Table 2

		$\Omega_1-\Omega_2$			
		Approx.	Exact	Approx.	Exact
$d/2h$	$R\backslash\Omega_r$	0·15		0.20	
2	0.01	0·0799	0·0818	0·1201	0·1201
	0·02	0·0650	0·0658	0·0982	0·0979
	0·03	0·0558	0·0562	0·0846	0·0843
4	0·01	0·0471	0·0473	0·0718	0·0716
	0·02	0·0309	0·0310	0·0477	0·0476
	0·03	0·0226	0·0226	0·0352	0·0351
6	0·01	0·0277	0·0278	0·0430	0·0429
	0·02	0·0147	0·0147	0·0232	0·0232
	0·03	0·0092	0·0092	0·0146	0·0146
8	0·01	0·0163	0·0163	0·0257	0·0257
	0·02	0·0070	0·0070	0·0113	0·0113
	0·03	0·0037	0·0037	0·0061	0·0061
10	0·01	0·0096	0·0096	0·0154	0·0154
	0·02	0·00333	0·00333	0·0055	0·0055
	0·03	0·00150	0·00150	0·00253	0·00253

E. BECK
E. SCHULTZE
H. MEYR

Research Division Hasler Ltd.
Belpstrasse 23, 3000 Berne 14, Switzerland

9th August 1976

References

1 BEAVER, W. D.: 'Theory and design principles of the monolithic crystal filter'. Ph.D. dissertation, Lehigh University, Bethlehem, Pa. 1967
2 SHEAHAN, D. F.: 'An improved resonance equation for AT-cut quartz crystals', *Proc. IEEE*, 1970, **58**, pp. 260–261
3 SYKES, R. A., SMITH, W. L., and SPENCER, W. J.: 'Monolithic crystal filters'. IEEE International Convention Record, 1967, **15**, Pt. II, pp. 78–93
4 SCHNABEL, P.: 'Frequency equations for *n* mechanically coupled piezoelectric resonators', *Acustica*, 1969, **21**, pp. 351–357
5 BECK, E., SCHULTZE, E., and MEYER, H.: 'An admittance approach to the dual monolithic crystal filter'. Proceedings of IEEE international symposium on circuits and systems, 1976, pp. 316–319
6 BEAVER, W. D.: 'Analysis of elastically coupled piezoelectric resonators', *J. Acoust. Soc. Am.*, 1968, **43**, pp. 972–981
7 Internal report, available on request from the authors

COMPUTER-PROGRAM DESCRIPTION

MICPA: EVALUATION OF MICROSTRIP-LINE PARAMETERS*

Indexing terms: Computer-aided analysis, Striplines

A subroutine for microstrip-line parameters is described which evaluates dispersive effects, microstrip dimensions, conductor attenuation and dielectric loss.

Introduction: During the last few years, a large number of papers on computerised methods of evaluating microstrip parameters have been presented. These usually require extensive subroutines to compute individual parameters, so that the associated programs are rendered expensive in terms of computer time. They are also invariably cumbersome for incorporation into a computer analysis/optimisation package.[1] It is therefore particularly desirable to seek alternatives which are efficient and this consideration, in turn, influences the choice of associated algorithms for the microstrip parameters.

In this letter, a subroutine is presented which computes the parameters most frequently required in designing microwave integrated circuits. The particular transmission structure considered is standard microstrip, i.e. an open structure comprising a single stripline deposited on a dielectric substrate backed by a metallic ground plane. The subroutine, however, may be used in conjunction with programs or independently. This subroutine represents an improvement over OPTIMAL, described previously.[1]

Input data: In computing the various parameters, the following are assumed to be known:

characteristic impedance Z_0, Ω

air length of microstrip l, cm

substrate thickness, h, mils

relative permittivity of substrate, ε_r

conductor thickness t, microinches

metalised conductivity of strip σ_c, S/m

dielectric resistivity of substrate ρ_d, Ωcm

Computed parameters: The following parameters are computed via the associated algorithms

(*a*) Conductor loss

(*b*) Dielectric Loss

(*c*) Line dimensions

(*d*) Dispersion

In the subroutine, the above parameters are evaluated by reference to the methods indicated below:

(*a*) Conductor loss: Schneider's approximation,[4] being simple and explicit, is used to estimate conductor losses in the strip and ground plane.

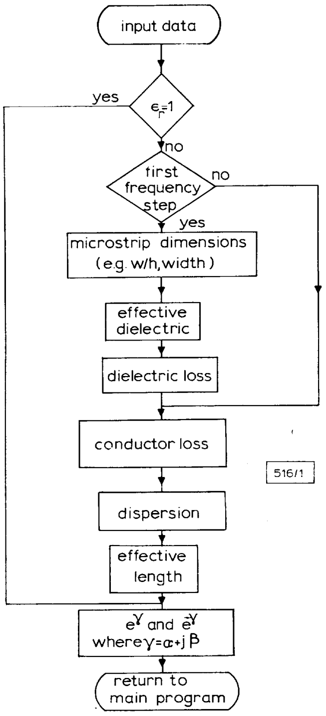

Fig. 1 *Flow diagram*

---

* The program listing and accompanying documentation are held in the IEE Library, Savoy Place, London WC2R 0BL, England. For further information, please contact the Library, quoting CP155

(*b*) Dielectric loss: this may be calculated if the loss tangent and also the electric-field distribution are known. Computation of the electric field is complicated and not practical for present purposes, so here we have used an empirical method, details of which will be published in due course.

(*c*) Line dimensions: the results of Wheeler[2] have been employed, expressing the ratio of width to thickness in terms of the characteristic impedance.

(*d*) Dispersion: of the many experimental and theoretical approaches reported, we have chosen the Gesinger model[3] as being the most appropriate for computer analysis.

A flow chart outlining the procedures is given in Fig. 1. In evaluating the dielectric loss, it is assumed that the conductivity of the substrate is substantially frequency independent.

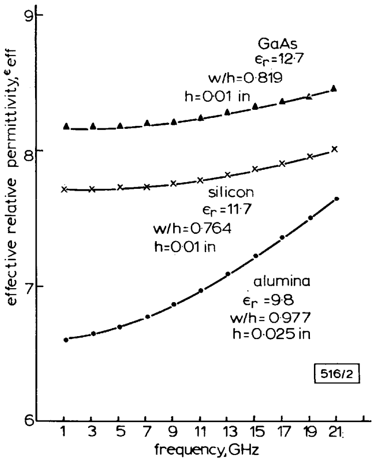

Fig. 2 *Effective relative permittivity against frequency for 50 Ω alumina, silicon and GaAs substrate*

To show how the substrate relative permittivity varies with frequency owing to dispersion, results are presented in Fig. 2 for 50 Ω, 635 μm (0·025 in) thick alumina microstrip and also for typical 254 μm (0·01 in) thick silicon and GaAs microstrip. Total losses with the above substrates are shown in Fig. 3, for copper conductors of 0·0381 μm ($1{\cdot}5\times10^{-6}$ in) thickness.

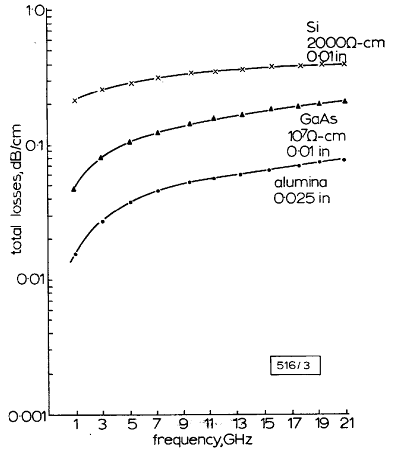

Fig. 3 *Total losses for 50 Ω silicon, GaAs and alumina substrate*
Conductor thickness = 0·0381 μm ($1{\cdot}5\times10^{-6}$ in)

Acknowledgments: This work is supported by the UK Science Research Council. The authors wish to thank K. Halstead of the Computer Unit for many helpful discussions.

N. M. HOSSEINI *9th August 1976*
H. V. SHURMER

Department of Engineering
University of Warwick
Coventry CV4 7AL, England

References

1 HOSSEINI, N. M., SHURMER, H. V., and SOARES, R. A.: 'OPTIMAL: a program for optimising microstrip networks', *Electron. Lett.*, 1976, **12**, pp. 190–193
2 WHEELER, H. A.: 'Transmission line properties of parallel strips separated by a dielectric sheet', *IEEE Trans.*, 1965, **MTT-13**, pp. 172–185
3 GETSINGER, W. J.: 'Microstrip dispersion model', *ibid.*, 1973, **MTT-21**, pp. 34–39
4 SCHNEIDER, M. V.: 'Microstrip lines for microwave integrated circuits', *Bell Syst. Tech. J.*, 1969, **48**, pp. 1421–1444

Program Details

(*a*) FORTRAN IV

(*b*) A maximum of 30 microstrip lines

(*c*) Complex and only single-precision arithmetic

(*d*) 139 cards, including comments

Performance Guide

(*a*) It is loaded on the XDS-Sigma 5 computer

(*b*) Core-size requirements: 17928 bytes

(*c*) Input medium: cards

(*d*) Output medium: line printer

(*e*) Work or data files needed: none

(*f*) Time taken to run submitted examples: compilation 01 : 07 min run 19 s

---

GENERATION OF CORRELATED LOG-NORMAL CLUTTER SAMPLES

Indexing term: Radar clutter

A method is described for generating random log-normal vectors with the desired correlation matrix and specified parameters. Such vectors may represent samples of correlated clutter signal. The presented method makes use of the suitable nonlinear transformation of a random normal vector with correlated components.

Introduction: Several recent investigations of natural clutter characteristics have shown that clutter returns can often be approximated by a log-normal distribution.[1] The log-normal clutter model is characterised by very long 'tails' and is, therefore, a much severer clutter environment than Rayleigh clutter.

The log-normal distribution is a function of two independent parameters and may be written as[2]

$$p(z;\,a,\,p)=\frac{1}{2z\sqrt{(\pi\ln p)}}\exp\left[-\frac{1}{4\ln p}\ln^2(z/a)\right],\qquad z>0,\ a>0,\ p>1 \quad (1)$$

where a is the median and p is the mean/median ratio. The mean value $E\{Z\}$ and the variance $D^2\{Z\}$ of a log-normal variable Z are given by

$$E\{Z\}=ap \quad (2)$$

$$D^2\{Z\}=a^2p^2(p^2-1) \quad (3)$$

The log-normal variable Z can be obtained by the transformation

$$Z=\exp X \quad (4)$$