ANNUAL REPORT

RESEARCH GRANT NGL-03-002-136
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

ANALYSIS AND SYNTHESIS OF DISTRIBUTED-LUMPED-ACTIVE NETWORKS BY DIGITAL COMPUTER

September 1, 1969 - August 31, 1970

Principal Investigator

Department of Electrical Engineering
University of Arizona
Tucson, Arizona 85721
1. INTRODUCTION

The primary goal of this research grant has been an investigation of ways in which a modern digital computing facility may be applied to the analysis and synthesis of DLA networks (networks containing Distributed, Lumped, and Active elements). This class of networks is of considerable importance in modern filter circuit design. One of the major reasons for this is because the fabrication techniques used to realize integrated circuits readily produce distributed, lumped, and active elements; thus, the DLA class of networks is directly realizable in integrated form. A second major reason for the importance of this class of networks is that DLA networks permit the ready realization of networks with resonant characteristics of the type usually characterized as bandpass and band-elimination, without requiring the use of inductors. The resulting inductorless realizations are attractive since, in general, they are smaller, lighter, and easier to synthesize than their purely lumped RLC counterparts. A final major reason for the importance of the DLA class of networks is that the realization of many of the more commonly required network functions can be made using considerably fewer components than would be required for a purely lumped realization, or for a lumped and active realization.

The advantages of DLA networks are not realized without
encountering some disadvantages. This class of networks is, in general, not amenable to analysis and synthesis by classical techniques, since it consists of elements modeled by partial differential equations (distributed elements) as well as elements modeled by ordinary differential equations and by algebraic relations (lumped and active elements). Digital computational techniques, however, may be applied to the analysis and synthesis of this class of networks with considerable success, as is evidenced by the reports previously published for this grant. During the preceding contract year major research efforts have been made in two general areas, namely the analysis and the synthesis of DLA networks. Details of these and other research accomplishments are given in the following sections.

II. RESEARCH IN ANALYSIS AND SYNTHESIS OF DLA NETWORKS

During the preceding contract year several important contributions to the general area of the analysis and synthesis of DLA networks have been made. These are summarized in the following paragraphs.

A. Two Dimensional Modeling of Distributed RC Networks

A computer program has been developed which has the capability of providing an analysis of a distributed RC network in which arbitrary terminal configurations can be imposed on either of the two resistive layers separated
by a dielectric layer which comprise the network. Thus this program effectively models a two-dimensional three-layer distributed RC network. A report has been submitted describing the details of the approach used by this program and documenting the results obtained from its application.\footnote{15}

B. A General DLA Optimization Program

A general computer program has been developed to provide for the analysis of arbitrary DLA network configurations at any desired points in the complex frequency plane. Thus this program may be used in connection with the GOSPEL software package described in a previous report.\footnote{5} As such it provides a powerful synthesis and analysis tool. Due to the generality of the program it is somewhat slower in the execution than individual programs which are written for specific network configurations. Its generality, however, makes it extremely useful for verifying the results obtained from such individual programs as well as for preliminary analyses of new network configurations. A report describing this program has been submitted.\footnote{14}

C. Constrained Complex Optimization

One of the most powerful general approaches which may be applied in synthesizing DLA networks is complex optimization. This technique achieves synthesis of a
desired dominant set of singularities on the complex frequency plane by maximizing and minimizing the magnitude of the network function at points in the plane where poles and zeros are desired. The general procedure has been described in a published paper. During the preceding contract year an extension of the method has been made to improve its convergence in optimization situations which have drastic irregularities in the error function topology. The method is called constrained complex optimization. It has been described in a published paper. A new report has been prepared during the contract period covered by this report which further describes complex optimization and the constraint procedure and which gives a summary of the application of the technique to several DLA network synthesis problems.

D. New DLA Network Configurations

During the preceding contract year several new and previously unreported DLA network configurations have been discovered. One of these is a high-Q network configuration which has zero sensitivity to the real part of the dominant pole location. Thus this network may be designed so as to realize narrow bandpass functions in which the instability problem, usually encountered in such realization, is minimized. A paper describing this network has been published. Two DLA network configurations have
also been discovered which provide second-order high pass and bandpass behavior with considerably improved sensitivities over their corresponding lumped-active counterparts. The high pass configuration is the first such DLA network to be reported in the literature. The bandpass configuration gives a "true" bandpass characteristic in that it provides zero transmission at the origin unlike most of the so called bandpass circuits which have been previously reported. A paper describing these networks is currently under preparation.

E. A Double-Zero Distributed RC Network

One of the most interesting distributed network configurations to result from the research conducted under this grant is the RC double-zero distributed network. This network may be fabricated from a three layer configuration of two resistive layers separated by a dielectric layer. It may be designed as a three-terminal distributed network which will produce two transmission zeros. Thus, it effectively replaces a pair of twin-tee lumped networks which would require a total of twelve individual network elements. In addition, the positions of the zeros are readily adjusted. This network should have considerable application for the simultaneous suppression of two of the harmonic components of a signal in which only the fundamental is of interest. Another possible application is
its use as a feedback element in an active network so as to produce a multi-pole network function for broad-band bandpass amplifiers. A report describing this network is currently under preparation. Continuing future research into the properties of this network and its application is planned.

F. A Set of General DLA Network Computer Programs

because of the complexity of the equations describing DLA networks, the analysis and synthesis of such circuits is best accomplished by digital computer means. During the past two years under the support of this grant a research effort has been implemented to produce a comprehensive collection of programs which will provide a complete analysis capability for any DLA network. This collection of programs is now nearing completion. It includes capabilities for plotting and determining root loci for dominant and non-dominant pole locations, determining frequency response characteristics, computing time domain network behavior, analyzing the network to determine element sensitivities, etc. A report describing this package of programs is currently under preparation. It is anticipated that considerable application of these programs will be made in evaluating existing DLA network configurations and in examining the capabilities of new ones which are as yet unreported.
III. CONCLUSION

In the preceding sections of this annual report some of the major research results obtained under this grant during the preceding year have been described. In addition some of the research efforts planned during the forthcoming year have been outlined. In general the response given by the academic and engineering communities to the results obtained under this grant have been very favorable. During the duration of the grant a total of twenty papers and reports have been published. During the preceding contract year the principle investigator for the grant was invited to two separate conferences to report on some of the specific results obtained under the grant. One of these invited papers was featured as a general conference paper. The second was presented as an invited session paper. Because of the power and generality of the computational tools developed under this grant, it is anticipated that the research results obtained during the coming contract year will be equally productive.

IV. LIST OF CONTRACT PUBLICATIONS

A. Items Published During Other Contract Years


B. Items Published During This Contract Year


