likely to arise if the results obtained by this method are taken in the proper context. Thus the results reported in the paper under discussion may not be compared with those cited by Waldron for the problem of a coaxial line, as the two problems are different.

Acknowledgment

The author wishes to thank Dr. J. R. Wait for a private communication on this subject.

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Computer Program Descriptions

Prefabricated Multilayer Section Design Program

PURPOSE: PMSDP searches within the transitional section of an electromagnetic window configuration for the arrangement of prefabricated multilayers that yields the best broad-band frequency-matching condition.

LANGUAGE: Fortran IV; source deck length 250 cards.

AUTHOR: D. L. Huffman, Wright-Patterson Air Force Base, Ohio 45433.

AVAILABILITY: ASIS–NAPS Document No. NAPS-01940.

DESCRIPTION: It is well known that suitably designed transitional sections can reduce the reflection from electromagnetic windows (radomes). The windows treated here are ideal one-dimensional, structures, built up of dielectric materials that are lossless. From the viewpoint of fabricating transitional sections, practical considerations usually dictate that they be composed of N homogeneous layers. In this computer program it is assumed that the N layers have been prefabricated, and the broad-band program is directed toward assembling the N layers in the proper order so that the lowest broad-band reflection coefficient is obtained from the assembled multilayered section. There are $N!$ (factorial) ways of positioning the layers in the multilayered section, and $N!$ multilayered sections are treated.

The order of the dielectric constants and the thicknesses for the prefabricated layers are represented by DK(I) and TH(I), with $I=1, \cdots, N$. A portion of the computer program generates the $N!$ permutations of layer position for the N-layered section. Another portion of the program calculates the input reflectivity for NF sampled frequencies. This input reflectivity calculation is repeated until all $N!$ multilayered sections have been considered. All $NF \cdot N!$ input reflectivity values are stored in a two-dimensional matrix. Another portion of the computer program processes the stored input reflectivity matrix data. For each multilayered section, the computer arranges in a descending order of magnitude the values of input reflectivity, that is, the values of input reflectivity that have been calculated for different sampled frequencies. Then the column elements of the processed input reflectivity matrix are listed in ascending value, according to the magnitude of the first row elements as arranged above. Fig. 1 indicates the multilayered transitional section.

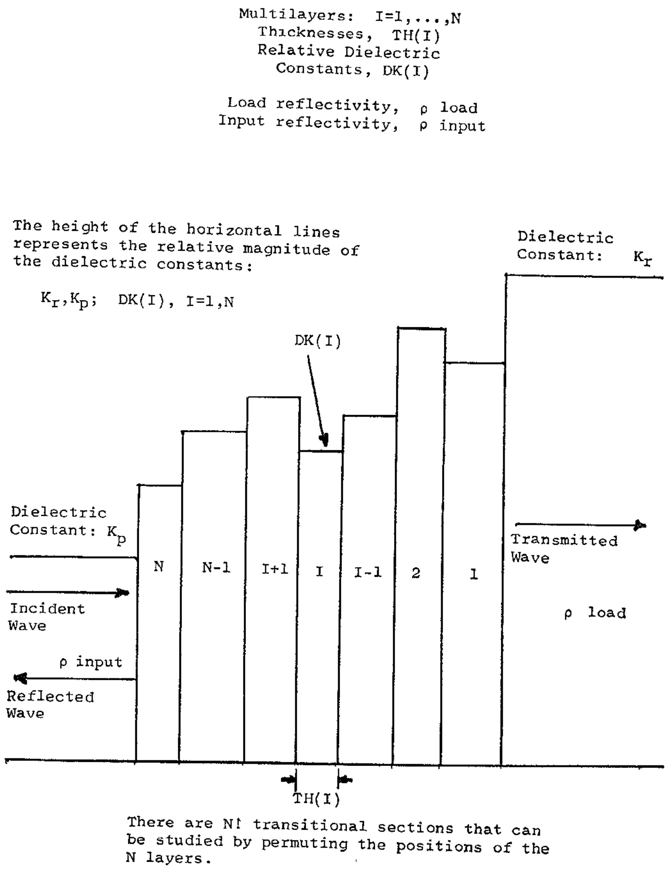

Fig. 1. Geometry of transitional section for an electromagnetic window configuration.

Application

A large number of electromagnetic window configurations can be studied by the permutation search method. The computer program is written for the normal incidence case and only the possibility of a single transitional section is discussed here. Required changes needed to study other general window configurations can easily be provided in the computer program. Experience with the program has indicated that, with $N!$ cases for permutation search available, some transitional sections can be found that produce the desired low reflectivity over a wide frequency range.

The distinct advantage of this permutation search method is that overall design requirements of space or weight are not involved because any improvement in the broad-band performance can be attributed to the positional arrangement of the prefabricated multilayers. Other optimization methods [1] develop improved broadband performance by modifying the values for the dielectric constants or the thicknesses of the layers. Such modifications may require an investigation to determine whether the use of the optimum transitional section is feasible.

Results and Computing Times

The basic computer program was executed on Wright-Patterson Air Force Base's CDC 6600 computer. The storage capacity of this computer is 400 000 octal words, thus permitting the chosen number of layers N to be as large as seven. For an electromagnetic window

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For program listing, order NAPS-01940 from ASIS National Auxiliary Publications Service, c/o CCM Information Corporation, 909 Third Avenue, New York, N. Y. 10022; remitting \$2.00 per microfiche or \$8.00 per photocopy.

configuration consisting of a transitional section only, the computer execution time is 36 s, with $N=6$ and $NF=6$. In one trial, computer printout results showed the broad-band matching of 141 (out of $6!=720$) permuted transitional sections to be superior to the tapered multilayer section which was used as a starting design. A modest improvement (4 percent) in the energy transmitted through the window was indicated when compared with the starting design. Only a modest improvement could be expected, because the tapered multilayer section used at the start had been established as an optimum design by another optimization method [1].

Reference

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Electrostatic Microstrip Analysis Programs—MICRO and INFSTR

PURPOSE: Each program determines the electrostatic capacitance of microstrip transmission lines. MICRO also returns characteristic impedance and relative phase velocity, INFSTR the charge density distribution.

LANGUAGE: Fortran IV, level G. MICRO source deck is 177 cards. INFSTR source deck is 179 cards.

AUTHORS: P. Silvester and P. Benedek, Department of Electrical Engineering, McGill University, Montreal 110, Quebec, Canada.

AVAILABILITY: The programs are available as ASIS–NAPS Document No. NAPS-01952. Copies of a source deck package containing both routines may be purchased through the first author at 15 dollars (U.S.), within three years of publication.

Manuscript received May 5, 1972; revised September 7, 1972.
For program listing, order NAPS-01952 from ASIS National Auxiliary Publications Service, c/o CCM Information Corporation, 909 Third Avenue, New York, N. Y. 10022; remitting \$2.00 per microfiche or \$5.00 per photocopy.

DESCRIPTION: MICRO [1] calculates the wave-propagation properties of microstrip transmission lines. The integral equation governing the electrostatics of microstrip configurations is solved using the substrip method. MICRO includes a main program and I/O statements. The required input is the number of subdivisions, the width-to-substrate height ratio, and the substrate relative dielectric constant. When N subdivisions are specified, the program automatically recomputes with $N/2$ subdivisions, and a quadratic Aitken extrapolation is used to return results equivalent to about $2N$ subdivisions. The output includes the capacitance and characteristic impedance, with and without dielectric, as well as the relative phase velocity. For further details see [1].

INFSTR calculates the electrostatic capacitance for microstrip transmission lines. The governing integral equation for the electrostatics of the microstrip is solved using a projective method [2]. The charge density distribution is expanded on a function space well suited to account for the edge singularities. INFSTR is in subroutine form and the required input parameters are: width-to-substrate height ratio, relative dielectric constant of the substrate, and the desired number of expansion functions. It is suggested that for maximum efficiency two expansion functions be utilized. This subroutine returns, in addition to the microstrip electrostatic capacitance per unit length, the vector of coefficients for the charge density expansion set. Therefore, a function describing the charge density distribution on the microstrip becomes available. There is usually no significant improvement in specifying more than two expansion functions. In its present form the program is usable for width-to-height ratios less than 3.0. This limitation can be removed by using higher order quadrature formulas. INFSTR calls subroutine SIMQ, part of the IBM Scientific Subroutine Package. If desired, any other general simultaneous equation solver may be substituted, by altering one Fortran statement.

Both programs have been repeated by run on IBM 360 machines, and MICRO has also been used on IBM 7094. In view of the standard Fortran employed, however, they should be completely portable. Comparative results and computation times for the two programes are given in [2].

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