Improving MMIC and RFIC Design Flows

New EDA technologies like Microwave Office 2002 and new foundry libraries help to streamline the development of RF and microwave ICs.

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In the 1990s, digital application specific integrated circuit (ASIC) designers experienced a process and productivity revolution that was brought about by advances in electronic design automation (EDA). Integrated solutions that included logic synthesis, standard cell libraries, and advanced place-&-route capabilities enabled the semiconductor industry to achieve orders of magnitude increases in productivity that made today's multi-million gate ASICs and systems-on-a-chip (SoCs) a reality. Unfortunately for the radio frequency (RF) and microwave design community, high-frequency analog EDA tools have languished in a relative &quotstone age&quot where productivity and design methodologies have remained largely unchanged for almost a decade. However, with the emergence of modern EDA platforms and new partnerships between commercial foundries and EDA vendors, monolithic microwave integrated circuit (MMIC) and RFIC design flows are beginning to move radically forward.
It is an obvious and well known fact that RFIC and microwave IC design presents a rather unique set of challenges that render many of the automation approaches for lower frequency analog or digital design useless. Some of the challenges include electromagnetic (EM) coupling, device and process variations, and distributed transmission line discontinuity modeling. Designers are also confronted with a multitude of challenges that are an unfortunate consequence of working with more exotic semiconductor materials, such as gallium arsenide (GaAs), silicon germanium (SiGe), and indium phosphide (InP). Both the materials and the frequency of operation present unique challenges in extracting accurate models. With all of the interactions between microwave elements, no one gainfully employed would trust turning their MMIC design over to an automated synthesis, placement and routing tool, even if it existed. However, that doesn't mean all hope is lost in terms of reducing design cycle and improving the chances of first-pass success.
While traditional EDA &quotframeworks&quot were open to integrating 3rd-party technology, the RF and microwave EDA industry more or less forced customers into buying a complete solution from a single vendor, or, in many cases, companies resorted to stitching tools together on their own. Today, many MMIC designers are burdened with getting designs out using a highly fragmented tool strategy built upon legacy design tools. Often, engineers use a different set of tools for circuit simulation, layout, and EM analysis. A typical MMIC design flow, shown in Figure 1, indicates where hand-offs occur and where iteration loops can potentially delay tape-out or, worse yet, introduce errors. With this fragmented approach, designs are often entered once into a circuit simulator and then manually re-entered into

the layout systems schematic editor for documentation purposes before creating the layout itself. As shown in the design process, the final verification and design-rule-checking (DRC) step may catch mask errors, but the numerous iterations between the layout tool and the circuit simulator can delay product delivery or increase fabrication costs. This fragmentation, partially the result of closed EDA systems, has hampered the growth and evolution of the microwave semiconductor industry while making the job of designers more tedious and error prone.

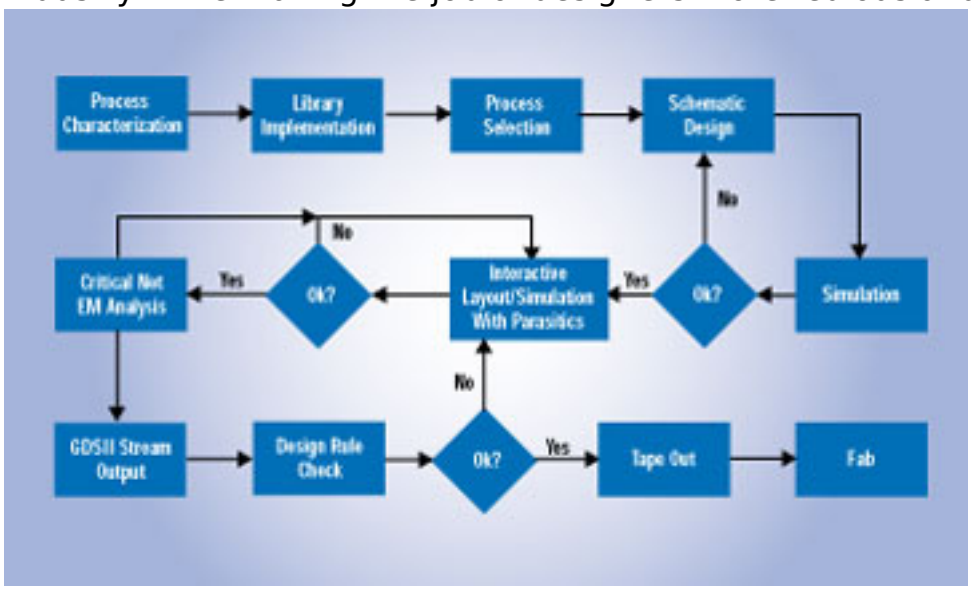

Figure 1. Typical MMIC design methodology using multiple EDA tools

This legacy methodology is gradually changing as new technology, EDA tools, and foundry libraries converge to provide the long awaited boost in high-frequency IC development. Microwave Office&#153 2002 design suite, developed by Applied Wave Research, Inc. (AWR), was intended to streamline the MMIC design process by addressing the three essential keys to improved productivity: accuracy, integration, and openness.

EDA Integration

To provide a robust integrated environment for MMIC design requires a different approach and different architecture from traditional EDA tools. For most digital or low frequency analog electronic designs, the layout process is distinct and independent of the simulation process. However, at RF and microwave frequencies, the layout process is so critical to performance that it is integral to the simulation process. RF and microwave design mandates that simulation be very closely connected to the layout tool. Microwave Office 2002 software was developed from the ground up using an object-oriented architecture that facilitates a &quotlayout centric&quot view of a design. The architecture, depicted in Figure 2, is a native Windows application that leverages Microsoft technology by using interoperable binary software components called component object models (COM). COM provides a solid foundation for higher-level software integration by enabling pieces of the Microwave Office design suite to work together more seamlessly and reliably. This integrated EDA solution combines an advanced IC layout editor with system, circuit, and EM analysis tools that all leverage a single object-oriented database. The schematic and layout data are implicitly synchronized by virtue of the underlying product architecture without a need for netlists or design synchronization routines.

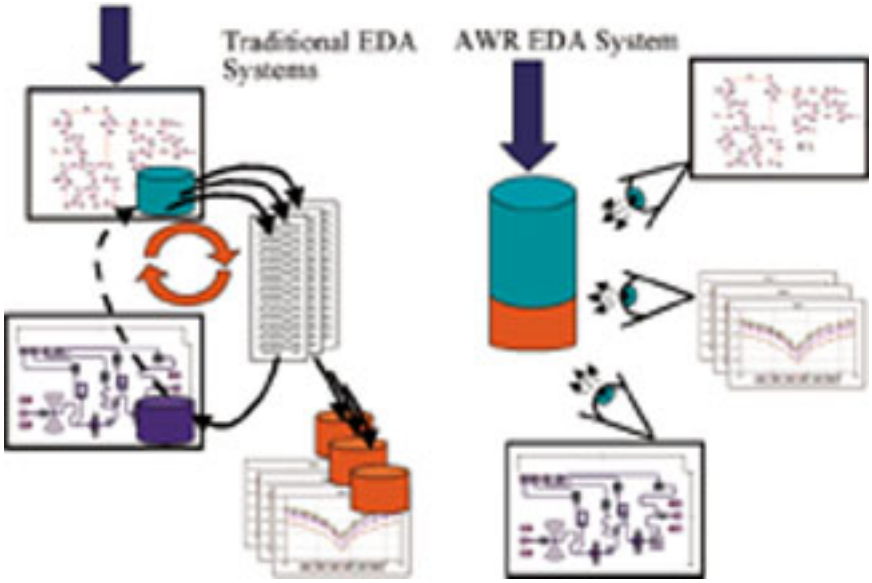

Figure 2. Applied Wave Research's Microwave Office 2002 was developed to streamline MMIC design from simulation through to final layout and DRC.

This advanced computer science results in a highly functional and very fast MMIC design tool. Microwave Office 2002 software is ideal for handling both the electrical and physical layout of MMIC and RFIC designs because the two representations are structured in software as &quotviews&quot of the same underlying data structures. Microwave Office 2002 was designed around a single object-oriented database that is always consistent with schematic and layout views. The layout editor directly drives the simulation engine without any intervening netlists, back annotation, forward annotation, or any need for design synchronization routines. The simulator uses an incremental computation algorithm that enables microwave circuits to be &quottuned in real-time.&quot Users can also physically re-route transmission lines and literally stretch layout cells, and the simulation output can be updated virtually instantaneously. Schematic, simulation, and layout data are always consistent because of the implicit connection through a common database.

MMIC Foundry Libraries

Modern microwave EDA solutions can provide powerful custom IC layout capabilities that are tightly integrated with the simulator. However, to take advantage of the integrated simulation and layout capabilities, users must have access to foundry specific libraries that tie together the electrical and physical representations of active and passive elements. In the digital ASIC design space, robust foundry libraries or process design kits (PDKs) have been well established. However, microwave foundries have been less consistent in the definition and actual delivery of PDKs. These inconsistencies are partially due to the broad variety of methodologies employed by foundry customers and, also, as a consequence of processes and modeling issues that tend to be more dynamic. The integrity of the electrical and physical model data is often a contentious issue between foundry customers, foundries, and EDA vendors.

Neither an EDA company nor a foundry can deliver an optimal PDK by itself. The foundry, while having a better understanding of the modeling issues, does not have the tools or software expertise to fully leverage the EDA platform. On the other hand, the EDA company can develop a library around a process guide, but without

access to validation data or the latest process changes, the library can quickly become out of date or unreliable. To overcome these issues, AWR has established close partnerships with leading RF and microwave foundries to deliver validated libraries. AWR is actively working with commercial MMIC foundries to provide validated PDKs that include integrated electrical models, parameterized cell libraries, and DRC rules files for integrated MMIC design. These partnerships, initially driven by mutual customers, are providing cost advantages for designers by establishing a validated standard that enables designers to focus more effort on the design and less time on configuring the software. End users, commercial foundries, and EDA vendors can all benefit from the reduced support effort, higher customer satisfaction, and shorter design cycle that results from integrated foundry libraries. Microwave Office2002 software foundry libraries are available today from Global Communications Semiconductor, Triquint Semiconductor, UMS, Velocium (A TRW Company), and WIN Semiconductor.

Accurate EM and Circuit Analysis

EM analysis and circuit simulation are clearly complementary technologies for RF and microwave IC design. While circuit simulators are extremely fast, they lack the ability to handle arbitrary structures such as interconnecting vias, airbridges, and the parasitic effects introduced by packaging MMICs. On top of the physical challenges, designers are also confronted with the challenge of getting accurate discontinuity models and integrated EM analysis into a coherent EDA-based design methodology. The Microwave Office 2002 design suite has unique EM-based discontinuity models that effectively deliver EM accuracy with the speed of circuit analysis tools. This library of discontinuity models is built around a database of full wave EM simulation data. The models, developed to specifically address the requirements for high-frequency communications applications, use EM analysis to provide vastly expanded ranges of validity in addition to improved accuracy. In addition, integrated EM analysis capabilities can display currents and E-field animations for arbitrary multi-layered structures. The Microwave Office 2002 solution supports integrated 3-D planar EMs simulation with the circuit simulation and layout tools, enabling arbitrary structures to be embedded within linear and nonlinear circuit simulations. The EM analysis engine can handle any number of layers and is ideal for analyzing.

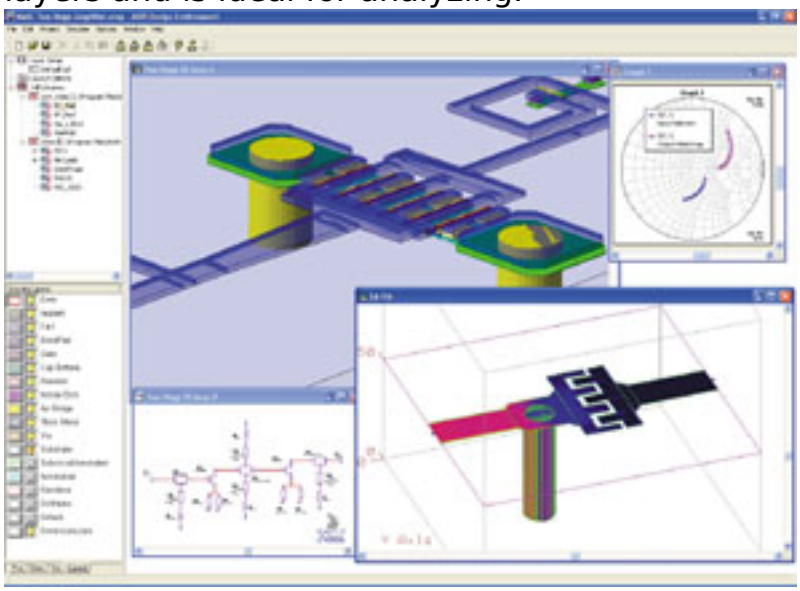

Figure 3. Microwave Office 2002 provides an integrated design

environment for circuit simulation, EM analysis, IC layout and verification.

Conventional design and simulation tools require that the user specify parameters for both interconnecting transmission lines and discontinuity models such as microstrip tees, crosses, steps, and bends. That requirement forces the user to specify physical parameters, creating an opportunity for inadvertent errors. Microwave Office 2002 software uses a novel set of models, called iCells (intelligent cells), that do not require these physical parameters. The iCells dynamically adapt, based on their electrical connections, effectively inheriting their properties from the connections and thus eliminating synchronization errors and increasing designer productivity.

Conclusion

Today, many new EDA technologies are streamlining the development of RF and microwave ICs. The combination of high quality layout editors with robust connections to simulation provides a basis for rapid product development cycles. Partnerships between foundries and EDA vendors are producing more capable and integrated MMIC PDKs that speed the design process while improving reliability.

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