From (6) we can find the optimum θ_0 spacing value minimizing the insertion loss

$$\theta_0 = \tan^{-1} \frac{2R_0(1-\omega_0^2 LC)}{\omega_0[L(2-\omega_0^2 LC)+CR_0^2]}. \tag{7}$$

If (7) is applied, at $f=f_0$ a zero of attenuation occurs. A wide band of operation can therefore be used across f_0, if the elementary low-pass cell characteristics are suitably chosen. In fact, if the tee cell is individually well matched, the same will be true for the overall network. Thus, optimizing the initial tee low-pass filter in order to limit its maximum mismatching loss to 0.20–0.25 dB ($X \leqslant 1.15$), and choosing f_0 about coinciding with the frequency corresponding to maximum of ripple, i.e., to maximum mismatching (this frequency, see (5), is $f_z/\sqrt{3}$), the best performance can be obtained in a multioctave band (see Fig. 4). Fig. 5 shows the return loss of a double θ_0-spaced tee cell configuration, in the case $X=0.9$. From (5), maximum mismatching occurs at $f=10$ GHz. Choosing $f_0=10$ GHz, applying (7) yields $\theta_0=45°$ at 10 GHz. As we can see from the figure, when $\theta_0=45°$ the network is well matched at 10 GHz, and in the range 2–18 GHz, VSWR is less than 1.35:1. When θ_0 is different from 45°, VSWR increases. However, for $30° \leqslant \theta_0 \leqslant 60°$, we note a maximum VSWR of about 1.5:1. Outside this electrical length range we observe a relevant degradation of performance. Isolation typically results 40–50 dB. Higher values can be obtained increasing the number of θ-spaced tee cells.

References

[1] L. Altman, *Microwave Circuits*, New York: Van Nostrand, 1964.
[2] "Reducing the insertion loss of a shunt PIN diode," HP Application Note #957-2.
[3] J. F. White, *Semiconductor Control*, Dedham, MA: Artech House, 1977.

Letters

Correction to "Asymptotic High-Frequency Modes of Homogeneous Waveguide Structures with Impedance Boundaries"

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The treatment of Section V in the above paper[1] was incomplete and, as such, a bit misleading. In fact, the existence question for solutions of equation (53) for $f_2=(\pi_2, m_2)$ did not properly take into account the degeneracy of the basic modes $f_1=(\pi_1, m_1)$. It is known that for a solution to exist, the right-hand side of a deterministic equation like (53) must be orthogonal to all solutions of the homogeneous adjoint problem, which in this case is the basic problem with solutions f_1. Without degeneracy, equation (56) would be that condition. However, since there are at least two linearly independent solutions f_{1i}, there are at least two such conditions, which leads to a contradiction except if f_1 in (53) is chosen in a special way. Let us denote the admissible f_1 in (53) by f_1' and it can be written as a linear combination of any complete set of degenerate basic modes corresponding to the same parameter β_1: $f_1' = \Sigma \alpha_i f_{1i}$. The orthogonality condition reads

$$({}_1f_i^*, Lf_2)-(f_{1i}^*, Bf_2)_b = 2\beta_2(f_{1i}^*, f_1')-2j\beta_1(f_{1i}^*, Mf_1')_b = 0 \tag{1}$$

and it should be satisfied for all $i=1\cdots n(n \geqq 2)$. This is an algebraic equation for the matrix $\boldsymbol{\alpha}=(\alpha_i)$

$$j\beta_1 \boldsymbol{M}\cdot\boldsymbol{\alpha} = \beta_2 \boldsymbol{F}\cdot\boldsymbol{\alpha} \tag{2}$$

where we denote $\boldsymbol{M}=(f_{1i}^*, Mf_{1j})$, $\boldsymbol{F}=(f_{1i}^*, f_{1j})$. The unknown coefficient β_2 is obtained as a solution of the eigenvalue equation

$$\det(j\beta_1 \boldsymbol{M} - \beta_2 \boldsymbol{F}) = 0 \tag{3}$$

and the corresponding admissible right-hand side of a (53) from the eigenvectors $\boldsymbol{\alpha}$ of (2).

The expression (56) giving β_2 in terms of f_1 is not incorrect but ambiguous, because if we would substitute f_1' for f_1 we would obtain the correct β_2. Hence, the general conclusions following (56) in Section V are valid if f_1' is understood everywhere in place of the ambiguous f_1.

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[1] I. V. Lindell, *IEEE Trans. Microwave Theory Tech.*, vol. MTT-29, pp. 1087–1091, Oct. 1981.

References

[1] C. Dragone, "High-Frequency behavior of waveguides with finite surface impedances," *Bell Syst. Tech. J.*, vol. 60, no. 1, Jan. 1981, pp. 89–116.

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