Precision Measurements and Models You Trust

Modelithics, Inc.
Solutions for RF Board and Module Designers

Introduction

Modelithics delivers products and services to serve one goal—accelerating RF/microwave design success through better circuit simulations. While state-of-the-art electronic design automation (EDA) software products provide excellent circuit design and simulation capabilities, there is often a significant gap between the results obtained with freely-available component models and what can be achieved with state-of-the-art models from Modelithics. Our mission is to put superior models in the hands of design engineers, enabling them to rapidly develop working circuits and systems, easily evaluate many "what-if" scenarios, reduce laboratory trimming and tuning, reduce or eliminate redesign time, accelerate product schedules, and thereby reduce development, manufacturing, and support costs. Modelithics provides model libraries for surface-mount (SMT) and discrete components that are fully integrated with your EDA software, and lead to unparalleled design success for board and module designers.

In any engineering effort, the total cost of a design error increases geometrically as the stage in which it is first discovered advances. A problem found by end-users could require repairs or recalls costing millions of dollars, and does immeasurable harm to the manufacturer's reputation. At earlier stages of development, the cost of a problem could require modules to be rebuilt, designs to be changed, prototypes to be re-fabricated, or ideally, just a simple software adjustment to a component value or circuit topology. Clearly, accurate models can yield an extremely high return on investment because they prevent design problems at the very earliest, least costly stage.

There are many characteristics of models that can be improved to yield better simulation results. In each design, some features are more important than others. For this reason, this paper is organized by the types of problems that RF/microwave designers commonly experience, coupled with just some of the solutions that our superior models provide to overcome them. Modelithics provides ready-to-use model libraries for capacitor, inductor and resistor SMT components in our CLR Library™, for discrete diodes in our non-linear diode library, the NLD Library™, and for discrete transistors in our nonlinear transistor library, the NLT Library™. The discussion below will focus on problems solved by the CLR Library.

THE PROBLEM – Tuning and rework

I use freely-available component models in my simulations. Sometimes I get acceptable results, but more often I end up spending hours in the lab fine-tuning my designs. My colleagues and I also frequently go through several design iterations before getting our microwave designs to meet specifications.

THE SOLUTION – First-pass design success

Your simulation results will never be better than the models they rely on. Among many other factors, most freely-available models do not accurately represent the component's characteristics on the substrate and mounting environment you are using. A set of S-parameters for one substrate (or test fixture) may bear little resemblance to the actual values on another. Modelithics models include parasitics, pad effects, and substrate characteristics. The model data sheets document the mounting environment so designers can use the models with confidence about reference plane location and knowledge of the suggested circuit application environment. Our customers frequently obtain first-pass design success—with measured performance matching their design simulations—and they also tell us they can achieve more aggressive design goals.

THE PROBLEM – Inaccurate models

I use the latest RF/Microwave simulation software. It has the capability to simulate complex microwave circuitry, which should save me days or weeks of bench time. But my simulations are inaccurate because the models for the components I want to use are overly simplified, missing, too basic, or just inaccurate. Sure, if I'm designing audio equipment, simple models like:

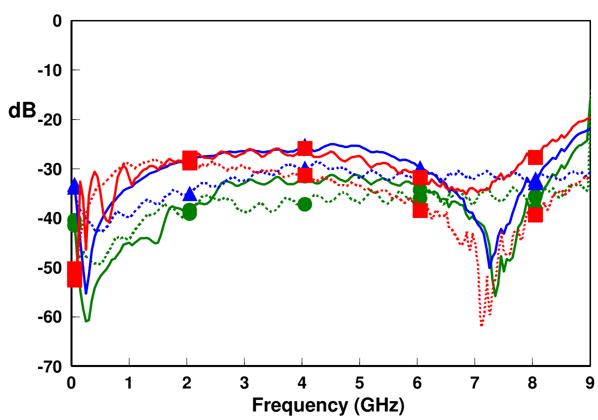
$$X_c = \frac{1}{2 \pi f C}$$

might be adequate. But my capacitor doesn't behave like this at 2.4 GHz. How can I obtain more accurate simulations?

THE SOLUTION – Accurate models

Accurate microwave simulation requires models that accurately reflect the behavior of each component under the actual circuit conditions. If there are

Legend: ■ 1 pF, ▲ 56pF, ● 150pF,
Solid Line - S11, Dashed Line - S21
Magnitude of the vector difference between measured and modeled data on a 5-mil FR4 substrate.

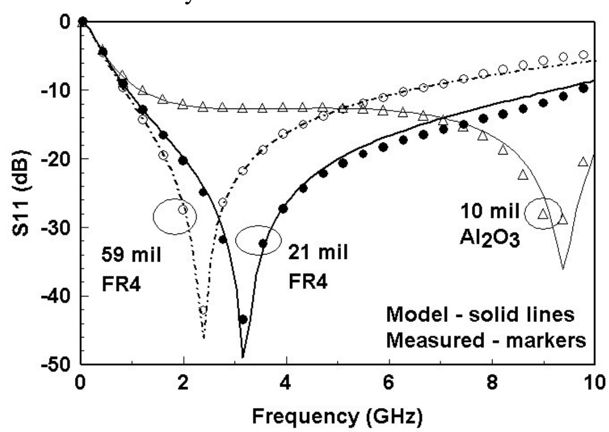


resonances, parasitics, substrate effects, small resistive components, or pad effects, those characteristics must be built into the model. The best way to accurately model a high-frequency device, like a surface-mount passive component or microwave transistor or diode, is to measure its response, then build a model that portrays the way it acts under real circuit conditions. This is precisely how Modelithics models are created. Combined with our unique modeling approaches and unparalleled documentation, our precise measurements produce accurate models that enable first-pass design success.

THE PROBLEM – The model is not applicable to my substrate.

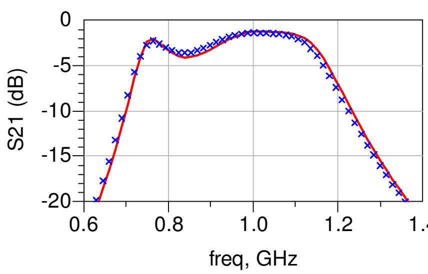
My component vendor provides a model for their part measured in a coaxial fixture using an alumina substrate. But my circuit is going to be on 8 mil Rogers material. I measured one of my components, and the S-parameters are significantly different. Now it looks like we have to characterize all of our components on 8 mil Rogers if we are to obtain accurate simulations.

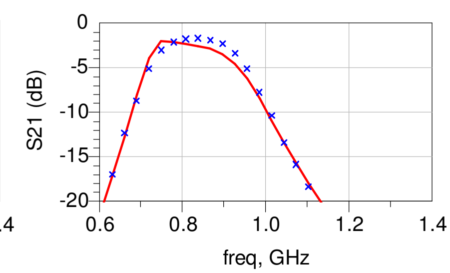
S11 for a common 0603 chip capacitor varies dramatically on three different substrate materials



THE SOLUTION – Global Models™ valid on a range of substrates

Modelithics has a patent-pending component representation called a Global Model that accurately depicts each part over a wide range of substrate thicknesses and dielectric constants. This means that you could change the substrate of your entire design (or even try several different substrates to find the best response) without ever having to take a single measurement. With our models, you won't be searching for new models, re-measuring parts, or trying to live with the errors. Just change the substrate values, and you can instantly re-simulate with confidence. This is one of many ways to save design time in addition to





Simulated (lines) and measured (x's) LC-based Band pass filter on 41 mil FR4 (left) and 5 mil FR4 (right).

giving accurate results that can generate first-pass success as you go to the prototype stage. Modelithics Global Models typically provide accurate results over a 16:1 ratio of h/ε_r (mils), which allows a single model to be used with a wide variety of substrate materials and thicknesses.

Since the models are accurate over a continuous range, you can even simulate the effect of expected manufacturing variations, or tolerances, in substrate thickness or dielectric constant, and assess the effect of these statistical variations on your circuit response (more on this below).

THE PROBLEM – Selecting from available part values

The calculated ideal part value is 9.57 pF. Can I automatically select and simulate the closest component value, in this case, 10 pF?

THE SOLUTION – Discrete optimization

Discrete optimization is the feature you need. Since each Modelithics Global Model is also part-value scalable, it includes all of the available part values in the specified family. Combined with your simulator's discrete optimization features, Global Models enable automatic part value selection. You can rapidly arrive at the closest available value for your simulation. If changes in related parts affect the ideal value as your design progresses, the value will shift to the new closest available value. There's no need to locate and plug in a new component model or S-parameter data set.

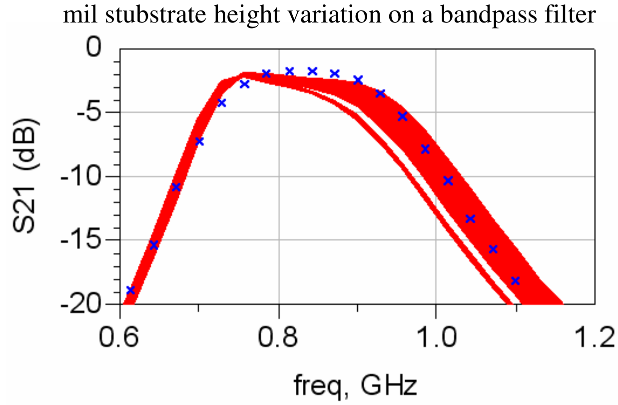
THE PROBLEM - Substrate variations and part-value tolerances

My entire design simulation was done for a 31-mil substrate. But when our incoming inspection measures the boards we receive, we find that they can vary a full mil or so in thickness. What is that going to do to my circuit performance?

THE SOLUTION – Statistical analysis of board and part tolerances

For the first time, you can now answer this question with simulations. Since the Modelithics Global models include the physical effects of substrate thickness (and dielectric constant, by the way) you can plug in statistical variations in these "constants" and find out just how tolerant your circuit is to changes in the substrate they are built on.

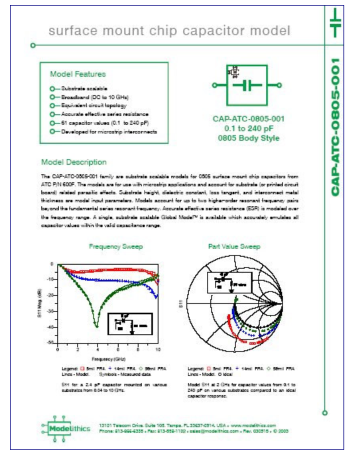
Monte Carlo simulation showing the effect of a 1 mil stubstrate height variation on a bandpass filter



THE PROBLEM – What are the parameters of the model?

I don't know the specific conditions under which each of the component's S-parameters were obtained. I can't even determine whether my models are intended to address my specific design requirements.

THE SOLUTION – Standardized data sheets



Every Modelithics model includes a detailed data sheet, explaining the test conditions during measurement, the valid frequency range, the part values it represents, pad stack geometry, measured-to-modeled comparison, and other features of the "virtual component." This standard, comprehensive method of representation ensures that your models are consistent across different families ***and*** various manufacturers. You no longer have to contend with the vastly different assumptions and techniques used by vendors when they characterize their components.

THE PROBLEM – No model is available

There isn't a model in the Modelithics library for the component I plan to use. What are my options?

THE SOLUTION – Custom modeling and special order models

If you are early enough in the design phase, you may want to choose a corresponding component that ***is*** in the Modelithics Library™. That way, you'll benefit from the predictability, accuracy, and convenience of having a measurement-validated, scalable model that you can use in nearly every situation. If the component selection cannot be changed, we'll be happy to help establish an appropriate model design use through our "models-on-demand" services.

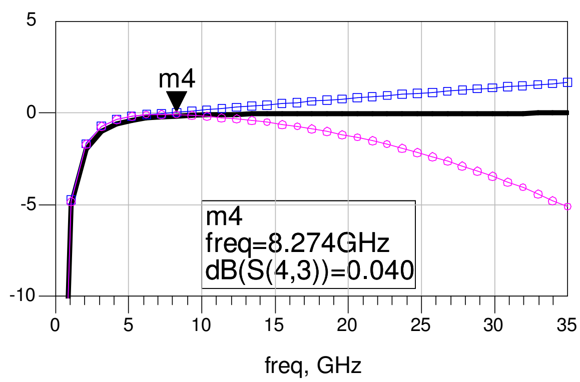
First you may want to contact Modelithics at support@modelithics.com to find out if our next library release might just include the specific model you need. Currently we are issuing two to four new library releases per year. If the model is not in process, you can request a quote for a "special-order" model for your application. As a Modelithics library customer, special-order models for popular components are provided at a significant discount compared to our standard custom modeling prices. Once developed, your new special-order models will be provided as an interim upgrade to your companie's Modelithics Library installation.

Don't forget that we model a very wide range of RF/microwave devices on a custom-basis including, passive RLC components, transistors, diodes, filters, couplers, baluns, RFICs, etc.
Please visit http://www.modelithics.com/services.shtml to learn more.

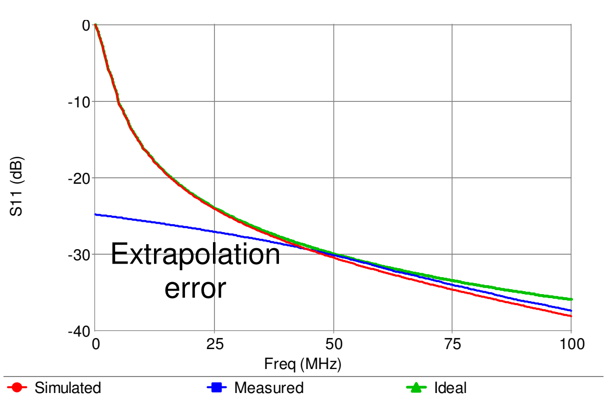
THE PROBLEM – Model extrapolation

Sometimes I know that the S-parameter files provided by the vendor for my parts do not quite cover the frequency I need to simulate, but the simulator automatically extrapolates above and below the S-parameter file range. Is there anything wrong with this approach? One thing I realize is that under harmonic balance simulation of my non-linear circuit designs, the passive component models used to represent my bias and matching circuits are required to be valid through five to ten times my actual design frequency.

THE SOLUTION – Physically-meaningful models



Here's a perfect example of how linear extrapolation can get you in trouble…a capacitor with gain! At low frequency the ideal capacitor S21 response (black line), measured data (blue line) and model (magenta line) may appear very similar. However, if the data is truncated at 6 GHz and you extrapolate higher in frequency, you will be modeling a capacitor as if it had gain. That gives a new meaning to the phrase "low-loss capacitor." Modelithics Global Models remain well-behaved far above and below the range of measured data used to develop the fitting coefficients for the equivalent circuit model. The model itself is derived from a physically motivated representation of the component. Hence, it does not exhibit non-physical (e.g. gain from a passive component) behavior under extrapolation. A similar problem can occur when the data is extrapolated below the measured or ideal range, as shown to the left. The model converges to correctly predict the DC response of this capacitor, but when data starting at 50 MHz is extrapolated down to determine the response at a lower frequency, significant errors often appear in the simulation. Perhaps worse, the designer might not even realize this is occurring unless careful checking is done!



THE PROBLEM – While better passive models should help remove uncertainties in my matching, bias network, and filter designs, I'm even more uncertain about the available models for the diodes and transistors in my mixer, amplifier and oscillator designs.

THE SOLUTION – Modelithics diode and transistor libraries and custom active device modeling services

Modelithics now offers high-accuracy diode and transistor model libraries and "models-on-demand" custom modeling services. Effects such as substrate and mounting parasitics, temperature, non-linear distortion and compression, and noise are accounted for as applicable in the many ready-to-use library models. Model data sheets document details such as test conditions used for model development, pad and via geometries, and measurement validations like pulsed IV, broad-band S-parameters, 1/f noise, noise parameters, load/source pull, and intermodulation distortion.

How about a road test?

Visit www.modelithics.com/products.shtml for more information on Modelithics' unprecedented passive component (CLR Library) models as well as our high accuracy nonlinear diode (NLD Library) and transistor (NLT Library) models. To obtain samples of Modelithics Library models to evaluate with your EDA software, visit www.modelithics.com/accelerate-my-design.shtml.

