PROJECT PROPOSAL FOR 4th YEAR STUDENTS

Project Title: Design of a fuzzy-neural tool for transistor modeling.

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Number of Students: Three students.

I – INTRODUCTION

The 21st century will be the information age characterized by ever-increasing needs for global and personal communications. This places severe constraints on the nature of the communicating terminal: it must be wireless and portable, cost-effectively produced in large numbers, and capable of broad bandwidth and high-power operation. In the same time, the demand for concurrent and multidisciplinary design with nonlinear behaviors, electromagnetic (EM) effects and reliability criteria considered simultaneously becomes increasingly important. Furthermore, the need for statistical analysis and yield optimization taking into account process variations and manufacturing tolerances in the components makes the computational tasks during simulation, statistical design and optimization, massive as well as highly repetitive. On the other hand, this trend should meet the time-to-market requirements where a single round of design is strongly required.

Field Effect (MESFETs and HEMTs) and Bipolar transistors (HBTs) are one of the most popular and efficient pieces of hardware used in today’s high frequency communications systems. When designing a system, designers are faced with various challenges when using the off-the-shelf components such as transistors to ensure the system’s compliance with a given set of standards. One of these challenges is the fact that the component characteristics, provided by the manufacture, fall within a given variance. This variance becomes critical for RF and Microwave frequencies. The aim of this proposal is to provide RF/microwave designers with nonlinear/EM-based transistor models into circuit simulators in order to achieve efficiently such statistical circuit analyses.

II – STATE OF THE ART

In RF/microwave systems, parameters are governed mainly by the active device behaviors. It is then extremely important that the transistor model generation must be both accurate and fast so that the design solutions can be achieved feasibly and reliably in commercial circuit/system simulators. To achieve a successful design, system designers have the option to select any appropriate existing models available in a commercial software library (such as Cadence, ADS, HSpice, etc…), plug it in, and then obtain the simulated circuit performance. Therefore, they are expecting the simulator will provide them with the best available models of a given device for both small- and large-signal applications. The research community has proposed a huge number of modeling techniques to make the design process easier, faster and more efficient. Most existing transistor modeling techniques use DC I-V measurements to represent nonlinear drain current and to obtain large-signal device model parameters.
such as transconductance and output conductance. However, the values obtained from DC measurements were not with a good agreement with their counterparts obtained from RF S-parameter measurements. This is due to low frequency dispersion and the self-heating and trap effects. There is a need, therefore, for further research towards development of efficient nonlinear models for such transistors.

First, in this process the designer should know the model parameter values accurately in order to use it efficiently. As a transistor model consists of passive and active circuit elements, appropriate values have to be assigned to model elements so that it best fits the measured device characteristics. The task of finding these values is called "parameter extraction" and it presents an undertaking challenge. The parameter extraction techniques are developed for that purpose. They are efficient, but need to start from an a priori transistor equivalent circuit topology as initial point. If this assumption is not valid and/or the device has a new technology, the parameter extraction process will be neither accurate nor as fast. Therefore, the generation of a library of models would be the first step of the present work. The key to identify the most reliable topology for a given transistor would be to use fuzzy logic approach.

Second, the extraction of equivalent circuit parameters and topology of existing models is based on small-signal data. Thus, highly nonlinear behaviors are not accurately described by this kind of circuit and therefore have to be included. Furthermore, if the extraction process generated many research works and publications for FETs and HBTs, no advanced work has been done to extract parameters using a general equivalent circuit topology approach.

Neural modeling of devices and circuits is one of the most recent trends in microwave CAD. Fast, accurate and reliable neural network models can be trained from measured or simulated data. Once developed, these neural models can be used in place of CPU-intensive physics/EM models of active/passive devices to speed up microwave design. Neural network techniques have been used to model a wide variety of microwave devices and circuits with significant successes. Furthermore, existing neural models for transistors use the concept of black box behavior or simple equivalent circuit technique (the non-linear elements are replaced by neural models in a standard equivalent circuit configuration). Thus, characterization of advanced large-signal neural models of FETs and HBTs would be the second target of the present proposal.

III – PROPOSED TASKS

The objectives of the proposed research can be listed sequentially as follow:

(a) Development of a classical extraction parameter algorithm for FETs and HBTs: With emphasis on optimal and statistical methods, the objective of this first part is to develop a classical algorithm for transistor parameter extraction using a standard topology. This step will assure a first order parameter values (first order solution) based on conventional approaches, e.g., conventional equivalent circuit topologies.

(b) Development of a library for optimum equivalent circuit topology of FETs: Since usual extraction techniques are based on an a priori topology, called standard topology, the purpose is to implement an automatic algorithm which can “identify” accurately the optimum equivalent circuit topology of the transistor. This can be achieved by generating a library of topologies using fuzzy logic theory.
(c) Development of a library for optimum equivalent circuit topology of HBTs: Since usual extraction techniques are based on an a priori topology, called standard topology, the purpose is to implement an automatic algorithm which can “identify” accurately the optimum equivalent circuit topology of the transistor. This can be achieved by generating a library of topologies using fuzzy logic theory.

(d) Global characterization of the two types of transistors using neural techniques: Once the libraries of both transistors are developed, a neural model of the best-selected topologies would be generated.

IV – IMPACT FOR STUDENT CURRICULUM

This proposal will allow students to use their present experience in circuit theory and computing to model efficiently RF/microwave transistors utilized in telecommunication systems. It will also allow students to have a deep knowledge of two of the most advanced intelligent algorithms, namely fuzzy logic and neural networks.

Moreover, the students will have the opportunity to achieve a project, which combine computer and electrical knowledge, master the characterization of transistors and advanced modeling techniques. Therefore, this mixing work is a significant asset to the student curriculum.