Microwave Journal

Layout-driven High Frequency Design Gets Boost from New EM Technology

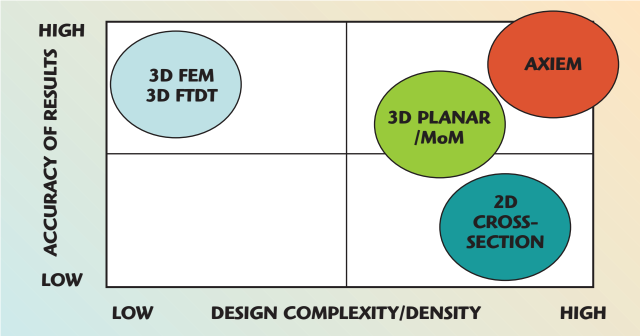
Competition to attract consumers in the wireless communications market is driving incredible innovation in the design of feature-rich devices in compact packages. Geometries are shrinking and integrated circuit (IC) densities are expanding, while at the same time application frequency and bandwidth grows. In order to reduce size and weight, and to improve the cost-effectiveness of the module, it has become necessary to migrate to fully integrated monolithic microwave ICs (MMIC) that include most or all of the above RF functions. These MMICs must be optimized for size and electrical performance simultaneously. This requires high frequency electrical design to progress concurrently with physical layout. Therefore, engineers need to know the electrical behavior of these densely packed components in "real-time." This challenge calls for an evolution in the electromagnetic EM technology used to characterize passive structures and interconnects. To fully support layout-driven electrical design, EM technology must solve large and small geometries rapidly within a well-defined yet flexible design flow without sacrificing accuracy.

Executive Interview Series

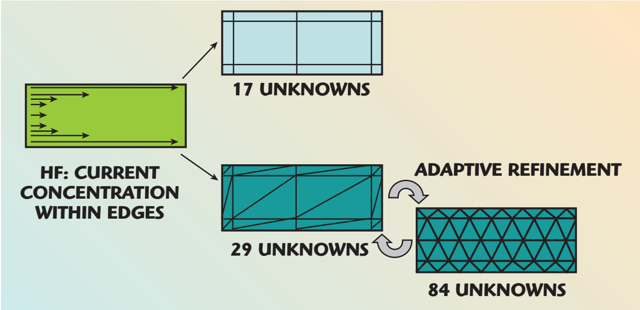
MWJ speaks with Sherry Hess, VP of Marketing, AWR. Visit www.mwjournal.com to read this in-depth interview.

AWR, an innovative company founded by microwave engineers committed to providing a better way to design, has been developing a completely new approach to fast, high capacity EM simulation. The results of this R&D effort is a new product called AXIEM,™ a breakthrough, pioneering EM technology that delivers speed, capacity and accuracy to the designers of microwave/RF products. AXIEM now enables EM analysis to be an integral part of the entire design flow and decision-making process, start to finish. By addressing long simulation run times and design flow inefficiencies, AXIEM is a practical design tool that goes beyond being a time-consuming, back-end verification step in a final go/no-go loop.

Applied Wave Research Inc.
El Segundo, CA



▲ *Fig. 1 The EM technology landscape.*



▲ *Fig. 2 Rectangles vs. triangles for equivalent accuracy prior to "AWR-hybrid" meshing.*

WHAT IS UNIQUE ABOUT AXIEM?

Today's EM tools as used for high frequency IC design fall into one of three camps: two-dimensional (2D) cross-section, three-dimensional (3D) planar, or general purpose 3D.

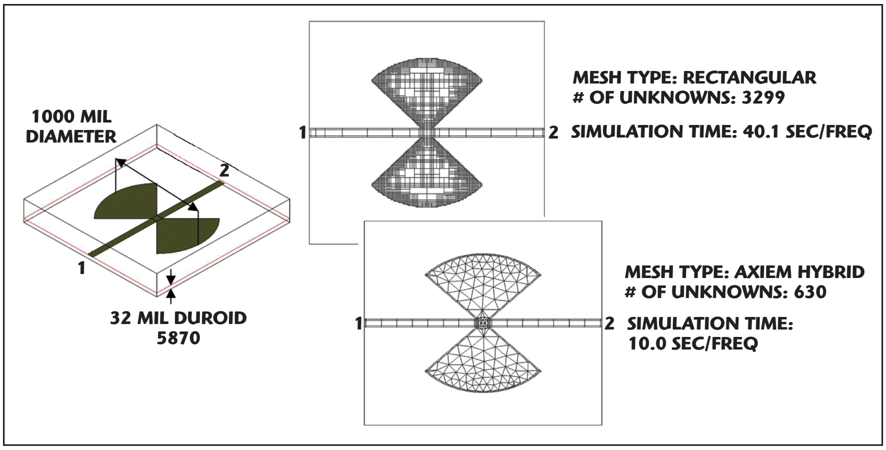
- 2D cross-sectional-based codes rely on either the method-of-moments (MoM) or the finite element method (FEM) to derive per-unit-length properties of conductor systems, including coupling, loss and characteristic impedance. They are extremely fast but are of limited use, especially for lines that are electrically long.
- 3D planar codes are optimized to the IC/planar nature of the device/circuit. Typical formulations are either closed-boundary, using a fixed "Manhattan" mesh and a fast Fourier transform to generate Green's functions; or open-boundary, using a triangular mesh and numerical integration techniques. Three-dimensional planar methods capture currents in three dimensions, where 2D solvers cannot, and can therefore be used to fully characterize most circuit problems, but at the expense of simulation time and computer memory.
- 3D FEM or finite difference time-domain (FDTD) tools, which attempt to provide a vehicle for solving all EM problems from antenna to motors and biological effects to EMI compliance, sacrifice computer run times and memory utilization when used by circuit designers for their IC designs.

Figure 1 conveys the choices available among EM technologies for designs for their fit (structure complexity and timeliness of results) versus accuracy of results.

To elevate EM simulation from verification tool to true design diagnostic tool, AWR developers focused on advancing the state-of-the-art in meshing technology, solver technology and the overall workflow. By starting from the ground up and implementing numerous technical innovations in these areas, AXIEM is able to achieve unprecedented simulation speed and accuracy for a wide range of microwave circuit structures. This powerful EM technology is then integrated into an AWR exclusive MMIC design flow that offers the users control and flexibility over passive circuit extraction.

AWR recently introduced the ACE™ technology, which provides interconnect model extraction in seconds as opposed to hours, and, more importantly, provides users with a "design tool" that encapsulates EM within it. The company now follows up this innovative capability with the industry's first EM technology that is able to keep pace with the rapid changes in IC design—a tool that no longer requires that designers make trade-offs across speed, accuracy and capacity, enabling them for the first time to use EM as a tool of standard adoption throughout the design flow and not just at the final stages.

EM solvers themselves are actually complex beasts that are combinations of complex mathematical techniques: meshing, a Green's function generator and the actual matrix solver algorithm. The speed and accuracy trade-off really comes down to what is the weakest link. The AXIEM technology was developed to tackle the problems of speed and accuracy by looking at each of the constituent pieces, and making each best-in-class.

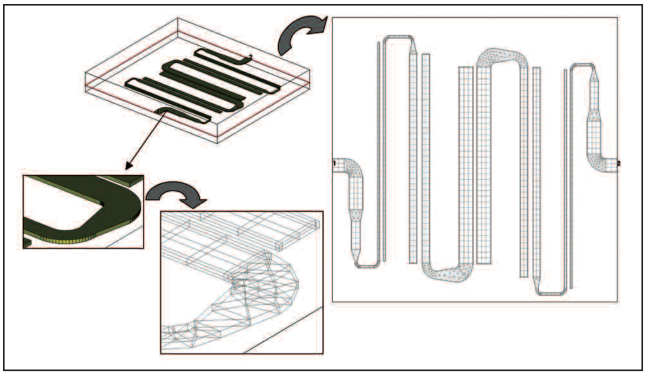


▲ *Fig. 3 AXIEM produces 5X fewer unknowns as demonstrated with a Nera radial stub example.*

MESHING TECHNOLOGY

Hybrid Meshing

The AXIEM product employs a unique, AWR-pioneered, intelligent hybrid surface mesh consisting of rectangles and triangles. By applying the optimum mesh type to a given surface, a hybrid mesh provides significant advantages to using a purely rectangular mesh or a triangular mesh. For instance, it is not possible to create an efficient rectangular mesh for arbitrary geometries such as curved or tapered metal traces. The hybrid approach uses rectangles where most effective and efficient,



▲ *Fig. 4 Nera filter example reveals metal thickness and AXIEM hybrid mesh.*

and then embraces triangular elements in regions where a rectangular mesh is an ill-conditioned choice.

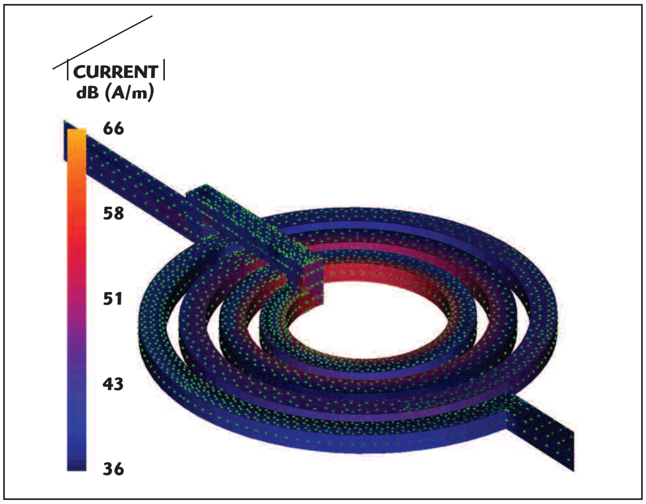
The AXIEM meshing process is fully automated. Its intelligent meshing process uses heuristic knowledge of the solution to automatically create a mesh that is optimized to provide the greatest accuracy while minimizing the number of unknowns required, thereby delivering speed of solution coupled with unprecedented accuracy at a touch of the button. ***Figure 2*** illustrates the advantage of rectangles over triangles for a quasi-TEM microstrip transmission line.

Generally speaking then, rectangles are the preferred element choice when the structure for analysis is friendly to rectangles; however, as designers know, this is often not the case. With AXIEM's hybrid meshing technology, the efficiency of rectangular elements is wed to triangles for their flexibility of fit to arbitrary shapes (that is, non rectangular) that is so often the case with today's microwave/RF IC designs.

As shown in ***Figure 3*** (supplied by Nera ASA, Bergen, Norway), a radial stub is 5X more efficient in terms of mesh production/population when the AXIEM technology is employed versus a typical rectangular meshing approach.

True 3D Metal

Additionally, the AXIEM product also differs from other planar solvers on the market in that the AXIEM mesher accurately and efficiently creates true 3D meshes of extruded planar geometries, and the final solution includes all x, y and z directed currents on all surfaces—making it an excellent fit for today's high frequency microwave/RF IC designs. ***Figure 4***, also from Nera, illustrates both the thick metal capability and the hybrid mesh technology of AXIEM, whereas ***Figure 5*** shows the results of AXIEM for a curved spiral inductor where the metal width is of the same dimension as its thickness.



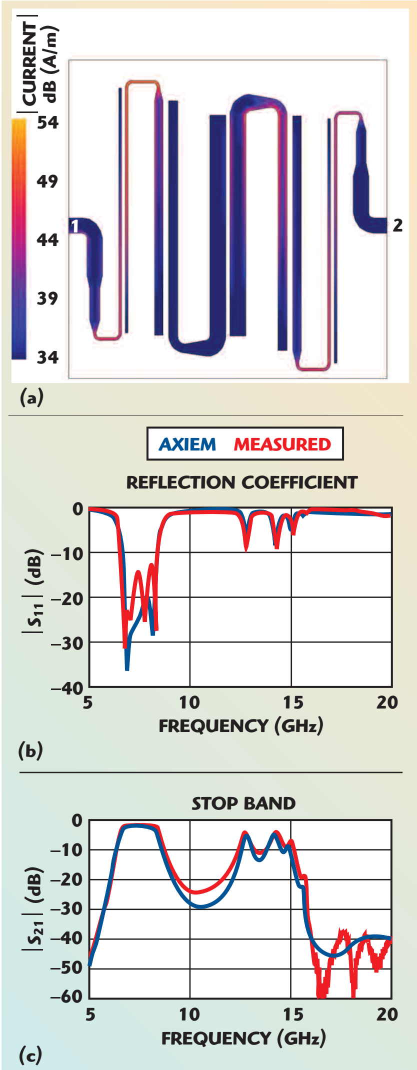
▲ *Fig. 5 Current flow for a thick metal spiral at 20 GHz.*

Solver Technology

While 3D planar EM technology is not news in and of itself, what is new and groundbreaking about the AXIEM technology is that it has been expressly pioneered to overcome the limitations of existing 3D planar formulations that rely on the Sommerfeld integral (or similar) for delivering speed of simulation, yet at the cost of accuracy and a decrease in dynamic range. AXIEM obtains a full-wave EM solution by employing an AWR-innovated method of moments (MoM) technology as its solver engine. Its solution methodology uses a proprietary technique that is similar to the fast multipole method, yet adapted for full-wave analysis.

As a result, the AXIEM solver scales similarly to the fast multipole method, which is the order of Nlog(N), as opposed to the order N^3 as is the case with most existing MoM solvers. The AXIEM solver is therefore orders of magnitude faster for its simulation speed than conventional MoM codes. As an example, ***Figure 6*** shows the results from AXIEM for the Nera filter design of Figure 4, including both passband shaded current display and $|S_{11}|$ and $|S_{21}|$ measured and simulated data. For this example, the simulation time was well under a minute for approximately 2000 hybrid mesh elements (or unknowns). Furthermore, given that the results of AXIEM will normally be employed by a nonlinear circuit simulator, accurate DC solutions are also a given.

It is also worth noting that the AXIEM technology is coupled to ad-



▲ *Fig. 6 Passband current (a), and $|S_{11}|$ (b) and $|S_{21}|$ (c) simulated vs. measured data.*

vances in computer architectures: it delivers even faster simulation time as the core solver was designed from its inception to enable parallel implementation on both multi-central processing unit (CPU) computers and/or distributed clusters. The parallel implementation enables designers to realistically solve very large designs in as little time as possible by dividing the computation (frequency data points or matrix computations) across multiple CPUs or computers.

DESIGN FLOW

As a stand-alone EM solver, AXIEM is a powerful addition to any designer's stable of tools. The meshing technology enables complexity by delivering robust representations of the currents with fewer unknowns. The solver provides accuracy regardless of complexity, and does so efficiently across the entire frequency range. The true value of AXIEM, however, lies in its integration into the overall AWR design flow, where it contributes significantly to AWR's commitment to accelerating GHz design.

While delivering innovations in its meshing and solver algorithms, the AXIEM technology also takes to a new level the AWR automated design flow philosophy. By employing features that automatically determine and set user options, the requirement of a super-user with years of EM design expertise to run the product is not necessary nor a prerequisite. In addition, AXIEM is tied to circuit and system simulation, layout and verification through the proprietary AWR unified data model (UDM). The UDM provides features such as extraction directly from simulation without having to perform explicit layout and EM setup steps, thereby incorporating EM directly and seamlessly into circuit simulation.

When used in conjunction with AWR's ACE technology, the same EM structures can be mapped back into circuit models in a matter of a few seconds, providing a window into the critical interconnects and couplings, and can be modified and designed accordingly, and then more accurately modeled or verified within the mainstream design flow with the AXIEM tool. The AWR UDM and ACE innovations, now combined with AXIEM as an integral part of the overall flow, compliment each other to further cut design time and iterations from the overall project.

CONCLUSION

Until recently, EM effects were second-, third- or even fourth-order effects to consider for successful IC design. With the increase in wireless and RF/microwave products in both military and consumer markets, and the effect of Moore's law in shrinking overall footprint size and increasing complexity/frequency/bandwidth, EM effects have become first- and second-order effects that must be accounted for. Today, every design requires some sort of EM analysis, but the technology has not kept pace with the demands of users who now must employ EM analysis as a design process diagnostic utility rather than the traditional back-end verification tool.

The breakthrough AXIEM technology delivers an industry-first design tool that meets today's advanced design requirements for an EM analysis tool that is fully integrated into the design flow—at the front end where it can help identify problems early in the process.

The pervasive miniaturization and complexity in nearly every next-generation wireless product has pushed the envelope on not only this technology, but the development technologies behind it as well—from tools, to foundry processes, to packaging, etc. The one constant is that time-to-market windows continue to shrink and the winners are those who can get working products to market in the shortest period of time.

AXIEM (www.axiem3d.com) is currently in beta test with existing customers and the commercial release is scheduled for Q1 2008. The product is priced at US$30,000 for locked licenses and supports Windows 2000, XP and Vista, and Linux. Additional information may be obtained via e-mail at info@appwave.com. In addition, AXIEM can be seen at the AWR booth no. 912 at the European Microwave Conference, October 9–12, in Munich, Germany.

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