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Admittance Analysis of Longitudinal Slot Coupled Shunt Tee Junction for Non-Standard Rectangular Waveguide

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Abstract: **The slots that couple power from primary guide to the radiating guide can be resonant and non-resonant. The resonant slots exhibits the peak of the conductance curve slightly away from resonance and the susceptance curve will have a cross over exactly at resonance. Such slots are characterized by small reactance and they are used for narrow bandwidth applications. The applications where considerable bandwidth is required, it is possible to use non-resonant slots. In this present paper, such longitudinal slots are considered to couple power from feed guide to the coupled guide. The analysis presented is valid for both longitudinal and inclined slots coupled junctions . However, the data on the variation of admittance, coupling and VSWR are computed for slots of non-resonant length and other slot parameters The additional feature of this work contains the use of non-standard waveguides as they provide additional parameters for the design of the junctions as well as array of such junctions.**

Keywords : **Key Words: Waveguides, Shunt Tees, Admittance Loading, H-Plane Tee, Slot coupled Tee Junctions**

I Introduction

The analysis of H-plane Tee junction containing standard rectangular waveguides is extensively reported [1-3]. In these junctions, coupling takes place through a rectangular slot from primary to secondary guide. Moreover, such structures cannot accommodate the slots of required dimensions due to the fixed dimension of waveguides. In order to have flexibility in the design, non-standard waveguides are proposed for the fabrication of H-plane Tee junctions.

The variational expressions are used to obtain slot admittance parameters by some researchers. The susceptances are obtained from stored energy considerations. It may be noted that a slot couples the energy to the Tee arm and the Tee arm in turn radiates into free space. The slot of present interest has rectangular ends. The data on susceptance parameter is used to obtain S- parameters and hence coupling and VSWR. The variations of admittance, coupling and VSWR are obtained as a function of frequency as well as slot and waveguide dimensions . The data presented in this work is unique and is extremely useful for the design of array of H-plane Tee junction radiators. The variational approach is found to be highly involved and it is difficult to bring out equivalent circuit parameter accurately. The equivalent network parameter as reported in the literature [94] is found to have a shunt element which consists of a constant real part and a variable imaginary part. This cannot be true as the conductance and the susceptance of the admittance parameter vary in coupling and VSWR. The analysis of the junction is carried out using hybrid modes as well as TE and TM concepts. The concept of self reaction proposed by Rumsey [4] and Harrington [5] is used to derive admittance parameter. The evaluation of equivalent shunt parameter takes care of energy storage in the feed guide. The self reactions involved in both the guides are evaluated along with discontinuity in modal current.

Self reaction in the primary guide is obtained from vector potential. This potential is obtained from the solution of Helmholtz equation. The hybrid mode concept is used to obtain the self reaction in the primary guide and TE and TM mode concept is used to obtain self reaction in the coupled guide.

II Analysis

Consider H-plane Tee junction of fig. 1 for the analysis.

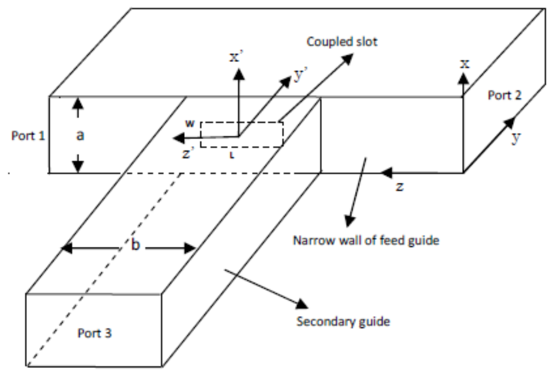

Fig. 1 *H-plane Tee junction using longitudinal slot*

Here, the feed waveguide and coupled guide have non-standard dimensions to have more flexibility in the design of the junction and also in the design of the junction radiators. The prime objective of the present work is to use the junction as the radiator of vertically polarized fields. Assume the electric field as sinusoidal and it is replaced by its equivalent magnetic current for the junction analysis. The admittance loading is evaluated using the concept of the magnetic current and the modal voltages of TE and TM modes are given by [5].

$$V^{e}_{mn} = \int_{-W/2}^{W/2}\int_{-L/2}^{L/2} \mathbf{E}_{slot}\cdot\mathbf{e}^{e}_{mn}\, dx'\, dz'$$

$$V^{m}_{mn} = \int_{-W/2}^{W/2}\int_{-L/2}^{L/2} \mathbf{E}_{slot}\cdot\mathbf{e}^{m}_{mn}\, dx'\, dz'$$

The dominant mode modal voltage in the coupled guide is given by

$$V^{e}_{10} = \oint_{slot} \mathbf{E}_{slot}\cdot\mathbf{e}^{e}_{10}\, da = \sqrt{\frac{2}{ab}}\;\frac{4W\frac{\pi}{L}\cos\frac{\pi L}{2b}}{\left(\frac{\pi}{L}\right)^2-\left(\frac{\pi}{b}\right)^2}E_s$$

Here, $\mathbf{E}_{slot}$ is the electric field along the slot, E_s is the maximum value of $\mathbf{E}_{slot}$ and $\mathbf{e}_{10}$ is the dominant mode vector function.

It is well known that the reaction on both sides of the slot interface is considered.

The electric field in the slot is given by

$$E_{slot} = \begin{cases} E_s\cos\frac{\pi z'}{L} & -\frac{L}{2}<z'<\frac{L}{2} \\ & -\frac{W}{2}<x'<\frac{W}{2} \\ 0 & \text{elsewhere} \end{cases}$$

The reaction concept in electromagnetic theory was introduced to find a fundamental observable representing measurement which can be performed practically. This concept simplifies the formulation of boundary value problems in electromagnetic theory. It has some important advantages when compared to variational technique. This concept is general and universal. Whereas, the variational technique is not universal and it is specific. Reaction technique is conceptually simple and leads directly to results which might not be possible by the variational approach because of complexity involved in mathematical formulation. Many of the parameters of interest in electromagnetic are proportional to reactions. For example, the impedance parameters of multiport network are proportional to reactions. Reaction is an useful quantity primarily because of its conservative property.

The reaction of the fields on their own sources is known as self reaction. The expression for self-reaction of fields ($\mathbf{E}_a$,$\mathbf{H}_a$) on their own sources ($\mathbf{J}_a$,$\mathbf{M}_a$) is given by

$$\langle a,a\rangle = \int_v (\mathbf{E}_a\cdot\mathbf{J}_a - \mathbf{H}_a\cdot\mathbf{M}_a)\, dv$$

The electromagnetic fields propagate freely in free space. However, when they are confined to continuous metallic waveguide structure, the propagation takes place with multiple reflections from the walls of the waveguide. If the walls of the waveguide are perfectly conducting, the fields cannot penetrate into walls, as neither **E** nor **H** exists inside a perfect conductor. On the other hand, the propagation characteristics of electromagnetic fields are completely modified in the presence of discontinuities. The properties of discontinuities are easily represented by equivalent networks.

The overall behavior of the fields in waveguides depends on the type of discontinuity as well as on the field propagation in the waveguides. In the equivalent networks, voltages and currents are introduced to represent the amplitudes of the fields at the terminals of the discontinuity and at all locations in waveguides. Such voltages and currents characterize the power flow into and out of discontinuity but not the fields in the immediate vicinity.For convenience, a field representation is made use of to obtain the relation between the terminal voltages and currents in the metallic structures containing discontinuities.

A longitudinal or an inclined slot in the narrow or broad wall of a rectangular waveguide produces a discontinuity in modal current. Marcuvitz and Schwinger [6] established the basic formula for the discontinuity in modal current and it is given by

$$I = jY_{01}\iint_{slot} \mathbf{a}_y \times \mathbf{E}_S \cdot \left(\mathbf{h}_{01}\sin\beta_{01}z + j\mathbf{h}_{z01}\cos\beta_{01}z\right)ds$$

Where, Y_{01} and b_{01} are the characteristic wave admittance and propagation constant, $\mathbf{h}_{01}$ and $\mathbf{h}_{z01}$ are the transverse and longitudinal modal vector functions of the magnetic field for dominant mode in feed guide

The junction provides vertically polarized fields irrespective of the slot orientation. The admittance loading is evaluated in the present work is obtained from the concept of self reaction and discontinuity in modal current.

The total self reaction is given by

$$\langle \mathbf{a}, \mathbf{a} \rangle_t = \langle \mathbf{a}, \mathbf{a} \rangle_l + \langle \mathbf{a}, \mathbf{a} \rangle_v + \langle \mathbf{a}, \mathbf{a} \rangle_c$$

Here, $\langle \mathbf{a}, \mathbf{a} \rangle_l$ **and** $\langle \mathbf{a}, \mathbf{a} \rangle_v$ correspond to self reaction of the longitudinal and vertical magnetic fields in feed guide respectively and $\langle \mathbf{a}, \mathbf{a} \rangle_c$ correspond to the coupled guide. The contribution of admittance loading due to energy storage in the primary guide is

$$y_p = \frac{-II}{\langle a,a \rangle_l} - \frac{-II}{\langle a,a \rangle_v}$$

The contribution of admittance loading due to the coupled guide is given by

$$y_c = \frac{-II}{\langle a,a \rangle_c}$$

Total admittance loading is hence given by

$$y = y_p + y_c$$

The normalized admittance loading is obtained from

$$y_n = \frac{y}{y_{01}} = g_n + b_n$$

Here, $\mathbf{y}_{01}$ is the characteristic admittance due to the dominant mode, $\mathbf{g}_n$ is the normalized conductance and $\mathbf{b}_n$ is the normalized susceptance.

III RESULTS

From the analysis presented in the preceding sections, variation of normalized conductance and normalized susceptance with frequency for different narrow wall dimensions are computed and presented in figs.(2-3) and the variation of above parameters for different broad wall dimensions are presented in figs. (4-5).

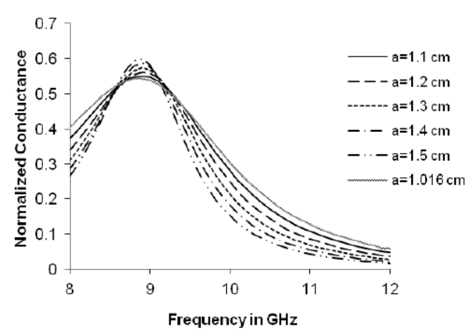

Fig. 2 Normalized Conductance vs Frequency for different waveguides with varying narrow wall dimension

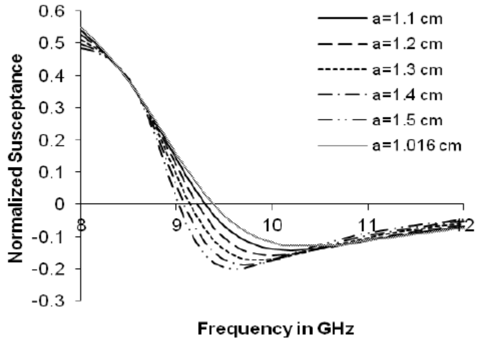

Fig. 3 Normalized Susceptance vs Frequency for different waveguides with varying narrow wall dimension

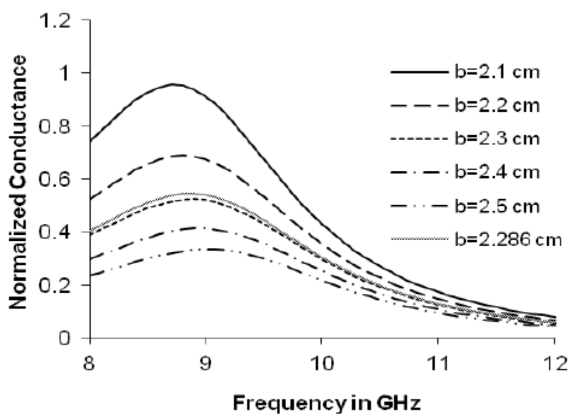

Fig. 4 Normalized Conductance vs Frequency for different waveguides with varying Broad wall dimension

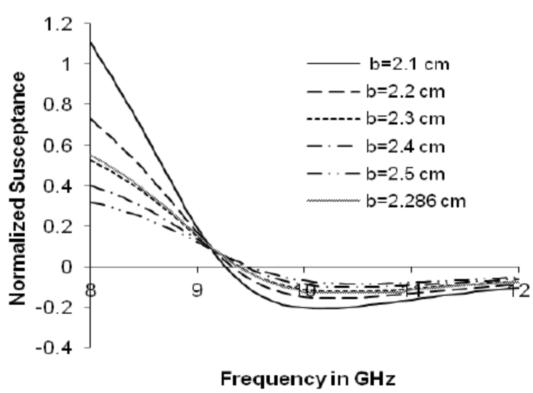

Fig. 5 Normalized Susceptance vs Frequency for different waveguides with varying Broad wall dimension

The variation of normalized conductance, normalized susceptance, with frequency for different narrow wall (1.1 to 1.5 cm) and broad wall (2.1 to 2.5 cm) dimensions in the H-plane Tee junction and also for different slot inclinations are computed. The variations of the above parameters with slot length are computed for a fixed frequency of 9.375 GHz for different narrow wall and broad wall dimensions It is evident from the results that as the narrow wall dimension increases the resonant frequency decreases. As the broad wall dimension increases the resonant frequency slightly increases.

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