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Slot coupled H-plane tee junction analysis

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Abstract

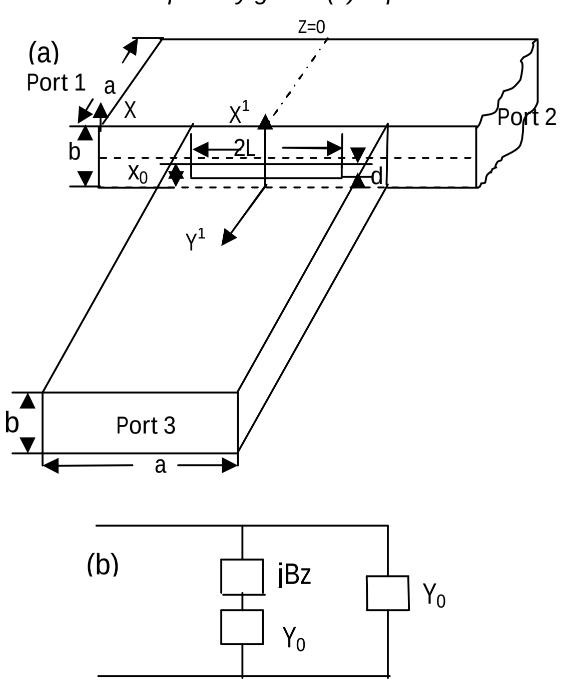
This paper deals with Slot coupled H-plane tee junction analysis through longitudinal slot in the narrow wall of primary guide. In this analysis wave guides is determined from self-reaction and discontinuity in modal current. Variation of coupling and impedance loading as the primary guide are determined from the equivalent parameters. In the present paper, the equivalent circuit parameter for a long axial shunt slot in the common narrow wall is determined from self reaction and discontinuity in modal current. Coupling and input VSWR are determined from the even and odd mode analysis. Variation of coupling, input VSWR, and impedance loading on the primary guide as a function of slot length are determined.

Keywords: Slot coupled H-plane, Tee Junction

Introduction

It is well known that slot radiators in one of the walls of the waveguide, is very popular due to compactness and space saving considerations (Marcuvitz,1951). Reports have been made on such radiators (Prasad & Das1973): however, mostly centered on infinitesimally thin slots. This is with an aim to achieve closed form expressions assuming the width of the slots to be negligible. However, such thin slots cannot withstand in high power applications as there will be electrical breakdown. In view of the above considerations, intensive studies are carried out in the present work to analyze very wide slots and wide slot coupled waveguide junctions. One of the main objectives in the present work is to carry out the analysis for impedance characteristics and coupling without any approximations. This has leaded us to use analytical approach to some extent and then to numerical evaluation. Oliner (1957) has carried out analysis to obtain equivalent impedance parameter as seen from the primary guide. The analysis involves variational approach and stored power in the waveguides is also considered. The results on theoretical and measured data are given for series displaced and inclined slots.

Fig.1. (a) H-plane Tee junction coupled through longitudinal slot in the primary guide. (b) Equivalent circuit



Analysis

Fig.1 shows h-plane tee junction coupled through longitudinal slot in the narrow wall of primary guide of length 2L and width d in the narrow wall between two rectangular waveguides. The slot is located at a distance Xo from the bottom broad wall of waveguides. The electric field distribution $\boldsymbol{E}_s$ in the aperture plane of the thin longitudinal slot can be considered equivalent to a surface magnetic current distribution $\overline{\boldsymbol{J}_z^m}$ and the two are related by

$\bar{J}_z^m = \bar{E}_s * \bar{n}$ (1)

Where $\bar{\boldsymbol{n}}$ is the unit vector normal to the aperture plane. The aperture field Es is assumed to be of the form

$\bar{E}_s = \bar{U}_x \bar{E}_o \sin k(L-|z|)\delta(x'-x_o)\delta(y'-a)$ (2)

Xo, a, 0 are the coordinates of the center of the slot $\boldsymbol{E}_o$ is the maximum electric field in the slot, and k=2 the vector potential due to longitudinal magnetic current density $\overline{\boldsymbol{J}_z^m}$ is given by (Prasad & Das, 1973), $\boldsymbol{\epsilon_n}$ and $\boldsymbol{\epsilon_m}$ are Neumann numbers. For the slot extending from -L to +L, performing the surface integration over the aperture, the expression for vector potential using (1) and (2)reduces to

$A_z = \sum_{n=0}^{\infty}\sum_{m=0}^{\infty}\frac{-\epsilon_n\epsilon_m V_m}{ab\gamma}\cos(\frac{n\pi x}{b})\cos(\frac{m\pi y}{a})$ .cosmπcos $(\frac{n\pi x_o}{b})\left\{\frac{\sin\frac{n\pi d}{2b}}{\frac{n\pi d}{ab}}\right\} . \frac{k}{k^2+\gamma^2}\left[e^{-\gamma|z|}coskL - e^{-\gamma L}cosh\gamma z - \frac{-\gamma}{k}sink(L-|z|)\right]$ Where

$$\gamma = \sqrt{\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2 - k^2} \quad (3)$$

The magnetic field $\boldsymbol{H_z}$ is obtained from the vector potential using Maxwell's equation as

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Fig.2. Variation of slot length Vs reactance and coupling. Slot width =1mm displacement = 2mmat λ=3.2cm

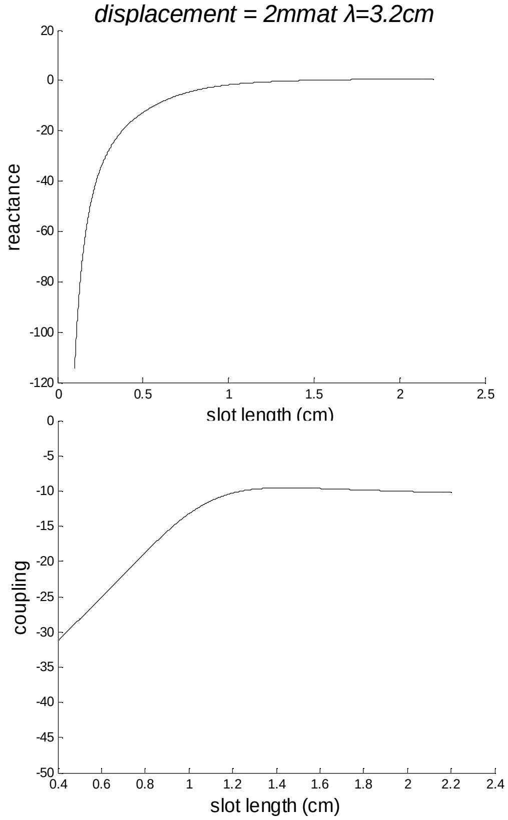


Fig.3.Variation of slot length Vs reactance and coupling. Slot width =1mm, displacement =4mm at λ=3.2cm

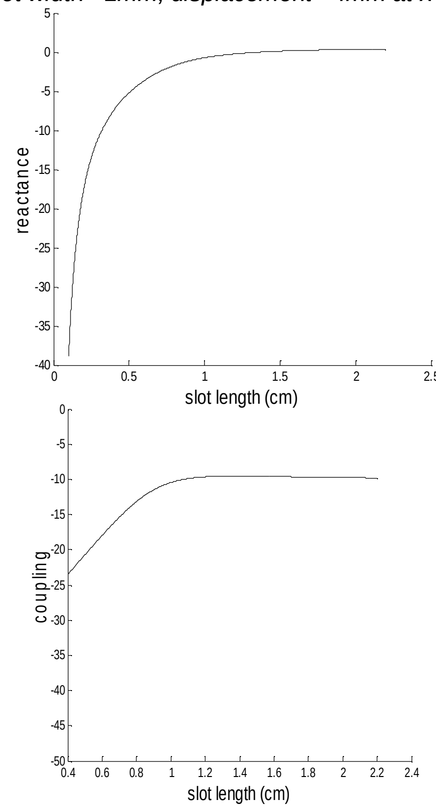


Fig.4. Variation of slot length Vs reactance and coupling. Slot width=2mm and displacement =1mm, at λ = 3.2cm

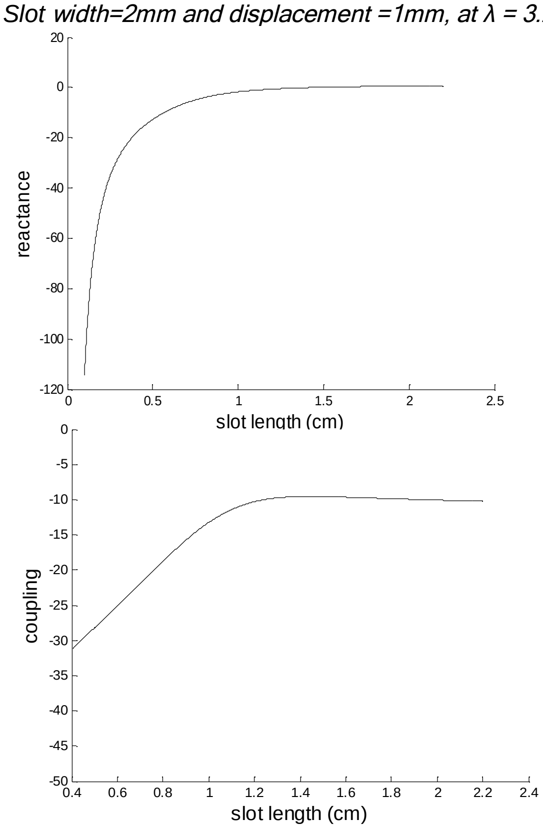
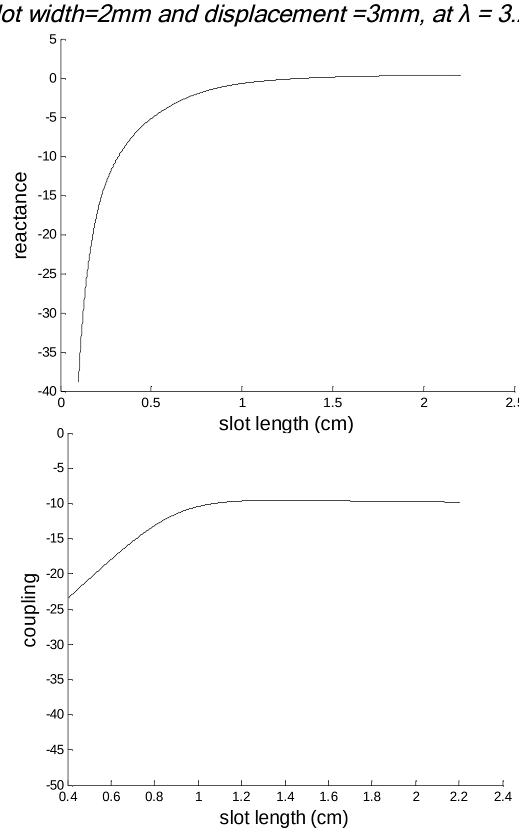


Fig.5. Variation of slot length Vs reactance and coupling. Slot width=2mm and displacement =3mm, at λ = 3.2cm



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$H_z = \frac{1}{j\omega\mu}\left[k^2 + \frac{\partial^2}{\partial z^2}\right] A_z$ (4)

The self reaction <a,a> of magnetic current $\overline{\boldsymbol{J_z^m}}$ is given by $< a, a > = -\int_v \bar{H}_z . \bar{J}_z^M \mathrm{dv}.$ (5)

A part of coupled volume v is in primary guide and the other part is the secondary (coupled) guide. In the general case of two dissimilar guides, the total self reaction is equal to the sum of self reactions <a,a> and <a,a> in the two volumes. In the particular case of two identical guides, the total self reaction is equal to twice that of a single guide. Using (1),(2),(3),-(5) and evaluating the integrals, the total self reaction of the equivalent magnetic currents of a longitudinal slot in the common narrow wall of two identical waveguides reduces to

$$< a, a > = \sum_{n=0}^{\infty}\sum_{m=0}^{\infty} \frac{4j\epsilon_n\epsilon_m V_m^2 k^2 cos^2 m\pi}{\omega\mu a b\gamma(k^2+\gamma^2)} . cos^2\left(\frac{n\pi x_o}{b}\right)\left\{\frac{sin^2\frac{n\pi x_o}{2b}}{\left(\frac{n\pi d}{2b}\right)}\right\} \left[0.5(1+e^{-2\gamma L}) - coskL\left(2e^{-\gamma L}coskL + \frac{\gamma}{k}sinkL\right)\right] \quad (6)$$

A longitudinal slot in the waveguide wall produces a discontinuity in the modal current, giving rise to shunt type of equivalent network parameter $B_z = \frac{1}{X_z}$ where X_z is given by (Pandharipande & Das,1979a,b)

$$x_z = \frac{<a,a>}{I^2} \quad (7)$$

The discontinuity in the modal current I for the dominant mode is obtained from the expression (Marcuvitz & Schwinger,1951)

$$\mathrm{I} = jY_{01}\int_{slot} \bar{n} * \bar{E}_s(\bar{h}\sin\beta_{01} z + j\bar{h}_z\cos\beta_{01} z)ds \quad (8)$$

Where

$$\bar{h} = \bar{u}_y \frac{\pi}{a} sin\frac{\pi y}{a}, \bar{h}_z = \bar{u}_z \frac{\left(\frac{\pi}{a}\right)}{j\beta_{01}}\cos\frac{\pi y}{a}, \ \beta_{01} = \sqrt{k^2 - \left(\frac{\pi}{a}\right)^2}$$

$$< a, a > 2 = \sum_{n=0}^{\infty}\sum_{m=0}^{\infty} \frac{4jk^2\epsilon_n V_m^2}{\omega\mu a b\gamma} sin^2\left(\frac{m\pi}{2}\right) cos^2\left(\frac{n\pi x_o}{b}\right) \left\{\frac{sin\frac{n\pi d}{2b}}{\frac{n\pi d}{2b}}\right\}^2 . \left\{\frac{\left(cos\frac{m\pi L}{a} - coskL\right)}{k^2 - \left(\frac{m\pi}{d}\right)^2}\right\} \quad (9)$$

Hence the equivalent network parameter will be

$$X_{zT} = \frac{<a,a>1 + <a,a>2}{I^2} \quad (10)$$

From (6),(8),(9) and (10) the expression for normalized reactance for a slot coupled tee junction reduces to

$$X_{zT} = \sum_{n=0}^{\infty}\sum_{m=0}^{\infty} \frac{\beta_{01}}{2ab\gamma}\left[\frac{cos^2\frac{n\pi x_0}{b}}{cos^2\frac{\pi x_0}{b}}\right]\left[\frac{sin\frac{n\pi d}{2b}}{\frac{n\pi d}{2b}}\right]^2 \left[\frac{\epsilon_n\epsilon_m}{k^2+\gamma^2} . \left\{0.5(1 + e^{-2\gamma L}) - coskL\left(2e^{-\gamma L} - coskL + \frac{\gamma}{k}sinkL\right)\right\} - 2\epsilon_n sin^2\frac{m\pi}{2}\frac{\left(cos\frac{m\pi L}{a} - coskL\right)^2}{\left(\frac{m\pi}{a}\right)^2}\right] / (cos\beta_{01}L - coskl)^2 \quad (11)$$

Evaluating the integral appearing in (8) over the slot aperture and using (6) and (7), the expression for the normalized reactance is obtained. The h-plane tee junction coupled through longitudinal slot in the narrow wall of primary guide and in the transverse cross section the secondary guide as shown in Fig 1(a).the corresponding lumped parameter equivalent network looking from port 1 of primary guide is shown in Fig.1 (b),Coupling coefficients is given by (Pandharipande & Das,1979a):

$$X_{11} = X_{14} = \frac{JB_z}{2+3JB_z} \qquad \text{Coupling } C_{dB} = 20\log\frac{\bar{B}_z}{\sqrt{4+9(\bar{B}_z)^2}}$$

Where $C_{dB} = 20\log\frac{\bar{B}_z}{\sqrt{4+9(\bar{B}_z)^2}}$ $\qquad \bar{B}_z = \frac{1}{X_z}$

Input VSWR = $\frac{1+|\bar{X}_{11}|}{1-|\bar{X}_{11}|}$

The equivalent network parameter is again given by the expression of the form (7).self reaction <a,a> in this case is determined separately for the two guides. The self reaction <a,a>1 in guide I is 1\2 <a,a>, where <a,a> is given by (6).the self reaction $<a,a>_2$ in secondary guide (guide II),obtained from the modal expansion of the magnetic field in this guide, is given by (Pandharipande & Das,1979b)

Results and conclusion

This paper deals with the analysis through longitudinal slot in the narrow wall of the slot coupled H-plane tee junction. The results are presented in Fig.2-5. The results of variation of normalized reactance and coupling with slot length for H- plane Tee junction are computed for λ =3.2cm, a=2.286cm, b=1.016cm, and reactance varies from-110 to 1 and coupling varies from -35 to -10, slot width d=1, 2mm for displacements of slot (1mm , 3mm and 4mm from center). It is observed from the results that as slot width d is increased the values of reactance are found to be enhanced. Similarly the value of coupling is also enhanced for a fixed value of wavelength.

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