page.

There is only one schematic design, HSUPA_UE_TX_test, under the HSUPA_RF_Verification_wrk. Currently, this design covers four basic 3GPP/HSUPA user equipment transmitter measurements. They are:

- Maximum power measurements
- Adjacent channel leakage power ratio (ACLR) measurements
- Peak code domain error (PCDE) measurements
- Error vector magnitude (EVM) measurements
  The DUT output signal can be sent to an Agilent ESG RF signal generator.

Test Bench Basics

The test bench schematic is shown in HSUPA_UE_TX Schematic.



HSUPA_UE_TX Schematic

HSUPA_UE_TX_test provides these features:

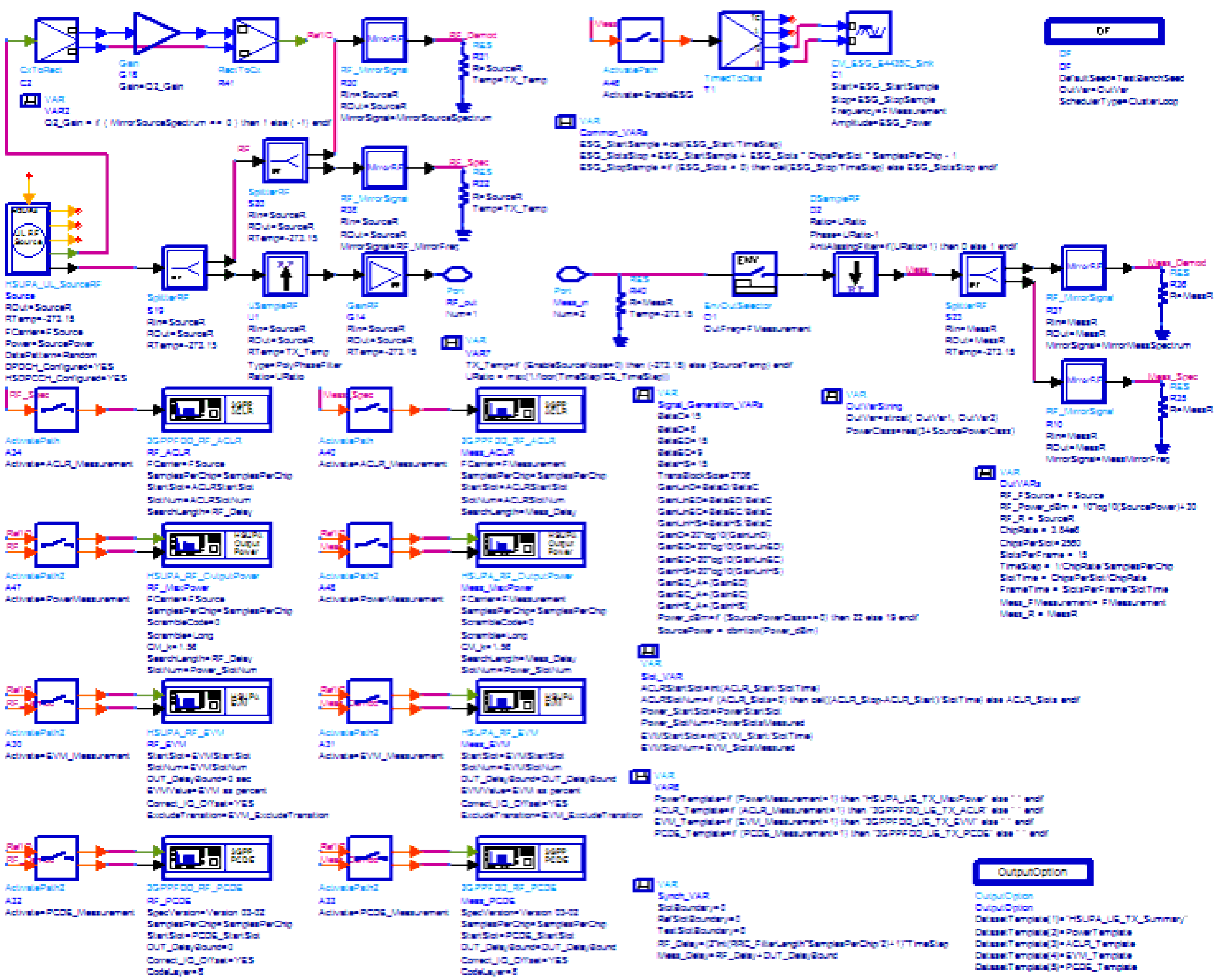
- WTB style
- subnetwork model HSUPA_UE_TX including both signal source and measurements
- various measurements
- analog/RF design schematic
- Envelope/WTB co-simulation
- Agilent ESG RF signal generator connectivity

This design measures four user equipment transmitter characteristics (Maximum Power, ACLR, PCDE, and EVM). By turning on/off certain measurements, any combination of said four measurements can be completed in just one simulation.

Test Bench Details

HSUPA_UE_TX is used to generate an RF uplink signal and complete the measurements; the schematic for this subnetwork model is shown in HSUPA_UE_TX Schematic; parameters are listed in Parameter Table of HSUPA_UE_TX.

HSUPA User Equipment Full Verification Test Bench



HSUPA_UE_TX Schematic

HSUPA_UE_TX

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

Description HSUPA user equipment TX test

Library
Class
Derived From

Parameters

Parameter Table of HSUPA_UE_TX

Name	Description	Default	Type	Unit	Range
Required Parameters					
CE_TimeStep	Circuit envelope simulation time step	1/3.84 MHz/8	real	sec	(0:inf)
WTB_TimeStep	Set CE_TimeStep <= 1/3.84e6/SamplesPerChip. SamplesPerChip is in Signal Parameters tab/category.				
FSource	Source carrier frequency	1950 MHz	real	Hz	(0:inf)
SourcePowerClass	Source power class: Class 3, Class 4	Class 3	enum		
FMeasurement	Measurement carrier frequency	1950 MHz	real	Hz	(0:inf)
MeasurementInfo	Available Measurements Each measurement has parameters on its tab/category below.				
PowerMeasurement	Enable power measurement?: NO, YES	YES	enum		
ACLR_Measurement	Enable ACLR measurement?: NO, YES	NO	enum		
PCDE_Measurement	Enable peak code domain error measurement?: NO, YES	NO	enum		
EVM_Measurement	Enable EVM measurement?: NO, YES	NO	enum		

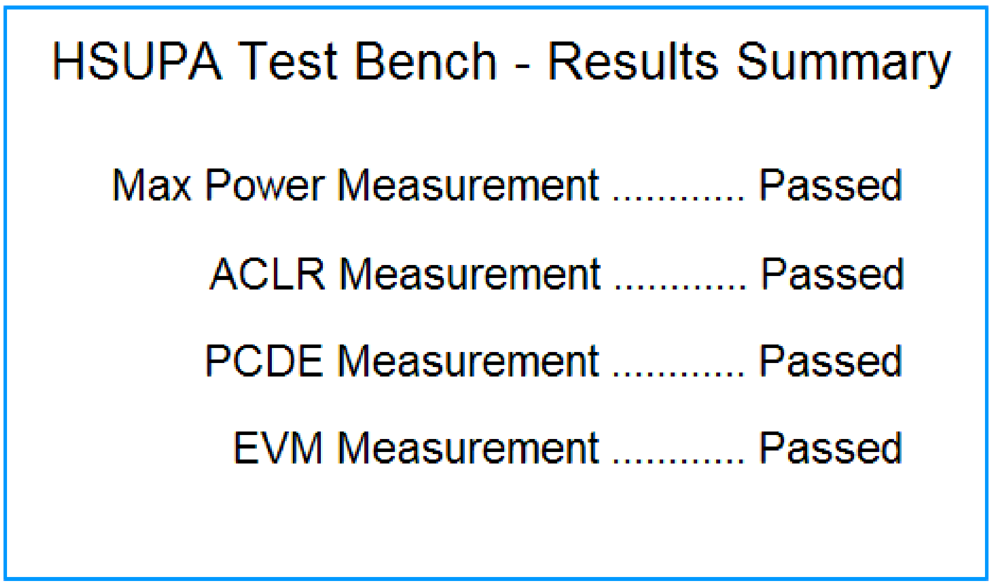
Basic Parameters					
SourceR	Source resistance	50 Ohm	real	Ohm	(0:inf)
SourceTemp	Source resistor temperature	-273.15	real	Celsius	[-273.15:inf)
EnableSourceNoise	Enable source thermal noise?: NO, YES	NO	enum		
MeasR	Measurement resistance	50 Ohm	real	Ohm	[10:1.0e6]
MirrorSourceSpectrum	Mirror source spectrum about carrier?: NO, YES	NO	enum		
MirrorMeasSpectrum	Mirror meas spectrum about carrier?: NO, YES	NO	enum		
RF_MirrorFreq	Mirror source frequency for spectrum/envelope measurement?: NO, YES	NO	enum		
MeasMirrorFreq	Mirror meas frequency for spectrum/envelope measurement?: NO, YES	NO	enum		
DUT_DelayBound	DUT delay bound	10.0 usec	real	sec	[0:(400.0/ 3840000)]
TestBenchSeed	Random number generator seed	1234567	int		[0:inf)
Signal Parameters					
GainImbalance	Gain imbalance, Q vs I	0.0	real	dB	(-inf:inf)
PhaseImbalance	Phase imbalance, Q vs I	0.0	real	deg	(-inf:inf)
I_OriginOffset	I origin offset (percent)	0.0	real		(-inf:inf)
Q_OriginOffset	Q origin offset (percent)	0.0	real		(-inf:inf)
IQ_Rotation	IQ rotation	0.0	real	deg	(-inf:inf)
SamplesPerChip	Samples per chip	8	int		[2:32]
RRC_FilterLength	RRC filter length (chips)	16	int		[2:128]
Power Measurement Parameters					
PowerDisplayPages	Power measurement display pages: 3GPPFDD_UE_TX_Power Equations 3GPPFDD_UE_TX_Power Table 3GPPFDD_UE_TX_Power Figures				
PowerStartSlot	Start slot	0	int		[0:inf)
PowerSlotsMeasured	Slots measured	5	int		[0:inf)
ACLR_Measurement Parameters					
ACLR_DisplayPages	ACLR measurement display pages: 3GPPFDD_UE_TX_ACLR Equations 3GPPFDD_UE_TX_ACLR Table 3GPPFDD_UE_TX_ACLR Figures				
ACLR_Start	Measurement start	0.0	real	sec	[0:inf)

ACLR_Stop	Measurement stop	(2560/3.84) usec	real	sec	(0:inf)
ACLR_Slots	Measurement slots	0	int		[0:100]
ACLR_SpecMeasResBW	Spectrum resolution bandwidth	0	real	Hz	[0:inf)
ACLR_SpecMeasWindow	Window type: ACLR_none, ACLR_Hamming 0.54, ACLR_Hanning 0.50, ACLR_Gaussian 0.75, ACLR_Kaiser 7.865, ACLR_8510 6.0, ACLR_Blackman, ACLR_Blackman-Harris	ACLR_none	enum		
PCDE_Measurement Parameters					
PCDE_DisplayPages	PCDE measurement display pages: 3GPPFDD_UE_TX_PCDE Equations 3GPPFDD_UE_TX_PCDE Table 3GPPFDD_UE_TX_PCDE Figures				
PCDE_StartSlot	Start slot	0	int		[0:inf)
EVM_Measurement Parameters					
EVM_DisplayPages	EVM measurement display pages: 3GPPFDD_UE_TX_EVM Equations 3GPPFDD_UE_TX_EVM Table				
EVM_Start	Measurement start	0.0	real	sec	[0:inf)
EVM_SlotsMeasured	Slots to measure	1	int		[0:inf)
EVM_ExcludeTransition	select YES for predictable power changes: NO, YES	NO	enum		
SignalToESG_Parameters					
EnableESG	Enable signal to ESG?: NO, YES	NO	enum		
ESG_Instrument	ESG instrument address	[GPIB0::19::INSTR][4790]	instrument		
ESG_Start	Signal start	0.0	real	sec	[0:inf)
ESG_Stop	Signal stop	(2560/3.84) usec	real	sec	[(ESG_Start+60/3.84e6/S):(ESG_Start+32/3.84/S)]
ESG_Slots	Slots to ESG	15	int		[0:1000]
ESG_Power	ESG RF output power (dBm)	-20.0	real		(-inf:inf)
ESG_ClkRef	Waveform clock reference: Internal, External	Internal	enum		
ESG_ExtClkRefFreq	External clock reference freq	10 MHz	real	Hz	(0:inf)
ESG_IQFilter	IQ filter: through,	through	enum		

	filter_2100kHz, filter_40MHz				
ESG_SampleClkRate	Sequencer sample clock rate	30.72 MHz	real	Hz	(0:inf)
ESG_Filename	ESG waveform storage filename	HSUPA_UL	string		
ESG_AutoScaling	Activate auto scaling?: NO, YES	YES	enum		
ESG_ArbOn	Select waveform and turn ArbOn after download?: NO, YES	YES	enum		
ESG_RFPowOn	Turn RF ON after download?: NO, YES	YES	enum		
ESG_EventMarkerType	Event marker type: Neither, Event1, Event2, Both	Event1	enum		
ESG_MarkerLength	ESG marker length	10	int		[1:60]

Simulation Measurement Displays

After running the simulation, results are automatically displayed in data display pages. The measurement data display templates corresponding to the selected measurements will also appear in the data display window.
This test bench also provides a *Results Summary* data display template that will appear in the data display window similar to the example shown in User Equipment Transmitter Test Bench - Summary.



User Equipment Transmitter Test Bench - Summary

The summary display page gives a *Passed / Failed* overview of the test results. For a deactivated measurement, *N/A* will be displayed.
Detailed measurement results pages can be accessed using the data display window's *Page* menu or toolbar button.

Baseline Performance

Reference simulation time, measured on a Pentium III/866M 384M PC running ADS 2005A on Microsoft Windows 2000:

- about 1.5 minutes for maximum output power measurement
- about 2 minutes for ACLR measurement
- about 2 minutes for PCDE measurement
- about 2 minutes for EVM measurement

References

1. 3GPP Technical Specification TS 25.101, "UE Radio transmission and Reception (FDD)," Version 6.11.0, Mar. 2006.

Measurement Results for Expressions for HSUPA 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))`
  HSUPA UE TX Measurement Results (adswtb3g) lists 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.

HSUPA UE TX Measurement Results

Measurement Results Name	Independent Variable Name
PCDE	
HSUPA_UE_TX.RF_PCDE.CodeDomainErr.I_CDE	Index
HSUPA_UE_TX.Meas_PCDE.CodeDomainErr.I_CDE	Index
HSUPA_UE_TX.RF_PCDE.CodeDomainErr.Q_CDE	Index
HSUPA_UE_TX.Meas_PCDE.CodeDomainErr.Q_CDE	Index
ACLR	
HSUPA_UE_TX.RF_ACLR	Index
HSUPA_UE_TX.Meas_ACLR	Index
Power	
HSUPA_UE_TX.RF_MaxPower.MPR	Index
HSUPA_UE_TX.Meas_MaxPower.MPR	Index
HSUPA_UE_TX.RF_MaxPower.CM	Index
HSUPA_UE_TX.Meas_MaxPower.CM	Index
HSUPA_UE_TX.RF_MaxPower.Power	Index
HSUPA_UE_TX.Meas_MaxPower.Power	Index
EVM	
HSUPA_UE_TX.RF_EVM.HSUPA_EVM.EVM	Index
HSUPA_UE_TX.Meas_EVM.HSUPA_EVM.EVM	Index
HSUPA_UE_TX.RF_EVM.HSUPA_EVM.Discontinuity	Index
HSUPA_UE_TX.Meas_EVM.HSUPA_EVM.Discontinuity	Index

RF DUT Limitations for HSUPA 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 SamplesPerChip provides adequate wireless signal definition and provides the WTB_TimeStep default value.
- Set CE_TimeStep = 1/(3.84e6/SamplesPerChip×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.