Guest Editorial
Process-Oriented Microwave CAD and Modeling

DESIGN by computer was once regarded by some with serious misgivings. It is now embraced by almost every engineer as an essential component of the art and science of engineering practice. Real, hands-on engineering design now includes computer hardware, computer software and information processing in various relevant forms. Indeed, technical advances have created a situation in which it is sometimes hard to distinguish between simulation of information processing systems and the information processing activity itself.

CAD software, once regarded as a novelty by microwave engineers, is all pervasive. Commercial activity is thriving, as international conferences and exhibitions verify. Numerical methods of modeling, simulation, optimization, design and control as well as data storage and manipulation are cornerstones of the theory and practice of electromagnetic fields, electronic circuits, microwave systems and measurements. As this Special Issue exemplifies, numerical methods are merging expertise from diverse practices such as active and passive device design on the one hand and system simulation on the other. Once separated by function and terminology, the numerical methods of electromagnetic field-theory practitioners and those of circuit-theory practitioners are increasingly intertwined. As digital circuits are to be driven even faster, analog circuit-theoretical and field-theoretical studies gain new relevance and impetus. Boundaries between areas of expertise have become significantly more elastic as open-architecture CAE systems are assembled.

We believe that only integrated CAD systems which directly link geometry, layout, physical parameter and process parameter descriptions with performance, yield and system specifications address the challenges of microwave IC circuit and design technology in this decade. Hierarchically structured CAD systems need to integrate field theory, circuit theory and system theory into a computational environment for process-oriented linear, nonlinear and statistical microwave simulation and design. Fast, predictable, physics-based modeling and simulation of (M)MIC devices and circuits will be important aspects of manufacturable designs. First-time success in a fabricated circuit meeting its design specifications is a realistic goal!

In our approach to microwave CAD and modeling the terms "analysis and synthesis" should give way to the terminology "simulation and optimization." Numerical analysis is highly mature in both field theory and circuit theory. The term "inverse" as used in the context "inverse problems," i.e., optimization [1], in field-theoretic studies is a contemporary manifestation of analysis fixation [2]. To a microwave circuit design engineer schooled in the exploitation of optimizers there is nothing inverse about optimization. On another note: the term "synthesis," for many years associated with the orthodox approach to design by analytically-oriented circuit theorists, shielded its adherents from facing the reality of competitive optimal design by iterative techniques. We should add, however, that the term synthesis is likely to make a strong comeback, but in the context of pseudo-analytical computer-oriented design, as more powerful automation and expert system methodologies emerge.

The direction in microwave techniques that we have adopted may be benchmarked by two relevant papers. The first is the Bandler *et al.* integrated approach to microwave design, first appearing in the 1975 IEEE International Microwave Symposium, reprinted in 1985 [3]. The second is the Jansen *et al.* proposal for an MMIC design engineering workstation [4], first described at the 1986 IEEE International Microwave Symposium, Workshop on Trends in Microwave CAD, organized by K. C. Gupta.

The terms *simulation-ready* and *optimization-ready* to describe a CAD module which is readily linked with a simulator or optimizer, respectively, appear quite descriptive of the computational philosophy we have in mind for this Special Issue. In this context, a *process-ready* CAD module may refer to a computer program which facilitates a path for technologically-oriented information from a process-, physically- or geometrically-based description of a device or circuit to readily interface with a yield-driven, optimization-oriented man-machine design environment. Process-independence and layout-orientation are essential at lower levels of the hierarchical structure, but *dependent* representations of equivalent circuits or mathematical models are necessary at the higher levels. The classical approach of employing equivalent circuit models with independent parameters hinders the effective representation of and optimal design with statistical effects and spreads in integrated circuits. It is more obstacle than aid to yield-driven design. Of course, the software engineering trend towards open-architecture software systems is quite consistent with our process-, simulation- and optimization-ready philosophy.

The bond between the various computational modules is further strengthened without compromising modularity through *efficient and accurate sensitivity information transfer*. Often neglected, particularly in commercial software of vintage architecture, this is the foundation of truly integrated optimization-driven simulators. We feel

that significant implementational inroads have yet to be realized in this arena. This is, of course, particularly true for structures evaluated by field simulation to be driven by optimizers.

With the foregoing thoughts in mind, we have solicited papers to benchmark existing microwave design methodologies and to highlight emerging techniques relevant to the process-oriented approach. We aimed at covering various specific topics, including (1) "next generation" microwave simulators, (2) CAD related automated measurement techniques, (3) deembedding and process-oriented parameter extraction, (4) device and circuit diagnosis and testing, (5) field-theoretic simulation techniques, (6) layout generation techniques and software, (7) CAD oriented computational methods, (8) device and component modeling, (9) advances in MMIC/CAD design technology, (10) statistical modeling and data bases, (11) yield optimization and design centering methodologies, (12) advances in linear and nonlinear simulation in the frequency and time domains, (13) simulation and modeling of high-speed digital circuits, (14) computer-aided manufacturing techniques, (15) system simulation and design, (16) advanced MMIC elements and circuits and (17) CAD solutions to novel devices, circuits and subsystems.

The microwave community, including both authors of submitted papers and reviewers we selected, interpreted the Call for Papers in a much broader manner, in instances more traditional, than we had originally envisaged. We decided to retain certain papers, whose focus was not directly process-oriented, but whose methodologies were considered noteworthy.

The wide distribution of papers submitted in methodology and applications could be separated into four broad categories. The first category, the essential area of active device modeling, particularly for the various design related aspects of FETs and HEMTs is still a topic of intense activity. We decided to group the accepted papers into a section on *Active Device Modeling*. High interest is also true for the second category, electromagnetic field theory analysis and characterization methods, 2D and 3D, applicable in various forms to the CAD of passive microwave IC configurations. It is increasingly hard to distinguish components from circuits as more and more full wave analysis is applied to arbitrary geometries. We placed relevant papers appropriately into *Simulation Techniques for Passive Devices and Structures*. However, the maturing of the art is best reflected by a group of papers dealing with process-related design on the full circuit level. These design methodologies take into account hierarchical design aspects such as process simulation, thermal analysis, statistical modeling and yield-driven design, as well as the methodology of mass production, including a full CAD example in the mm-wave region. Papers in this area are concentrated under *Yield-driven CAD* and *Nonlinear Circuit Simulation and Design*, the latter overlapping both *Yield-driven CAD* and *Active Device Modeling*. The fourth category is also process-oriented but in a broader sense. It is related to waveguide components and thus to manufacturing techniques clearly distinct from microwave IC process technology. Some of these papers have been subdivided into *Passive Component Modeling* and *Modeling of Transmission Structures*. We also decided to expose two distinctive papers under the heading *Novel CAD Applications*. Finally, the section of *Short Papers* contains contributions that span the entire spectrum of our Special Issue.

We are particularly pleased by the contributions from industry reporting implementation. It is interesting to note the large number of excellent contributions from Europe, confirming disproportionately high interest and activity w.r.t. the United States.

In preparing this editorial, it was particularly interesting to peruse the pages of previous Special Issues, such as the Special Issues of the IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES on Computer-Oriented Microwave Practices (1969 and 1974) and on Microwave Computer-Aided Design (1988). Many papers therein are as fresh and relevant now as they appeared then, others more so! In particular, the echoes of the 1988 Editorial by K. C. Gupta and T. Itoh are unattenuated to this day.

A very interesting recent trend is also apparent to us. Some developments reported as state-of-the-art and presented by speakers at international symposia are simultaneously featured in commercially available software and can be observed in the commercial exhibits associated with the symposia. Furthermore, features actually available for some time in some commercial software, are often innocently presented as novel in the sessions. Perhaps these observations are a manifestation of our singular perspective influenced by our own individual academic, research and commercial pursuits. In any case, we draw the conclusion that our subject is fast-paced, exciting and highly competitive.

We have enjoyed working together towards this volume, which was conceived several years ago. We thank the very large number of authors and reviewers who devoted much time to its success, and also Dr. Stephen A. Maas, Editor, for his cheerful cooperation. The names of the reviewers appear below.

REFERENCES

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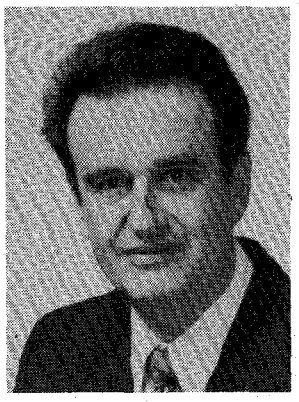
Guest Editors



John W. Bandler (S'66–M'66–SM'74–F'78) was born in Jerusalem, on November 9, 1941. He 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.

He 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, ON, Canada, in 1969, where he is currently Professor of Electrical and Computer Engineering. Dr. Bandler 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.

Dr. Bandler has pioneered contributions in simulation, sensitivity analysis and optimization of linear and nonlinear circuits, statistical design centering, design with tolerances and postproduction tuning, yield-driven design optimization, fault diagnosis of analog circuits, optimal load flow in power systems, GaAs device statistical modeling and parameter extraction. He is President of Optimization Systems Associates Inc. (OSA), which he founded in 1983. OSA implemented a first-generation yield-driven microwave CAD capability for Raytheon in 1985, followed by further innovation in linear and nonlinear microwave CAD technology for the Raytheon/Texas Instruments Joint Venture MIMIC Program. OSA introduced its state-of-the-art nonlinear circuit CAE workstation systems HarPE™ in 1989, OSA90™ and OSA90/hope™ in 1991. In addition, he is President of Bandler Research Inc., founded in 1989.

Dr. Bandler contributed to *Modern Filter Theory and Design* (Wiley-Interscience, 1973) and to *Analog Methods for Computer-Aided Analysis and Diagnosis* (Marcel Dekker, Inc., 1988). He has published about 250 papers, four of which appear in *Computer-Aided Filter Design*, (IEEE Press, 1973), one in each of the *Microwave Integrated Circuits* (Artech House, 1975), *Low-Noise Microwave Transistors and Amplifiers* (IEEE Press, 1981), *Microwave Integrated Circuits*, 2nd ed. (Artech House, 1985), *Statistical Design of Integrated Circuits* (IEEE Press, 1987), and *Analog Fault Diagnosis* (IEEE Press, 1987). Dr. Bandler was an Associate Editor of the IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES (1969–1974) and Guest Editor of the Special Issue of the IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES on Computer-Oriented Microwave Practices (March 1974). He joined the Editorial Boards of the *International Journal of Numerical Modeling* in 1987, and the *International Journal of Microwave and Millimeterwave Computer-Aided Engineering* in 1989. He is on the MTT-S Technical Committee on CAD. He is a Fellow of the Royal Society of Canada, a Fellow of the Institution of Electrical Engineers (Great Britain), a member of the Association of Professional Engineers of the Province of Ontario (Canada) and a Member of the Electromagnetics Academy.

Rolf H. Jansen (M'75–SM'84–F'89) was born in Cologne, Germany, on June 24, 1946. He received the Master's degree and Ph.D. in electrical engineering from the University of Aachen (RWTH), Germany, in 1972 and 1975, respectively.

From 1976 to 1979 he was a Senior Research Associate at RWTH Aachen. In 1977 he became an Industrial Research Associate for the radio communication division of Standard Elektrik Lorenz AG(SEL) in Pforzheim, Germany. He served as a Professor of Electrical Engineering from 1979 to 1985 at the University of Duisburg, Germany, teaching and carrying out research on electromagnetic theory, microwave techniques and CAD, measurement techniques and modeling. He is Manager and Head of Jansen Microwave, Ratingen, Germany, which he established in 1985. Since then, he has also been a Senior Research Consultant and Subcontractor to Plessey Research Caswell, U.K., now GEC-Marconi Materials Technology, and has been engaged in developing a CAD Workstation for GaAs MMICs using new, layout- and physics-related design concepts. Further, from 1985 to the present, he initiated and conducted a larger number of hybrid MIC hardware projects mainly for the German communications industry.

He is known for his contributions to the field of microwave and mm-wave CAD, particularly with regard to MIC and MMIC design, and developed various field theory-based and physics-related simulation approaches. He is one of the pioneers in the field of 3-D electromagnetic simulators for CAD, analytical microstrip structure modeling, spectral domain techniques and geometry-related active device modeling. He developed and introduced the first layout-oriented general purpose microwave CAD package in the German production-oriented communications industry 1979–1981 and is the principal author of the advanced, field theory-based linear and nonlinear LINMIC +/N package for MIC and MMIC design.

Dr. Jansen was a co-founder of the German MTT-S Chapter and its first Chairman during the period of May 1985 to May 1987. During 1987–1988 he served as an IEEE Distinguished Lecturer for MTT-S, lecturing worldwide on the CAD of microwave and mm-wave ICs. Dr. Jansen serves on the ADCOM of the IEEE MTT-S Society as an elected member since 1989 and has the function of the MTT-S European Coordinator and Co-Chairman of the Transnational Committee. He was Chairman of the 1992 European GaAs Applications Symposium (GaAs'92), Noordwijk, Netherlands, April 1992. He is a member of the Editorial Boards of various international journals related to microwaves, CAD and numerical modeling. He is a Member of the Electromagnetics Academy. He holds two patents and is the author or co-author of about 80 publications.

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