cādence®

Spectre RF Option

Golden reference for phase noise, foundry certified

The Cadence® Spectre® RF Option is the "golden reference" for analysis of oscillator phase noise. The Spectre RF Option uses the Harmonic Balance method to perform frequency-domain, periodic steady-state (PSS) analysis of RF and millimeter-wave circuits, the Shooting Newton method to perform time-domain, periodic steady-state analysis of analog circuits, and combines these analysis methods with transient analysis for simulation of modulated signals.

Overview

The Spectre RF Option was developed for simulation of high-performance RF circuits providing superior accuracy and performance. As designers' requirements have evolved, the Spectre RF Option's legendary accuracy and performance have been extended to support RFIC designs with the integration of Spectre Accelerated Parallel Simulator [Spectre APS] technology.

The Spectre RF Option provides two engines for PSS analysis. Harmonic Balance analysis is used to calculate the frequency-domain PSS and Shooting Newton analysis is used to calculate the time-domain PSS. These two engines complement each other. For example:

Harmonic Balance analysis is more effective for high-frequency systems, such as:

- Low-noise amplifiers
- Mixers
- Voltage-controlled oscillators
- Power amplifiers
- Circuits containing transmission line components from rfTlineLib and mtline
- Circuits containing components modeled with simulated or measured S-parameters

Shooting Newton analysis is more effective for circuits with:

- Fast-changing time-domain waveforms
- Discrete-time sampling mixers
- Dynamic comparators
- Ring oscillators

From the single-tone or multi-tone PSS large-signal response of the circuit, key parameters related to distortion can be calculated: Intercept point (IIP3), and compression point (P1dB). In addition, the PSS of both driven circuits (such as an LNA) and autonomous circuits (such as an oscillator) can be calculated.

The Spectre RF Option provides an extensive set of small-signal analyses calculated from the PSS operating point, including periodic ac, periodic noise, periodic transfer function, periodic S-parameter, and periodic stability analysis. These analyses can be used in the same way traditional small-signal analysis is used: calculating gain, noise, susceptibility to power supply transients, etc. However, since the periodic operating point is used, the effects of frequency translation are also included in the analyses. Consider a mixer that converts RF signals to baseband frequencies, it also converts high-frequency noise, noise at the RF and local oscillator frequency, into noise at the baseband frequency. This effect is ignored by traditional small-signal noise analysis but is properly accounted for when using periodic noise analysis.

The Spectre RF Option provides Envelope Following analysis. Envelope Following integrates PSS analysis with transient analysis enabling transistor-level simulation of circuits with modulated signals. An accelerated version of Envelope Following called Fast Envelope Following analysis was developed and integrated with the Spectre RF Wireless Testbench to enable verification of a circuit's compliance with wireless standards such as Bluetooth Low Energy.

Spectre RF Analyses

The Spectre RF Option provides a comprehensive solution to your RF simulation challenges from block characterization to full-chip verification. Supported analyses include:

Analysis	Frequency Domain	Time Domain
Operating Point	hb	pss
ac	hbac	pac
noise	hbnoise	pnoise
xf	hbxf	pxf
stability	hbstb	pstb
S-parameters	hbsp	psp
Modulated Signals	Envelope Following	

Simulating Oscillators

Oscillators are autonomous circuits and are challenging because the tool needs to find both the period and the PSS response at the same time. In addition, oscillators need to be analyzed with the ancillary circuitry, for example, output divider for generating quadrature signals, Voltage Reference, and LDO to generate a quiet power-supply voltage. The Spectre RF Option has the performance and capacity to include them in the PSS calculation and oscillator noise analysis has been enhanced to account for their contribution to the overall phase noise of the oscillator.

Simulating Modulated Signals

In real systems, the receiver and transmitter process modulated signals, not sine waves, and designers need to analyze the effect of the modulated signals on the dynamic range of their designs. The Spectre RF Option's Envelope Following analysis allows designers to simulate the effect of amplitude-, frequency-, and phase-modulated signals on the performance of their design. Envelope Following analysis can be used with Wireless Testbenches to verify design compliance with many common wireless standards.

Easier to Use

One challenge for designers when using RF analysis is how to set up the analysis. Until the simulation is run, it is difficult to know how to allow for the transient response to stabilize or how many harmonics the Harmonic Balance analysis needs to achieve accurate results. The Spectre RF Option automates the simulation for designers. Designers just set the Spectre RF Option to use the automatic option and it will monitor the simulation and set up the analysis for the user.

RF Testbench Components

The Spectre RF Option also provides designers a rich set of specialized components for RF design from simple testbench elements such as bias elements and dc blocks. The rfTlineLib provides designers with a library of distributed components such as microstrip elements and bends to model the effect of on-chip interconnect components.

Simulating with S-Parameters

The Spectre nport allows designers to include S-parameter data from measurement data in simulation. Using S-parameters can cause convergence issues due to passivity and causality issues of the data. Cadence's Broadband SPICE® technology has been integrated into the Spectre RF Option. Broadband SPICE eliminates convergence issues and enables simulation of larger nports, that is, S-parameter with a large number of ports. Broadband SPICE is compatible with both the Harmonic Balance and the Shooting Newton engines. The Spectre RF Option's nport also supports convolution-based S-parameter simulation.

ADE Integration

The Spectre RF Option is tightly integrated into the Virtuoso® Analog Design Environment (ADE), to allow designers to focus on design and not spend time on simulation and debugging results. Using the Spectre API integration, Virtuoso ADE directly accesses the Spectre RF Option, eliminating simulation overhead and accelerating simulation time.

Summary Analysis for Noise and Distortion

After simulation, Virtuoso ADE generates summaries of the results from periodic noise analysis and periodic ac distortion analysis. These summaries allow designers to identify the root cause of circuit performance issues and correct them. Using the flat mode, the results are displayed by device and hierarchal mode, or are displayed by block for easy visualization of the bottleneck.

Direct Plot

One of the greatest challenges designers face is understanding the results of simulation. Just looking at waveform data provides little insight into the how the circuit is behaving. Virtuoso ADE provides Direct Plot analysis so designers can easily measure the parameters they want and focus on design. The measurements can be saved to Virtuoso ADE, so they only need to be performed once, after which the results are displayed automatically when the simulation completes.

Re-Usable Testbenches

One of the challenges designers face is setting up and debugging testbenches. Virtuoso ADE allows designers to create re-usable testbenches. Traditionally, Virtuoso ADE has supported design variables, such as fin. Design variables can be used as parameters for components allowing the parameter values to be swept. This capability is an important exploration of the design space. In IC61, design variables can be used for component values and for analysis and outputs. So a designer can create a testbench to characterize an LNA and then use it to simulate three different LNA designs—a 900MHz ISM band design, a 2.4GHz ISM band design, and a 5GHz ISM band design—just by changing the fin design variable. The result is greater productivity: more time spent designing and less time spent simulating and debugging.

Real Time Tuning

Beginning in IC617, Virtuoso ADE Explorer now supports real-time tuning, enabling designers to manually tune schematic values to optimize circuit performance.

Real-time tuning can be used to tune the performance of small linear circuits, such as input-matching networks or impedance transformers.

Advanced Analyses

The Spectre RF Option provides specialized analyses to improve designer productivity and address the complex simulation challenges of advanced RFIC designs.

Perturbation Analysis for Distortion Analysis

Perturbation analysis is an extension of ac small-signal analysis that enables distortion analysis. Perturbation analysis can be performed after either a dc operating-point calculation for linear circuits (such as an LNA), or a periodic operating point for non-linear circuits (such as mxers). Perturbation analysis can be used to calculate either compressive or intermodulation distortion of the circuit. Perturbation analysis is supported by the Virtuoso ADE summary table, allowing designers to identify the components that contribute to distortion. In addition, Perturbation Analysis also supports triple-beat analysis, allowing efficient analysis of distortion due to cross-modulation.

Multi-Divider Harmonic Balance Analysis

Today's advanced RFICs for mobile devices feature multiple receivers, which can result in issues due to LO leakage. In addition to the challenge of simulating circuits with multiple LO signals, these simulations need to include the effect of leakage due to post-layout parasitics, further increasing the challenge. Traditionally, simulators are unable to handle designs with dividers operating at multiple frequencies. However, the Spectre RF Option's Harmonic Balance analysis has been enhanced to support simulation with multiple frequency dividers.

Large-Signal S-Parameter

One of the challenges of power amplifier design has been using S-parameters from small signal analysis to design matching networks. For power amplifiers, the signal levels effect the bias point of the circuit so the small signal S-parameters are not valid. Using the Spectre RF Option's Harmonic Balance analysis, designers can easily configure the analysis to measure the large signal S-parameters of a design.

Voltage-Controlled Oscillator Tuning Mode

Typically, voltage-controlled oscillators are characterized at user-specified frequency by specifying an input voltage. However, this approach does not work when characterizing the effect of variation on the circuit, such as performing Monte Carlo or corner analysis because the input voltage level needs to be adjusted for each simulation. The Spectre RF Option's Voltage-Controlled Oscillator Tuning mode allows the user to specify the frequency to characterize the voltage-controlled oscillator. Then tuning mode will adjust the input voltage to set the voltage-controlled oscillator to oscillate at the target frequency, simplifying the task of characterizing the effect of process variation on the design.

nDB Compression Point Analysis

The Spectre RF Option's Harmonic Balance analysis has been enhanced to speed-up compression point analysis. Instead of using a fixed step for the input power level, the Spectre RF Option uses nDB compression point analysis to search for the compression point. As a result, compression-point simulation time can be significantly reduced compared to simulating with a fixed-input power step size.

Jitter Analysis

When designing many communication systems, the designers want to know the jitter of their circuit. The Spectre RF Option's pnoise and hbnoise analysis have been enhanced to calculate jitter from the oscillator noise analysis results.

Semi-Autonomous Harmonic Balance Analysis

Traditionally, designers have been able to analyze the response of driven circuits (such as an LNA) or autonomous circuits (such as oscillators). However, there are times when designers would like to analyze mixed systems, that is, systems with both autonomous behavior and driven inputs. The Spectre RF Option's Harmonic Balance analysis has been enhanced to support semi-autonomous harmonic balance analysis. Semi-autonomous harmonic balance analysis is able to simulate circuits containing both oscillators and driven inputs.

Wireless Testbench

In the past, RF designers have focused on block-level design and left system integration and validation to the system designers. However, as the level of integration has increased, RF designs are now designing integrated transceivers. As a result, RF designers are now responsible for verifying that their design is compliant with wireless standards. This verification brings many challenges, in particular, how to setup the simulation properly to achieve accurate results. The solution is the the Spectre RF Option's Wireless Testbench. The Wireless Testbench allows designers to add a signal source and signal probes to their schematic and define the measurements they would like to perform. From there, the Spectre RF Option will automatically configure the simulation for the measurement. The Virtuoso waveform browser has been enhanced to display results like ACPR with spectral mask. The Wireless Testbench allows RF designers to verify compliance with standards without having to become system engineers. Supported standards include:

- Zigbee
- IEEE 802.11a
- IEEE 802.11b
- IEEE 802.11n
- IEEE 802.11ac
- IEEE 802.11af
- IEEE 802.11p
- Bluetooth (LE and HS)
- Smart meter
- LTE

Foundry Support

The Spectre RF Option is supported by all major foundries. Customers can receive certified device models from foundries by request.

Device Models

The Spectre RF Option supports a wide variety of device models for devices from 600V GaN transistors to 10nm FinFETS. Cadence is a member of the Compact Modeling Council and invests significant effort in support and development of open models. Supported models include:

- MOSFET models, including latest versions of BSIM3, BSIM4, BSIM6, PSP102, PSP103, HISIM, MOS9, MOS11, and EKV
- FinFET: BSIMCMG
- Silicon-on-insulator (SOI) models including latest versions of BSIMSOI, SSIMSOI, BTASOI, and HiSIM SOI
- FDSOI: BSIM-IMG and UTSOI
- High-voltage MOSFET models, including latest versions of HVMOS and HiSIM HV
- PSpice® IGBT and HiSIM IGBT models
- TMI model support from TSMC
- Bipolar junction transistor (BJT) models, including latest versions of VBIC, HICUM L0, HICUM L2, Mextram, HBT, and Gummel-Poon model
- GaAs MESFET models, including latest versions of GaAs, TOM2, TOM3, and Angelov
- Rensselaer Polytechnic Institute (RPI)'s P-Si and a-Si Thin-Film Transistor models
- Diode, JFET, FinFET, and flash cell models
- Users can create their own custom device models, or modify existing device models using Verilog-A compact device modeling
- Specialized reliability models (AgeMOS) for HCI and NBTI analysis are also supported

Supported Platforms (update for 15.1)

x86 32-bit and 64-bit: Redhat RHEL Linux V5, V6, and V7 SUSE SLES Linux 11

Licensing

The Spectre RF Option is enabled by either the standalone Spectre Classic license with a RF simulation option license or by using the Multi-Mode Simulation [MMSIM] license.

Cadence Services and Support

- Cadence application engineers can answer your technical questions by telephone, email, or Internet—they can also provide technical assistance and custom training
- Cadence certified instructors teach more than 70 courses and bring their real-world experience into the classroom
- More than 25 Internet Learning Series (iLS) online courses allow you the flexibility of training at your own computer via the Internet
- Cadence Online Support gives you 24x7 online access to a knowledgebase of the latest solutions, technical documentation, software downloads, and more
- For more information, please visit www.cadence.com/support-and-training.