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Modeling - The Hot Potato In The RF & Microwave Industry

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In my first week on the job at E-Systems, St. Petersburg, Florida in 1982, I was introduced to the computer-aided-engineering (CAE) package “Compact” and the HP8410 vector network analyzer. Tasked with modeling an S-band balanced amplifier, I set about with the confidence of youth to construct a circuit simulation using a combination of built-in models and measured data. The simulation proved useful in making second source transistor decisions; however, simulation/measurement comparisons fell far short of my fresh-grad expectations, due to passive model inaccuracies. The experience made me a devout advocate of CAE software use, but I was also convinced that accurate models are the real key to efficient RF & microwave circuit design.

The past two decades have added many new tools to assist with modeling and design. Modern CAE simulation packages include Volterra-Series and Harmonic Balance analyses, digital/analog co-simulations, time/frequency domain versatility and facilitate 2-D and 3-D electromagnetic (EM) analyses. Significant advances have been made in instrumentation such as enhancements to vector network analyzers, as well as commercialization of test systems for load and source pull, noise parameters, pulsed I-V, phase noise and digitally modulated stimuli, and on-wafer probing.

Model advances have included substrate and temperature dependent passive models, in addition to non-linear (Gummel-Poon, Mextram, VBIC, BSIM, Curtice, Statz, Root, TOM, Angelov, etc., etc.), and noise (e.g. Fukui, Pucel, Pospieszalski) models for bipolar and FET transistors, and diodes of many flavors (e.g., BJT, HBT, MOSFET, MESFET, HEMT, pHEMT, mHEMT, PIN, Varactor, Schottky). Although, model extraction software, like Agilent’s IC-CAP, helps translate measurements into input parameters for such models, effective model extractions and subsequent setup in a given CAE package still requires a high level of expertise. Very often, custom extraction/optimization solutions are required; thus, the modeler must not only be well-trained, but a creative problem solver as well.

Advanced proficiency is also needed to consistently get good measurements for model development and validation. The integrated multi-instrument test systems required for signal, noise and non-linearity testing, require significant dedicated expertise to maintain and to utilize effectively for characterization and model verification purposes. As a result, RF& Microwave modeling is an expensive, resource intensive and complex proposition. It is no wonder that accepting responsibility for creating models has been something of a “hot potato” in the RF & Microwave industry!

Some say responsibility for modeling should lie with the CAE software providers, because everyone agrees that accurate simulations require accurate up-to-date models. Open up any of the leading software packages and you’ll find libraries of models for commercial parts, microstrip and to a lesser degree coplanar waveguide, transmission line and discontinuity models, via models, bond wire

models, etc.. Look closer and you'll have a hard time finding measured data comparisons or information as to the origin, methods or vintage of these models. Many come from vendor data sheets that may represent a part that was built several years ago; current parts may or may not behave in accordance with an out-dated model due to process changes. To be fair, at various times, software vendors such as EEsof, Compact Software and Agilent (formerly HP) have had internal laboratory support for model development, some still do, but all would agree the process of maintaining up-to-date CAE models is challenging.

Do existing models help designers quickly build working circuits? Well, at the least approximate models can get the design in the ball park, and the old paradigm for many still involves many circuit iterations and a lots of bench tuning. As an industry we need a new paradigm that places much more confidence in CAE, a confidence that will only be won with better models.

Some say that the parts and semiconductor manufacturers should provide CAE models for their parts and ICs. In fact, CAE vendors are now trying to help by supplying model development software tools. This sounds good, but only some vendors are in a position to respond. A lot of parts vendors do testing, but it is less common for them to have CAE software and more critically the in-house specialized expertise required to construct and provide customer support for CAE models of their parts. That said, most provide S-parameters to their designer customers and some have their own modeling software. Semiconductor foundries, especially in the GaAs business often have good in-house modeling expertise. They routinely provide sophisticated "design kit" modeling packages for their foundry customers. Still, there are also foundries, on both the Silicon and GaAs side of the aisle that have made business decisions not to allocate significant resources to in-house RF & Microwave characterization and modeling.

In addition to the resource issue, another major problem with software or manufacturer supplied models is that many models depend on operating bias, temperature, power and frequency conditions, connection technique, package and substrate parameters. There are indeed too many variables to anticipate the needs of every designer, so the best that can be done by a vendor is to provide models for typical situations.

Today, it is the designers and the product-oriented companies that employ them who most often shoulder the load for modeling. Large companies that do RF design have dedicated modeling groups; medium and small companies may only have one person, and often designers do some of their own modeling. The introduction of commercial EM analysis software in the late '80s is an example of where the modeling job for distributed passives was pushed on the designer. For other devices, including surface mount and active devices, measurement-based models are the best solution and this is what presents the dilemma for smaller companies that try to do modeling. A well-funded team, not one or two people, is really needed to achieve "critical mass" for microwave modeling. Another important question design companies have to constantly address is how many valuable RF experts should be tied up doing modeling versus product design, or how much design time is lost on modeling. Regardless, design companies must continue to play a strong role in RF & Microwave model development either internally and/or through outsourcing. After all, they are the ones that ultimately bear the costs for the longer design cycles, the missed market opportunities and the product re-design associated with the lack of accurate design simulation models.

Dr. Tom Weller and I founded Modelithics, Inc. in 2001 (see www.modelithics.com) to better address the industry-wide need for RF & Microwave models. As we see it there is a shake-out ahead in the industry as the different sectors struggle with the modeling dilemma: they are expensive to develop, but it is also expensive for vendors and designers alike not to have accurate up-to-date models available for needed parts and ICs.

In closing, as I look back over the past twenty years, many new tools have emerged, yet in another way not that much has changed. Designers still need good models and the responsibility for generating such models has passed from designer to software vendor to parts and IC vendor in much the same way as a non-working circuit goes from the test bench back to simulation and re-fabrication. As far as the modeling hot potato goes - throw it this way!

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