Consider Outsourcing to Meet Your Complex

RF Data and Model Requirements

Lawrence ("Larry") Dunleavy

President & CEO
Modelithics, Inc.

Abstract

In today's challenging economic times, capital budgets and internal capabilities are being reduced at many companies. For the sake of the long term health of the industry, we all hope this is a short-term trend. The fact is that RF and microwave characterization equipment and in-house modeling capabilities are cost centers at companies not in the business of providing directly related services to their customers. Moreover, to be effective at RF characterization and modeling, a team of experts need to be retained to cover the spectrum of measurements and custom models required for new product designs. Whether you are a circuit designer or a component, device or IC supplier, outsourcing some of your measurement and modeling requirements to a company that specializes in RF measurement and modeling services may prove to be a cost effective way to get your job done and satisfy customer needs.

At Modelithics, the most popular outsourced services where only measurements are requested include noise parameters, 1/f noise and load-pull measurement services. In the area of modeling, trends we have seen over the last couple years include an uptick in requests for noise and non-linear models for various types of microwave transistors. There has also been an increase in requests for non-linear behavioral models for IC devices, like packaged RFIC amplifiers. These types of requests are not surprising as the related measurement and modeling generally require dedicated expertise, test setups and software not all companies can justify maintaining in-house.

What combination of make vs. buy is logical for your company in these challenging times is likely to evolve in the coming year and certainly will vary with the size and corporate philosophy at your company. Factors in your make/buy decision for RF models and characterization data will no doubt include cost and budget, availability of needed capital equipment and personnel skills needed to accomplish the mission internally, schedule and priority, and the challenges and risk factors involved with getting data and models that can be relied upon for enhancing design success, while minimizing rework and bench tuning.

Let's consider for a moment the fixturing challenges that need to be overcome for producing accurate RF characterization data for wafer level, diced chip or packaged devices. Despite a wide range of solutions being available, we have yet to find a truly universal approach. Today, a relatively high level of skill is required to achieve test ready devices with suitable calibration standards and fixturing. The first task is to establish an approach that will provide for properly calibrated, or de-embedded, phase and amplitude reference planes at the desired device bond pads or package terminals. At Modelithics, we use RF wafer probing techniques extensively for nearly all measurements for which the power levels of the required testing can be handled by probing equipment. Recent advances in the area of high power probes have moved this level up to at least 10 W for most applications. For devices where "probe-tip" reference planes are suitable, we use commercial CPW calibration substrates. "ProbePoints™" CPW-to-microstrip transition substrates and corresponding microstrip calibration substrates are available from Jmicro Technology in multiple alumina thicknesses that are very useful for enabling RF probe testing of diced chips. Other companies that provide needed RF probes and calibration

equipment to accomplish the above include GGB Industries, Cascade Microtech and Karl Suss. From a cost point of view a good pair of microwave probes and calibration substrates will run a few $K (mm-wave probing takes this to another level so we'll not go there in this article). Of course we also need a probe station, which can cost from below $15K for a low-cost manual station to over $250K for a semi-automatic solution with a temperature chuck.

Often, the required reference planes need to be different than at the probe tips, in which cases custom on-wafer or on-board calibration standards need to be available to remove the effects of CPW-microstrip transitions and access lines. We make lots of custom PCB boards with suitable device mounting pads, vias, TRL and lumped element calibration structures, and we often assist IC designers in calibration structure design. A word of caution here is that not all PCB houses can meet the tight specifications required on via hole and line uniformity to achieve quality on-board calibrations. We still use coaxial fixtures for most of our high power device testing, particularly above 10W or so. Here again appropriate calibration standards need to be developed and excellent calibrations are in general harder to achieve in coaxial fixtures at high frequencies, so much care in fixture design and selection is needed. A commercial coaxial fixture with calibration standards can easily cost $10K or more, and will need to be customized in some way to accommodate various package styles and device sizes. Custom PCB board runs meeting our requirements tend to run a little under $3K, and more if thin film fabrication is required.

Instrumentation needs will vary with the test data required for your application, and fundamental to all RF and microwave testing is a high performance vector network analyzer (VNA). There is strong competition in this area and some exciting new developments from companies like Anritsu (e.g. the 70kHz to 70GHz ultra-broadband Vector Star) Agilent (e.g. PNA-X and its many options for non-linear, noise and multi-port testing) and Rhode & Schwartz (with new pulsed S-parameter and strong multi-port capabilities). Cost will depend on frequency range and many other factors, but a new unit likely will cost between $50K and $150K.

If you want to do semiconductor characterization and modeling you'll need an array of power supplies and bias tees in addition to a DC parameter analyzer from, for example Keithley or Agilent– something on the order of $70K to $120K budget for these is a good start for a small lab. Accurate modeling of III-V devices like GaN HEMTs and GaAs pHEMTs will also required pulsed IV testing – better budget another $100K – Auriga has a good solution here, others are emerging.

If working on receivers, noise parameters will be important, and for addressing power and linearity requirements in transceivers, you'll need a load-pull setup. Noise parameters and load-pull are among the high skill requirement tests we'll discuss a bit further below. There are many configurations for noise parameters and load-pull equipment, but to have separate dedicated setups – again a good start would be $150K or so each for the needed hardware, software and supporting instrumentation. Modelithics uses Maury Microwave tuner/controller equipment and software. Focus Microwave also offers solutions in this space. Many facets of these benches become frequency or band dependent, so you can plan on spending more to address future frequency requirements after the initial purchase. The above is certainly not a complete list and omits many important tests (e.g. the whole area of digitally modulated signal analysis) that Modelithics and dedicated RF and microwave and wireless oriented test labs generally can provide.

The final consideration is one I'll call the "Guru Factor." Let me first say that I have had the privilege of touring many labs around the world and have the pleasure of knowing several experts who know how to do RF characterization and modeling correctly. My next comments are not meant to take anything away from these established Gurus. They in fact will all agree that getting reliably accurate RF data is not trivial. For the types of testing mentioned above – VNA calibration accuracy is fundamental to the whole concept of a reference plane whether you are talking about a simple set of S-parameters or a complex load-pull measurement. A mastery of a range of calibration solutions is required to deal with the multi-faceted fixture and calibration standard scenarios. This is needed for just making good S-parameter measurements! As the

complexity of the setup and the measurement goes up more issues can and do arise. This is the case as one moves, for example, to the noise parameter bench. As an example of the recognition of the specialized skills needed some companies are even providing titles like “Load Pull Engineer” to its characterization specialists. The ability to quickly troubleshoot problems as they arise in such setups is only gained through years of experience and with good grounding in the fundamentals of microwave theory. The Guru factor here may make the difference between a problem solved on the same day to one that delays your project by days or weeks. Or as I have concluded after Modelithics’ 8+ years in the RF measurement and modeling services business and my own 27+ years (yikes!) around microwave technology: Murphy was an optimist and he was born in a microwave lab!

We have focused for the most part here on the challenges and cost of measurements. On the modeling side substantial software investments will also be needed for device extraction software like Agilent ICCAP, and you will also need the circuit simulator that the designer plans to use. In the microwave space, circuit simulators from companies like Agilent, AWR, Ansoft and Cadence in general require customized model preparation and at least software specific model validation. You may also need an electromagnetic analysis tools to address package and passive structure modeling. Most of the circuit simulator companies mentioned above also have companion EM analysis tools; other companies with tools in this space include Sonnet Software, CST, and EMAG Technologies. Hence, a versatile lab will need multiple software tools and engineers fluent in same. An initial software budget for a new lab supporting model development and validation might easily be $150-$250K. Considerable experience and engineering education are needed for effective non-linear model extractions for even one type of device (e.g. diodes or transistors) for use in a single circuit simulator and the Guru Factor is again at play as much or more on the modeling side as it is on the measurement side.

In closing let me say that, to be sure, the needs out there vary considerably. For some companies S-parameters are enough. For other companies, I am told that internal and external customers of their application and modeling teams are trending to rely on simulation-based design and they are asking for more data and more models to facilitate such designs. If you plan to continue meeting your needs internally, perhaps the comments above will help make sure the appropriate capital and personnel resources are in fact dedicated to the mission. If you think about outsourcing some of your needs, a service provider like Modelithics may just be able to help you meet your technical and budgetary goals for the short or even long term. I’m looking forward to your feedback and your questions. Please feel free to email me directly at Ldunleavy@modelithics.com .

About the Author

Lawrence P. Dunleavy co-founded Modelithics, Inc. in 2001 to provide improved modeling solutions and high quality microwave measurement services for RF and microwave designers. Prior to this, Drs. Dunleavy co- developed the University of South Florida’s innovative Center for Wireless and Microwave Information Systems (The WAMI Center). He maintains a part-time position as a Professor within USF’s Department of Electrical Engineering, where has been on the faculty since 1990. Prior to this he worked for Hughes Aircraft and E-Systems companies. Dr. Dunleavy received the B.S.E.E. degree from Michigan Technological University in 1982, and the M.S.E.E. and Ph.D. degrees in 1984 and 1988, respectively, from the University of Michigan. Dr. Dunleavy is a Senior Member of IEEE, and is active in the IEEE MTT Society, and the Automatic RF Techniques Group (ARFTG).