Computer Program Descriptions

Computation of Step Discontinuities in Coaxial Line

PURPOSE: Computation of the capacitance of discontinuities formed by coplanar steps in both conductors of a coaxial line.

LANGUAGE: Fortran IV.

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AVAILABILITY: ASIS—NAPS Document No. NAPS-01875

DESCRIPTION: The two configurations shown in Figs. 1 and 2 require different programs which have been named DSCAP1 (Fig. 3) and DSCAP2 (Fig. 4), respectively.

The case of Fig. 1 has been explicitly analyzed by Whinnery, Jamieson, and Robbins (WJR) [1]. This case was therefore programmed following closely the method of Somlo [2] in programming the single-step cases. Several changes were made in the details of the programming, and also some of the special subroutines written by Somlo were replaced by subroutines that are generally available to computer users. The two single-step cases programmed by Somlo have been included in the program. A misprint has been noted in [1]: In the equations giving the matrix elements [1, p. 708], the denominator of the expression giving h_p should be $p^2\pi^2 r_1 r_2$.

The case of Fig. 2 has not been analyzed by WJR [1]; however, it is a simple matter to derive the equations starting from the appropriate boundary conditions. When this is done, it is found that a straightforward adaptation of the previous computational scheme Is not feasible. First, the expressions corresponding to β_{0n}, β_{pn}, and γ_{pn} of [1, eqs. (33)–(35)] apply in this case to a slightly different physical configuration. In addition, there are now cross-product terms, such as $Z_0(k_{Bn}r_2) \times Z_0(k_{Bn}r_0)$, which have no equivalent in WJR's analysis. Thus the auxiliary functions L_0, L_p, M_p [1] and their evaluation with the help of Hahn's functions could not be used. Instead of this, the appropriate auxiliary functions were defined and computed by summing the series to 1000 terms. In other respects DSCAP2 has the same structure as DSCAP1.

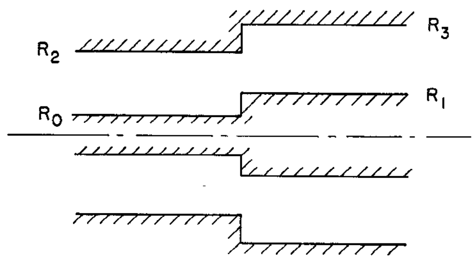

Fig. 1. Computation of step discontinuities.

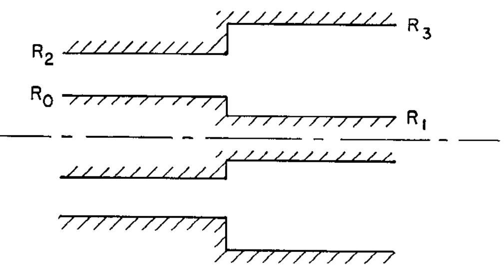

Fig. 2. Computation of step discontinuities.

R0	R1	R2	R3	IJK
0.209672	0.310205	0.714375	0.714375	0

FREQ. INCR.	FREQ. POINTS
0.100D 01	5

FREQUENCY GHZ	CAPACITANCE FARADS	PRECISION
0.000	0.1887112905D-13	0.100D-17
1.000	0.1887742237D-13	0.100D-17
2.000	0.1889635437D-13	0.100D-17
3.000	0.1892808243D-13	0.100D-17
4.000	0.1897287338D-13	0.100D-17

Fig. 3. Sample output of program DSCAP1.

R0	R1	R2	R3	IJK
0.310205	0.209672	0.714375	0.714375	0

FREQ. INCR.	FREQ. POINTS
0.100D 01	5

FREQUENCY GHZ	CAPACITANCE FARADS	PRECISION
0.000	0.1887101768D-13	0.100D-17
1.000	0.1887731097D-13	0.100D-17
2.000	0.1889624288D-13	0.100D-17
3.000	0.1892797080D-13	0.100D-17
4.000	0.1897276154D-13	0.100D-17

Fig. 4. Sample output of program DSCAP2.

Input Variables

R0, R1, R2, R3: Radii of the coaxial lines in centimeters, as shown in Figs. 1 and 2.

IJK: A control parameter; if IJK = 1, the program will expect another set of input dimensions after computing the present one. If IJK = 0, the program will terminate after completing the computation.

IFREQ: Number of frequencies, including 0, for which the discontinuity capacitance is to be computed.

FINCR: Increment between the frequencies at which the capacitance is to be computed, expressed in gigahertz.

Output Variables

FR: Frequency, in gigahertz.

CAPLIM: Capacitance, in farads.

EPS: Precision parameter for subroutine DTEAS. If the subroutine cannot find the limit to the precision initially specified (EPS $= 10^{-18}$), EPS will be successively increased by an order of magnitude until a limit is found. An unusually high value of EPS would be an indication of computational problems in earlier sections of the program.

Subroutines Required (Listings have been Provided)

MAHON: A subroutine giving the roots of the equation

$$J_0(x)Y_0(kx) - J_0(kx)Y_0(x) = 0 \quad \text{for} \quad x > 50$$

using McMahon's method.

BESJ, BESJF, BESYF: Subroutines for computing Bessel functions. These are library subroutines of the National Research Council Computation Centre.

BESASM: A subroutine for computing Bessel functions by the asymptotic formula of Hankel. This program is used for $x > 50$, since BESJF and BESYF take a very long time for large arguments.

HAHN: A subroutine for computing the Hahn functions S_0, S_p, and U_p. This is used only by DSCAP1.

SOLVD: A library subroutine of the National Research Council Computation Centre for solving matrix equations.

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For program listing, order document NAPS-01875 from ASIS National Auxiliary Publications Service, c/o CCM Information Corporation, 909 Third Avenue, New York, N. Y. 10022; remitting $4.00 per microfiche or $8.00 per photocopy.

DTEAS: A program from the IBM Scientific Subroutine Package for finding the limit of a sequence by the method of nonlinear transformations.

The subroutines MAHON, BESASM, and HAHN are transcribed from Somlo [2].

Performance

Values computed for the limiting case of a step on one conductor only have been compared with Somlo's published values. The agreement was found to be within about 0.05 percent. For the same limiting case, the values computed by DSCAP1 and DSCAP2 are in agreement within 0.01 percent.

The programs have been run on an IBM 360/67 computer. The time required to compute one value is about 1 min; values for additional frequencies with the same dimensions take about $\frac{1}{2}$ min per frequency.

Storage requirements are 60 000 bytes for DSCAP1 and 80 000 bytes for DSCAP2.

Acknowledgment

The author wishes to thank P. I. Somlo for a copy of the listing of his program.

References

[1] J. R. Whinnery, H. W. Jamieson, and T. E. Robbins, "Coaxial-line discontinuities," *Proc. IRE*, vol. 32, pp. 695–709, Nov. 1944.
[2] P. I. Somlo, "The computation of coaxial line step capacitances," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-15, pp. 48–53, Jan. 1967.

DISFIL, A Computer Program for the Optimum Synthesis of TEM Transmission-Line Filters

PURPOSE: DISFIL uses exact network synthesis techniques to produce the final cascade of unit elements and *LC*-type resonators, for all common kinds of optimum high- or lowpass Butterworth or Chebyshev filters, terminated either at a single side or at both sides in a finite nonzero resistor.

LANGUAGE: Fortran IV; length of card deck 2400 cards.

AUTHORS: G. Hoffman and H. Vanooteghem, Laboratory for Electromagnetism and Acoustics, University of Ghent, B-9000, Ghent, Belgium.

AVAILABILITY: ASIS–NAPS Document No. NAPS-01880.

MACHINE REQUIREMENTS: One card reader for input, one line printer for output, or one time-sharing terminal for both. 124 K of memory is required, but using built-in overlay structure, a partition as small as 40 K is sufficient.

DESCRIPTION: DISFIL has been written in order to bring the design of distributed quarter-wave filter structures, based on exact network techniques, into easy reach. For any common kind of commensurate filter two-port, it computes the cascade of shunt- or series-type resonators and the interconnecting transmission lines. The computational method used closely follows the normal synthesis procedure, and needs as input data the ordinary specifications necessary for filter design. The essential steps to be taken are as follows.

1) Determine the equivalent circuit of the physical structure: bandpass or bandstop type, the number m of series- or shunt-type resonators, and the number n of unit elements.

2) Determine whether the circuit is terminated at both sides in a finite nonzero resistor, which is the common situation for filters, or whether there is only one termination, a case that often arises in diplexers where bandpass and bandstop structures are connected in series or parallel.

3) Specify the central frequency f_0 (GHz) and the relative bandwidth w (percent) of the filter.

4) Specify the desired response type, Butterworth or Chebyshev. In the latter case also specify the maximum ripple (dB) allowable over the passband.

The procedure to compute the filter elements is then based on the following definitions.

1) Richards' variable S is defined as

$$S = j\Omega = j \tan \frac{\pi}{2} \frac{f}{f_0}. \tag{1}$$

2) The cutoff point on the Richards-plane imaginary axis is then

$$\Omega_c = \tan \frac{\pi}{2} \left(1 - \frac{w}{200}\right). \tag{2}$$

3) The approximation functions to be used are

$$|Z_{21}(j\Omega)|^2 = \frac{1}{1 + F^2(\Omega)}. \tag{3}$$

For optimum Butterworth filters, we have the following.

a) Bandpass case:

$$F(\Omega) = \left(\frac{\Omega_c}{\Omega}\right)^m \sqrt{\left(\frac{1+\Omega_c^2}{1+\Omega^2}\right)^n}. \tag{4}$$

b) Bandstop case:

$$F(\Omega) = \left(\frac{\Omega}{\Omega_c}\right)^m \left(\frac{\Omega}{\Omega_c}\sqrt{\frac{1+\Omega_c^2}{1+\Omega^2}}\right)^n. \tag{5}$$

For optimum Chebyshev filters, we have the following (ϵ is the ripple factor).

a) Bandpass case:

$$F(\Omega) = \epsilon \cos\left[m \cos^{-1}\frac{\Omega_c}{\Omega} + n \cos^{-1}\sqrt{\frac{1+\Omega_c^2}{1+\Omega^2}}\right]. \tag{6}$$

b) Bandstop case:

$$F(\Omega) = \epsilon \cos\left[m \cos^{-1}\frac{\Omega}{\Omega_c} + n \cos^{-1}\frac{\Omega}{\Omega_c}\sqrt{\frac{1+\Omega_c^2}{1+\Omega^2}}\right]. \tag{7}$$

Expressions (3) to (7), introduced by Horton and Wenzel [1], are called optimum approximation functions, because they treat the unit element as a basic selective element of the cascade.

4) One of the expressions (4) to (7) is used to generate the positive real input impedance of the terminated filter. If the filter has double terminations, (3) is interpreted as the power transfer of the filter, normalized to the available power of the generator:

$$|S_{12}(j\Omega)|^2 = |Z_{12}(j\Omega)|^2. \tag{8}$$

The input impedance is constructed from

$$Z(S) = \frac{1 \pm S_{11}(S)}{1 \mp S_{11}(S)} \tag{9}$$

where

$$S_{11}(S)S_{11}(-S) = 1 - |S_{12}(j\Omega)|^2|_{\Omega^2=-S^2}. \tag{10}$$

The plus or minus sign in (9) is chosen in accordance with the singularity type of the equivalent circuit in the stopband.

If there is only one terminating resistance, the approximation function (3) is treated as the real part of the input impedance or admittance of the terminated filter.

5) The input impedance is broken down into its elementary parts by use of a Darlington synthesis technique. The sequence is quite arbitrary, but is conveniently chosen to be the topology of the equivalent circuit.

Using DISFIL, this procedure is reduced to the specification of a valid combination of design parameters. The generation and manipulation of polynomials, finally resulting in the element values of the filter cascade, has been implemented for all valid sets of specification data. Needless to say that the special cases $n = 0$ (classical prototypes) and $m = 0$ (quarter-wave impedance transformers and lowpass filters)

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