Computer Program Descriptions

Calculation of the *S*-Parameters of an Unsymmetric Microstrip *T*-Junction

PURPOSE: The program TSTRIP calculates the frequency-dependent *S*-parameters of an unsymmetric microstrip *T*-junction.

LANGUAGE: FORTRAN IV (for the Control Data Computer Cyber 76).

AUTHOR: W. Menzel is with the Department of Electrical Engineering, University of Duisburg, Duisburg, West Germany.

DESCRIPTION: *T*-junctions of different geometries are used in a variety of microstrip integrated circuits. Applying computer aided design methods, especially for higher frequencies, the frequency-dependent behavior of the *T*-junctions must be known. This computer program calculates the frequency-dependent *S*-parameters of a *T*-junction shown in Fig. 1. Dimensions and denotation of the junction ports in the computer program as well as the reference plains (dashed lines) refer to this figure.

The *S*-parameters are calculated using a waveguide model and a mode matching method [1]. The waveguide model consists of a parallel plate waveguide of width w_{eff} and height h (h is height of the substrate material) filled with a medium of effective dielectric constant ε_{eff}. w_{eff} and ε_{eff} are frequency dependent. For zero frequency, $w_{\text{eff}}(0)$ and $\varepsilon_{\text{eff}}(0)$ are calculated with expressions given in [2]. Dispersion characteristics are approximated by analytical equations. For the dispersion of w_{eff}, the formula is given in [3], for the dispersion of ε_{eff}, a formula similar to that of Schneider [4] is used:

$$w_{\text{eff}}(f) = w + (w_{\text{eff}}(0) - w)/(1 + f/f_g)$$

with

$$f_g = c_0/(2w\sqrt{\varepsilon_r})$$

and

$$\varepsilon_{\text{eff}}(f) = \varepsilon_r \varepsilon_{\text{eff}}(0)\left[\frac{(f/f_c)^2 + 1}{\sqrt{\varepsilon_{\text{eff}}(0)}(f/f_c)^2 + \sqrt{\varepsilon_r}}\right]^2$$

with

$$f_c = c_0/(6h\sqrt{(\varepsilon_r - 1)w/h})$$

where w is the line width, h the substrate height, ε_r the dielectric constant, and f the frequency. In the connecting region of the junction, an equivalent dielectric constant is calculated [5] taking into account the electric stray field only at those sides of the region where no line is connected.

In the waveguide model, complete solutions for the electromagnetic field exist, and the *S*-parameters of the junction are calculated using mode matching techniques. The resulting infinite set of equations is truncated and solved numerically. Convergence is good, and results of sufficient accuracy are obtained taking into account only five higher order modes. Results have been confirmed by experiments on Polyguide substrate material ($\varepsilon_r = 2.32$, $h = 0.158$ cm, and $h = 0.0794$ cm) and alumina substrate material ($\varepsilon_r = 10$, $h = 0.0635$ cm) in a frequency range up to 12.4 GHz. For higher frequencies the validity of the expressions for the dispersion of ε_{eff} and w_{eff} has to be tested.

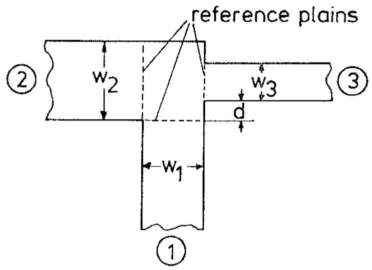

Fig. 1 Unsymmetric microstrip *T*-junction

LIST OF INPUT VARIABLES

Fortran name	Dimension	Type	Variable	Meaning
W1, W2, W3	cm	Real	w_1, w_2, w_3	linewidths
D	cm	"	d	offset of line 3
H	cm	"	h	substrate height
EPSR	—	"	ε_r	dielectric constant
N	—	Integer	n	number of higher order modes
FANF	GHz	Real	f_1	first-frequency point calculated
FEND	GHz	"	f_2	last-frequency point calculated
DF	GHz	"	Δf	difference between frequency points

Manuscript received November 7, 1977; accepted December 7, 1977.

See NAPS document No. 03214 for 10 pages of supplementary material Order from NAPS c/o Microfiche Publications, P.O Box 3513, Grand Central Station, New York, NY 10017 Remit in advance for each NAPS accession number Institutions and Organizations may use purchase orders when ordering, however, there is a billing charge of $5.00 for this service Make checks payable to Microfiche Publications. Photocopies are $3.00 Microfiche are $3 00 each Outside of the United States and Canada, postage is $3 00 for a photocopy and $1.00 for a fiche

REFERENCES

[1] I Wolff, and W. Menzel, "A method for calculating the frequency dependent properties of microstrip discontinuities," *IEEE Trans Microwave Theory Tech.*, MTT-25, pp. 107–112, Feb. 1977.
[2] E O Hammerstad, "Equations for microstrip circuit design," presented at *Proc. European Microwave Conf*, Hamburg, Germany, C 4.2, 1975
[3] G Kompa, and R Mehran, "Planar waveguide model for calculating microstrip components," *Electron. Lett.* vol 11, pp 459–460, 1975.
[4] M. V. Schneider, "Microstrip dispersion," *Proc. IEEE*, vol 60, 1972, pp 144–146.
[5] I Wolff, "Statische Kapazitaten von rechteckigen und kreisformigen Mikrostrip-Scheibenkondensatoren," *AEÜ*, vol. 27, 44–47, 1973.