A THEORETICAL STUDY OF DIELECTRIC-FILLED EDGE-SLOT ANTENNAS

FINAL REPORT

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by

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1. Introduction

This is the final report summarizing the work done from 1 June 1979 to 31 May 1980, under Contract No. DAAG 29-79-C--096 which has been a continuation of a previous Grant No. DAAG 29-77-G-0152.

The Harry Diamond Laboratories (HDL) has developed a number of Dielectric-Filled Edge-Slot (DFES) antennas [1] which are very simple to fabricate, can be conformally mounted on conducting bodies of revolution and appear to have considerable potential for application to various systems. In its simplest form, the antenna consists of a disc of dielectric substrate mounted between the two halves of a conducting cylinder, and is excited at its center by a coaxial stub. It can be tuned for a desired operating frequency with the help of a number of axially oriented passive metallic posts located inside the dielectric region. The work done at HDL has been mostly experimental leading to an empirical design of such antennas. Our study originated from the need for a theory for the DFES antennas so that their performance may be better understood and their design carried out more efficiently.

During the previous two years a theory was developed for a basic (untuned) DFES antenna and for a tuned DFES antenna using one and two tuning posts. The results were summarized in a previous final report [2]. During the current year, attention has been devoted to the generalization of the previously developed theory to the case of multi-element DFES antennas, and to the development of a theory for DFES antennas using metallic fins or septums as tuning elements.

2. Technical Accomplishments

Multi-element DFES Antennas. For analysis, a multi-element DFES antenna has been modelled as a symmetrically excited E-type radial waveguide loaded with the tuning posts, and terminated by an equivalent admittance appropriate for the radiating aperture. Circuit parameters for the metallic posts have been determined by detailed field analysis using mode matching techniques and by taking into account any mutual interaction effects between the passive posts. These are then used along with the equivalent transmission line circuit of the antenna, to obtain the input reflection coefficient as a function of frequency. Satisfactory agreement has been obtained between theory and the measured results obtained at HDL for basic, two-element and single ring antennas containing arbitrary numbers of tuning posts. For DFES antennas having more than two elements and/or one ring, the theory needs improvement when the total number of tuning posts used exceeds a certain value dependent on the radius of the antenna and when the innermost ring of posts is placed too close to the exciting post. A technical paper entitled "Theory of DFES Antennas" describing the detailed theory is scheduled to appear in the July 1980 issue of the IEEE Transactions on Antennas and Propagation.

DFES Antennas Using Metallic Fins. As a first phase of the study of DFES antennas using metallic fins, we have initiated a field solution for a boundary value problem consisting of an infinite radial waveguide excited at its center by a line source and having a number of radially directed metallic fins connecting the two parallel plates. The z-directed edges of the fins are located at some constant distance $\rho = \rho_o$ from the center and extend from $\rho = \rho_o$ to $\rho = \infty$. Thus, for N such metallic fins there are N + 1 regions, one radial waveguide region of extent $\rho = \rho_0$, and N sectoral horn regions extending from $\rho = \rho_0$ to $\rho = \infty$. With N = 2, the present problem reduces to the analysis of the junction effects between the radial waveguide and the two sectoral horn regions. Using orthogonality conditions of the modes, an infinite set of equations with infinite number of unknowns (mode coefficients) have been obtained by using standard mode matching techniques. Two major techniques along with several variations of each have been attempted in order to solve this system of equations.

The first technique involved writing the infinite set of equations in matrix form and solving for the unknown infinite column vector. By writing the system of equations in appropriate form it should be possible to truncate the set of equations to some value M which could be numerically solved for the desired unknown coefficients. The value of the coefficients would converge as M increases. No appropriate form for the set of equations has yet been found to give convergence within the limitations of our computing system here.

The second technique involves a residue calculus approach. Under certain assumptions, the infinite set of equations has been written as several infinite series. By considering each series to represent a residue series of a meromorphic function, it is possible to determine the unknown mode coefficients, if the meromorphic function can be found. At the completion of the present contract, our effort was directed at the residue calculus method which appears promising to provide an analytic expression for the desired mode coefficients.

3. Conclusions

A theory has been developed for the DFES antennas. It clearly brings out the effects of various parameters on the performance of the antenna, and can be used for the design of such antennas under a variety of conditions. In addition to the theory of DFES antennas, we wish to emphasize the following accomplishments: (a) the equivalent circuit of DFES antennas and (b) the equivalent circuit parameters for the tuning posts in a radial waveguide. The techniques used and the results obtained may be applied to other antennas, e.g., to probe-fed patch antennas tuned by metallic posts.

The results of the investigation of the modified DFES antenna with metallic fins appear to be promising; however, due to lack of time the analysis could not be carried into completion.

4. Reports, etc.

The following literature resulted during the current period:

(i) D. L. Sengupta and L. F. Martins-Camelo, "Theory of Dielectric-Filled Edge-Slot Antennas, " to appear in IEEE Transactions on Antennas and Propagation, Vol. AP-28, No. 4, pp. -----, July 1980.

(ii) D. L. Sengupta and L. F. Martins-Camelo, "Metallic Posts in a Radial Waveguide," 1980 International Symposium Digest, Antennas and Propagation, Vol. 1, IEEE, pp. 40-43.

5. Recommendations for Future Work

Theory of DFES antennas using metallic fins is important not only on its own merit but also because it may be conveniently applied to develop a better theory for multi-element DFES antennas using an arbitrary number of tuning posts. It is therefore recommended that the work started on the DFES antenna using semi-infinite fins be completed, and the theory be applied to the DFES antennas using finite size fins.

6. References

[1] D. H. Schaubert, H. S. Jones, Jr., F. Reggia, "Conformal Dielectric-Filled Edge-Slot Antennas for Bodies of Revolution," HDL-TR-1837, Harry Diamond Laboratories, Adelphi, MD 20783, September 1977.

[2] D. L. Sengupta and L. F. Martins-Camelo, "Theory of DFES Antennas," Final Report on Contract DAAG 29-77-G-0152, The University of Michigan, Radiation Laboratory, Ann Arbor, MI 48109, June 1979.

7. Personnel Involved

In addition to the Principal Investigator the following graduate students participated in the research.

1. L. F. Martins-Camelo; Ph.D. candidate.
2. J. F. Pond; 1st year Ph.D. student.