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MICROSTRIP COMPUTER-AIDED DESIGN IN EUROPE

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Summary

The purpose of this survey is to provide a general idea about present microstrip research in Europe, emphasizing computer-aided design. Attention is drawn to the particularities of microstrip, which make it a particularly difficult field. The survey covers the description of microstrip lines, discontinuities and patch antennas, applications to circuit layout, followed by a brief description of MIC and nonlinear CAD.

Introduction

First of all, C.A.D. is only feasible when a suitable mathematical description is available - not too complex, but accurate enough. At microwave frequencies, particular challenges are presented by size and device environment. Microstrip systems present peculiarities, their design is very demanding in terms of accuracy.

No room for adjustments

Most "classical" microwave designs, in waveguide, include provisions for final adjustments: tuning screws or inductive posts. Who ever heard of a filter which met the specifications without a "final tuning"? How should one transpose this procedure to microstrip, which has little or no capability for adjustments ?

To realize a microstrip circuit, one first must draw a layout, analyze its theoretical response, optimize it to meet the desired performance, draw the circuit's outline, cut the mask, reduce it photographically, expose it, etch, dry, then mount the finished circuit and measure it. If it doesn't meet the expectations, what then ? Return to case one... or almost, hoping that things will work out better next time...!

Microstrip design should be just right the first time! A very accurate description for all the components of the circuit is therefore an absolute must.

Three-fold inhomogeneity

In terms of the electromagnetics, microstrip is quite complex, presenting three inhomogeneities:

a) the propagation region, over which the fields spread out, is part dielectric, part air.

b) the metal layer on top of the dielectric only covers it partially.

c) the dielectric substrate and the ground plane have finite dimensions.

These three inhomogeneities, render an accurate study of microstrip almost prohibitively difficult, In the past, a number of simplifying assumptions were made, yielding approximations not always adequate.

Knowing that some rich research institute can solve complicated problems is of little help to the engineer. The researcher must "translate" his results into a form useful to the practitioner.

Measurement problems

Measurements are never taken on the microstrip itself. Test setups are always in coaxial line or waveguide, so that the microstrip is actually "seen" through transitions and connectors. It is thus difficult to determine the properties of the structure one wants to measure. The "gating" function of the HP8510 Network Analyzer can now be used to separate connector from circuit. Still, no reliable data can be obtained across a transition really lossy or poorly matched.

Activities in Europe

Over the years, the microwave field has been quite active, as evidenced by the number of contributions presented at the yearly European Microwave Conference. So many projects are in progress now, in many places spread all over Europe, that space won't permit listing them all here. Only the main topics related to CAD will be discussed.

Microwave CAD/CAM was emphasized in Liège, Belgium in 1984 at the 14th European Microwave Conference [1], which devoted, in addition to the contributed papers, 4 invited papers, a tutorial session, a specialized exhibition and, last but not least, a CAD workshop organized by Professor G.R. Hoffman, of the University of Ghent. Since then, a specialized workshop was held in November 1985 in London, under the auspices of the IEE. A special issue of the IEE Part H Proceedings will shortly be devoted to this topic, with Dr. R. Pengelly as Guest Editor.

Transmission Lines

Whereas loads of new models and approaches were being presented during the 70's to describe the single microstrip transmission line, this topic has now quieted down. The conformal mapping approach developed by Schneider [2] (a US-based Swiss) and later on retouched by Hammerstad [3] has provided accurate relationships, used by most designers nowadays. Research proceeds over the lossy and inhomogeneous substrates encountered in MIC's [4].

Coupled lines come next: here too, a number of approaches used to enliven the technical literature. Emerging from the lot are the equations of Kirschning and Jansen [5], which combine high accuracy with ease of operation for CAD purposes. Here also, lines laid over semiconducting substrates are being evaluated [6]. The analysis has also been extended to lines having more than two upper conductors [7, 8].

In a related area which is drawing a lot of attention, in conjunction with MIC design, are coplanar lines, either conductor-backed or not [9, 10].

Microstrip computer programs for a variety of geometries have been commercialized in Germany [11].

Bends, Junctions and Discontinuities

The study of discontinuities of all kinds has been most active in Germany, under the guidance of Professor Ingo Wolff and his group. A recent bibliographical survey lists no less than 135 papers [12]. The spectral domain approach for MIC was recently described by Jansen [13]. Effects of radiation and surface waves can now also be taken into account, making use of an approach devised for patch antennas [14]. An extensive compilation carried out by Hoffmann produced the most comprehensive book on microstrip available to-date, listing altogether 1256 references [15]

Patch Antennas

Much of the R & D. work on microstrip antennas in Europe has been coordinated within the frame of the COST-204 project [16] - presently followed by project COST-213 - of the European Communities, which deal with phased array antennas. Patch antennas and arrays were designed in England [17, 18], Belgium [19] and France [20]. The European Space Agency set up a specialized symposium [21]. The rigorous treatment of radiation from microstrip structures was considered, making use of an integral formulation in terms of Green's functions, followed by the numerical evaluation of Sommerfeld integrals [14, 22]. A project looked at the edges of the dielectric substrate [23]. The time-domain response of microstrip antennas was covered [24]. Microstrip patches can also be used as feed elements [25].

Analysis and Synthesis

In France, the high-level program ACLINE has been for some time the generally-accepted standard for microwave designers. It actually offers impressive optimization facilities to its users, and a number of microstrip elements are available, in an interactive way [26]. For microwave amplifier design, the CAD package ACCAD offers several novel approaches [27]. Symbolic logic is now becoming available for microwave CAD [28].

Layout

No matter how well a particular design may have been analyzed and optimized, making use of the latest and best available descriptions, a delicate step remains: its physical realization. Very accurate masks can be cut on coordinatographs or drawn on photoplotters, which are, unfortunately, quite expensive machines, well-beyond the financial reach of many small research laboratories or academic institutions

A lower cost program for the layout and cutting of masks is presently available [29] It operates on desktop computers, cutting the masks on standard plotters, making use of a specially designed cutting tool The program was designed to be "user-friendly" it is self-contained, *i.e.* does not require extensive reading before its use. The operator specifies circuit dimensions, operating frequency, substrate permittivity and width, characteristic line impedance. He then has a number of elements available to design his circuit, he can position and interconnect them at will. He may also define his own elements if he wishes The masks for microstrip circuits made of couplers, hybrids, dividers, step transformers, filters, user-defined elements, joined by bends and lines can be realized in a matter of minutes with computer accuracy.

Microwave Integrated Circuits

The field of MICs is closely related to that of microstrip. It contains a mixture of distributed elements (to be considered in terms of microstrip line theory) and of lumped and concentrated elements (small with respect to a wavelength, can be treated by network theory). The considerations made for microstrip in the beginning remain valid for MICs, becoming even more stringent. As devices tend to be crammed close to one another to save real estate, coupling effects become significant. Semiconductor substrates are in general stratified and lossy, so that the characterization of lines and components becomes even more difficult [30]. Still, the challenge has been picked up and many realizations have been reported. In England, the Allen Clark Research Centre develops computer bases, involving device modelling from both theoretical prediction and experiment. From Germany comes the CAD package LINMIC, which provides a new approach to layout oriented design of single or multilayered MICs/MMICs [31]. A quasi-monolithic approach for GaAs was developed in Italy [32]. An interesting new approach to randomly modelise MIC passive components was devised by Baden Fuller [33].

Nonlinear Analysis

Finally, as many devices implanted or introduced within microstrip systems exhibit nonlinearities. - wanted or unwanted - a definite need did exist for nonlinear analysis. Professor Rizzoli, from Bologna, developed a computer technique for this difficult problem. Computation times become significant, but can be considerably reduced by using a vectorial processor or supercomputer [34]. A new approach for the optimization of nonlinear circuits comes from Limoges [35]. Nonlinear CAD was applied to optimize a mixer [36].

Conclusions

It is hoped that this brief survey will provide a reliable first impression about who is doing what in microstrip CAD in Europe, and maybe lead to fructuous future exchanges. The information presented is like the tip of an iceberg: it was selected by the author, taken from a rather impressive pile of data The aim was to provide a fairly even coverage, drawing mostly attention to recent results The author wishes to thank all the researchers who actively contributed to the survey by responding on rather short notice.

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