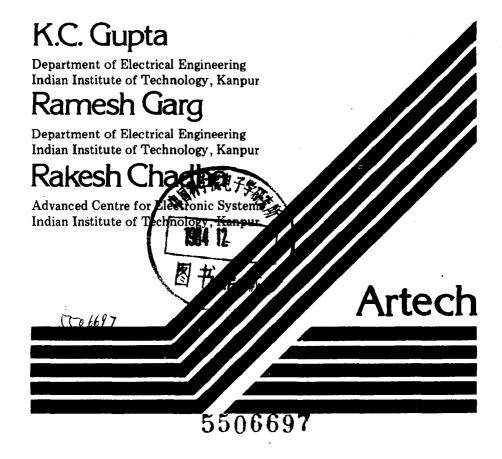
# COMPUTER-AIDED DESIGN OF MICROWAVE CIRCUITS

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## COMPUTER-AIDED DESIGN OF MICROWAVE CIRCUITS



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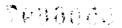
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Library of Congress Card Catalog Card Number: 81-69400

Standard Book Number: 0-89006-106-8



### **Preface**

With the introduction of hybrid microwave integrated circuits (MICs), computer-aided design (CAD) techniques have become an essential tool for microwave circuit designers. The circuit design process has become increasingly complex because a large variety of active and passive components are now available for use at microwave frequencies and the increased complexity of modern systems demands more precise and accurate design of circuits and subsystems. Also the hybrid MIC approach provides a very limited possibility of trimming or adjusting the circuit after it has been fabricated.

The area of computer-aided circuit design — including computer-aided microwave circuit design — has undergone rapid advances in recent years. Although there are a number of books available on the CAD of electronic circuits at lower frequencies, there is no book dealing with the CAD of microwave circuits. Since the area of CAD of microwave circuits has now matured, a book on this topic is expedient; the present book is an endeavour in this direction. It is designed to provide a detailed exposition of the concepts and techniques used in the computer-aided analysis and design of microwave circuits.

Any CAD process consists of three important segments, namely, i) modelling, ii) analysis, and iii) optimization. This book discusses these three aspects vis-a-vis microwave circuits. We discuss modelling

of various constituents of microwave circuits. These include transmission lines, discontinuities, lumped elements, planar components, and semiconductor devices. Network representation suitable for analysis is introduced and matrix techniques for analysis of microwave circuits are discussed. Sensitivity analysis and various optimization techniques are presented.

The book is divided into five parts. In Part I, the first chapter describes the evolution of microwave circuits and introduces the concept of the computer-aided circuit design. Chapter Two is a review of the various representations used for microwave circuits.

Modelling of active and passive components is a crucial part of any circuit design; this is discussed in the eight chapters that make up Part II. At microwave frequencies, there is a need to characterize precisely not only the constituent components, but also the associated parasitic reactances. This book contains seven chapters devoted to characterization of various transmission structures, discontinuities, lumped elements, planar components, and semiconductor devices. Sensitivities of various components are useful in tolerance analysis and optimization of circuits. A chapter is devoted to the characterization of the sensitivities of transmission structures. Accurate characterizations of some of these elements (for instance semiconductor devices) is obtained by measurement of S-parameters over the frequency range of interest. Computer-aided measurement techniques using network analyzers are commonly employed. One chapter is devoted to these techniques including six-port measurement concepts.

Circuit analysis is the most important component of the computeraided design approach. Part III deals with various methods used for analysis. Microwave circuit analysis is usually carried out in terms of S-matrices. Various chapters deal with the evaluation of the S-matrix of the overall network using the known S-matrices for the individual components, the sensitivity analysis, the tolerance analysis, and the time-domain analysis. All these analyses involve solutions of matrix equations, techniques for which are discussed in a separate chapter.

There are several techniques available for optimization of microwave circuits. Both direct search and gradient methods have been used. Basic concepts in optimization, one-parameter optimization, and multi-parameter optimization techniques are discussed in the three

chapters in Part IV. Methods discussed include pattern search, Rosenbrock's method, simplex method, Newton-Raphson method, Davidon-Fletcher-Powell method, and a method for optimizing least square objective functions.

Part V includes two chapters describing CAD programs. A microwave circuit analysis program (MCAP) developed at IIT Kanpur is described. The final chapter, contributed by Mr. Les Besser of Compact Engineering, is a review of some commercially available programs.

Several algorithms have been included in this book in Chapter Thirteen and in later chapters. These have been written in an ALGOL type language and could be skipped over in the first reading when the reader is not familiar with this type of language.

This book evolved from a set of lecture notes first prepared for a graduate course on CAD of microwave circuits offered at IIT Kanpur in the spring semester of 1978. Part of the material has been used subsequently for a course on microwave circuits. Work on CAD of microwave integrated circuits carried out at IIT Kanpur formed a part of a project sponsored by the Department of Electronics (Government of India, New Delhi) and contributed to the contents of this book. Parts of this material were used for a series of seminars delivered at Eidgenossische Technische Hochschule, Zurich in summer 1979 and appeared as an internal publication (Bericht Nr. 79-10) of the Mikrowellen Laboratorium there.

The proposed book will serve microwave circuit designers and graduate students in microwaves. It could be used as a supplementary text for courses on microwave circuits and computer-aided network analysis and design. Part V on CAD programs may be read without going through the rest of the book. Chapter 19 on MCAP could be used directly for analysis of microstrip and stripline circuits.

The authors are grateful to Mr. Les Besser for contributing Chapter 20. Discussions with several colleagues at IIT Kanpur and at Eidgenössische Technische Hochschule Zurich are thankfully acknowledged. Facilities extended by the Department of Electrical Engineering and the Advanced Center for Electronic Systems at IIT Kanpur are acknowledged. The typing of the manuscript has been handled efficiently by Mr. C.M.

Abraham and the art-work has been done by Mr. R.K. Bajpai and Mr. J.C. Verma. The preparation of the manuscript has been supported by the Quality Improvement Programme of IIT Kanpur. This support is thankfully acknowledged.

Thanks are also due to Dr. H.E. Green and Academic Press for their permission to include Table 5.1 from their publication.

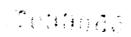
K.C. Gupta Ramesh Garg Rakesh Chadha

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