From May 2009 *High Frequency Electronics*

Behavioral Models Improve Accuracy in Simulation and Linearization

By Gary Breed
Editorial Director

Behavioral models use measurements to create complete and accurate characterization of circuits and subsystems

Computer simulation of high frequency circuits and systems requires accurate models. When designing circuits, the component models are most important. When a circuit "module" is completed, its overall behavior may become a subsystem model. This subsystem characterization enables fast simulation and analysis of a larger system. At all levels, the simulation relies on accurate models.

Analytical Models

In our early EE classes, we learn basic component behavior as simple equations. For computer simulation, those equations are modified and expanded to include the parasitic resistances and reactances that have increasing effects at higher frequencies. These theory-based component models are *analytical models*, which are quickly and easily solved by mathematical computation. Developing such models involves comparing the transfer function with the actual behavior of the device and adapting the equivalent circuit until there is acceptable agreement. However, the model is still an equation or set of equations.

Behavioral Models

Complex circuits, especially those with nonlinear characteristics, may be difficult to represent by a set of equations. In these cases, a *behavior model* can be created, based on measured data taken over a sufficient range of operating parameters—voltage, bias, temperature, frequency, signal level, etc.

The need for behavioral models arises from two things: the need for accurate characterization of devices that cannot be described by straightforward analytical modeling, and the ability to characterize entire circuits or subsystems, which enables them to be handled as a single "building block" in system simulation.

The earliest use of behavioral modeling was the collection of S parameter data that manufacturers provided for RF/microwave transistors. This type of device characterization was later extended to passive components, then entire circuits or subsystems. Today, behavioral modeling may even be used without measurements—using data derived from highly accurate (but slow) electromagnetic simulation.

A behavioral model is a matrix of data points that represent the device in computer simulation. In some cases, point-by-point data will result in computations that are considered too slow. In these cases, mathematical techniques such as curve-fitting may be used to convert all or part of the data into a system of equations for faster computation. As an example, power amplifier linearization techniques benefit from behavioral modeling, but require real-time calculation speeds. In particular, digital predistortion techniques require the determination of amplifier behavior over all anticipated operating conditions in order to modify the input signal in a way that compensates for the amplifier's nonlinearities.

In summary, behavioral models are required when equivalent circuit analytical models cannot adequately represent the component or circuit, due to nonlinearities or compexity. They provide an accurate model of actual performance that allows higher computation speeds—and faster simulation results.