**Transistor Modeling**

- *with an eye towards the future*

Ubiquitous, but rarely seen, high-frequency and high-power transistors are an essential component of many electronic systems. They have important roles in mobile phone infrastructure, satellite communications, terrestrial broadcast, avionic and weather radar systems, and microwave backhaul, to name but just a few applications. The performance of these systems is primarily limited by the power amplifier, and there are significant world-wide research activities devoted towards improving its capabilities. Motivations for continued improvement range from enabling higher frequency applications and increasing communications bandwidths, to reducing the operating costs of mobile phone companies required to operate and cool these devices.

Transistors developed for modern power amplifiers for communications systems are tightly specified in terms of the required linearity performance, multichannel capability, bandwidth, and so forth. Demands for accurate transistor models and the push towards computer-aided design methodologies continue to increase. Simultaneously, there is a quest for higher-efficiency operation that can be realized through nonlinear modes of operation and increasingly complex power amplifier architectures. To complicate matters further, power amplifiers must now operate within digital pre-distortion systems to correct the inherent nonlinearities of the transistor that occur during high power operation. The demands resulting from tight design specifications are generally conflicting, and the designer is faced with a multi-dimensional compromise. Additionally, the increasing complexity of power-amplifier designs and the reliance on CAD-based design methodologies places a premium on the availability of accurate models and efficient simulation algorithms.

Market demands for increased power and efficiency show no sign of abating, and more circuit functions are expected to be incorporated into a design. For the successful design of high-frequency and high-power devices in the future we shall need to consider a comprehensive, or global view, of the entire design hierarchy. An illustration of this hierarchy is presented in Figure 1, where semiconductor device, circuit, and systems levels are linked using compact and behavioural models.

Each technique has its importance at a different level of the modeling hierarchy, as illustrated in Figure 1. This all seems similar to the old adage that 'beauty is in the eye of the beholder'. Applied to transistor modeling, this means that what is important for a model to predict depends on location of the 'beholder' in the hierarchy. The traditional view of modeling and design procedures is for the most part within narrow regions of this hierarchy. This issue of the Microwave Magazine spans the modeling hierarchy and presents a comprehensive overview of the various techniques in place today and to highlight areas in need of development for active researchers in this field.

The first of these articles "Transistor Modeling and TCAD," by Peter Blakey provides an overview of circuit simulation, transistor modeling and TCAD. In it he shows several different methods as to how process and device-level simulations can be used in circuit simulation through measurement substitution and model substitution processes.

No matter the origin for a compact model, whether it be physics-based or its characteristics obtained from measurements or TCAD-based simulations, compact models are essential for the efficient simulation, and design, of RF circuits, MMICs, power amplifiers, and nonlinear systems. David Root provides an in-depth review in the second article titled "Advanced Compact Transistor Modeling Techniques".

In the third article, "Modeling and Simulation of RF and Microwave Systems," by John Wood, he describes what is required for successful behavioural models for system-level simulation. In the final article of this issue "Modeling and Simulation of Terahertz Devices," by Stephen M. Goodnick and Marco Saraniti, they describe a physics-based approach to the simulation of THz transistors that spans several layers of the hierarchy as they optimize the performance of a THz transistor using a comprehensive multi-physics approach.

With this issue I hope that we've been able to convey the importance of the modeling hierarchy, and the relative places that each technique inhabits. There will continue to be advancements in new semiconductor materials for which new types of models will be required, but there is also a great need for simulation and techniques to span the entire modeling hierarchy. After all, the goal is not to just model the transistor but to enable the best performance of the entire system.

In summary, I hope that you find this issue of the Microwave Magazine interesting, and perhaps you see the beauty in it as I do.

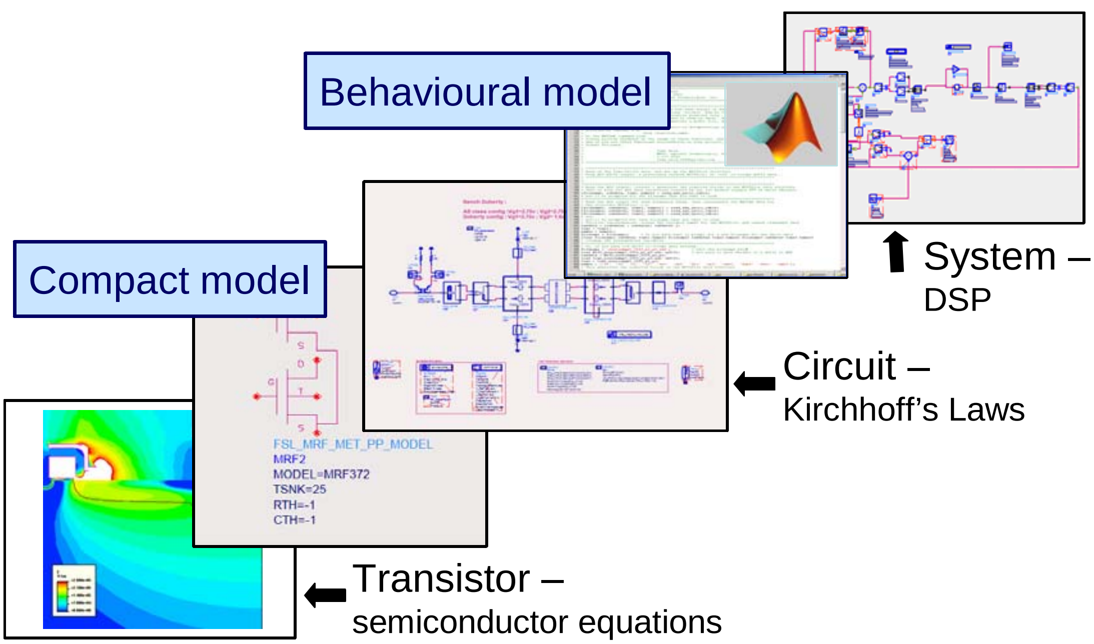


Figure 1. The modeling hierarchy. Reprinted with permission from Aaen, Pla, Wood, Modeling and Characterization of RF and Microwave Power FETs (Cambridge University Press 2007).