EXPLORATION OF NEW INITIATIVES IN COMPUTER-AIDED ENGINEERING OF (M)MIC CIRCUITS

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Introduction

This document reports on a technical visit by Dr. J.W. Bandler and Dr. Q.J. Zhang to Jansen Microwave in Ratingen, West Germany, with the aim of exploring new initiatives in the computer-aided engineering (CAE) of (monolithic) microwave integrated circuits (M)MIC. The visit took place in October, 1989.

The aim of the visit was to discuss ways of addressing the demand for fast and accurate software systems suitable for MMIC circuits. The key items to discuss were ways of meeting industrial requirements for handling nonlinear and large-scale circuits, statistical variations and process/geometrical parameters.

A principal objective was the acquisition of foreign technological innovation under the Technology Inflow Program (TIP) of the Canadian Department of External Affairs.

Objectives

The main aim of this project is to work towards sharing of technology with the most prominent group in Europe in the process-oriented and field-theoretic approach to (M)MIC CAD technology. A joint OSA/Jansen Microwave venture to build a comprehensive software system suitable for yield- and cost-driven design of microwave circuits in terms of layout/geometrical and process/technological parameters is planned. The system should have a layout-oriented, process independent CAD system, based on a combined field/circuit theoretical approach. The system should provide a direct link to geometry, physical parameters, field theory based process-oriented description of (M)MICs leading to design of circuits with optimal performance and optimal yield.

Combined Expertise of OSA and Jansen Microwave

OSA/Jansen Microwave have long and extensive experience in CAE and a high level of technical and mathematical expertise. Both companies have implemented advanced theory and techniques in commercial software. They enjoy a high standard of professional programming. They have experience on many platforms and with several programming languages.

Of utmost importance is the fact that the two companies complement each other's expertise, such that the joint expertise covers all the aspects of the planned venture.

Participants

The participants representing OSA were Dr. J.W. Bandler and Dr. Q.J. Zhang. Participants from Jansen Microwave included Dr. Rolf H. Jansen, Dr. Ludger Wiemer and Mr. Jorgen Sauer.

Work Carried Out

The market potential for a brand-new generation of layout-driven, field theory/circuit theory based linear and nonlinear circuit simulator was discussed. It was agreed that a serious educational effort is important to assist practising engineers to break from traditional design rules to meet the upcoming challenges of the next generation of MMIC production. To that end it was decided to jointly write a review paper on microwave CAD and to propose a jointly edited special journal issue on microwave CAD (see under "Followup Research and Development).

Mutual understanding between the two companies was enhanced after discussing many sensitive issues relating to the rights of each other's contributions, sharing of risks and benefits. Jansen suggested that OSA/Jansen Microwave may come up with a general purpose linear/nonlinear simulator in a short time based on OSA's HarPE and Jansen Microwave's linear element library. This product will directly compete with EEsof's Libra, Compact Software's Microwave Harmonica and Hewlett-Packard's Microwave Design System. OSA/Jansen Microwave would not be too late in this market and may have an excellent chance of succeeding. Unresolved factors in this project include the availability of manpower and funding.

Jansen Microwave personnel exposed Bandler and Zhang to all their major products and in-house development programs. Their novel CAD technology differs considerably from traditional CAD approaches. Their approach makes direct, automated use of a very general, rigorous field theoretical approach to generate design information for a wide class of strip type structures with validity for complex substrate configurations and up to high mm-wave frequencies. They demonstrated their enhanced spectral-domain technique which computes the required design data in the form of multi-dimensional look-up tables.

In particular, Bandler and Zhang were given in depth demonstrations and explanations of LINMIC+ Version 2.1, which incorporates technology OSA is seeking to explore. We also saw Jansen Microwave's nonlinear simulator, their own physics-based parameter extractor and their computer controlled measurement system. Bandler pointed out room for major improvements to LINMIC's optimization. The arrangement of error function and the selection of optimization algorithms, he felt, can both be improved.

OSA's HarPE program was demonstrated in depth to Jansen Microwave engineers. Jansen made a number of suggestions about OSA's HarPE program. Jansen Microwave expressed interest in marketing HarPE in the European and Japanese market. Jansen felt that HarPE's image as a pure parameter extractor should be changed to a single device general purpose nonlinear simulator, model builder and parameter extractor. Jansen also raised the possibility of reducing price and modifying product name. He felt that microwave engineers do not trust multi-device nonlinear simulators yet. Many engineers would be happy if they can just experiment with a single device nonlinear simulator.

State-of-the-art presentations were made by each participant. Detailed analyses of the state of existing commercial products were made, and their features, advantages and disadvantages were discussed. Technical requirements specifications for joint future work was outlined. The general structure of a new product was addressed. We discussed the linear and nonlinear analysis capability, optimization and field theoretic analysis and look-up table principles. We discussed microwave elements and modelling techniques. We addressed possible user-friendly features expected of the new product.

We addressed at length compatibility issues between the existing codes and software architectures existing within each company. We discussed ways of implementing our technology and programming languages. Time-domain analysis capabilities via well-organized Fast Fourier Transform algorithms to general time-domain output were addressed.

We intend to create an architectural/feature document. We will list the modules of a proposed new product. We have yet to plan scheduling of a prototype and discuss ways of synchronizing our respective efforts.

We discussed security aspects relating to data and access to technological parameters within data bases.

We spent considerable time discussing ways of attracting funds and investments, attract potential customers, solicit technical interaction with the microwave industry, and to seek technical cooperation in the development of products.

Followup Technology Exchange

Intended future collaboration is to lead to a comprehensive software system suitable for yield- and cost-driven design of microwave circuits in terms of layout/geometrical and process/technological parameters.

Methods of sharing the participants' technology and exploiting the latest research results of both parties were discussed. Close communication between the parties is planned over the next few years.

An outstandingly successful outcome of the visit was the agreement to exchange software. Thus, OSA agreed to provide a full working version of HarPE Version 1.2 to December 31, 1990. In turn, Jansen Microwave agreed to provide a full working version of LINMIC+ Version 2.1 to December 31, 1990. The intent is for both companies to study each other's software.

These agreements are currently being put into effect.

Followup Cooperative Research and Development

It was decided to jointly write a review paper on microwave CAD combining the expertise of Bandler of OSA, Jansen of Jansen Microwave and Dr. Fred Myers of Plessey. Dr. Myers is Senior Department Manager, Gallium Arsenide Integrated Circuit Department, Plessey Research and Technology, Caswell, United Kingdom.

The paper, to be compiled by Bandler, will be submitted to the IEEE Transactions on Microwave Theory and Techniques, the most prestigious journal in the authors' field. A tentative title is "Foundation of Process-Related MMIC CAD". The project is to be completed by the end of 1990. The paper should combine the CAD approaches represented by the three authors and develop a common point of view. This project would have a serious and beneficial impact on aligning the relevant research and development of OSA (Canada), Jansen Microwave (Germany) and Plessey Research (United Kingdom) more closely.

It was also decided to propose to the IEEE Transactions on Microwave Theory and Techniques a jointly edited special issue on microwave CAD for September 1991. The theme is to be "Process Related Microwave CAD and Modelling". This will coincide with the end of the US DoD's MIMIC Program Phase I, and should attract results produced under that Program.

The topics to be included encompass the interests of all the participating companies. They include (1) Survey of "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 Modelling, (9) Advances in MMIC/CAD Design Technology, (10) Statistical Modelling and Data Bases, (11) Yield Optimization and Design Centering Methodologies, (12) Advances in Linear and Nonlinear Simulation, (13) Computer-Aided Manufacturing Techniques, (14) System Simulation, (15) Advanced MMIC Elements and Circuits, (16) CAD Solutions to Novel Devices, Circuits, Subsystems and Antennas.

This proposal has recently been presented by Jansen to the Editor of the IEEE Transactions on Microwave Theory and Techniques.

Spinoff Technology Exchange with Plessey

Dr. Myers of Plessey was also visiting Jansen during the visit by Bandler. The introduction resulted in a promise of cooperation on statistical modelling of devices between Plessey and OSA. Myers agreed to supply Plessey measurement data, under appropriate conditions, and to assist OSA in development and testing new software. This will facilitate the alignment of OSA with Plessey's data base formats.

Biography: JOHN W. BANDLER

Ph.D., D.Sc.(Eng.), P.Eng., C.Eng., Fellow of the IEEE, Fellow of the IEE (London), Fellow of the Royal Society of Canada

Dr. Bandler is OSA Founder, President and Research Director. He is Professor of Electrical and Computer Engineering and Director of the Simulation Optimization Systems Research Laboratory, McMaster University, Hamilton, Ontario. He has 27 years of professional experience. He is an expert in optimization methods and their applications to computer-aided network design, sensitivity analysis of electrical circuits, least pth and minimax optimization, fault location of analog circuits, optimal load flow in power systems, microwave filter and multiplexer design. He is recognized for his pioneering work in optimal design centering, tolerancing, tuning and yield optimization. Dr. Bandler is author of more than 220 publications. He is listed in Who's Who in Engineering, American Men and Women of Science, Who's Who in America and in Canadian Who's Who.

Biography: ROLF H. JANSEN

M.S., Ph.D., Fellow of the IEEE

Dr. Jansen was with RWTH Aachen Microwave Laboratory as a Senior Research Engineer. He directed the thin-film technology of the microwave laboratory. He worked as a research associate for radio communication at Standard Elektrik Lorenz AG (SEL). In 1979, he became Professor of Electrical Engineering at the University of Duisburg. His research topics included electromagnetic theory, microwave techniques and CAD, measurement techniques, and modelling. Dr. Jansen is author of 60 technical papers in the field of microwave CAD and related topics and the recipient of the outstanding publications award in 1979 from the German Society of Radio Engineers. He is cofounder of MCAD Software and Design Corp. He was one of the two Distinguished Microwave Lecturers appointed by the MTT-Society for the year 1987/88.

Biography: QI-JUN ZHANG

Ph.D., MIEEE

Dr. Zhang obtained his Ph.D. from McMaster University in 1987. He is currently a Research Engineer with OSA. He is also an Assistant Professor (part-time) of Electrical and Computer Engineering at McMaster University. Dr. Zhang has 6 years of professional experience in large-scale optimization, nonlinear circuit simulation, small- and large-signal model parameter extraction, statistical design and modelling, sensitivity analysis, tuning and diagnosis. He is author of 20 publications.