REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave blank*)

2. REPORT DATE

3. REPORT TYPE AND DATES COVERED
Reprint, 2/22/93 - 9/30/94

4. TITLE AND SUBTITLE
New Trends and Ideas in the Fields of Microwave Technology

5. FUNDING NUMBERS
DAAH04-93-G-0068

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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Research Office
P.O. Box 12211
Research Triangle Park, NC 27709-2211

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
ARO 30921.21-EL

11. SUPPLEMENTARY NOTES
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12a. DISTRIBUTION/AVAILABILITY STATEMENT
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12b. DISTRIBUTION CODE

ABSTRACT (*Maximum 200 words*)

This paper presents a subjective view toward new directions and some examples for changing microwave research. The paper is written primarily from the point of view of how the electromagnetic research must change and what kind of impact such a change can give rise to stimulation for the device and circuit research for microwave technology. It is emphasized that interdisciplinary treatment of electromagnetic research is vital for the future of microwave technology.

14. SUBJECT TERMS
Electromagnetic microwave technology

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

MIKON '94

NEW TRENDS AND IDEAS IN THE FIELDS OF MICROWAVE TECHNOLOGY

Tatsuo Itoh*

ABSTRACT

This paper presents a subjective view toward new directions and some examples for changing microwave research. The paper is written primarily from the point of view of how the electromagnetic research must change and what kind of impact such a change can give rise to stimulation for the device and circuit research for microwave technology. It is emphasized that interdisciplinary treatment of electromagnetic research is vital for the future of microwave technology.

I. INTRODUCTION

Recently, the microwave and "radio" engineering has drawn a renewed interest due to a significant interest in personal and mobile communications and intelligent automobile And others. At the same time, due to the end of the cold war era, the traditional use of microwave is changing to dual use from military use. Expanded role of microwave technologies to civilian and commercial use require some changes in design philosophy and fabrication methods of microwave devices, circuits, components and subsystems. Accurate first-pass design is now more important. Packaging must be integral part of the circuit and component design to reduce the assembly cost. Working environment of these commercial-use components is as harsh as or even more harsh than the military components.

It is of no doubt that the research on new devices and new fabrication method will be enhanced. As one climbs the "food chain" of the microwave technology, the new system design responsive to the need for the commercial application will emerge. Traditionally, the circuit design filled the link between these two extremes of the food chain. Here, the role of electromagnetics has been well understood.

As the key element of the microwave technology, this paper addresses the

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changing need for the electromagnetics. It is well appreciated that the electromagnetics have been a fundamental subject of study but is essential to microwave circuit and component design. Nevertheless, the research on electromagnetics, especially the one exercised in the academic community has not been very responsive, or not sufficiently so, to the practical problems. It is necessary to expand the role of electromagnetic research by making it more interdisciplinary. By this, it is meant that the traditional electromagneic research must be evolved into a "system" science by including the wave interaction aspects of the circuits with active devices, packaging effect and the visualization oriented analysis and design. By means of examples, some of the effort along this line will be explained in this paper. Appropriate exploitation of such an approach is believed to reach a new plateau for the modern electromagnetics from which new and enhanced capability of microwave technology will emerge.

2. INTERACTION WITH ACTIVE DEVICES

The interaction of the electromagnetic wave with active devices needs to be considered carefully and must be understood well in the new microwave circuits which are increasingly complex. In many cases, the passive and active part of the circuit cannot be distinguished clearly. In such cases, it is important to characterize the entire circuit with a single design process. For such a purpose, the enhanced electromagnetics should play an important role. The wave-device interaction must be taken into account. In addition to the comprehensive design approach, a new type of circuit/component may be created. An example is the active antenna. The antenna acts not only as a radiating element but also provides a circuit function such as diplexer or resonator. This latter function becomes an integral part of the active circuit such as the oscillator[1,2]. Fig.1 shows an example of active antenna. The patch antenna is not only a radiating element but also a resonant feedback element for the active device to form an oscillator. The structure is a two-element array. In this arrangement, the radiation pattern can be switched from the difference pattern to the sum pattern. Because the two oscillators are strongly coupled by a connecting microstrip line, they support two oscillation modes under a small signal condition. However, due to the large signal nonlinear behavior of the circuit, only one of them becomes a stable oscillation mode under steady state condition. As to which mode becomes stable has been a subject of study in [3].

It is well known that the antenna is one of the bottleneck issues for personal communication. The concept of an active antenna can add some "intelligent" function right at the antenna. The design and analysis of this type of circuits must be enhanced.

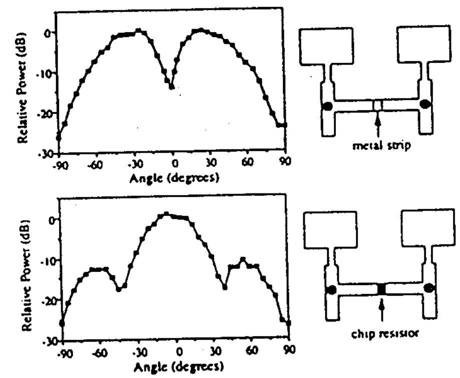


Fig.1 Two-element active antennas

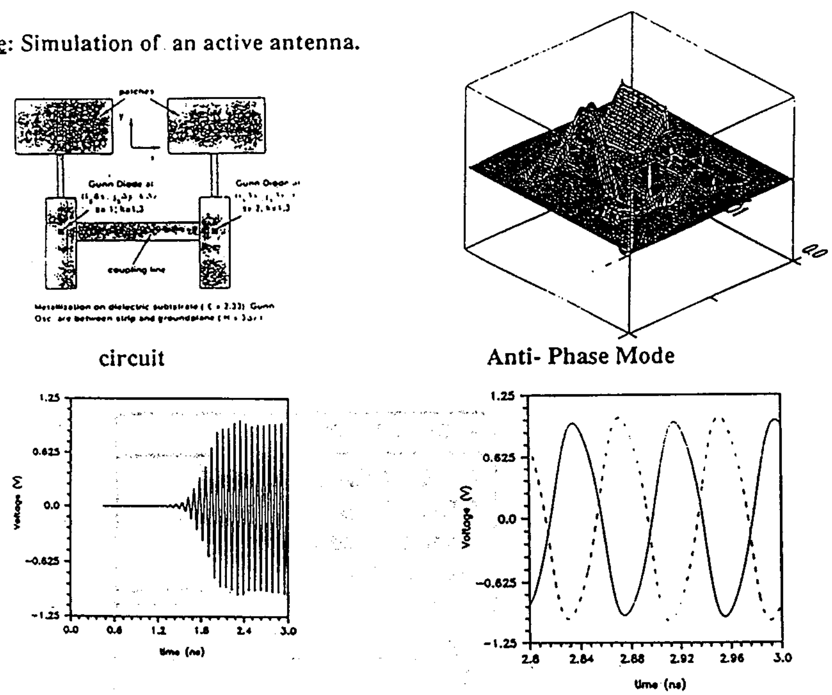
3. UNIFIED ELECTROMAGNETIC CHARACTERIZATIONS OF MMIC

State of the art microwave and millimeter wave circuits are becoming more complex. They perform multiple tasks, are electrically smaller and are more dense. In some cases, the circuits are multimoded. In many cases, the current computer aided design tools are unable to correctly predict the circuit behaviors. In most of the microwave integrated circuit design, the passive part and the active part are treated differently. In the last several years, a significant advance has been reported in the area of computer aided design (CAD). Advances in the passive part now allows EM simulators which incorporate electromagnetic behaviors of the passive circuit instead of classical quasi-static analysis. Electromagnetic coupling between nearby elements can be included correctly and increasingly the environmental effects such as packaging and multi-chip interconnect can be taken into account. The interactions of the passive part with the active devices, however, have been carried out typically by a circuit simulator such as the harmonic balance method. Therefore, electromagnetic interactions with the passive and active elements of the circuits may not be correctly included. In the next generation of the CAD, it is necessary that all of the effects including the packaging effects to the active devices and the electromagnetic coupling between the active devices are taken into account correctly.

Most of the frequency domain analysis methods for the passive structure cannot easily handle active devices in the dynamic mode. Certain approximate steady state analysis can be made, however. On the other hand, the time domain algorithm such as the TLM (Transmission Line Matrix) method and the FDTD (Finite-Difference Time-Domain) method can include the active device in its dynamic (transient) as well as steady state operations. This is due to the fact that the time domain method is an initial value problem and hence can include the build up of the nonlinear device operation in the time evolving history until the steady state is reached. Hence, by the use of the time domain algorithm, it is possible to simulate the entire microwave circuit including the nonlinear active device and the packaging effect. Here, the latter is interpreted in a broad sense.

A recent effort by the author's group has produced a remarkably interesting results for a number of microwave circuits including the active devices. An example is shown in Fig.2. By means of the modified FDTD, the correct oscillation mode is established for

Example: Simulation of an active antenna.



Simulation predicts correct steady state oscillation mode.

Fig.2 Active antenna characterized by enhanced FDTD

the coupled active antenna shown in Fig.1. The visualization aspect of the FDTD is particularly a welcome addition for simulation, because the defective design can be exhibited and the design concept can be visually verified.

In contrast to many frequency domain techniques such as the integral equation technique which has a numerical efficiency at the expense of the high analytical labor, the time domain methods typically require a small amount of the analytical processing. Instead, a large memory and a long computation time are needed [4,5]. Also, the inputting the structural data and the extraction of the needed design parameters are where effort must be spent. The latter has an advantage that it is possible to obtain more information such as the dynamic field behavior than the simple circuit parameters.

As the computational power is increasing, the computational burden is being reduced. Nevertheless, a significant effort has been expended to make the time domain method algorithmically and computationally more efficient. Diakoptics and the system identification are two of such examples. In the first, a large linear passive portion is replaced with its characteristics at the "terminal" plane. By means of the Diakoptics or numerical Green's function indicating the impulse response at that terminal plane, the computational volume can be reduced [6]. This concept is useful in design of a large circuit in which a small portion is tuned but the large portion unchanged. In addition, the concept can make the calculation more efficient in the circuit which contain an active device. The terminal plane of the active circuit can be made to interact with the device. On the other hand, the system identification technique is a prediction method based on the technique developed for the linear system theory [7].

Due to its algorithm, the time domain methods such as FDTD are suited for parallel processing. Although a parallel processing machine can be used, the parallel algorithm can be implemented into a parallel virtual machine (PVM) made up of a cluster of workstations.

4. PACKAGING, INTERCONNECT AND MULTIMODING EFFECTS

Recently, importance of the effect of packaging has been recognized by the circuit designer. In many cases, the packaging effect implies the deviation of the designed circuit performance when it is placed in a package. However, the meaning of the packaging should be interpreted in a wider sense. For instance, a multilayered circuit as shown in Fig.3 can be considered as the case in which the packaging is an integral part of the circuit design [9]. In a highly complicated circuit configurations, possible "multi-mode" situations may exist. Such modes may include undesirable ones such as the ones

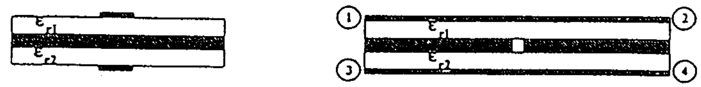


Fig.3 Multilayered interconnect/packaging structure

that are leaky. One of the highly publicized phenomena is the lateral leakage in a conductor backed slot line of coplanar waveguide[8]. This leakage is due to the parallel plate mode and is now well understood. Although this leakage is detrimental in many cases, such a leakage can be advantageously used for constructing a new type of passive device [10]. More recently, a new method for controlling such a leakage by means of a multilayered structure has been invented [10].

5. CONCLUSIONS

A subjective view has been presented for the new trends and ideas for microwave technology from the point of view of enhanced electromagnetics. This concept is believed useful for advancing state of the art of microwave circuits and components design. Several examples have been described.

ACKNOWLEDGMENT

The contents in this paper have been supported by a number of research contracts and grants including those from Army Research Office under DAAH04-93-G-0068 and Joint Services Electronics Program from Air Force Office of Scientific Research under F49620-92-C-0055.

REFERENCES

[1] J. Birkeland and T. Itoh, "Planar FET oscillators using periodic microstrip patch antennas," IEEE Trans. Microwave Theory and Techniques, Vol. 37, No. 8, pp. 1232-1236, Aug. 1989.

[2] J. Lin, T. Itoh and S. Nogi, "Mode switch in a two-element active array," 1993 IEEE AP-S Symposium Digest, pp.664-667, June 28-July 2, 1993, Ann Arbor, MI.

[3] S. Nogi, J. Lin and T. Itoh, "Mode analysis and stabilization of a spatial power combining array with strongly coupled oscillators," IEEE Trans. Microwave Theory and Techniques, Vol.41, No. 10, pp.1827-1837, October 1993.

[4] K. S. Yee, "Numerical solution of initial boundary value problems involving Maxwell's equations in isotropic media," IEEE Trans. Antennas & Prop., vol. AP-14, No.,302-307, May 1966.

[5] W. J. R. Hoefer, "The transmission line matrix method - Theory and applications," IEEE Trans. Microwave Theory and Tech., Vol.MTT-33, No.10, pp.882-893, Oct. 1985.

[6] T. W. Huang, B. Houshmand and T. Itoh, "The FDTD Diakoptics method," IEEE MTT-S International Microwave Symp. Dig., pp.1435-1438, June 1993, Atlanta, GA.

[7] B. Houshmand and T. Itoh, "Microwave structure characterization by a combination of FDTD and system identification methods," IEEE Microwave and Guided Wave Letters, Vol.3, No.8, pp.262-264, August 1993.

[8] H. Shigesawa, M. Tsuji and A. A. Oliner, "Conductor-backed slot line and coplanar waveguide: dangers and full-wave analysis," IEEE MTT-S Int. Microwave Symp. Dig., pp.199-202, May 1988, New York, NY.

[9] A. M. Tran and T. Itoh, "Open-ended microstrip lines coupled through an arbitrary aperture in a thick common ground plane," 23rd European Microwave Conference, p.435, September 6-9, 1993, Madrid, Spain.

[10] Y. Liu, T. Hirota and T. Itoh, "Coupling phenomena in conductor-backed slotline structures," IEEE MTT-S Int. Microwave Symp. Dig., pp.1203-1206, Atlanta, GA.

[11] Y. Liu and T. Itoh, "Leakage phenomena in multilayered conductor-backed coplanar waveguide," IEEE Microwave and Guided Wave Letters, Vol.3, No. 11, pp.426-427, November 1993.