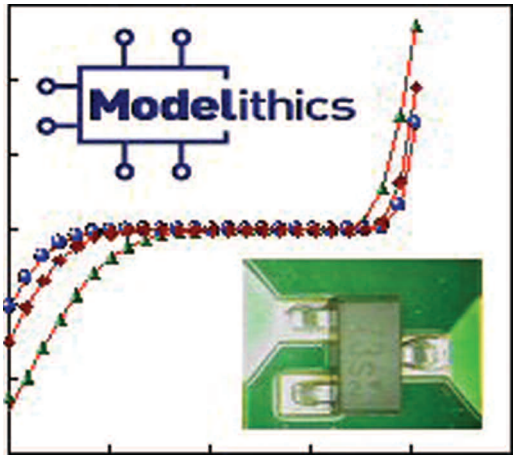
Microwave Journal



Nonlinear Diode Models for Enhanced Simulation Accuracy

A library of robust models featuring substrate scalability and temperature dependence is now available for surface-mount diodes. The Modelithics Nonlinear Diode (NLD™) Library contains a compilation of measurement validated nonlinear diode models developed from I-V, C-V, small- and large-signal S-parameter characterization data. Over-temperature testing, combined with Modelithics' patent-pending substrate-scalability features, extends the accuracy of nonlinear simulations over a wide range of assembly and operating conditions. No other set of diode models contains the same high levels of validation, accuracy, range of multi-variable applicability and documentation. The NLD Library is currently available in design kit format for Agilent's Advanced Design System (ADS™).

The range of validity for any model used in electronic design automation (EDA) software depends on the internal topology and the types of characterization data from which it is extracted. Models in the NLD Library use proprietary, physically-motivated equivalent circuit topologies that correctly emulate device performance over DC bias, RF drive level and temperature. Extensive IV and CV data sets acquired using an automated Keithley 4200-SCS test system are used in conjunction with broadband S-parameter measurements made with an Anritsu Lightning VNA. Different novel intrinsic models are used to represent the Schottky, varactor and PIN diodes included in the NLD library.

Accuracy in developing an equivalent circuit model is contingent on representing the intrinsic characteristics of the device and also accounting for the extrinsic effects that arise due to the circuit environment in which the part is mounted. In addition, package-to-substrate coupling effects are included in order to capture variations in performance parameters such as impedance and resonant frequency due to different mounting configurations.

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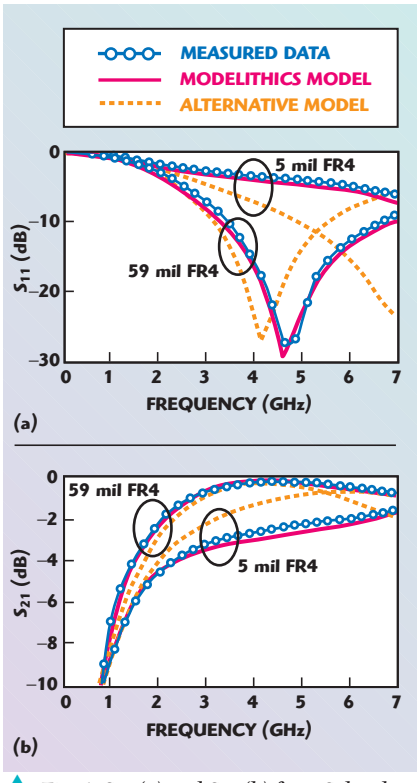

Fig. 1 S_{11} (a) and S_{21} (b) for a Schottky diode biased at 16 V on 5 and 59 mil thick FR4 substrates.

ACCOUNTING FOR SUBSTRATE EFFECTS

The presence of substrate-dependent parasitic effects in the frequency response of surface-mount (SMT) components typically becomes evident above a few- to several-hundred megahertz. These effects are attributable to complex interactions between the part, the package, board and solder pad stacks, and depend on the physical size of the component and the internal package configuration. (For a discussion of such effects on RLC passive SMT components see "Comprehensive Models for RLC Components to Accelerate PCB Designs," *Microwave Journal*, May 2004.)

An accurate model of an SMT diode must account for these parasitic effects as well as representing the intrinsic nonlinear behavior of the diode. The models should be capable of scaling all circuit parameters with changes in the substrate height and dielectric constant to increase the versatility of the model. This capability becomes increasingly important in nonlinear simulations involving multiple high frequency harmonics, where the impedance presented to a harmonic can change significantly as a function of substrate type (see ***Figure 1***).

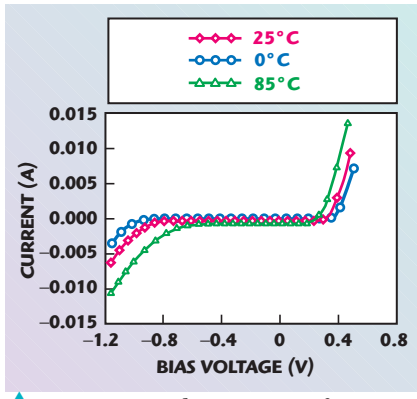

Fig. 2 DC-IV characteristics of a cross-over quad Schottky diode at different temperatures (markers indicate measured data, solid lines are model results).

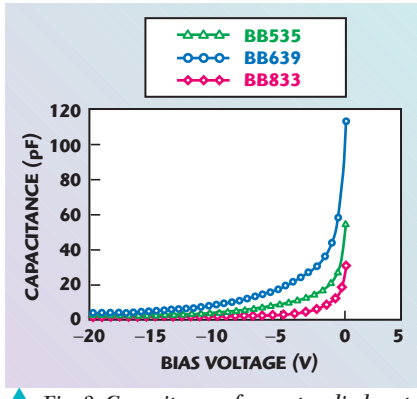

Fig. 3 Capacitance of varactor diodes at 1 MHz (markers indicate measured data, solid lines are model results).

COMPLETE MODEL VERIFICATION

In addition to providing unique substrate-scaling features, each Modelithics model is provided with datasheets to document the model development process, to define each model's range of validity and to provide typical measured-to-modeled comparison graphs. These datasheets fill an important and all too common void in the EDA simulation community — in general a designer has access to little or no information regarding the conditions under which a given model can be used. In this situation the designer may find it necessary to perform his own model verification, or at the very least have less confidence in trusting the model, especially over bias, temperature or power level variations. The Modelithics datasheets specify the test conditions for each model and provide representative measurement-to-model comparisons, such as those shown in ***Figures 2*** and ***3***.

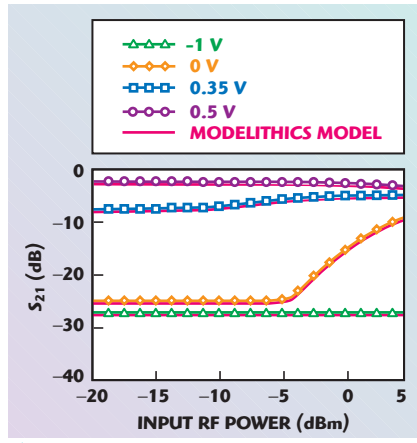

Fig. 4 Large signal S_{21} of a Schottky diode at different bias conditions at 1 GHz (markers indicate measured data).

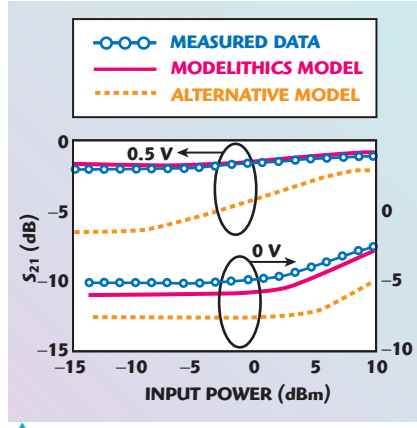

Fig. 5 Large signal swept power characteristics of a PIN diode at 1 GHz.

ACCURATE NONLINEAR PREDICTIONS

Extracting a nonlinear model using a wide set of characterization data types results in a versatile, robust simulation model. In the case of a diode model, I-V, C-V and S-parameters (small- and large-signal) are the most common test data types. If these data sets are fitted appropriately, accurate prediction of power compression (see ***Figures 4*** and ***5***) is an example of how the model can be applied.

The accuracy obtained with nonlinear frequency domain simulations also extends to transient (time domain) simulations. Validation of a PIN diode tested at zero-bias with an input frequency of 1 MHz and input amplitude of 0.5 V is shown in ***Figure 6***. An accurate prediction of the reverse recovery time, defined as the

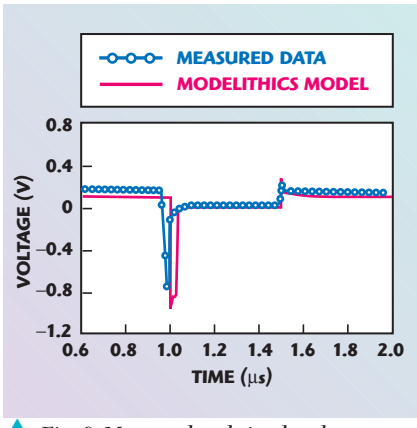

Fig. 6 Measured and simulated output voltage waveforms for a PIN diode at an input bias of 0 V.

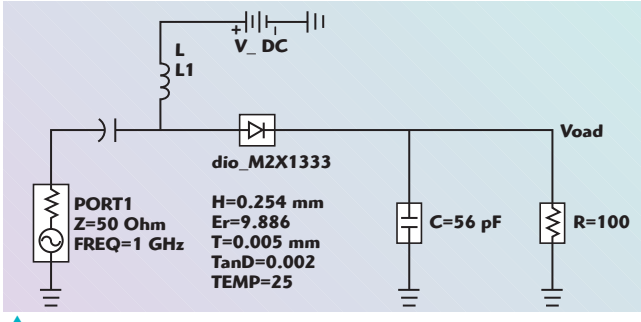

Fig. 7 Schottky diode detector schematic.

time taken to switch between the off and the on states, is illustrated.

DIODE DETECTOR EXAMPLE

A simplified schematic for a diode detector circuit, configured for a nonlinear simulation in ADS, is shown in ***Figure 7***. The combination of C1 and L1 acts as a bias tee and provides a DC return path for the diode. The 56 pF output capacitance presents a low impedance to ground for transmitted RF harmonics. ***Figure 8*** illustrates the excellent fit between predicted and measured output DC voltage under different bias conditions.

CONCLUSION

A nonlinear diode library that provides designers with new levels of accuracy and flexibility has been described. For the first time, designers can take advantage of substrate and temperature effects in performing linear, nonlinear and time domain simulations for a wide range of commercially available Schottky, varactor and PIN diodes. For further information or to request a free demonstration trial, visit http://www.modelithics.com/diodes_vend.shtml.

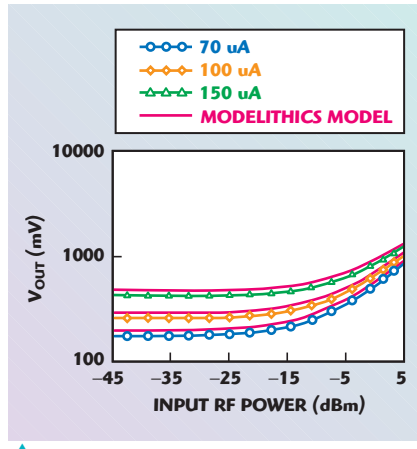

Fig. 8 Detected output voltage at 1 GHz at different bias conditions (markers indicate measured data).

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