GENERALIZED ANALYSIS OF E-PLANE SEPTA DISCONTINUITIES

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ABSTRACT

A novel technique for analyzing generalized E-plane septa discontinuities is proposed in this paper. A set of numerical results are given. The curves for unilateral septa and summetrical bilateral septa have a good agreement with [3]. They show that the present method is precise and reliable. The curves for asymmetrical bilateral septa have not been revealed ever before in literatures.

INTRODUCTION

The E-plane filters composed of all metal septa or unilateral and bilateral longitudinal septa with full height are prefered for millimeter wave band-pass filters due to their simpler structure and low cost. It is necessary to calculate the equivalent parameters of the discontinuity before designing the filters. The generalized configuration of E-plane septa is shown in Fig.1. A few authors have investigated the discontinuities of some specific configurations. Schwinger [2] treated all metal septa by the traditional variational method. Shih [3] analyzed single unilateral and bilateral longitudinal septa by the modified residue calculas technique (MRCT). These methods are restricted to unilateral or symmetrical bilateral septa with equal length and are difficult to be extended to asymmetrical bilateral septa or multiple parallel-connected longitudinal septa as shown in Fig.1.

In present paper a novel technique combining resonance method with SDT is proposed for generalized of E-plane septa discontinuities including unilateral, symmetrical bilateral as well as asymmetrical bilateral septa. The numerical results given for asymmetrical bilateral septa have not been revealed yet in literatures.

THEORETICAL ANALYSIS

Fig.2 is the equivalent T-network of Fig.1. In case of lossless line, the imaginary equivalent parameters can be obtained by resonance method . At first, suppose two ideal metallic shorting planes are inserted at some distance away from the reference planes of the discontinuity so that the configuration becomes a lossless resonator. It is assumed that only dominant mode can propagate in the region outside the reference plane of the discontinuity. The highermodes excited by the discontinuity are negligible at the shorting planes. The resonator is equivalent to a network as shown in Fig.3. If the discontinuity is longitudinally symmetrical then $Z_{11}=Z_{22}$.

When the discontinuity is excited in odd mode the symmetrical plane becomes an electric wall and the resonance condition is

$$Z_{11}=-Z_o \qquad (1a)$$

Similarly when excited in even mode, the symmetrical plane is a magnetic wall and the resonance condition becomes

$$Z_{11}+2Z_{12}=-Z_e \qquad (1b)$$

where Z_o and Z_e are the odd and even mode impedance respectively at the reference plane towards shorting plane.

$$Z_{o(e)}=j\tan(\beta l_{o(e)}) \qquad (2)$$

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β is the phase constant of dominant mode which can be determined in advance [1].

It is obvious that if $l_{o(e)}$ is known both Z_{11} and Z_{12} can be obtained from equation (1) and (2). Assuming a TE_{10} mode incident wave, the higher modes excited at the discontinuity will be TE_{m0} mode only because E-plane longitudinal septa are invariant in y-direction. The total fields in the closed resonator can be expressed in terms of Hertz vector potential $\bar{\pi}$ only with y-component.

$$\begin{aligned} \bar{E} &= -j\omega\mu\bar{\pi} \\ \bar{H} &= \nabla\times\bar{\pi} \\ \bar{\pi} &= \pi(x,z)\bar{u}_y \end{aligned} \qquad (3)$$

where $\pi(x,z)$ satisfies Helmholtz equation:

$$\frac{\partial^2\pi}{\partial x^2} + \frac{\partial^2\pi}{\partial z^2} + \varepsilon_{ri}k_o^2\pi = 0 \qquad (4)$$

$$\pi\big|_{x=0} = \pi\big|_{x=a} = 0$$

Refering to Fig.4 the Fourier transformation of $\pi(x,z)$ is introduced with respect to z via

$$\tilde{\pi}(x,\beta_n) = \int_{-B}^{B} \pi(x,z)\, e^{j\beta_n z}\, dz \qquad (5)$$

where β_n is discrete spectra in z-direction and

$$\beta_n = \begin{cases} \dfrac{n\pi}{B} & \text{for elec. wall} \\ \dfrac{(n-\frac{1}{2})\pi}{B} & \text{for mag. wall} \end{cases}$$

In the spectral domain eq.(4) becomes

$$\frac{\partial^2\tilde{\pi}_i}{\partial x^2} + \gamma_{in}^2\tilde{\pi}_i = 0 \qquad (6)$$

$$\gamma_{in}^2 = \beta_n^2 - \varepsilon_{ri}k_o^2 \qquad i=1,2,3$$

The solution of eq. (6) is

$$\begin{aligned} \tilde{\pi}_1(x) &= A_n \operatorname{sh}(\gamma_{1n}x) \\ \tilde{\pi}_2(x) &= B_n \operatorname{sh}\gamma_{2n}(x-a_1) + C_n \operatorname{ch}\gamma_{2n}(x-a_1) \\ \tilde{\pi}_3(x) &= D_n \operatorname{sh}\gamma_{1n}(a-x) \end{aligned} \qquad (7)$$

The boundary conditions to be imposed on $\tilde{\pi}_i$ (i=1,2,3) are

$$x=a_1 \begin{cases} \tilde{\pi}_1 - \tilde{\pi}_2 = 0 \\ \dfrac{\partial\tilde{\pi}_1}{\partial x} - \dfrac{\partial\tilde{\pi}_2}{\partial x} = \tilde{J}_{1y} \end{cases} \qquad (8a)$$

$$x=a_1+d \begin{cases} \tilde{\pi}_2 - \tilde{\pi}_3 = 0 \\ \dfrac{\partial\tilde{\pi}_2}{\partial x} - \dfrac{\partial\tilde{\pi}_3}{\partial x} = \begin{cases} 0, & \text{for unilateral} \\ \tilde{J}_{2y}, & \text{for bilateral} \end{cases} \end{cases} \qquad (8b)$$

where $\tilde{J}_{1y}$ and $\tilde{J}_{2y}$ represent the Fourier transformation of surface current on the septa at $x=a_1$ and $x=a_1+d$ respectively.

For unilateral case

$$\tilde{\pi}_1 = \tilde{\pi}_2 = \tilde{G}\tilde{J}_{1y} \qquad \text{at } x=a_1 \qquad (9)$$

where $\tilde{G}$ is the Green function in spectral domain. For bilateral case the potentials on the surface $x=a_1$ and $x=a_1+d$ represented by $\tilde{\pi}_1$ and $\tilde{\pi}_2$ can be expressed as

$$\begin{pmatrix} \tilde{\pi}_1 \\ \tilde{\pi}_2 \end{pmatrix} = \begin{pmatrix} \tilde{G}_{11} & \tilde{G}_{12} \\ \tilde{G}_{21} & \tilde{G}_{22} \end{pmatrix} \begin{pmatrix} \tilde{J}_{1y} \\ \tilde{J}_{2y} \end{pmatrix} \qquad (10)$$

The elements of Green function matrices $[\tilde{G}]$ are functions of γ_{1n} and γ_{2n}. Using Galerkin´s method and choosing an appropriate set of current base functions $J_{1y,m}$ and $J_{2y,m}$, a matrix equation for expansion coefficients will result:

$$[K][C] = 0 \qquad (11)$$

where C_m is the coefficient of base function of surface currents. For unilateral case

$$[K] = [K_{im}]_{M\times M} \qquad (12)$$

$$K_{im} = \sum_{n=-\infty}^{\infty} \tilde{J}_{1y,i}\tilde{G}\tilde{J}_{1y,m}$$

For bilateral case

$$[K] = \begin{pmatrix} [K_{11}] & [K_{12}] \\ [K_{21}] & [K_{22}] \end{pmatrix}_{(M_1+M_2)\times(M_1+M_2)} \qquad (13)$$

Where the element of $[K_{pq}]$, (p,q=1,2) is

$$(K_{p,q})_{im} = \sum_{n=-\infty}^{\infty} \tilde{J}_{py,i}\tilde{G}_{pq}\tilde{J}_{qy,m} \quad (14)$$

The necessary and sufficient condition for solving (11) is

$$\det\,[K] = 0 \quad (15)$$

which is an eigenvalue equation of $l_{o(e)}$. Eq. (15) is a nonlinear function of both ω and $l_{o(e)}$, from which the resonance distance $l_{o(e)}$ can be computed if theoperating frequency ω is given. Then $l_{o(e)}$ is substituted into eq.(1) and (2) to obtain the equivalent parameters of the discontinuity.

NUMERICAL RESULTS

The above technique is used to compute unilateral and equal length bilateral septa at Ka-band. The numerical results are shown in Fig.5 and Fig.6 respectively. It is obvious that Fig.6 has a good agreement with [3]. Fig.7 shows the equivalent parameters of asymmetrical bilateral septa which has not been revealed yet in literatures.

CONCLUSIONS:

The resonance method combining with spectral domain technique is used to analyze a generalized E-plane longitudinal septa discontinuities. The numerical results show that the present method is effective and reliable. It is straightforward to extend the method for more complicated cases such as multiple parallel-connected longitudinal septa in filters or single-layered septa in directional couplers.

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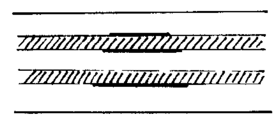

Fig.1 E-plane septa Discontinuity

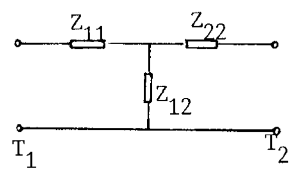

Fig.2 Equivalent Network

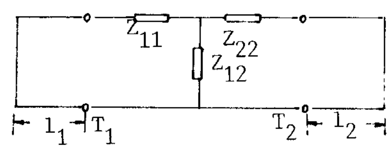

Fig.3 Closed Resonator

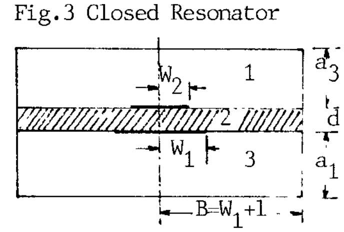

Fig.4 Asymmetrical Bilateral Septa

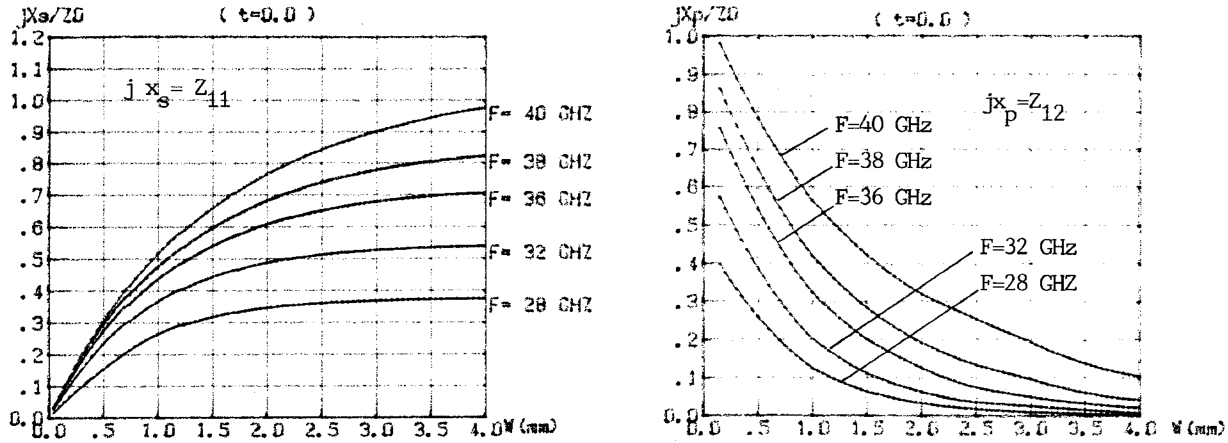

Fig.5 The Equivalent Parameters of Unilateral Septum
a= 7.112mm, $a_1 = \frac{1}{2}a$, d= 0.254mm, $\varepsilon_r = 2.22$

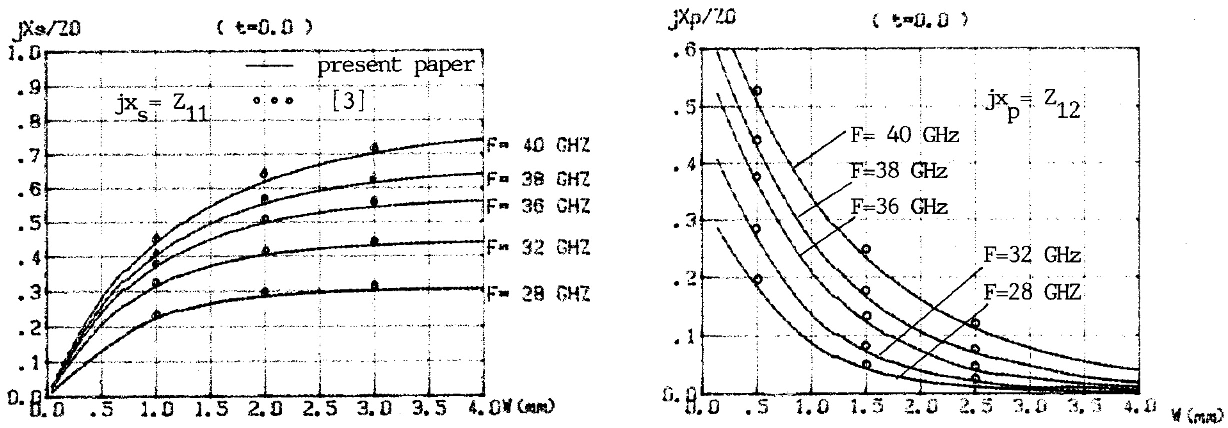

Fig.6 The Equivalent Parameters of Symmetrical Bilateral Septa ($W_1 = W_2 = W$)
a= 7.112mm, $a_1 = \frac{1}{2}(a-d)$, d= 0.254mm, $\varepsilon_r = 2.22$

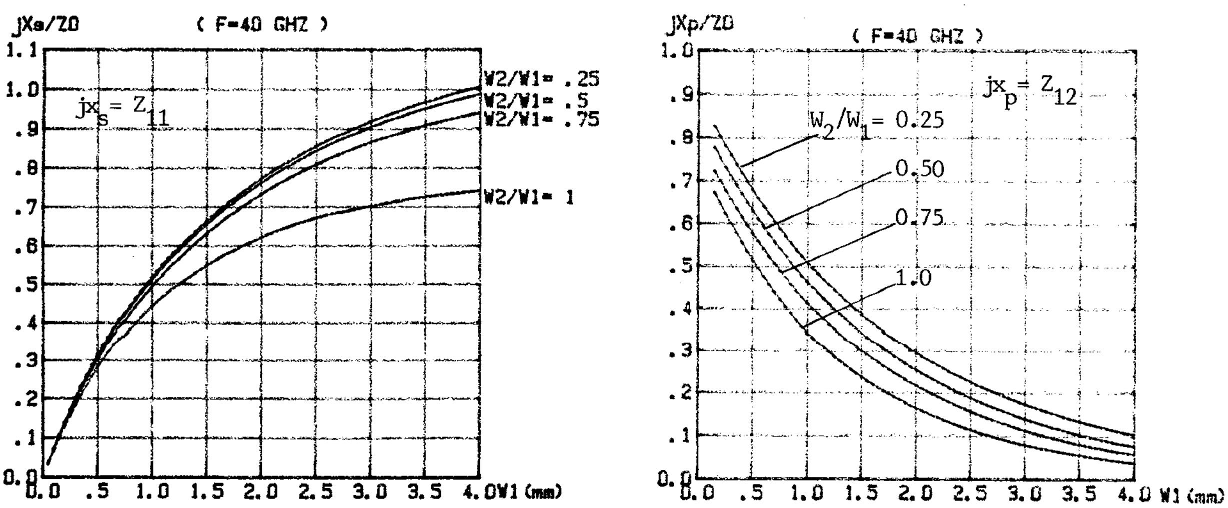

Fig. 7 The Equivalent Parameters of Asymmetrical Bilateral Septa
a= 7.112mm, $a_1 = \frac{1}{2}(a-d)$, d= 0.254mm, $\varepsilon_r = 2.22$