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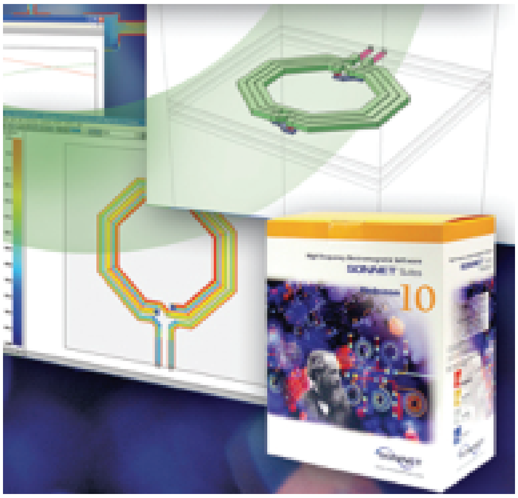

PLANAR EM ANALYSIS: A NEW STANDARD FOR HIGH FREQUENCY APPLICATIONS

At the end of this year, Version 10 of the Sonnet® 3-D planar EM analysis software is being released. This article discusses a few of the new features, including automatic generation of thick metal models for its exclusive conformal meshing, porting of Sonnet's software to Linux, in addition to Windows and Unix, a new very powerful Cadence interface, a new very flexible interface to Eagleware and a new broadband SPICE model generator.

Even within a seemingly narrowly defined field like high frequency EM software there are many niches. Sonnet's niche is the analysis of predominantly planar circuits. While the circuits are 3-D, the dielectric is mostly layered and planar portions of the circuits dominate.

In EM analysis, accuracy and speed are also sometimes compromised (often necessarily so) in the attempt to analyze more general structures. One indicator of EM accuracy is current distribution. For high accuracy analysis, the calculated current must be smooth and show a clear edge singularity (high current at conductor edges). For example, when I^2R loss is to be determined, an accurate current distribution, especially the high edge current, is an absolute requirement. By restricting the class of problems to 3-D planar, the simulator's accuracy is additionally enhanced.

Sonnet's accuracy is derived directly from its fast Fourier transform (FFT)-based techniques that provide well over 100 dB dynamic range and can analyze circuits of over one million cells on a normal desktop PC or workstation. For the class of circuit for which it is intended, the FFT achieves both speed and accuracy.

CONFORMAL MESHING THICK METAL

Recall that when an FFT is used in signal processing, the time signal must first be uniformly sampled. In EM analysis, the surface of the substrate must be uniformly sampled, yielding a fine underlying FFT mesh. The mesh can be as fine as the pixels on a typical computer screen. In EM analysis, these pixels are called "cells." Only the metal of a circuit is divided into cells. A typical large circuit, for example, might have one million cells.

These cells are then merged into larger subsections. In EM analysis, a matrix must be

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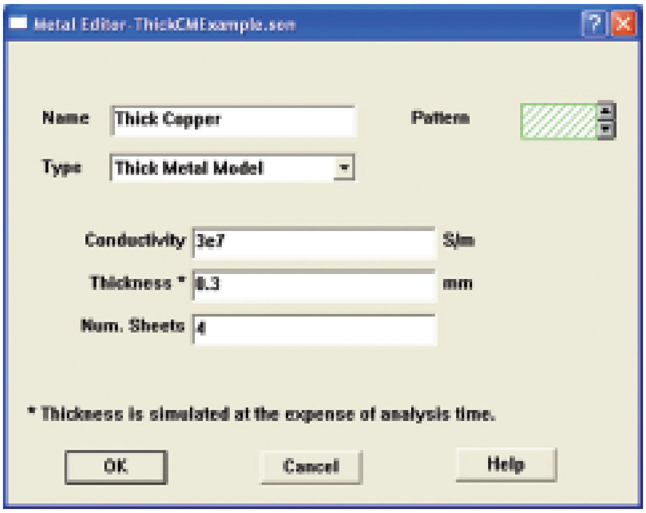


▲ *Fig. 1 The automatic thick metal option now extended to conformal mesh.*

filled and inverted. There is one row/column in the matrix for each subsection. It is important to keep the number of subsections to a minimum for fast analysis. Sonnet's conformal meshing does this very effectively by merging cells into subsections that curve to follow curving transmission lines, and the subsections automatically include the critical high edge current. A one million-cell circuit can be reduced to as few as 1000 subsections. Inverting a 1000 × 1000 matrix requires only a few seconds.

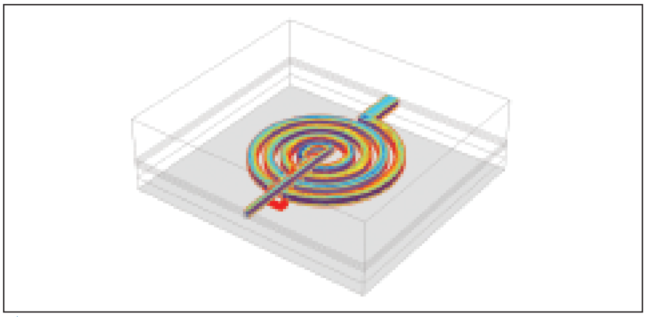
With Version 9, Sonnet introduced an automatic thick metal option. The user can set the level of sophistication (and thus, the accuracy and analysis time) by adjusting the fineness of the meshing in the vertical direction. While it is commonly known that mesh size must be small with respect to wavelength, it must also be small with respect to variation in the current distribution. When metal thickness is important, the mesh must be small with respect to the metal thickness. A "one size fits all" thick metal model is not sufficient.

For example, when two lines are separated by a gap about equal to their thickness, a simple "two-sheet" model provides enough accuracy for all but the most demanding situations. When the gap is a small fraction of the thickness, multi-sheet models are nearly always required.

With the Sonnet thick metal model, the user simply specifies the number of sheets to use, as shown in ***Figure 1***. All the sheets are automatically generated and connected together. By adjusting the number of sheets, the user can control the analysis time versus accuracy tradeoff. To test if there are enough sheets, simply change the number of sheets, reanalyze and see if the change is significant with respect to requirements.

The initial implementation of automatic thick metal did not include areas using conformal mesh. Conformal thick metal is now allowed in Version 10. In addition, via attachment to conformal mesh subsections has been made much more efficient, even when the automatic thick metal is invoked.

Figure 2 shows a spiral inductor using thick metal and conformal mesh. Note the critical high edge current (red). Also notice that there is very little current on the interior of the thick metal (black), but substantial current on the



▲ *Fig. 2 The new 3-D current viewer (red is high current, blue is low current).*

sides. In addition, note how the high edge current switches from side to side along the spiral. This is called "current crowding." These details of the current distribution must be accurately determined in order to correctly calculate I^2R loss, or Q.

The figure also shows the new 3-D current viewer (a new 3-D geometry viewer is also included). Because of the FFT, Sonnet works especially well for structures with large numbers of layers, where non-FFT-based techniques have significant difficulty. For example, the displayed spiral inductor has six dielectric layers. Given that Sonnet can efficiently analyze circuits with 100s of layers, a 3-D current viewer is important.

A structure of this complexity (four-sheet thickness model, high edge current included, circular spiral) can probably not be analyzed by any other EM tool today on any desktop computer. With Sonnet's thick metal conformal mesh, this analysis takes 37 minutes on a 2.4 GHz AMD processor using the illustrated cell size (500,000 cells). With a larger cell size, almost the same result is obtained in as little as 17 seconds per frequency. When a large number of sheets is required to analyze very thick metal, it is possible to select a calibrated space mapped model that allows much faster analysis with little compromise in accuracy.

LINUX AND CADENCE

Over the last decade the company has seen a gradually increasing call from users for porting Sonnet to Linux. Then Cadence decided to port to Linux, and several large Sonnet customers began firmly suggesting a strong interface into Cadence. Thus, the company decided to port to SUSE Linux Professional 9.0 and Redhat Linux Enterprise 3.0. Other versions of Linux might work, but they are not tested or supported.

In parallel, the existing Sonnet-Cadence Virtuoso interface was completely reformed. The necessary Cadence tools and training were acquired through Sonnet's membership in the Cadence Connections program, and Sonnet continues to draw from the considerable resources that Cadence provides to Connections Program partners for interface development and support. Substantial time was spent working with several major customers carefully investigating design flows and making sure everything in the interface existed that was needed to allow fast, pain-free communication between tools in a high pressure, high volume design environment.

Figure 3 provides an overview of the interface. The design starts in the Cadence Virtuoso Layout Editor. Af-

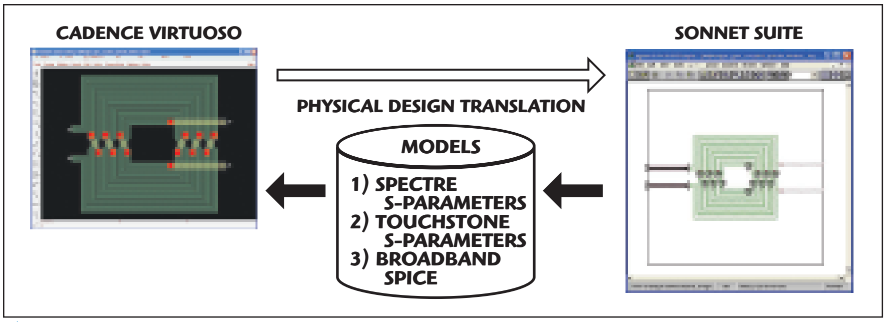


Fig. 3 The Cadence Virtuoso/Sonnet Suite interface.

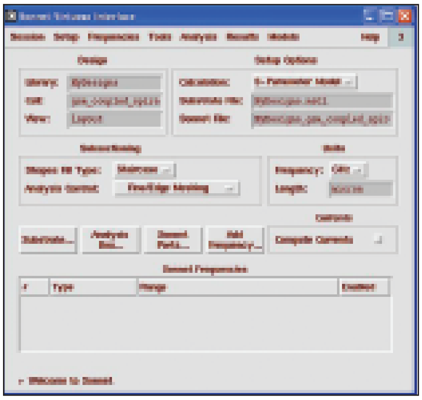


Fig. 4 The additional information required by Sonnet for the Cadence Virtuoso layout.

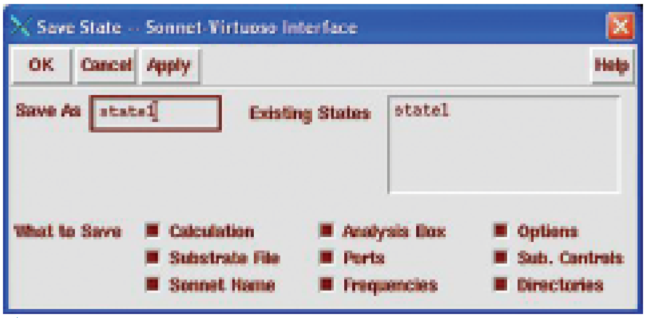


Fig. 5 The saving state capability.

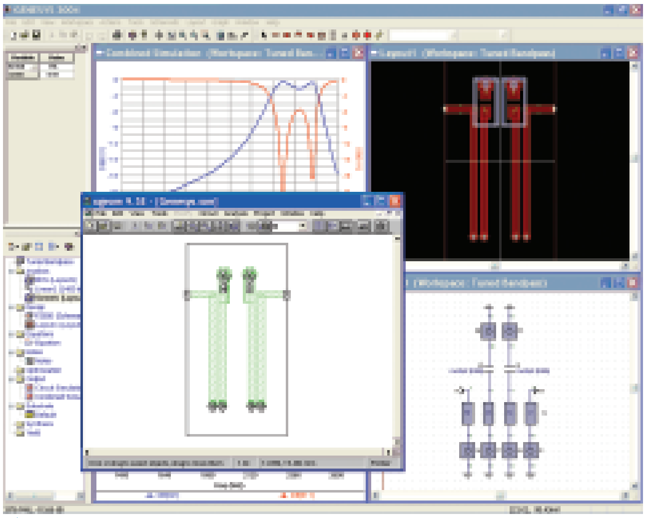


Fig. 6 A combline filter simulated in Sonnet with the help of an interface to Eagleware's GENESYS.

ter providing additional information needed by Sonnet (see ***Figure 4***), the layout is transferred to Sonnet. After Sonnet analysis, the result is brought back to Cadence via Spectre S-parameters, Touchstone S-parameters, or a new broadband SPICE model synthesis.

While synthesis of broadband SPICE models has become common, the models synthesized by Sonnet are especially compact and are always causal. Proprietary techniques related to its Adaptive Band Synthesis interpolation are used. Sonnet's broadband SPICE models support both Cadence and PSpice. Also, these proprietary ABS techniques are further leveraged to generate results at zero frequency (DC).

One example of how the interface is made useful in a high volume design environment is the concept of "state." The state of the interface is the information needed by Sonnet to properly accept the layout from Cadence. It was found that designers often had to change the state of the interface in the midst of a complicated design process. The ability to save a given state and to return to that state at any later time was then added, as displayed in ***Figure 5***. This speeds the design process and eliminates the possibility of manually re-entering a given state incorrectly.

The Cadence interface also allows the user to specify Sonnet conformal mesh and thick metal models. It was also found that mapping the substrate definitions from Cadence to an EM solver was especially error prone when a text-based interface was used. Therefore, the substrate mapping specification is now performed by means of a carefully designed Graphical User Interface (GUI).

EAGLEWARE INTERFACE

Several forward looking framework vendors have decided that interfacing to third party tools is critically important to the success of a framework, even if the third party tools might in some way compete with one or another tool offered by the framework vendor. The company has previously worked closely with two such framework vendors, Agilent and AWR, in developing very functional interfaces into their frameworks. Work was recently completed with a third such vendor, Eagleware, developing an interface into their tool set as well.

Specifically designed for Eagleware customers who prefer Sonnet's simulator, the Sonnet integration is available in GENESYS 2004. The integration enhances the use of Sonnet in an integrated corporate environment and extends the capabilities of both the Sonnet simulator and GENESYS.

With the ability to simulate directly from the production layout (including lumped elements), the integration takes the Sonnet Simulator to a new level. The integration directly supports lumped-elements such as transistors and capacitors automatically, a feature unique to Eagleware's GENESYS. ***Figure 6*** shows a combline filter being simulated in Sonnet, automatically including the lumped capacitors. The required Sonnet internal ports were created automatically as GENESYS detected and included the capacitors on the layout. This direct-from-layout simulation enhances Sonnet's capability, making simulation of complete microwave circuits especially easy when used in the GENESYS environment. The interface is available from Eagleware, and works with all Sonnet Suites, including the free SonnetLite.

The company feels that interoperability is the defining issue of this decade in high frequency software. Success in theframework area will require successful interoperability, even when that requires cooperation between potentially competing vendors.

USABILITY ENHANCEMENTS

Sonnet's convenient data plotting can save plots that have been specified to disc. If additional data has been calculated since the plot was saved, opening the plot file also loads updated project data. However, if the plot file is moved to another computer, then that data is no longer available. Now Sonnet can save a graph archive that stores the complete data from all projects referenced by the graph. The archive can then be moved to another computer with no difficulty and saved for posterity.

Another convenient new feature allows the user to email a complete project to Sonnet support. The operator selects the project and specifies his/her country in a drop-down menu. Then Sonnet packs the project and emails it to the appropriate support location along with the user's description of the problem.

CONCLUSION

Sonnet Version 10 is setting a new standard for high frequency EM software. New features include automatic thick metal now available for its exclusive conformal mesh, a new port to Linux, a new very powerful interface to Cadence, a new very flexible interface to Eagleware, new 3-D geometry and current viewers, a new broadband SPICE model synthesis, and more.

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