VI-3. IMPEDANCE AND ATTENUATION OF TRANSMISSION LINES SUPPORTING TEM-MODES

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The characteristic impedance and the attenuation of transmission lines supporting a TEM mode can be determined by the following methods:

1 Resistive thin film method (analog computation).

2 Finite difference methods combined with relaxation technique (digital computation).

Both techniques have been used to determine the properties of a large variety of transmission lines, particularly lines suitable for microwave printed circuits.

The resistive film technique is shown in Figure 1. A nickel-chromium film with a uniformity of ±0.5 percent is deposited on a glass substrate. Gold electrodes with the exact shape of the inner and the outer conductor of the transmission line are evaporated through a molybdenum mask to provide

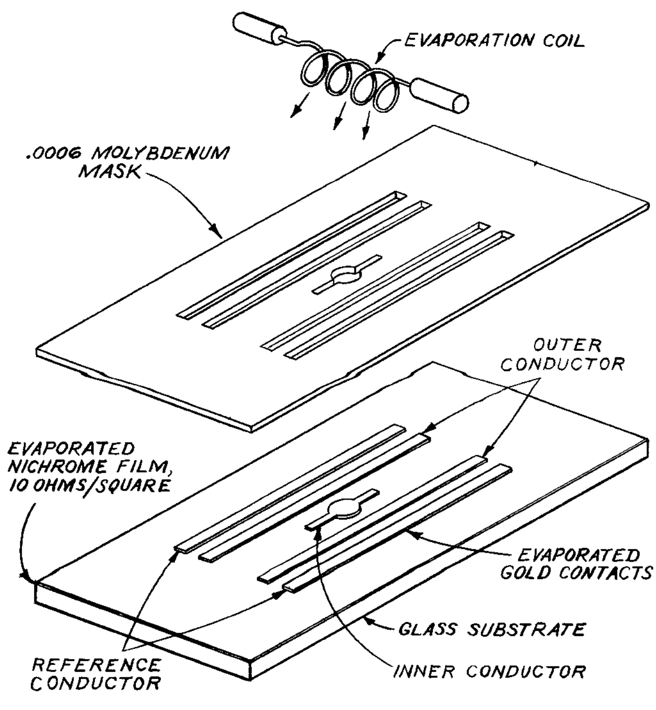

Figure 1. Evaporation of Gold Contacts on Resistive Nickel-Chromium Layer

contacts to the nickel-chromium film. The impedance is obtained by measuring the resistance between the electrodes representing the inner and the outer conductor and the attenuation can be found by using a second mask with a slightly contracted inner and a slightly expanded outer conductor (incremental inductance rule) The characteristic impedance of a structure which has been used for a transition from strip transmission line to slab line is shown in Figure 2. The accuracy of the method is presently better than 1 percent and is determined by the quality of the contacts, the tolerance achieved in mask fabrication and the uniformity of the resistive film. It can be further improved by using a novel evaporation scheme suggested by K. H. Behrndt (Reference 1).

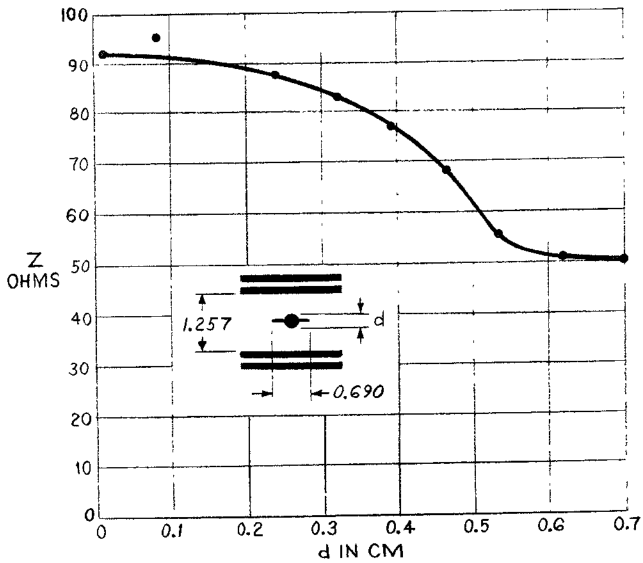

Figure 2. Characteristic Impedance of a Taper from Strip Line to Slab Transmission Line

Another approach for finding line parameters is to solve the Laplace equation for the domain between the inner and the outer conductor by finite difference methods. The domain is replaced by a finite set of mesh points with a lattice spacing as shown in Figure 3. An initial or guess potential $U^o_{j,k}$ is assigned to each mesh point and fixed potentials are assigned to each boundary. Successive approximations $U^n_{j,k}$ are obtained from the equation

$$U^{n+1}_{j,k} = \alpha(U^{n+1}_{j-1,k} + U^n_{j+1,k} + U^{n+1}_{j,k-1} + U^n_{j,k+1}) - (4\alpha-1)\, U^n_{j,k} . \qquad (1)$$

The relaxation factor α determines the rate of convergence. The lattice is scanned either by a systematic or by a random process (Monte-Carlo method) and Equation (1) is applied successively to each mesh point. The mesh is subdivided several times to obtain a large number of lattice points on boundaries B1 and B2.

The characteristic impedance Z and the attenuation α are obtained by numerical integration of the electric field E_n along both boundaries

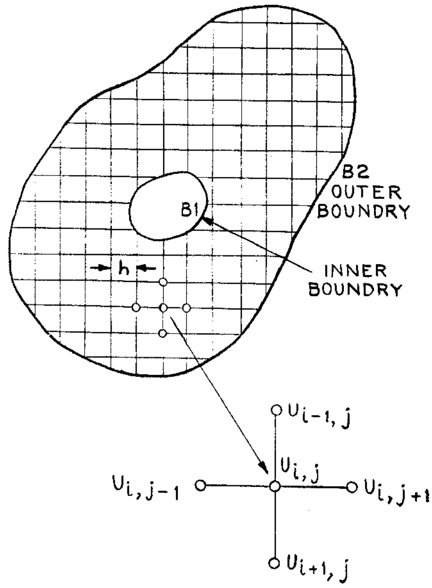

Figure 3. Square Mesh for Solving the Laplace Equation for Domain Defined by Boundaries B1 and B2

$$Z = \sqrt{\frac{\mu_o}{\epsilon_o}} \frac{V}{\oint_{B2} E_n ds} \tag{2}$$

$$\alpha = \frac{R_M}{2} \sqrt{\frac{\epsilon_o}{\mu_o}} \frac{\oint_{B1+B2} E_n{}^2 ds}{\oint E_n ds}, \tag{3}$$

R_M is the sheet resistance of the wall material and V is the potential difference between the two fixed potentials assigned to the boundaries.

Results obtained for the attenuation of a square coaxial transmission line and a round hole in a square peg are shown in Figure 4. The case of a coaxial line and a slab line are listed for comparison. Figure 5 is a plot of the skin resistance $R_N = 2\alpha_N Z$ as a function of the ratio $\rho = D/d$. The skin resistance of all lines approaches asymptotically the case of a coaxial transmission line. This is in perfect agreement with Wheeler's theorem (Reference 2) which states that the skin resistance of all Wheeler lines is the same for large ratios of ρ.

Figure 6 is a plot of the characteristic impedance of shielded strip transmission lines obtained by the relaxation process. An accuracy of better than 0.5 percent is obtained for a total computation time of approximately 0.01 hour on the IBM 7094. Higher accuracies can be achieved by further subdivision of the mesh.

The present technique can be extended to transmission lines which are partially filled with dielectric material. The case of a partially filled strip transmission line is of particular interest because the attenuation can be reduced by mounting the dielectric support in such a way that the high field regions at the re-entrant corners are avoided.

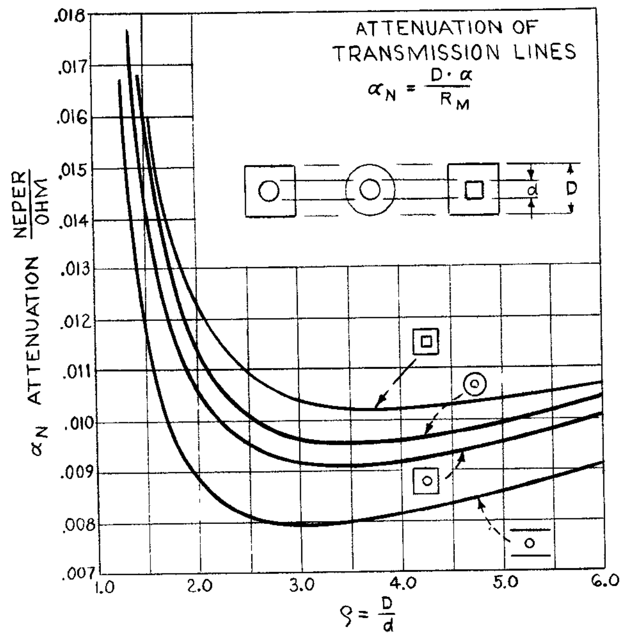

Figure 4. Normalized Attenuation α_N of Wheeler Transmission Lines

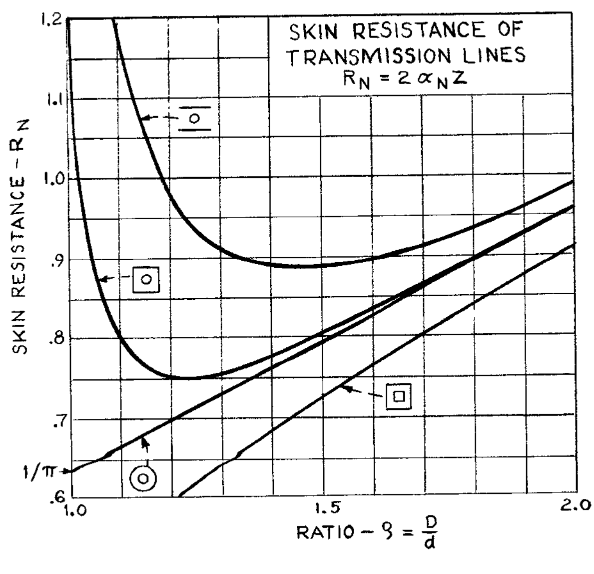

Figure 5. Skin Resistance of Wheeler Transmission Lines

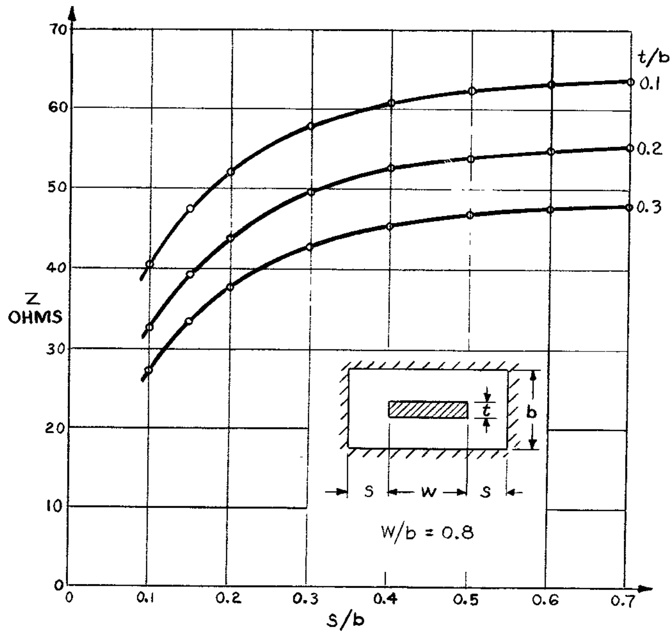

Figure 6. Characteristic Impedance of a Shielded Strip Transmission Line for a Fixed Ratio w/b = 0.8

REFERENCES

1. Behrndt, K. H., "Thickness Uniformity on Rotating Substrates," Transactions of the American Vacuum Society, pp. 379-384, 1963.

2. Wheeler, H. A., "Skin Resistance of a Transmission-Line Conductor of Polygon Cross Section," Proc. IRE, Vol. 43, pp. 805-808, July, 1955.