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Studies on Effect of Waveguide Dimensions on Resonant Frequency of Shunt Tee Junction

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Abstract: *H-Plane Tee junctions are commonly used for power division and as a radiator with vertical polarization. The coupled arm is fed with a rectangular slot either longitudinal or inclined. The slot between the feed waveguide and coupled guide , couples power. Shunt Tee is used as array element. Array antennas are popular in different radar and communications applications. They are preferred for both scan and non-scan applications. Such a junction is found to resonate and susceptance changes from positive to negative at resonant frequency. However, conductance peak occurs at a frequency slightly less than the resonant frequency. It is evident from literature that the resonant frequency is controlled by slot parameters. In order to provide additional parameters to control resonant frequency, some investigations are carried to find the variation of admittance characteristics with frequency. From these variations, the resonant frequency is identified from the cross over point of susceptance.*

It is found from the results that change in resonant frequency is considerable with both the dimensions of wave guides. For higher narrow wall dimensions, when the broad wall dimension is fixed, the resonant frequency is found to reduce and vice versa with the increase in broad dimensions for fixed narrow dimension. The results of the present work provide useful data for array designer.

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

I. Introduction

Basically the H-Plane Tee is a three port device. The main guide containing two ports is in shunt with the coupled arm , that is why it is known as Shunt Tee [1] . Shunt Tees are common for power division applications, whereas in the present work these are used as radiators with vertical polarization. For this purpose, the power is fed at the input port of main guide with the corresponding output port matched terminated. The power is radiated through the coupled arm.

The Tee arm is coupled to the main guide usually by a longitudinal slot. However, the coupling can be made by inclined slot [2] in the narrow wall of main guide. This structure is also useful to produce vertically polarized waves. This coupling system provides additional design parameter that is waveguide dimensions, for the array designer. Longitudinal slot coupled Shunt Tees are analyzed by few researchers [3], but inclined slot coupled wave guide Shunt Tees are not reported in open literature.

Arrays of slots cut in one of the walls of the rectangular waveguides are extensively used due to their compactness. In conventional open ended slot arrays, there exists mutual coupling between the slots [4] causing distortion in radiation patterns. Slot coupled Shunt Tees are more suitable for arrays applications as it is possible to suppress cross polarized components there by reducing mutual coupling between slots.

II. Analysis for admittance characteristics

The mechanism of inclined slots is interpreted in terms of two modes each radiating linear polarization. It is well known that a vertical slot in narrow wall of rectangular waveguide does not radiate. The electric field in such a slot is horizontally directed. But in applications where vertically polarized fields are required from inclined slots, it is possible to obtain them by coupling the slot into shunt Tee arm forming a Shunt Tee.

In the present paper, the admittance characteristics of inclined slot in narrow wall of Shunt Tee is determined from self reaction and discontinuity in modal current [5]. The analysis consists of two parts: 1st part consists of evaluation of self reaction for the feed guide. This in turn consists of evaluation of self reaction of horizontal and vertical components of the magnetic current. The second part consists of evaluation of self reaction for the Tee arm.

In the present work, the analysis is carried out to obtain variation of slot conductance [6] and susceptance as a function of resonant slot length. The result is numerically obtained for varied slot widths.

Consider a waveguide shunt Tee coupled through an inclined slot of length 2L and width 2w, on the narrow wall as shown in Fig.1.

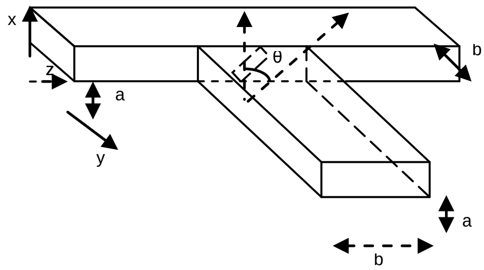

Fig.1 Inclined slot coupled waveguide shunt Tee

The slot radiator is analysed for its admittance characteristics using self-reaction and discontinuity in modal current. The admittance characteristics in the coupled waveguide radiator are evaluated using TE and TM mode field concepts. In the present work the equivalent network parameter is obtained [7]. It is assumed that slot is incline an angle θ from the vertical axis and coupling takes place through inclined slot in narrow wall of the primary feed waveguide.

Total self-reaction <a,a> due to equivalent magnetic current in the coupling slot is the summation of self-reaction $\langle a,a\rangle_1$ due to longitudinal component of the magnetic current, self-reaction $\langle a,a\rangle_2$ due to transverse component of the magnetic current in the primary waveguide and self-reaction $\langle a,a\rangle_3$ due to magnetic current in the coupled guide.

The shunt impedance loading on the primary guide due to the slot coupled shunt Tee can be expressed as

$$Z = -\frac{\langle a,a\rangle}{I\,I} = -\frac{\langle a,a\rangle_1}{I\,I} - \frac{\langle a,a\rangle_2}{I\,I} - \frac{\langle a,a\rangle_3}{I\,I} \qquad (1)$$

The expression for self-reaction $\langle a,a\rangle_1$ is given by

$$\langle \mathrm{a,a}\rangle_1 = \frac{j4K^2V_o^{\,2}\sin^4\theta}{\mu\omega \mathrm{ab}} \sum_{m}^{\infty}\sum_{n}^{\infty} \frac{\in_m \in_n}{\gamma_{mn}\left(k^2+\gamma_{mn}^2\right)} \cos^2 m\pi \,.\, \cos^2\frac{n\pi}{2}\left[\frac{\sin(nF)}{(nF)}\right]^2$$
$$\left[0.5\left(1+e^{-2\gamma_{mn}L\sin\theta}\right) - \cos(KL\sin\theta).\left\{2e^{-\gamma_{mn}L\sin\theta} - Cos(KLSin\theta) + \frac{\gamma_{mn}}{K}Sin(KL\sin\theta)\right\}\right] \qquad (2)$$
$$Where\, F = \frac{\pi W\sin\theta}{\mathrm{a}}$$

The expression for self-reaction $\langle a,a\rangle_2$ is given by

$$\langle \mathrm{a,a}\rangle_2 = \frac{j2K^2V_o^{\,2}\cos^2\theta}{\mu\omega \mathrm{abW}} \sum_{m=0}^{\infty}\sum_{n=1}^{\infty} \frac{\in_m}{\gamma^2_{mn}} \cos^2 m\pi \,.\, sin^2\left(\frac{n\pi}{2}\right)\left[\frac{1}{K^2-\left(\frac{n\pi}{a}\right)^2}\right]$$
$$\left[\cos\left(\frac{n\pi L\cos\theta}{a}\right) - \cos(KLCos\theta)\right]^2 .\left[2\cos\theta + \frac{e^{-2\gamma_{mn}W\cos\theta}}{\gamma_{mn}W} - \frac{1}{\gamma_{mn}W}\right] \qquad (3)$$

The expression for self-reaction $\langle a,a\rangle_3$ is given by

$$\langle a,a\rangle_3 = 2\sum_{m=0}^{\infty}\sum_{n=1}^{\infty}(Y_o)^e_{mn}(V^e_{mn})^2 + 2\sum_{m=0}^{\infty}\sum_{n=1}^{\infty}(Y_o)^e_{mn}(V^m_{mn})^2$$
$$where\;\; (Y_o)^e_{mn} = \frac{(\gamma_{mn})}{j\omega\mu};\, (Y_o)^m_{mn} = \frac{(j\omega\varepsilon)}{\gamma_{mn}};$$
$$\gamma_{mn} = \sqrt{\left[\left(\frac{m\pi}{b}\right)^2 + \left(\frac{n\pi}{a}\right)^2 - K^2\right]}$$

2w

The expression for discontinuity in modal current I, due to an inclined slot in the narrow wall of the excited guide (guide1) is given by

$$I = -2jY_{01}V_0\sin\theta.\frac{\sin(W\beta_{01}\cos\theta)}{W\beta_{01}\cos\theta}.\left(\frac{2}{ab}\right)^{\frac{1}{2}}\frac{\pi}{b\beta_{01}}.\frac{K}{(\beta_{01}\sin\theta)^2-K^2}\left[\cos(\beta_{01}L\sin\theta)-\cos KL\right]$$

III. Results & Discussions

The normalized conductance and susceptance values for the slots in non-standard waveguides are found to be smaller than those of standard waveguides.

Using the above expressions, computations are carried out to obtain the variations of normalized conductance and susceptance as a function of frequency for the slots in non- standard x-band waveguides.

In the present work, non-standard wave guides are considered, as the slots of resonant length at small inclinations cannot be accommodated entirely in the narrow wall of a standard waveguide. When the slot is inclined at small angle 10^0 it is essential to broaden the narrow wall if the slot is not permitted to protrude into the broad wall. For the above small inclinations, the data on the above parameters are also obtained and are presented in figs.(2-5).

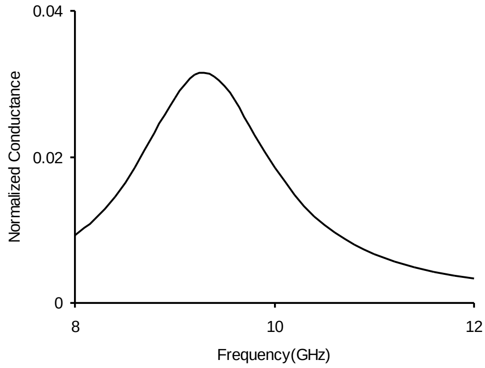

Fig.2 Variation of normalized Conductance with frequency
[Slot width=0.1cm, narrow wall =1.5cm, broad wall=2.286cm, Theta=10^o]

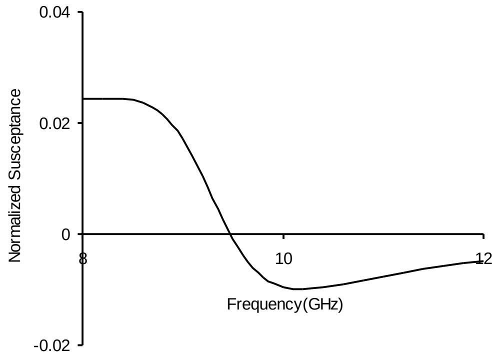

Fig.3 Variation of normalized Susceptance with frequency
[Slot width=0.1cm, narrow wall =1.5cm, broad wall=2.286cm, Theta=10^o]

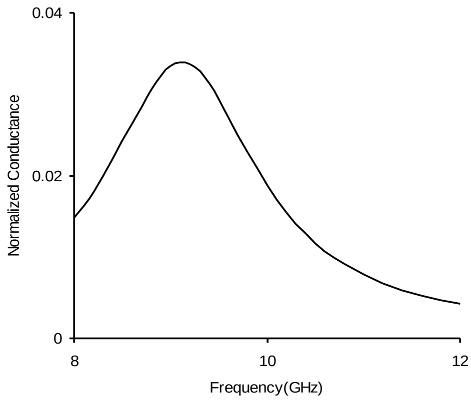

Fig.4 Variation of normalized Conductance with frequency
[Slot width=0.2 cm, narrow wall =1.5cm, broad wall=2.286cm, Theta=10^o]

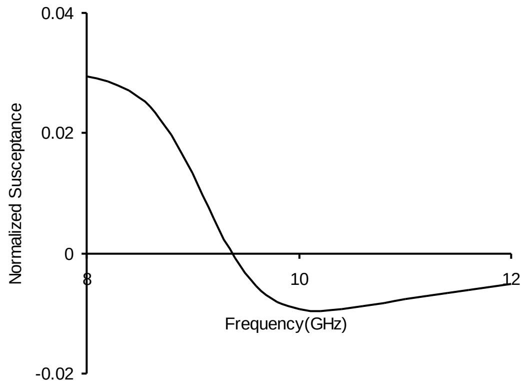

Fig.3 Variation of normalized Susceptance with frequency
[Slot width=0.1cm, narrow wall =1.5cm, broad wall=2.286cm, Theta=10^o]

IV. Conclusions

It is evident from the data, the maximum conductance at resonant frequency for the slot in the non-standard waveguide is less than that of the standard waveguide. Another interesting feature is, the resonant frequency is constant in both the cases. Moreover, the slot is found to resonate at slightly higher frequency. For low inclined slots in the non-standard waveguides, i.e. for Theta $\theta=10^0$, Slot width (2W) =0.1cm Narrow wall dimension =1.5cm, and Broad wall dimension =2.286cm , the normalized conductance and susceptance values are found to be reduced. When the width of the slot is 0.2cm, the rest of the parameters having the same values, there is a small decrease in the values of conductance and susceptance. However, the resonant frequency is increased marginally.

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