



Be in your ELEMENT

Electromagnetics & Microwave Engineering Team

INTRODUCTION

In this information age, the needs in the microelectronics industry for manufacturability-driven design and time-to-market demand powerful and efficient Computer-Aided Design (CAD) techniques. Furthermore, the recent advances in radiofrequency (RF) and Microwave Integrated Circuits (MICs) require a permanent upgrading of existing CAD tools. In fact, with ever-higher integration and miniaturization, the needs for concurrent and multi-disciplinary design become increasingly important, requiring that the available CAD tools be not only fast but also accurate so that the design can be achieved reliably. Fast, because of the repetitive computations involved in simulation and optimization of modern MICs. Accurate, because to be close to experimental data, simulated circuit responses need to be obtained from component models that fully integrate higher-order nonlinear, thermal, and electromagnetic (EM) effects.

The central focus of the **ELEctromagnetics & Microwave ENgineering Team** is the development of Computer-Aided Design (CAD) models and software tools for high frequency linear/non-linear system design, and the validation of these tools by checking their predictions against measurements.

Led by Dr. Mustapha C.E. Yagoub, our team has a good experience in advanced device modelling, radiofrequency and microwave simulation algorithms, neural-based modelling, and circuit analysis, simulation and optimization. Development of computational electromagnetic techniques for numerical modeling of guiding as well as radiating structures is also being carried out.

RESEARCH TOPICS

We are always interested in solving problems that engineers in industry could face. However, as regard to our planned research, we are currently working on the following research tasks:

EM-Based CAD Tools for RF/Microwave Circuit Modelling and Design

Any RF/microwave circuit simulated response, like gain or dispersion, depends closely on how the implemented miniaturized components are modeled. To be efficient, this aspect requires the resolution of several EM issues related to the complexity of the integrated structure due to the hybrid nature of the EM field. Strip thickness, finite conductivity, and number of layers, are factors that can significantly affect the propagation and attenuation characteristics of EM field in high-density multilayered hybrid/monolithic MICs. Such characteristics have been widely investigated using various techniques like the perturbation technique, the mode-matching method, and the method of lines. However, the perturbation approach is not suitable for MICs since the skin depth and the strip thickness are in the same order, while the above fullwave methods are CPU time consuming. Thus, easier and faster methods need to be developed to meet the evolution of MICs.

Our team has developed various EM numerical tools using the spectral domain method through the derivation of dyadic admittance Green's functions via a recursive process, which significantly enhances the CPU time.

EM-Based CAD Tools for RF/Microwave Circuit Simulators

Another key aspect to be considered in MIC design is the parasitic coupling. Coupling is becoming more of a concern in MICs as packing densities of devices are increased and frequencies are pushed higher. Although such coupling plays an important role in circuit performance, this quantity is very complex to evaluate and several numerical techniques in bringing this forward into circuit design space have been investigated. Mainly based on the resolution of Maxwell's equations, such EM methods have demonstrated their efficiency, but still require huge computation time and memory space. This aspect is crucial when modern design tools lead to massive and highly repetitive computational tasks during simulation, optimization and statistical analysis. Furthermore, recent lumped EM-based models seem to be helpful in obtaining a quick initial design, but they are developed under perfectly shielded conditions excluding parasitic coupling between neighbouring components, and hence, they tend to be inefficient for circuit-level simulation.

In this topic, our team has proposed a novel technique for computation of EM parasitic coupling in passive structures based on simple circuit theory and de-embedding concepts.

Compact Transistor Models For RF/Microwave Circuit Design

Since Field Effect (FETs) and Heterojunction Bipolar Transistors (HBTs) are widely used in the RF/microwave range, a large number of modelling approaches are being proposed. Detailed physics-based transistor models are accurate, but slow. Table look-up models can be fast, but suffer from the disadvantages of large memory requirements and limitations on number of parameters. Nevertheless, they are difficult to develop, equivalent circuit models remain the most common modelling approach, where the element values can be determined either by direct extraction or by optimization-based extraction. Fast and simple to implement, direct-extraction techniques provide adequate values for the more dominant circuit elements, but they cannot determine all the extrinsic elements uniquely. On the other side, optimization-based extraction techniques are more accurate but computationally intensive and relatively sensitive to the choice of starting values. Furthermore, to make them attractive to non-experienced users, such extraction techniques often assume a prior universal circuit topology referred as the FET standard topology or the HBT standard topology.

Determining the most suitable small-signal equivalent circuit configuration (topology) and accurately extracting its element values was the preliminary target of our team. Based on an exhaustive literature review, a circuit library has been created that contains the most widely used topologies. Thus, by combining the Fuzzy c-means method and neural network capabilities, a method was developed that efficiently selects the most suitable small-signal circuit topology for a given set of measured S-parameters. The goal is to extend this generic approach to generate nonlinear/thermal FET and HBT models. In fact, many roadmaps now recognize advanced nonlinear and thermal analyses as two of the major challenges in electronic product innovation due to ongoing push of technology towards higher power and complexity, and reduced size.

Advanced Tools for RF/Microwave Antenna Design

Our team has demonstrated its know-how in antenna design. We completed successful contracts for the Defence Research and Development Canada (DRDC) on the topic of designing planar antennas for ultra wideband (UWB) applications, especially for direction finding systems. We developed an innovative technique for UWB (2-18GHz) sinusoidal planar antenna design and balun integration, along with original non-uniform tapered UWB couplers for the sinusoidal antenna feed. Furthermore, we designed new kinds of very sensitive and highly miniaturized dosimetric probes for accurate measurements of EM radiation effects on the human body. Such probes will enhance the knowledge of EM radiation effects of cellular phones, microwave ovens and other daily RF equipment on human health.

RESEARCH COLLABORATION

Our team is developing a very fruitful collaboration including common research axes and training through supervision, intensive courses and seminars. Part of this collaboration is successfully supported by granted research programs.

RESEARCH FACILITIES

The team forms part of the RF & Microwave Group (whose website can be found at www.genie.uottawa.ca/research/rsrch_site.php). The following facilities are available in our laboratories:

- Far-Field Anechoic Chamber
- Planar Near-Field Anechoic Chamber
- Network Analyzers (Up to 60 GHz)
- Spectrum Analyzers
- load-pull bench for embedded and on-wafer transistor characterization
- Commercial and In-House Electromagnetic Simulation Tools (HFSS, Ansoft Designer, IE3D, FEKO, Agilent ADS)

Our technician Mr. Alain Le Hénaff sees to the day-to-day running of the lab facilities.