WORKING WITH AUTOMATIC MICROWAVE CIRCUIT ANALYSIS PROGRAMS*

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Summary

Techniques for utilizing available, automatic frequency analysis programs for microwave circuits are described. Common-sense generalizations of computer-oriented design experience are also presented. Finally, methods of enhancing program usefulness by circumventing apparent program limitations are illustrated.

Introduction

Interactive microwave circuit analysis programs have recently become commercially available to the microwave public. At the beginning of 1970, no programs of this type were available on the market or on a time-sharing service. Now there are at least five. By investing an hour in learning to use such a program, the engineer can analyze complicated microwave circuits very rapidly, without writing circuit equations, without programming, and without waiting. The value of these programs is that they can conveniently and rapidly provide an engineer with a great amount of analytical information.

This paper will consider techniques of utilizing automatic microwave programs and for circumventing program limitations in measuring and modeling components. Real-life examples of circuit applications will be given in the oral presentation.

It is assumed that the reader is familiar with the basic features of these programs, i.e., that they perform frequency analysis of cascades of linear two-ports, allowing side branches. They are interactive, and communication between engineer and computer takes place in a microwave engineering vocabulary, not in a programming language.

Techniques of Effective Use

The basis of computer-oriented design is that it is possible to make accurate mathematical models of most circuits, and, having done so, to make accurate predictions of circuit performance. Automatic interactive programs allow the engineer to eliminate much activity which is not directly productive (such as deriving equations and writing programs) in favor of uninterrupted design work.

An accurate equivalent circuit is essential. Thus, it is worthwhile to spend appreciable thought in preparing the equivalent circuit before approaching the machine. Parasitic effects should be taken into account, although it turns out that approximate corrections are often adequate.

Having committed oneself to a computer-oriented approach, one should have the faith to follow through with it. When a computer-oriented design has been completed, the physical structure it represents should be constructed exactly in accordance with the design; the tests which are made on the piece should be made under the exact conditions assumed for the design. Only in this way can the inevitable discrepancies between predicted and measured performance be tracked down.

Once a circuit has been designed on the computer, it is a good idea to explore the entire frequency range over which the model holds, and not just the band of interest. This will prevent unfortunate holes in the stop-band and out-of-band oscillations from turning up only after the component has been built and put on the test bench.

It is possible to optimize many practical circuits without using a sophisticated optimization routine by consecutively adjusting one or, at most, two elements at a time. The basic rule is: Introduce no more uncertainty in the stated problem than is absolutely necessary! If the circuit can be broken down into subcircuits which can be optimized separately, then these subcircuits should be worked on separately.

Sometimes it is possible to start with a circuit of known response, or with a simple approximate circuit that can be converted into the actual circuit. Then one element at a time should be measured, modified, and optimized.

Experience has shown that if a program does not have an optimization routine, much time can be wasted by attempting on-line optimization in which more than two elements need adjustment. Exceptions occur only when these adjustments are essentially independent, or of relatively small effect, and, therefore, possibly convergent.

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Getting Around Program Limitations

Since the automatic program turns out so much data so fast, it is often worthwhile to spend time in getting around its apparent limitations. For a simple example, the broadband doubler circuit of Fig. 1 might appear unsuited for automatic analysis because it involves interaction of two frequencies, and these programs handle only one frequency at a time. This limitation is only apparent, however.

Observe that only ω_1 exists to the left of the inverter and only $2\omega_1$ exists to the right. Then the entire circuit can be evaluated at ω_1 with the correct impedance and power relations on the right, provided that the value of every inductance, capacitance, and length of line on the right is entered as twice its actual value.

Although some programs do not have controlled sources, parallel branching makes it possible to model circuits which require controlled sources by using the equivalences of Fig. 2. An equivalence of this type is applied in Fig. 3, which shows the modeling of a transistor in common-emitter connection.

Group delay is a measure of the time required for the modulation envelope of a signal to traverse a two-port. Most automatic programs do not measure group delay, but by an artifice, a direct measurement is possible in the passbands of components having reasonably low dissipative and reflection losses.

The technique is to simulate an increment, $\Delta\sigma$, in the real part of complex frequency by augmenting the circuit with lossy elements such that $R/L = G/C = \alpha v = \Delta\sigma$ for each inductance L, capacitance C, and transmission line of propagation velocity v. It can be shown that group delay, τ, is given by $\tau = 0.11513 \Delta TRLO/\Delta\sigma$, where ΔTRLO is the change in transducer loss in decibels due to the change in real frequency $\Delta\sigma$.

However, if the circuit was lossless before adding the lossy elements, an excellent approximation to ΔTRLO is found by a single measurement of the power loss (ratio of real power delivered to the two-port to power dissipated in load in decibels), which is zero for a lossless two-port.

Although it should be much less than the radian frequency ω, the value selected for $\Delta\sigma$ can be consistent with actual losses expected for the structure being modeled, and if it is chosen as a decimal multiple of 0.11513, the numerical value of power loss printed out by the automatic program will be equal to the numerical value of group delay in appropriate units of time.

Conclusion

The purpose of this paper is to stimulate the thinking of users, would-be users, and designers of automatic microwave circuit analysis programs, so that these programs can be applied effectively to a greater range of problems.

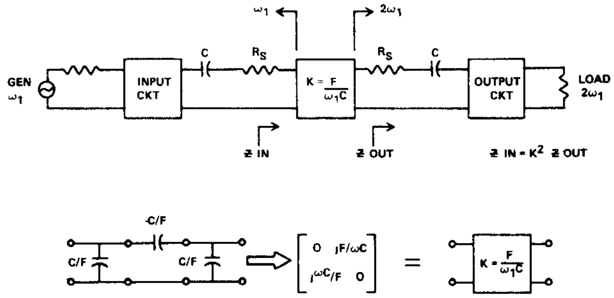

Figure 1. Broadband Frequency Doubler

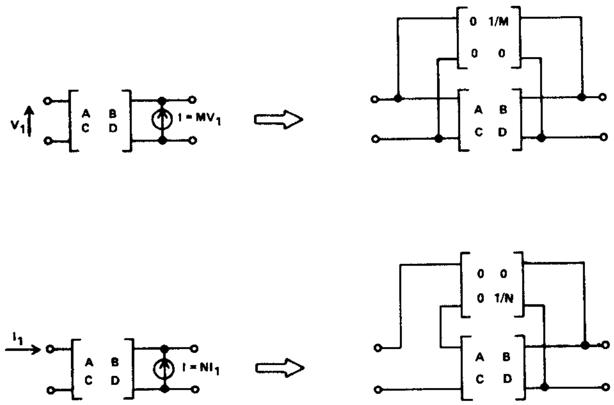

Figure 2. Matrix Equivalents for Controlled Current Sources

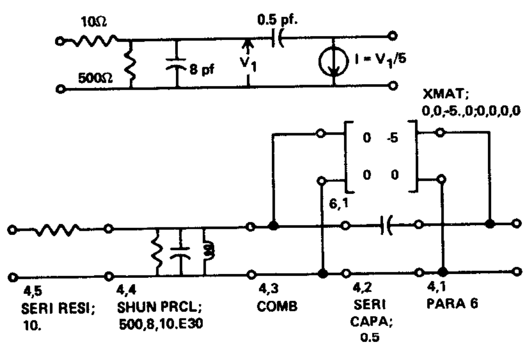

Figure 3. Grounded Emitter Transistor Model