

Calendar Item:

SCV-CAS

TOPIC: Neural Networks for High-Frequency Electronic Modeling and Design

SPEAKER: Prof. Q. J. Zhang, Carleton University

DATE: Monday, August 18, 2003

Location: Cadence Design Systems, 2655 Seely Ave San Jose 95134

Time: Refreshments and Networking 6:30pm

Lecture 7:00pm

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Article

Neural Networks may be Future Help for RF/Microwave Designers.

In consumer driven economic environment where cost-reduction is pushing systems designers to push as much of a design onto a single chip as possible, including the majority of analog and RF components, a major challenge is system simulation and verification. One approach to this is to reduce the complexity of the simulated system by extracting the relevant block characteristics for system level simulation, through a process of characterization. For digital circuits we care primarily about delay, and we use circuit simulation in the process of digital library characterization. While this approach is being extended into the analog & RF world, the number of variables that must be determined in the process is large, and the types of variables are different for each type of model characterized, requiring extensive hand's on work. However, ever increasing operating frequency, circuit size and complexity, coupled with tightened design tolerances and shortened time-to-market cycles, makes CAD automation increasingly critical.

Simpler models are fast but are often under limited assumptions or mismatch may occur between computer solutions and hardware measurements. Accuracy, speed and flexibility have been for most of the time contradictory, until recently when neural models for microwave components were introduced.

This talk presents this emerging area in RF/microwave computer-aided design (CAD) exploiting artificial neural networks (ANN). It is aimed at achieving higher levels of speed, precision, and automation, in order to meet the challenges posed by next generation of high-frequency electronics design. We present cutting-edge achievements in ANN-based approaches in high-frequency CAD, leading to significant increase in efficiency in modeling, simulation, and optimization. ANN's ability to learn and generalize allows us to convert many conventional trial-and-error-based manual tasks in modeling of passive and active electronic circuits, into automated computer-based tasks. Applications presented will include modeling and design of high-speed/high-frequency semiconductor devices and circuits, high-speed VLSI interconnects, embedded passives, multi-layer printed circuits, electromagnetic structures, and wireless and telecommunication systems. The talk highlights fundamental concepts and methodologies, recent research results, industrial applications, and future trends in R&D. The recent birth of a new interdisciplinary area of scientific research that combines ANN concepts with electronic CAD technologies has created numerous opportunities for technical discovery and industrial applications.



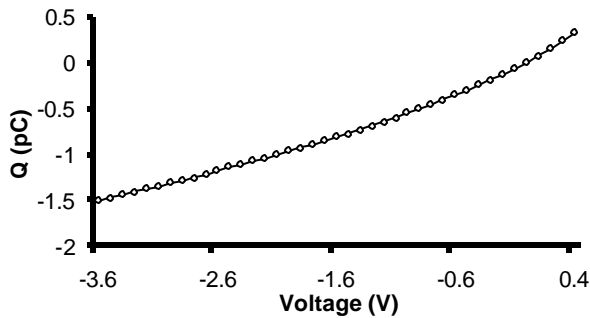
Artificial Neural Networks are information processing systems inspired by the ability of human brain to learn from observations and to generalize by abstraction. The fact that neural networks can learn totally different things led to their use in diverse fields such as pattern recognition, speech processing, control, medical applications and more. Neural models can be much faster than original detailed models, more accurate and flexible than empirical models, and easier to develop when a new device/new technology is introduced.

A Neural model contains a set of neurons and connections between neurons. Each neuron has an activation function processing the incoming information from other neurons. Take a neural model for microwave transmission line as an example, the transmission line geometrical parameters (say x) will be model inputs sent to some neurons called input neurons. After internal processing of all neurons, the neural model will produce electrical quantities (say y) of the transmission line at some neurons called output neurons. In model development stage, samples of x - y data are generated (e.g., from EM simulation or measurement). The model is then trained to learn from the data. Training is similar to an optimization process where internal parameters of the neural model are adjusted such that modeled solution best fits training data. A trained neural model can then be used online during

microwave design stage providing fast model evaluation replacing original slow EM simulators. Since neural model is trained directly from data, the model can be developed even if original problem formulae do not exist.

Examples of unknown relationships that can be learned by neural networks are: nonlinear current or charge formulas in FET models, and bias-dependency of FET parameters.

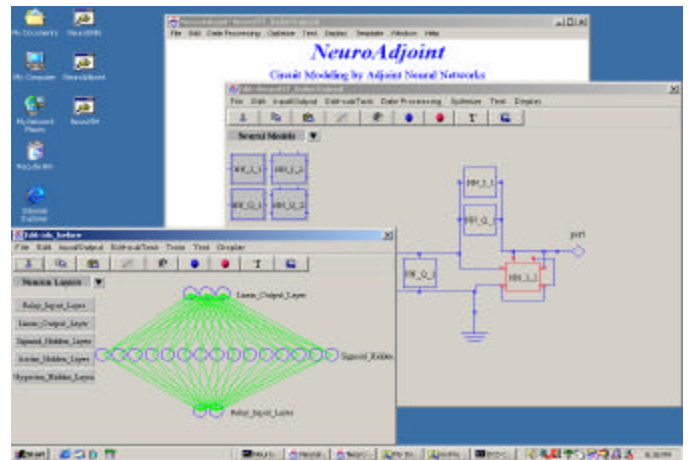
NONLINEAR CHARGE MODEL IN FET WITHOUT KNOWING CHARGE FORMULA



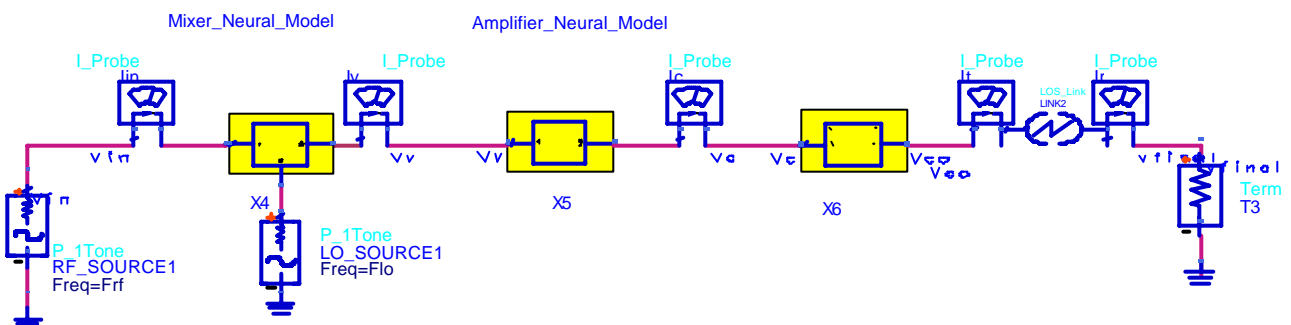
In this example, what we have are bias-dependent capacitor data. What we do not have is a nonlinear charge formula. Here we solve this modeling problem using the integration ability of the adjoint neural network method. We first train an “adjoint neural model” to learn bias dependent capacitor data. After training, we automatically get (without re-training) a nonlinear charge-model (i.e., Q-model). The figure at the left shows an example of comparison of charge model with analytical integration. The good agreement verifies the integration effect of training the adjoint neural model. This is a solution to one of the frequently encountered obstacles in developing a charge model for nonlinear capacitors required for harmonic balance simulators with only capacitor data available.

LARGE-SIGNAL FET MODELING WITH UNKNOWN CURRENT AND CHARGE FORMULAE

In this example, what we have are DC and bias-dependent small-signal data, and a FET equivalent circuit topology. What we do not know are the formulas for the nonlinear current and charge sources in the FET model. Manually creating such formulas could be time-consuming. Here we use neural networks to automatically learn such unknown relationships. In this example, the gate-source charge Q_{gs} and drain current I_d as nonlinear functions of gate and drain voltages are to be determined. However we do not have explicitly the charge data Q_{gs} and dynamic current data I_d for training the model. The available training data is the DC and bias-dependent S-parameters of the overall FET. To solve this problem, we use a theoretical concept that small-signal parameters reflect the derivative information of large-signal model. NeuroAdjoint does this trick and trains the Q_{gs} and I_d neural networks to complete the overall FET large-signal model.



TRANSMITTER EXAMPLE: In this example, neural models are trained to learn circuit level behaviors of two amplifiers and a mixer using training data from detailed harmonic balance simulations of Agilent-ADS. After training, the neural models are plugged into a transmitter system. A system level simulation is subsequently carried out in ADS enjoying original circuit behaviors with neither the expense nor the complexities of detailed circuit simulations.



Neural Networks are gaining recognition as a useful tool in the high-frequency CAD area showing promising strength in addressing growing challenges in EM-based and physics-based circuit design [1]. Neural networks can be trained to learn EM and physics based behaviors from component data, and the trained neural network can be used in high-level circuit and systems design allowing fast optimization including EM and physics effects in components. Recent works have led to the use of neural networks for a variety of circuit modeling and design applications [2,3]. Neural networks can be used for both passive and active modeling and optimization [4,5,6]. An important research topic is the concept of knowledge based neural networks where existing circuit models can be combined with neural networks allowing us to exceed the accuracy limitations in existing models [7]. Training of neural based circuit models can be further automated with the Automatic Model Generation (AMG) algorithm [8]. Large signal transistor device modeling can be automated exploiting neural network learning from DC and small-signal data [9]. Behavioral modeling of nonlinear circuits for wireless system simulation can also be achieved by dynamic neural networks (DNN) [10].

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About the Speaker: Qi-jun Zhang received the B.Eng. Degree from East China Engineering Institute, Nanjing, China in 1982, and the Ph.D. Degree in Electrical Engineering from McMaster University, Hamilton, Canada, in 1987. He was with Optimization Systems Associates Inc. (now acquired by Agilent), Dundas, Ontario, Canada during 1988-1990, developing advanced microwave optimization software. He joined the Department of Electronics, Carleton University, Ottawa, Canada in 1990 where he is presently a Professor. His research interests are neural network and optimization methods for high-speed/high-frequency circuit design. He has more than 150 publications in the area. He is an author of *Neural Networks for RF and Microwave Design* (Artech House, Boston, 2000), a coeditor of *Modeling and Simulation of High-Speed VLSI Interconnects* (Kluwer, Boston, 1994), a contributor to *Analog Methods for Computer-Aided Analysis and Diagnosis*, (Marcel Dekker, New York, 1988), a contributor to the upcoming *Encyclopedia of RF and Microwave Engineering* (Wiley, New York, 2004), a Guest co-Editor for a Special Issue on High-Speed VLSI Interconnects for *the International Journal of Analog Integrated Circuits and Signal Processing* (Kluwer, Boston, 1994), and a Guest Editor for two Special Issues on Applications of ANN to RF and Microwave Design for *the International Journal of RF and Microwave CAE* (Wiley, New York, 1999, 2002).

Dr. Zhang is a member of the Professional Engineers Ontario, and a Senior Member of the IEEE. He is a member of the Editorial Board of the IEEE Transactions on Microwave Theory and Techniques, and a member of the Technical Program Committee of the IEEE MTT-S International Microwave Symposium.