RESEARCH PROJECTS

DECEMBER 1992 - NOVEMBER 1993

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INDEX

INTRODUCTION

During the fiscal year 1992/1993 we continued our research work on the following three projects:

(1) Advances in Microwave Computer-Aided Design (CAD),

(2) Yield-Driven Design of Nonlinear Microwave Circuits,

(3) Statistical Modeling of Microwave Integrated Circuits and Devices.

Our overall research effort and net financial contribution were divided between the three projects as follows:

Project No. 1	50%	$38,502
Project No. 2	30%	$23,101
Project No. 3	20%	$15,401
Total claimed for the Investment Tax Credit in respect of Scientific Research and Experimental Development (SR & ED)		$77,004

The Canadian partial funding of our research (not included in the aforementioned figures) during the fiscal year was:

(1) Natural Sciences and Engineering Research Council's contribution to the salary of Industrial Research Fellow Dr. Shen Ye (December 1992 to March 1993).

RESEARCH PROJECT 1:

ADVANCES IN MICROWAVE COMPUTER-AIDED-DESIGN (CAD)

Objective of the Research

The main objective of the project is to survey the field of microwave CAD and to research and implement advanced features and techniques as either extensions to state-of-the-art existing software systems or as a basis for new software systems. This includes pioneering novel theories and developing new algorithms for parameter extraction, simulation and design optimization of both linear and nonlinear microwave circuits.

Software products exploiting the new features and techniques will be able to meet a strong industrial demand for efficient and reliable tools for nonlinear device parameter extraction (in particular GaAs FETs) coupled to sufficiently fast nonlinear circuit simulation and design (including yield-driven design). Such products should then be more competitive.

Nature of the Research

This research is essentially applied. However, many aspects of basic research are involved. The fields of science involved are mathematics: numerical methods, optimization theory, Fourier transforms; system theory: system identifiability; engineering: electrical circuit theory, electromagnetic field theory; and computer science: software architecture, parsers, data structures, graphics. Engineering applications are found in all aspects of linear and nonlinear analog circuit design.

Reference Material

Many references can be cited. A few important ones are:

V. Rizzoli, A. Lipparini and E. Marazzi, "A general-purpose program for nonlinear microwave circuit design", *IEEE Trans. Microwave Theory Tech.*, vol. MTT-31, 1983, pp. 762-769.

K.S. Kundert and A. Sangiovanni-Vincentelli, "Simulation of nonlinear circuits in the frequency domain", *IEEE Trans. Computer-Aided Design*, vol. CAD-5, 1986, pp. 521-535.

S.A. Maas, *Nonlinear Microwave Circuits.* Artech House, 1988.

Uncertainty of the Research

The main uncertainty of the project lies in the mathematical robustness and reliability of the methods being developed. We will not be able to implement them if they turn out to be unreliable, or fail to provide satisfactory results.

It is not clear how large the improvement in efficiency will eventually be and whether the methods will be sufficiently cost-effective in their implementation. Many of the features being developed will be buried deeply in new software products, and as such may be appreciated by more advanced users only.

Novelty of the Research

This research represents new work on state-of-the-art software systems. Our group has achieved world recognition in this area. As such our contributions are novel.

Advance in Scientific Knowledge

After this research is successfully completed, the advanced features and techniques developed will constitute a true breakthrough in CAD tools available to microwave circuit design engineers. In particular, parameter extraction of microwave active devices based on physics equations, consistent models for all types of circuit simulation and design, and field theory based component analysis, all in a user-friendly CAD environment, are of utmost importance.

Method of Research

Accepted scientific methods are employed. Since the team members have been actively working in this research area for a number of years no extra literature search was necessary except for recent periodicals. Existing CAD software systems are continually studied.

Long-term and short-term goals are carefully defined and milestones are scheduled. Theoretical investigations are conducted and then the new concepts are implemented in computer programs and verified through numerical examples. Promising algorithms are further tested on a number of industrial examples.

Progress to Date

The starting date for this project in its present form was August 1, 1988. However, different components of the project had been carried out since early 1987. By November 1992 we had already developed, released and marketed three computer programs: (1) HarPE - for nonlinear device parameter extraction, (2) OSA90/hope - a novel, state-of-the-art general purpose CAD software system featuring open architecture achieved through our research on high speed interprocess data communication [11], and (3) Empipe - for direct electromagnetic simulation and optimization. We pioneered the parameter extraction method based on large-signal power spectrum measurements and the harmonic balance simulation technique [6,9,15]. We laid a foundation for analytical unification of DC, small-signal and large-signal circuit simulations and optimizations [10]. We developed adjoint sensitivity technique for harmonic balance simulations [7,8]. We have developed models for microstrip structures to expand our library of linear elements [13,14], and made a significant progress in connecting external simulators to our software and exploiting them to solve important practical problems [16-21].

Between December 1, 1992 and November 30, 1993 we continued our work on different parts of the project. In particular we were developing models and techniques for direct electromagnetic field simulation and optimization. A new robust method of optimization using the Huber function was developed for microwave CAD.

Reports

The papers [26-33], manuals [22-25] and reports [34-39] summarize our new work within the framework of this project. Our new robust Huber optimization technique for CAD [26] was published in *IEEE Transactions on Microwave Theory and Techniques*. It is the most reputable journal in the field. Our methods of direct electromagnetic field optimization [27,28] were presented in 1993 IEEE MTT-S International Microwave Symposium and the 23rd European Microwave Conference (September, 1993), and were recognized internationally as a pioneering work in the field. The methods have been successfully applied to solve a very difficult problem in the design of high-temperature superconducting microwave filters [30]. Four new papers [30-33] were submitted to 1994 IEEE MTT-S International Microwave Symposium and 1994 IEEE International Symposium on Circuits and Systems. All of them were accepted for presentation.

Description of the Project

Within the framework of this project we make an effort to combine different techniques with the aim of integrating them into versatile, user-friendly and state-of-the-art software systems. It involves developing new methods as well as enhancing some of the existing techniques.

The advances in GaAs material development and wafer processing achieved in the past few years have made monolithic microwave integrated circuits (MMICs) practical. The modeling of MMIC devices is recognized as a subject of fundamental importance [1,2,4,5]. Also, the harmonic balance method has become an important tool for the analysis of nonlinear circuits. The excellent paper of Kundert and Sangiovanni-Vincentelli [3] provided systematic insight into that method. Our achievements in the adjoint sensitivity analysis technique [7] and its expedient implementation in general purpose CAD software [8] has made the harmonic balance method attractive for design optimization. These techniques are now being applied in conjunction with the state-of-the-art electromagnetic field level simulation of individual components [12].

Our research efforts have been concentrated on the following subjects:

(1) development and/or implementation of new nonlinear device models,

(2) investigation of seamlessly integrated, consistent DC/small-signal/large-signal circuit simulations and optimizations,

(3) efficiency and robustness of mathematical algorithms,

(4) open architecture and flexible data structures for CAD tools,

(5) accessing internal variables and processing capabilities of CAD systems,

(6) user-friendliness of CAD tools,

(7) state-of-the-art CAD tools for GaAs FET small-signal, DC and large-signal model simulation, optimization and parameter extraction,

(8) work towards a new generation comprehensive software system suitable for yield and cost driven design of microwave circuits in terms of layout/geometrical and process/technological parameters.

(9) direct electromagnetic field simulation and optimization for accurate circuit design taking into account electromagnetic effects such as radiation and coupling.

To date we have made progress in all of these subjects. Implementation of these features and techniques has been made within the new releases of our software systems HarPE [25], OSA90/hope [23], and in our interface of Empipe [24] to the electromagnetic simulator ***em*** [12] from Sonnet Software.

Our new optimization technique using the Huber function [26] was published in *IEEE Transactions on Microwave Theory and Techniques*. This new technique provides a robust optimization method for microwave CAD. Its features have been demonstrated in device modeling, circuit diagnosis and design centering [33] which will be presented at 1994 International Symposium on Circuits and Systems (London, England, May 1994).

We have significantly advanced our work on item (9). Utilizing our inter-program pipe communication technique for high speed numerical interactions between independent programs, we have interfaced ***em*** (Sonnet Software) and SPICE (public domain) to OSA90/hope [24,35]. The interfaces between OSA90/hope and the external simulators provide a very friendly and powerful environment for performance- and yield-driven circuit design [32]. We have contributed to the area of microstrip filter design [27,34]. For the first time, we developed a novel and exciting optimization technique, called Spacing Mapping (SM) for solving extremely difficult optimization problems. These problems may be encountered in electromagnetic design due to high sensitivities, long simulation times, etc. Using the SM technique and in cooperation with Westinghouse Science and Technology Center of Pittsburgh we successfully approached design of a narrow-band filter to be realized in HTS (high-temperature superconductor) technology [30]. With the SM technique we have solved a number of CPU intensive simulation and optimization problems such as ***em*** optimization using coarse grids [32].

Using our efficient harmonic balance (HB) simulator of OSA90/hope we have successfully performed compression analysis of a high power bipolar transistor amplifier [39]. The amplifier was used by Microwave Engineering Europe to challenge the major microwave RF CAD vendors in the whole world [40]. The amplifier worked well in practice but proved very difficult to simulate using nonlinear HB simulators [40]. Only four companies worldwide reported their results [40]. OSA was the quickest company to report results and was the only company whose first attempt was successful [40].

In our future work we will continue to concentrate on further development of direct electromagnetic field simulation and optimization of arbitrary geometrical structures.

Technical Personnel

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Dr. S.H. Chen

Dr. S. Ye

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RESEARCH PROJECT 2:

YIELD-DRIVEN DESIGN OF NONLINEAR MICROWAVE CIRCUITS

Objective of the Research

The main objective of the project is to develop new methods and algorithms suitable for statistical design of analog electrical circuits, in particular nonlinear microwave circuits operating in the steady state under large-signal periodic excitations. Our aim is to produce novel results and software relevant to the emerging area of monolithic microwave integrated circuits (MMICs). Software products exploiting such methods should be capable of designing high yield practical nonlinear circuits. These software products will then be competitive commercially.

Nature of the Research

This research is both basic and applied. It is our aim to extend specific techniques and methods by applying them to a larger class of microwave circuits. The fields of science involved are mathematics: optimization theory, statistical analysis; and electrical circuit theory. Engineering applications are specifically found in all aspects of nonlinear analog circuit design including analysis, optimization, parameter extraction, statistical design and modeling.

Reference Material

Many references can be cited. An important contribution is:

J.W. Bandler and S.H. Chen, "Circuit optimization: the state of the art", (invited), *IEEE Trans. Microwave Theory Tech.*, vol. 36, 1988, pp. 424-443.

Uncertainty of the Research

The main uncertainty of the project lies in the feasibility and reliability of the methods being developed since they are computationally intensive and partially heuristic in nature. We will not be able to fully implement them if they turn out to be unreliable, highly sensitive to computational accuracy or fail to provide satisfactory results for a large variety of circuits. Fast workstations and large-scale optimization techniques are likely to be required, which introduces further risk and uncertainty.

The uncertain future of statistical design of microwave integrated circuits, and acceptance of the necessary software tools by microwave engineers also makes this a high risk project. The prognosis for the affordable manufacture of monolithic microwave integrated circuits (MMICs) is still uncertain.

Novelty of the Research

This research is a followup of state-of-the-art published works by members of the team, e.g., [2,3]. As such it is novel.

Advance in Scientific Knowledge

If this research is successfully completed, the algorithms may constitute a true breakthrough in the numerical approach to the simulation and statistical analysis and yield optimization of large and nonlinear engineering systems.

Method of Research

Accepted scientific methods are employed. Since the team members have been actively working in this research area for a number of years no extra literature search was necessary except for recent periodicals. According to our expectations, appropriate mathematical manipulations are conducted and then the new concepts are programmed. The algorithms being developed are then tested on a number of circuit examples.

Progress to Date

The starting date for the project was August 1, 1986. By November 1992 we successfully demonstrated feasibility of an extremely efficient method [5] for quadratic approximation of circuit response functions, including testing, reliability studies and, especially, applying these methods to yield optimization of a large-scale practical microwave circuit, namely a 5-channel multiplexer [4]. We pioneered yield optimization of nonlinear circuits operating in the steady-state under large-signal excitations [6], and developed a fast gradient based technique for such applications [7]. We developed a quadratic modeling technique based on both simulated responses and their gradients [9]. We researched yield optimization of MMIC circuits in terms of physical and geometrical parameters of active devices and passive components, including correlations [10]. We also introduced Monte Carlo analysis into HarPE [14]. We have completed development of yield optimization capabilities for our general purpose CAD software system OSA90/hope [13]. We have devised a new algorithm for yield optimization [16] and investigated the predictability of simulated yield [15]. We have researched yield optimization of microwave circuits with passive components accurately analyzed by an electromagnetic field simulator [12].

Between December 1, 1992 and November 30, 1993 we continued our work on this project. We have developed a novel approach for yield-driven electromagnetic optimization using multilevel multidimensional models [22,23]. We have investigated a novel Huber optimization technique in design centering [25].

Reports

The papers [22-25], manuals [18-20] and reports [26-31] summarize our new work within the framework of this project. Our method for yield-driven electromagnetic yield optimization using multidimensional models [23] was published in *IEEE Transactions on Microwave Theory Techniques*. A paper describing our method [22] was presented in 1993 IEEE MTT-S International Microwave Symposium. Two new papers [24,25] were submitted to 1994 IEEE MTT-S International Microwave Symposium and 1994 IEEE International Symposium on Circuits and Systems.

Description of the Project

Statistical circuit design, or yield optimization has been a subject of extensive research in the last decade, e.g., [1]. It is important to truly reflect the actual statistical spreads during computer simulations. Therefore, the primary physical and geometrical parameters must be available. Unfortunately, component simulation in terms of such parameters is extremely slow. This makes yield optimization of practical nonlinear microwave circuits a challenging task because of complexity and computational effort involved. In this research we concentrate our efforts on algorithms for statistical design of nonlinear circuits operating in the steady state under large-signal periodic excitations.

In our previous work we have successfully researched physics-based design and yield optimization of MMICs. Our research results were very well recognized internationally and were described in our large paper [17] published in the Special Issue of *IEEE Transactions on Microwave Theory and Techniques* on Process-Oriented Microwave CAD and Modeling. We have implemented a new algorithm for yield optimization, more suitable for gradient based optimizers because of the smoothness of the objective function [16]. We have also advanced our previous work on the predictability of simulated yield as compared to yield determined directly from device measurements [15].

Between December 1, 1992 and November 30, 1993 we devoted great effort to development of efficient techniques for yield-driven electromagnetic optimization. In this context we have developed a number of methods such as multilevel multidimensional quadratic modeling [22,23,25,27,28,29] and one-sided Huber centering [25].

Our method of multilevel multidimensional modeling for yield-driven electromagnetic optimization was presented in 1993 IEEE MTT-S International Microwave Symposium [22] and published in *IEEE Transactions on Microwave Theory and Techniques* [23]. We have tested this method within our Empipe [20] which is the only software system handling direct electromagnetic optimization in the world. Our CAD environment for performance and yield driven circuit design employing electromagnetic field simulators [24] has been submitted to the 1994 IEEE International Symposium on Circuits and Systems and was accepted for presentation.

We have applied Huber optimization technique in design centering and yield optimization. To this end we devised a one-sided Huber optimization technique. A paper consisting of our research results [25] was submitted to the 1994 IEEE International Symposium on Circuits and Systems and was accepted for presentation.

In the future we will concentrate our efforts on further improvements of the algorithms and methods for statistical design of analog and microwave circuits, particularly for direct electromagnetic yield-driven design.

<u>Technical Personnel</u>

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RESEARCH PROJECT 3:

STATISTICAL MODELING OF MICROWAVE INTEGRATED CIRCUITS AND DEVICES

Objective of the Research

The main objective of the project is to establish the mathematical theory and algorithms aimed at modeling the statistical behaviour of manufactured microwave integrated devices. Software products implementing such algorithms should provide reliable statistical device models for yield analysis and optimization. These software products will build the bridge between process engineers and circuit designers in a volume production environment.

Nature of the Research

This research is both basic and applied. It is our aim to solve specific practical problems in microwave circuit modeling and design. In that sense it is applied. However, many aspects of basic research are involved. The fields of science involved: numerical methods, electrical circuit theory, microwave theory and techniques, statistical analysis, physics. Engineering applications will be found in all engineering areas involving mathematical modeling and volume production.

Reference Material

Two important papers can be cited:

S. Liu and K. Singhal, "A statistical model for MOSFETs", *IEEE Int. Conf. on Computer-Aided Design* (Santa Clara, CA), 1985, pp. 78-80.

J. Purviance, D. Criss and D. Monteith, "FET model statistics and their effects on design centering and yield prediction for microwave amplifiers", *IEEE Int. Microwave Symp. Digest* (New York, NY), 1988, pp. 315-318.

Uncertainty of the Research

The uncertain future of statistical modeling and design of microwave integrated circuits, and acceptance of the necessary software tools by microwave engineers makes this a high risk project. The prognosis for the affordable manufacture of monolithic microwave integrated circuits (MMICs) is still uncertain. Recent cuts throughout the high-tech microwave industry may slow down these developments.

Novelty of the Research

Statistical modeling of microwave integrated circuit devices is being pioneered by only a few research groups worldwide, including OSA. This research extends, where possible, statistical modeling techniques used in VLSI digital circuits to microwave circuits. We develop new techniques otherwise. As such, this research is novel.

Advance in Scientific Knowledge

The methods and algorithms developed within this project will help the microwave engineers to investigate, better understand, and, as a consequence, to utilize device statistics in the process of circuit design. This research is aimed at establishing a framework for complete statistical characterization and design of microwave integrated circuits.

Method of Research

Accepted scientific methods are employed. Since the team members have been actively working in this research area for a few years no extra literature search was necessary except for recent periodicals. Long-term and short-term goals are carefully defined and milestones are scheduled. Theoretical investigations are conducted and then the new concepts are implemented in computer programs and verified through numerical examples. Promising algorithms are further tested on a number of industrial examples. The project particularly requires interaction with integrated circuit process and fabrication engineers to determine and obtain relevant measured data. Interaction with industry also provides important feedback.

Progress to Date

The starting date for the project was June 1, 1988. By November 1992 we had reviewed the state-of-the-art in statistical modeling; we had developed the theory for combined discrete normal statistical modeling [7]; and we had developed the theory for optimization based statistical modeling, tested it, and implemented it in our commercial software product HarPE Version 1.4+S (the current version is 1.6 [9]). We had experimented with the Ladbrooke model [6] and processed wafer measurement data from Plessey Research Caswell Ltd. Encouraging results were obtained [8]. We had also attempted to extend the Khatibzadeh and Trew model [4] to statistical applications. Our experiments indicated that statistical representation of device statistics by the Khatibzadeh and Trew model was not satisfactory. This led us to investigate the possibility of combining the two models into one model exploiting their respective advantages [12]. The combined model (KTL) was implemented in HarPE. We have presented our work on physics based KTL model in our comprehensive paper [11].

Between December 1, 1992 and November 30, 1993 we continued our work on new optimization technique based on the Huber function. We intensified our research on physics-based statistical modeling of GaAs MESFETs. We have developed a novel approach to statistical modeling using cumulative probability distribution fitting. It is based on a solid mathematical foundation.

Reports

The papers [14-17], manual [13] and reports [18-20] summarize our new work within the framework of this project. Our research results of statistical modeling using the Huber function [14] was presented at the 1993 IEEE MTT-S International Microwave Symposium. Our paper about robust physics-oriented statistical modeling of GaAs MESFETs was submitted to 1994 Gallium Arsenide Application Symposium and was accepted for presentation. The paper of our novel approach to statistical modeling using cumulative probability distribution fitting was submitted to 1994 IEEE MTT-S International Microwave Symposium and was accepted for publication.

Description of the Project

Statistical modeling is a prerequisite to using statistical design techniques. Such a procedure has been successfully used in the design of MOSFET devices, CMOS and other types of VLSI digital circuits [1,2]. GaAs integrated circuits now play an important role in microwave engineering. How to obtain the statistical models is a vital step towards effective use of yield analysis and optimization. However, such modeling techniques are relatively new to most microwave engineers. The literature on this subject is very sparse, e.g., [3,5,7,8].

Generally speaking, statistical modeling is to find a model and the statistical distribution of the model parameters. The available information are measurements of the external behaviour of circuits or devices, and possibly process/geometrical measurements. Different levels of information may be hierarchically classified, from top to bottom, as response level, electrical model parameter level, intermediate parameter level and basic process/geometrical parameter level.

Our work on physics-based statistical modeling was one of the leading achievements in this area in the world. This was reflected by our research results presented in a comprehensive paper [11] published in the Special Issue of *IEEE Transactions on Microwave Theory and Techniques* on Process-Oriented Microwave CAD and Modeling.

Between December 1, 1992 and November 30, 1993 we concentrated our efforts on developing new algorithms and methods for statistical modeling to increase the model efficiency and accuracy. We also advanced our research on physics-based statistical modeling in the context of robustness and accuracy.

Based on our previous work we have carried out research on a new and robust optimization technique for statistical modeling [14,17]. It is based on the Huber function which combines advantages of the least-squares and the ℓ_1 norms. We obtained very good results [14] which were presented at the 1993 IEEE MTT-S International Microwave Symposium (Atlanta, GA, June 1993).

We have advanced our research on physics-based statistical modeling based on the KTL model [15,18]. We included the statistics of DC measurements in our parameter extraction. The model parameter statistics were obtained by postprocessing the extracted models for the corresponding wafers. The model accuracy was greatly increased. Our paper in this subject [15] was submitted to 1994 Gallium Arsenide Application Symposium and was accepted for presentation.

One of the significant achievements in this project in the reported period was that we have developed a new method for statistical modeling [16,20]. The new approach is based on a solid mathematical foundation and proves to be more accurate and reliable. Using our new technique the statistical model is determined by fitting cumulative probability distributions or histograms of the model responses to those of the measured data. The optimization variables can include the mean values and standard deviations of the statistical parameters. The model parameter statistics are obtained directly instead of from postprocessing a set of individually extracted models. Our paper in this topic [16] was submitted to 1994 IEEE MTT-S International Microwave Symposium and was accepted for publication.

In the future we will continue research in all of the aforementioned subjects.

Technical Personnel

Dr. J.W. Bandler, Director of Research

Dr. R.M. Biernacki

Dr. S.H. Chen

Dr. S. Ye

We have also interacted with Dr. Q. Cai of McMaster University [15,16,18,20]. Dr. Cai joined OSA in December, 1993 and will be involved in our research.

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TECHNICAL PERSONNEL

Director of Research

Dr. J.W. Bandler is President of Optimization Systems Associates Inc., established in 1983, and Director of Research.

Dr. Bandler studied at Imperial College of Science and Technology, London, England, from 1960 to 1966. He received the B.Sc. (Eng.), Ph.D and D.Sc. (Eng.) degrees from the University of London, London, England, in 1963, 1967 and 1976, respectively.

Dr. Bandler joined Mullard Research Laboratories, Redhill, Surrey, England in 1966. From 1967 to 1969 he was a Postdoctorate Fellow and Sessional Lecturer at the University of Manitoba, Winnipeg, Canada. He joined McMaster University, Hamilton, Canada, in 1969, where he is currently a Professor of Electrical and Computer Engineering. He has served as Chairman of the Department of Electrical Engineering and Dean of the Faculty of Engineering. He currently directs research in the Simulation Optimization Systems Research Laboratory. He has some 260 research publications. Dr. Bandler is a Fellow of the Royal Society of Canada, a Fellow of the Institute of Electrical and Electronics Engineers and a Fellow of the Institution of Electrical Engineers (Great Britain). He is a member of the Association of Professional Engineers of the Province of Ontario (Canada).

Senior Research Personnel

Dr. R.M. Biernacki received the Ph.D. degree from the Technical University of Warsaw in 1976. He has more than 20 years of professional experience which includes several academic and research positions.

Dr. Biernacki joined Optimization Systems Associates Inc., in 1986, as Senior Research Engineer. In 1988 he was appointed Professor of Electrical and Computer Engineering (part-time) at McMaster University, Hamilton, Canada.

Dr. Biernacki's research interests include system theory, optimization and numerical methods, computer-aided design of integrated circuits and control systems. He has more than 80 publications in IEEE journals and proceedings of IEEE and other conferences. Dr. Biernacki is a Senior Member of the Institute of Electrical and Electronics Engineers.

Research Personnel

Dr. S.H. Chen received the B.S.(Eng.) degree from the South China Institute of Technology, Guangzhou, China, with top class honours, in 1982. Between 1983 and 1987, he pursued his graduate studies in the Department of Electrical and Computer Engineering, McMaster University, Hamilton, Canada, where he received the Ph.D. degree in 1987.

Dr. Chen joined Optimization Systems Associates Inc. in 1987 as Research Engineer. He is responsible for developing state-of-the-art CAD mathematics, algorithms and software.

Dr. Chen's professional interests include optimization theory and algorithms, computer-aided microwave circuit design, statistical analysis and yield optimization, robust device modeling, and user-friendly computer graphics. He has contributed to some 30 technical papers, including an invited paper for the 1988 Special Issue on Computer-Aided Design of the IEEE Transactions on Microwave Theory and Techniques entitled "Circuit optimization: the state of the art".

Dr. S. Ye received the B.Eng. and M.Eng. degrees from Shanghai University of Technology, Shanghai, China, in 1982 and 1984, respectively, and the Ph.D. degree from McMaster University, Hamilton, Canada, in 1991, all in electrical engineering.

Dr. Ye was a teaching and research assistant in the Department of Electrical Engineering, Shanghai University of Technology from 1984 to 1986. He joined the Simulation Optimization Systems Research Laboratory and the Department of Electrical and Computer Engineering, McMaster University as a graduate student in 1986. He held an Ontario Graduate Scholarship for the academic year 1989/90.

In 1991 Dr. Ye was awarded an NSERC Industrial Research Fellowship and joint Optimization Systems Associates Inc., Dundas, Canada, as Research Engineer. His research interests include circuit CAD software design, simulation and optimization techniques, active and passive device modeling and parameter extraction and statistical circuit design. In 1993 Dr. Ye joined Com Dev Ltd., Cambridge, Canada.

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