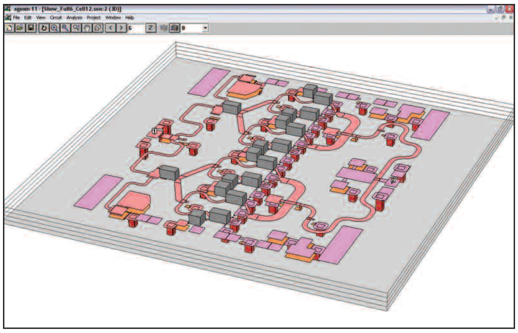
Microwave Journal

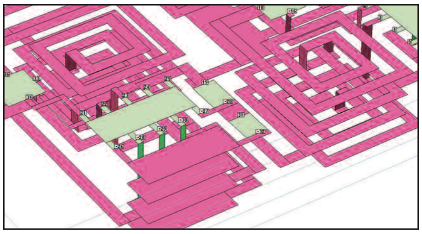


Perfectly Calibrated Ports for EM Analysis

Sonnet pioneered the high frequency EM (electromagnetic) market, shipping the first commercially viable product in 1989. Since then, the company has continued regularly introducing significant capability into this market. Sonnet's new Version 11 expands upon this tradition with multiple new features that fundamentally change high frequency design methodology in many areas, but especially in the field of radio frequency integrated circuit (RFIC) design.

Each of the new Sonnet Version 11 features deserves an entire article. However, following a brief description of the new features, this piece will focus on the most significant feature, the new "Co-calibrated™ ports," shown in ***Figure 1***. These are perfectly calibrated ports on the interior of a high frequency circuit, never before available in any EM tool. Perfect port calibration will completely change how high frequency design is accomplished, especially in the RFIC world.

Fig. 1 A 3-D planar circuit with numerous internal ports used for mounting surface-mount devices.



Prominent among Version 11's new features is a fully revised interface to the Agilent Advanced Design System (ADS) framework. Designed with the support of Agilent, the interface now easily installs as a design kit. In addition, a free ADS interface to the free SonnetLite EM analysis is available. Absolutely invaluable to ADS users who use Sonnet as their primary EM tool, the interface is also seeing wide use by ADS users using Sonnet to double check EM results from other sources, and by project teams using multiple EM tools. Two menu selections literally transfer an entire EM layout into Sonnet, including all analysis and substrate information. The interface is completely bi-directional, so users can confidently go back and forth as desired. Finally, one attractive new feature is that Sonnet can create the popular ADS "layout look-alike" symbols in the ADS schematic. The user can actually see in the ADS schematic where a port is in the layout, as shown in

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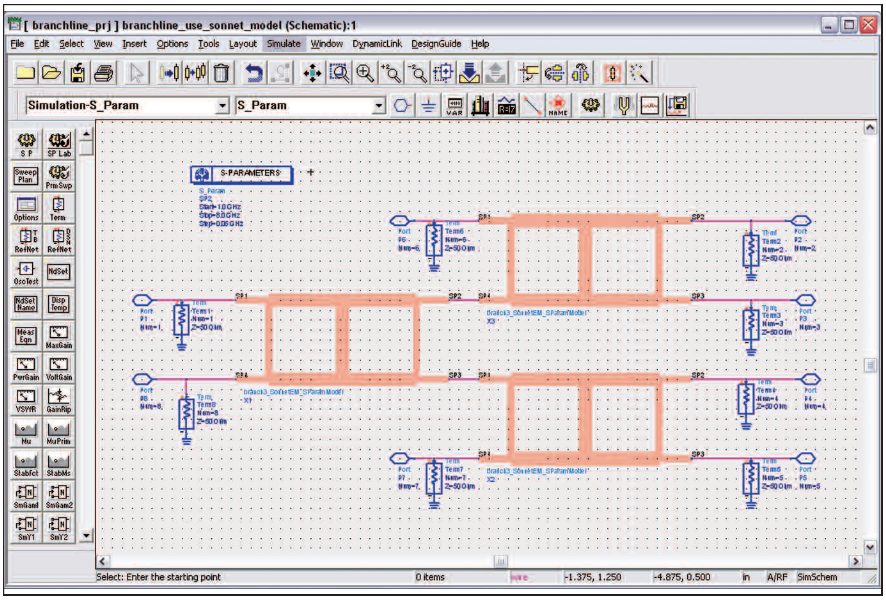
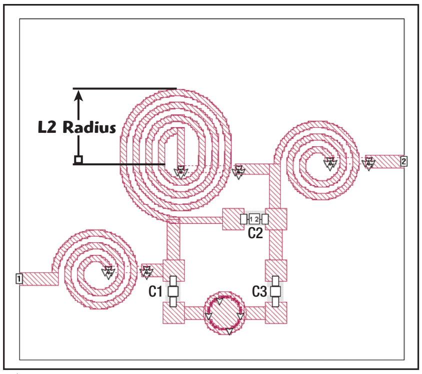
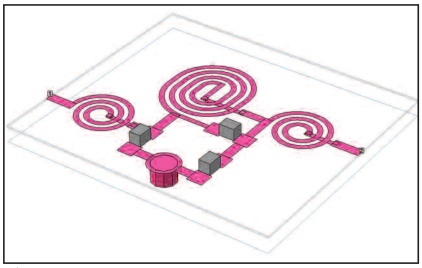


▲ *Fig. 2 Agilent ADS schematic with three "layout look-alike" schematic elements (pink) from Sonnet.*



▲ *Fig. 3 Top view of an elliptic low pass filter with three pairs of Co-calibrated ports (C1, C2 and C3).*



▲ *Fig. 4 3-D view of the same filter.*

Figure 2. This is useful if there are dozens, or even hundreds of ports, a situation expected to become common with the introduction of Co-calibrated ports.

The same easy bi-directional transfer also continues to be available in the AWR Microwave Office interface and in the Cadence Virtuoso interface. New with Version 11 is an interface to AWR's X-model capability, where users can create parameterized high frequency models based directly on Sonnet data.

New to all three interfaces (Agilent, AWR and Cadence) is the ability to specify use of Sonnet's thick metal model and Sonnet's patented conformal meshing. The thick metal model uses multiple sheets to model thick metal. Simpler "tube-like" models of thickness force all current to flow on the surface of the metal regardless of frequency. That model loses validity when metal thickness is less than several skin depths. This is not a problem with the Sonnet multi-sheet model, which is valid over the complete frequency range. Sonnet's conformal meshing lowers subsection count by a factor of up to 100 for curving transmission line structures, all the while still including the high edge current necessary for high accuracy.

To further enhance Sonnet's interoperability, there are procedures for bi-directional transfer and specification of the new Co-calibrated ports in all three frameworks, even though no framework is yet aware of this new concept. All three framework interfaces also now support direct use of Sonnet's remote execution and cluster computing capability. With remote execution, users set up and administer remote batch queues, easily submitting jobs to be performed anywhere on the network. With the addition of this capability to the interfaces, users may use these functions directly from the framework of their choice.

The cluster computing capability splits a multi-frequency job into multiple jobs for simultaneous execution. For example, if a job takes one hour per frequency and requires 10 frequencies, it is automatically split into 10 jobs with complete results (including interpolation capability) available in one hour. This means that what were previously overnight jobs now barely allow time for a cup of coffee and a chat with a friend.

A second cluster option is now available. Previously, cluster computing required use of third-party software. While that software is widely available in some large companies, availability is problematic elsewhere. Thus, cluster computing is now offered "for everyone else," that is, no third-party software is needed and it is easily administered.

Sonnet also now includes a 64-bit analysis engine. This means problem sizes over 2 Gbytes are now feasible. These analysis engines are available for Windows XP64, Redhat 64 Linux and SuSE 64 Linux, and are even included in the cluster computing solution.

Any and all of these features are major events by themselves, but the really major event in Version 11 is "Co-calibrated ports." This is a completely new concept in high frequency EM analysis, so a little background is in order.

Sonnet analyzes 3-D planar circuits. Planar means that much of the circuit is on the surface of one or more stacked substrates. Vias connect between circuitry on different levels. 3-D means that all coupling between metal in all three dimensions is included.

Sonnet is a "shielded" analysis, that is, it analyzes the circuit inside a conducting, shielding box. This shielding box allows a mathematical formulation that results in an extremely low numerical noise floor, typically 140 to 180 dB down. There is another subtle, but incredibly important result of analyzing with a shielding box: The shielding sidewalls form perfect short circuit reference planes.

Thus, from the very beginning, Sonnet has always had perfectly calibrated sidewall ports. What is new in

Version 11 is that a way has been discovered to perfectly calibrate all ports internal to the planar circuit. This allows perfectly calibrated, global ground referenced ports to be placed anywhere. All the tiny stray inductances and capacitances associated with (and between) all the internal ports in a group are now exactly removed.

This is a fundamental and brand new capability for high frequency EM design. Take, for example, a power FET amplifier, perhaps in the form of an RFIC. EM analysis cannot analyze the FET. Therefore, the FET is left out and internal ports are included in the EM analysis. Later, using a favorite framework, the nonlinear FET model is connected and a harmonic balance analysis is performed.

The problem with this old way is that the internal ports always include at least some tiny stray capacitances and inductances, electromagnetic artifacts of the way internal ports must be created and which are present in all EM analyses. These tiny port discontinuities cause large errors in certain situations, for example, at the inputs and outputs of power FETs, where they operate with impedances of only a couple ohms. Most EM analyses make no attempt at all to calibrate internal ports. Now, with Co-calibrated ports, exactly calibrated groups of internal ports are easily realized. The internal ports for the power FET are analyzed with absolutely all of the port discontinuities exactly removed.

The potential applications are limitless. For example, if the power FET is removed and perfectly calibrated ports substituted, why not take out all the resistors and capacitors in the RFIC and substitute Co-calibrated ports there, too? Now, with a single EM analysis, one may repeatedly populate the RFIC with different resistors, capacitors and transistors until an optimum design is achieved. ***Figures 3*** and ***4*** show a low pass elliptic filter designed in exactly this way.

With this design flow, design iterations are done at circuit theory analysis speed, hardly time enough for even a sip of coffee. In the old way, the designer would physically change one (or more, if you are desperate) components and then repeat the entire EM analysis. That approach can require weeks to complete a single design. In the new way, the best possible design can be determined in minutes. The old way of doing design is simply no longer viable.

The potential of perfectly calibrated internal ports is mind-boggling. Continuing with the power FET example, the power FET consists of an input manifold, gate fingers and an output manifold. Designers usually have a pretty good model for a single gate finger, but a model for the entire power FET can be elusive. Now the answer is simple. For the EM analysis, take out all the gate fingers and substitute a group of internal ports. If there are ten gate fingers, there are now 20 ports for the gate region. There is another port for the input to the gate manifold and one more port for the output manifold, for a total of 22 ports. Now simply connect 10 copies of the single gate finger model into the 20 internal ports.

Sonnet even includes the ability to automatically connect a user specified S-parameter data file or an ideal lumped component to the internal ports. There is no need to resort to a complicated schematic in the selected framework to do the connection. The S-parameter file can come from measurement, from a model in any design framework, from vendor supplied data (including models for surface-mount devices), or even from another Sonnet EM analysis. All this thanks to the box sidewalls providing perfect short circuit reference planes, critical in achieving Sonnet's perfect internal port calibration.

CONCLUSION

Sonnet's new Version 11 with 64-bit capability, an easy-to-administer cluster computing capability, significantly enhanced interfaces to Agilent, AWR and Cadence, and the new fundamentally significant Co-calibrated ports is simply going to change everything in planar microwave design.

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