$$T_A = T_S \quad (3)$$

$$\Gamma_A = -\Gamma_S \quad (4)$$

where

$T_{S,A}$ = transfer function for symmetric and antisymmetric excitation, respectively,

$\Gamma_{S,A}$ = reflection coefficient.

Thus the outputs at the various ports are

$$A_1 = 0$$
$$A_2 = T_S$$
$$A_3 = 0$$
$$A_4 = \Gamma_S.$$

The frequency response of the network is given by

$$L = 10 \log_{10} \frac{1}{|T_S|^2}. \quad (5)$$

Assuming $2\theta = \phi$, the first resonance occurs at $\phi_0 = \pi/2$. In the vicinity of resonance, (4) becomes

$$T_S| = \frac{1}{(\cosh 2\alpha + \sinh 2\alpha)\cos\phi + j1}$$
$$\phi \simeq \pi/2$$
$$\phi = 2\theta \quad (6)$$

For narrow bandwidth filters,

$$(\cosh 2\alpha + \sinh 2\alpha) \simeq 4\cosh^2 \alpha \simeq \frac{4Q_L}{\pi}$$

and

$$\cos\phi \simeq \pi/2 - \phi,$$

then

$$T_S \simeq \frac{1}{\frac{4Q_L}{\pi}(\pi/2 - \phi) + j1} \simeq \frac{1}{2Q_L\left(1 - \frac{2\phi}{\pi}\right) + j1}. \quad (7)$$

Since $\phi_0 = \pi/2$,

$$\left(1 - \frac{2\phi}{\pi}\right) = \frac{\phi_0 - \phi}{\phi_0}$$

and

$$2Q_L\left(\frac{\phi_0 - \phi}{\phi_0}\right) = \omega'.$$

Therefore,

$$L = 10 \log_{10}(1 + \omega'^2). \quad (8)$$

Eq. (8) is equivalent to the insertion loss formula for a single resonator Butterworth filter.

Practical development of traveling-wave directional filters in strip-line form is time consuming due to unavoidable discontinuities which exist in the loop. The effects of dielectric post supports and loop corners are to cause the resonant frequency to shift from the derived value and to produce a double resonance in the frequency response. These effects may be taken into account, at least approximately, by replacing the transmission lines which represent the loop sides in the above analysis by a line having image parameters Z_I and ϕ_I. The image line is derived so as to take discontinuities into account. Fig. 5 shows the procedure for a discontinuity whose equivalent circuit is in the form of a symmetrical Tee (such as a mitered corner). A difficulty in pursuing this method further lies in the fact that expressions for the equivalent circuit parameters of mitered bends are not readily available. (Mitered bends are normally used in practice since they present the minimum discontinutiy.) If right angle bends are considered[3] it is found that

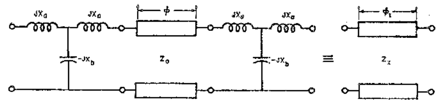

Fig. 5—Loop side equivalent with corner discontinuities.

1) The image impedance characteristics are poor.
2) The terminal planes at which the equivalent circuit is known extends well into the region of the coupled lines. Thus local fields become a problem.

In summary, it has been shown that narrow bandwidth strip-line traveling-wave filters yield a Butterworth response. A method of accounting for loop discontinuities has been suggested. Difficulties in applying the method are outlined. Work in this area is continuing.

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[3] A. A. Oliner and H. M. Altschuler, "Discontinuities in the center conductor of symmetric strip transmission line," IRE Trans. on Microwave Theory and Techniques, vol. MTT-8, pp. 328–339; May, 1960.

Contributors

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