OSA's INNOVATIONS IN MICROWAVE CAE

OSA-89-OS-4-V

January 11, 1988

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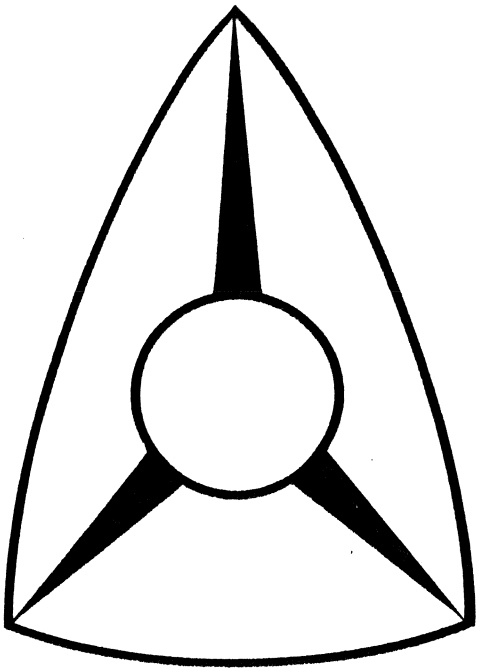
Optimization Systems Associates Inc.
Dundas, Ontario, Canada



Optimization Systems Associates Inc.

OSA's Competence

microwave circuit analysis, design and optimization

statistical estimation of production yield

robust active and passive device modeling

harmonic balance simulation of nonlinear circuits

automated processing of DC, RF and harmonic measurement data

statistical modeling of devices

powerful performance and yield driven optimizers

manufacturing tolerance assignment and cost minimization

customized gradient and minimax optimizers

computer optimization of matching networks, filters and multiplexers

algorithms for automated production alignment and tuning

Optimization Systems Associates Inc.

Distinctive Experience of OSA

long and extensive experience in CAE

high level of technical and mathematical expertise

implementation of advanced theory and techniques in commercial software

high standard of professional programming

experience on many platforms

Apollo, CRAY, FPS, IBM mainframe, PC, VAX

several programming languages

Optimization Systems Associates Inc.

OSA's Microwave CAE Innovations

OSA has originated features never previously offered by commercial microwave software houses

key role in current releases of popular microwave CAE products

Super-Compact
Microwave Harmonica
Super-Compact PC
Microwave Harmonica PC
Touchstone

RoMPE - OSA's FET parameter extractor

subcontractor on the Raytheon/Texas Instruments/Compact Software MIMIC team

Optimization Systems Associates Inc.

Major Contributions by OSA to MIMIC/CAD

yield-driven and cost-driven optimization

consideration of tolerances and exploitation of device statistics

consideration of measurement/reference plane errors

worst-case design

nonlinear optimization

improved algorithm efficiency

Optimization Systems Associates Inc.

OSA's Computers

hardware

1 DEC microVAX II
1 Apollo DN3500 workstation
6 IBM AT or AT compatible personal computers

software

UNIX, VMS and DOS operating systems
FORTRAN, C and Pascal language compilers
various linkers
graphics libraries
various simulation and optimization software

OSA's Technical Personnel

J.W. BANDLER, Ph.D., D.Sc.(Eng.), P.Eng., C.Eng., FIEEE, FIEE, Fellow, Royal Society of Canada; OSA President; Prof. Electr. and Comp. Eng., McMaster Univ.;
25 years experience; listed in Who's Who in Eng., American Men and Women of Science, Who's Who in America, Canadian Who's Who

R.M. BIERNACKI, Ph.D., SMIEEE; Senior Research Engr.; Prof.(part-time) Electr. and Comp. Eng., McMaster Univ.; 20 years experience

S.H. CHEN, Ph.D., MIEEE; Research Engr.; 5 years experience

J. LOMAN, B.Sc.; Software Engr.; 1.5 years experience

M.L. RENAULT, M.Eng., MIEEE; Research Engr.; 6 years experience

Q.J. ZHANG, Ph.D., MIEEE; Research Engr.; 5 years experience

Innovations in Microwave CAE by OSA - Introduction

advances in GaAs MMIC circuit design demand the next generation CAE software

adequate CAE of nonlinear circuits is crucial for the microwave and millimeter-wave IC chips essential for the coming generation of radar systems, space technology and radio-frequency communications

for such systems cost reduction is recognized as the number one task, consequently yield optimization methodology is essential

Yield Optimization

manufacturing yield is particularly important for large volume production of MMICs

OSA's work is directed at a hardware/software system for design of analog microwave circuits that takes into account manufacturing tolerances, model uncertainties, variations of process parameters, environmental uncertainties, etc.

yield optimization is computationally intensive

- optimization is iterative
- each iteration requires simulation of
  - many statistically related circuits
- simulation of each nonlinear circuit is iterative

yield optimization requires advanced optimizers and circuit simulators, efficient approaches to statistical representation of devices

Optimization Systems Associates Inc.

Yield Optimization of Nonlinear Microwave Circuits

pioneered by OSA

comprehensive treatment

statistical representation of nonlinear devices

efficient harmonic balance simulation

multidimensional statistical distributions of the intrinsic and parasitic parameters of FETs fully accommodated

yield enhanced from 25% to 61% for a frequency doubler design having 34 statistically toleranced parameters

Nonlinear Circuit Simulation

most analog microwave circuits operate under steady-state conditions

harmonic balance has become the major tool for simulating nonlinear circuits

drawbacks in existing harmonic balance programs

- extensive number crunching inhibits fast optimization and its extension to yield-driven design
- inaccurate and inefficient sensitivity calculations

Compact Software's Microwave Harmonica:

- large memory requirements
- limited variety of device models
- no yield optimization

EEsof's Libra:

- neither optimization nor statistical design

Efficient Sensitivity Analysis

hierarchical approach to circuit simulation

- elimination of unnecessary calculations
- convenient to handle large circuits
- consistent with the syntax-oriented hierarchical circuit description
- potential for parallel processing

EAST (exact adjoint sensitivity technique)

- a theoretical breakthrough in harmonic balance
- 50 times faster than perturbation in our tests
- expensive to implement in general purpose programs

FAST (future adjoint sensitivity technique)

- an expedient implementation of the EAST concept
- unmatched speed and accuracy over perturbations
- implementable in general purpose CAE architectures

Device Modeling

simulation of linear/nonlinear circuits requires accurate linear/nonlinear device models

major deficiencies of present parameter extraction techniques are nonuniqueness, wild solution values

small-signal modeling exploiting DC characteristics

- bias-dependent parameters constrained by DC characteristics
- substantial improvement of uniqueness and reliability
- commercial product (RoMPE) available

large-signal modeling using harmonics

- pioneered by OSA
- multi-bias, multi-power-input, multi-frequency and multi-harmonic measurements
- powerful EAST implemented
- identifies all nonlinear parameters
- commercial product in progress

Statistical Modeling

yield optimization requires statistical models of devices

model statistics originate from simple random variations of basic process/physical/geometrical parameters and are reflected in complicated distributions and correlations of device responses or equivalent model parameters

two important approaches

- equivalent circuit based approach
- process/geometry based approach

important distributions

- one-dimensional uniform, normal, lognormal, exponential, user-defined
- multi-dimensional normal distribution with correlation
- multi-dimensional discrete

confidence levels indicate the accuracy of statistical modeling

Optimization Systems Associates Inc.

OSA's Role in Microwave CAE

comprehensive CAE software system

yield- and cost-driven design of microwave integrated circuits

optimal accommodation of tolerances and device statistics

features for the designer for enhancing wafer/chip yields

workstation environment

layout/geometrical and process/technological parameters

based on combined field/circuit theoretical approach

OSA's Plans

maintaining, upgrading and providing support to OSA's RoMPE

specialized modules for device parameter extraction and modeling, including statistics

- nonlinear parameter extraction within a harmonic balance simulation environment
- statistical modeling of linear devices for small-signal applications
- statistical modeling of nonlinear devices for large-signal applications within a harmonic balance environment
- high performance software engine for the next generation microwave CAE systems

goal: comprehensive system for general microwave circuit simulation, modeling and design, including statistics

Cooperation between OSA and Canadian Industry

exploring ways of including industry's device models and fabrication statistics into our software

making our CAE products compatible with the industry's hardware/software

testing our software on specific industrial problems

organizing in-house and on-site demonstrations

Relevance to Canada

significant Canadian thrust in the design and manufacture of microwave integrated circuits

CAE systems currently purchased from the United States

increased automation in the communications and electronics industry

maintaining Canada's position in relevant areas

substantial improvement in productivity

contribution to the viability of Canadian high-technology products

export of Canadian originated and owned CAE