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Influence of Slot width of Inclined Slot Coupled Waveguide Shunt Tee on Resonant Frequency

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Abstract

The paper presents an analysis of waveguide Tee junction made by rectangular waveguides coupled through an inclined slot in the narrow wall. Such waveguide Tee junctions are used for power division applications. As per the open literature available, analysis of Waveguide Tee junction coupled through a longitudinal slot is carried out by several authors. However, no data is available for waveguide Tee junction coupled through an inclined slot. Such a junction is useful to reduce EMI problems due to cross polarized components in the radiated fields from coupled arm. In such a junction, the designer will an additional parameters namely inclination of slot to control admittance characteristics. This data is required for the design of an array for a specified radiation beam. In this work, analysis is presented to obtain variation of normalized conductance and normalized susceptance as a function of frequency for the resonant length. The analysis is made in terms of self-reaction and discontinuity in modal currents in the main guide as well as Tee arm. This structure is also useful to produce vertically polarized waves. Its design requires the knowledge of admittance characteristics of the shunt Tee. The results are numerically obtained for varied slot widths. It is observed from the results that Slot width has a lot of influence on the admittance parameter and resonant frequency

Key Words: Inclined slot, Waveguide, shunt Tee , Resonant Frequency

I. Introduction

Shunt Tee or H-plane Tee Junction is a three port device. In power division applications when the power is fed to the coupled arm, it gets divided equally in two parts of the main guide. The main guide containing two ports is in shunt with the coupled arm , that is why it is known as Shunt Tee [1] . In the present work these are used as radiators with vertical polarization. For this purpose, the power is fed at one of the ports of main guide with the corresponding other port terminated in matched termination. The power is radiated through the port of 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 new coupling system provides additional design parameter for the array designer. Longitudinal slot coupled Shunt Tees are analyzed by few researchers [3], but data on inclined slot coupled wave guide Shunt Tees are not reported in open literature.

Array antennas are popular in different radar and communications applications. They are preferred for both scan and non-scan applications. 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. Shunt Tee is used as array element. 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. 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. No work has been reported on such inclined coupled waveguide Shunt Tee. Although the analysis is highly involved, it has been possible to obtain admittance data as a function of slot parameters and frequency.

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

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II. Analysis for admittance characteristics

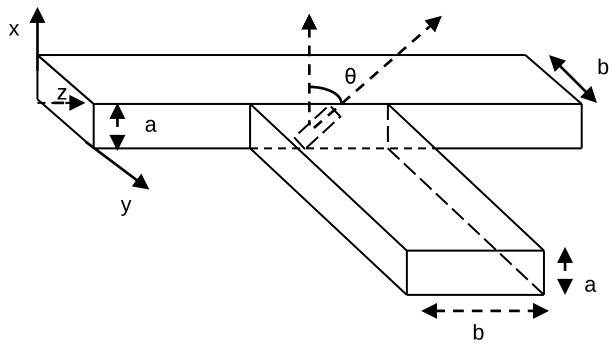

Fig.1 Inclined slot coupled waveguide shunt Tee

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. 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 inclined at 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 <s,s> due to equivalent magnetic current in the coupling slot is the summation of self-reaction $<s,s>_1$ due to longitudinal component of the magnetic current, self-reaction $<s,s>_2$ due to transverse component of the magnetic current in the primary waveguide and self-reaction $<s,s>_3$ 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

$$Z = -\frac{\langle s,s\rangle}{I\ I}$$

$$= -\left[\left(\frac{\langle s,s\rangle_1}{I\ I} + \frac{\langle s,s\rangle_2}{I I} + \frac{\langle s,s\rangle_3}{I I}\right]$$

The expression for self-reaction <a,a>$_1$ is given by

$$\langle s,s\rangle_1 = \frac{j4K^2V_o^2\sin^4\theta}{\mu\omega ab}\sum_m^\infty\sum_n^\infty \frac{\in_m\in_n}{\gamma_{mn}(k^2+\gamma_{mn}^2)}\cos^2 m\pi.\cos^2\frac{n\pi}{2}\left[\frac{\sin(nF)}{(nF)}\right]^2$$

$$\left[0.5\left(1+e^{-2\gamma_{mn}L\sin\theta}\right) - \cos(KL\sin\theta).\left\{2e^{-\gamma_{mn}L\sin\theta} - Cos(KLSin\theta) + \frac{\gamma_{mn}}{K}Sin(KL\sin\theta)\right\}\right]$$

$$Where\ F = \frac{\pi W\sin\theta}{a}$$

The expression for self-reaction <a,a>$_2$ is given by

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

$$\left[\cos\left(\frac{n\pi L\cos\theta}{a}\right) - \cos(KLCos\theta)\right]^2 . \left[2\cos\theta + \frac{e^{-2\gamma_{mn}W\cos\theta}}{\gamma_{mn}W} - \frac{1}{\gamma_{mn}W}\right]$$

The expression for self-reaction <a,a>$_3$ is given by

$$\langle s,s\rangle_3 = 2\sum_{m=0}^\infty\sum_{n=1}^\infty (Y_o)^e_{mn}(V^e_{mn})^2 + 2\sum_{m=0}^\infty\sum_{n=1}^\infty (Y_o)^e_{mn}(V^m_{mn})^2$$

$$where\ \ (Y_o)^e_{mn} = \frac{(\gamma_{mn})}{j\omega\mu};(Y_o)^m_{mn} = \frac{(j\omega\varepsilon)}{\gamma_{mn}};$$

$$\gamma_{mn} = \sqrt{\left[\left(\frac{m\pi}{b}\right)^2 + \left(\frac{n\pi}{a}\right)^2 - K^2\right]}$$

The Modal Voltages are given by

$$V^{e}{}_{mn} = \frac{V_0}{\pi}\left[\frac{ab\varepsilon_m\varepsilon_n}{(ma)^2+(nb)^2}\right]^{\frac{1}{2}}\frac{1}{2}\left[(\frac{m\pi}{b}\cos\theta+\frac{n\pi}{a}\sin\theta).(\cos KL-\cos AL)\frac{2K}{K^2-A^2}\frac{\sin BW}{BW}.\right.$$

$$\left.\sin\overline{m+n}\frac{\pi}{2}+(\frac{m\pi}{b}\cos\theta-\frac{n\pi}{a}\sin\theta).(\cos KL-\cos CL).\frac{2K}{K^2-A^2}\frac{\sin DW}{DW}\sin\overline{m-n}\frac{\pi}{2}\ \right]$$

$$V^{m}{}_{mn} = -\frac{V_0}{\pi}\left[\frac{ab\varepsilon_m\varepsilon_n}{(ma)^2+(nb)^2}\right]^{\frac{1}{2}}\frac{1}{2}\left[(\frac{n\pi}{a}\cos\theta-\frac{m\pi}{b}\sin\theta).(\cos KL-\cos AL)\frac{2K}{K^2-A^2}\frac{\sin BW}{BW}.\right.$$

$$\left.\sin\overline{m+n}\frac{\pi}{2}+(\frac{n\pi}{a}\cos\theta+\frac{m\pi}{b}\sin\theta).(\cos KL-\cos CL).\frac{2K}{K^2-A^2}\frac{\sin DW}{DW}\sin\overline{m-n}\frac{\pi}{2}\ \right]$$

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 & Conclusions

Using the above equations, variation of normalized conductance (g_n), normalized Susceptance (b_n), Coupling and VSWR is numerically obtained as a function of frequency . Slot length is the resonant length for each slot with considered at f=9.375GHz i.e at the center frequency of the X-Band, narrow wall dimension a=1.016 cm, broad wall dimension b=2.286 cm ,slot width 2w=0.1, 0.2, 0.3cm and a lot inclination θ = 70^0 .

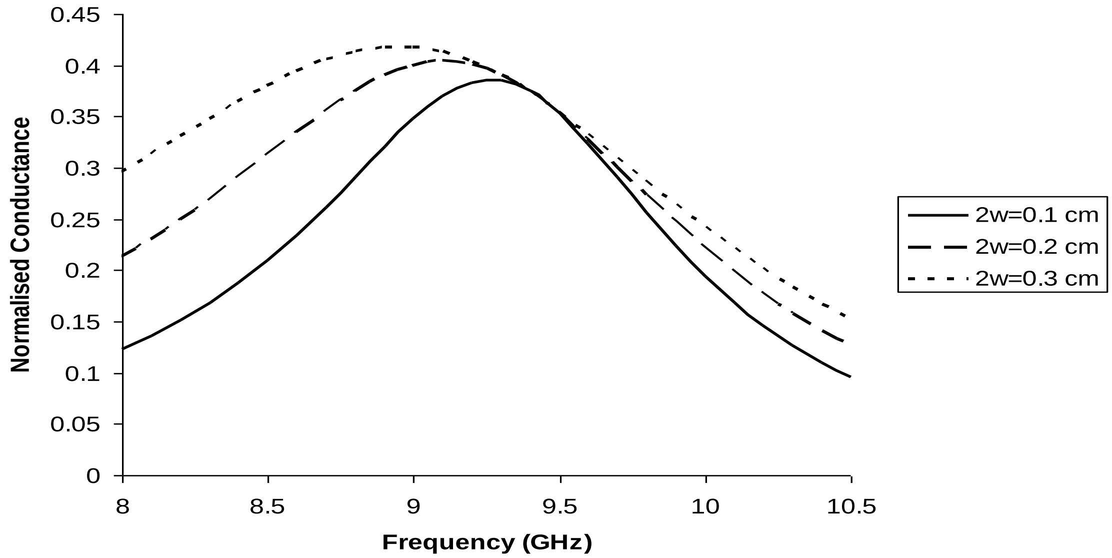

Fig.1 Variation of Normalised Conductance with Frequency for θ=70^0

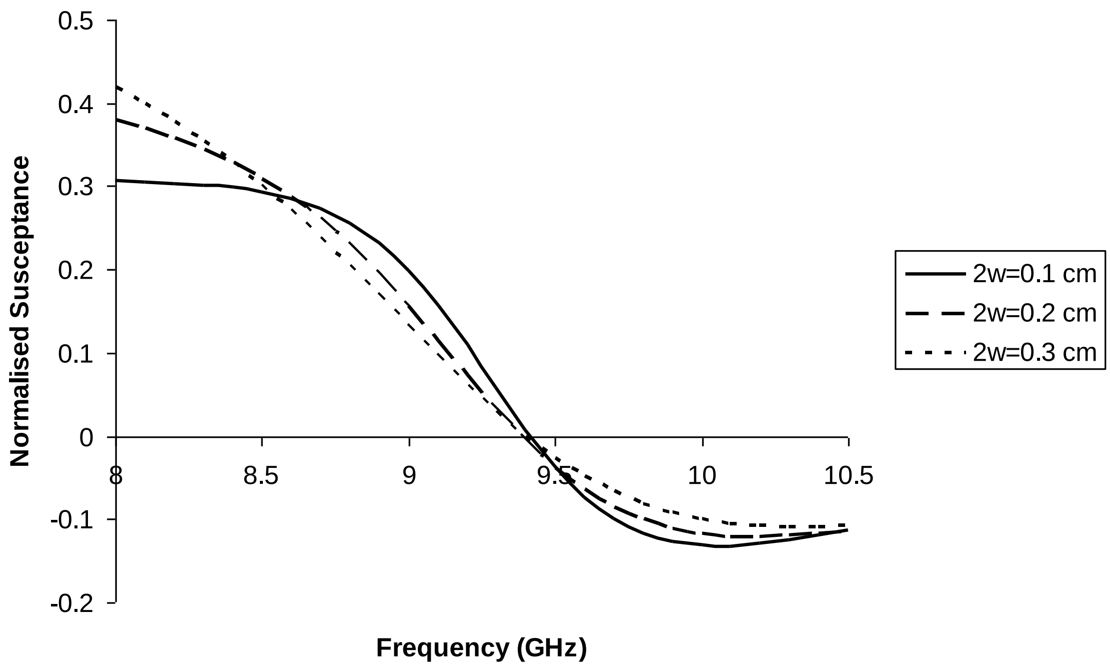

Fig.2 Variation of Normalised Susceptance with Frequency for θ=70^0

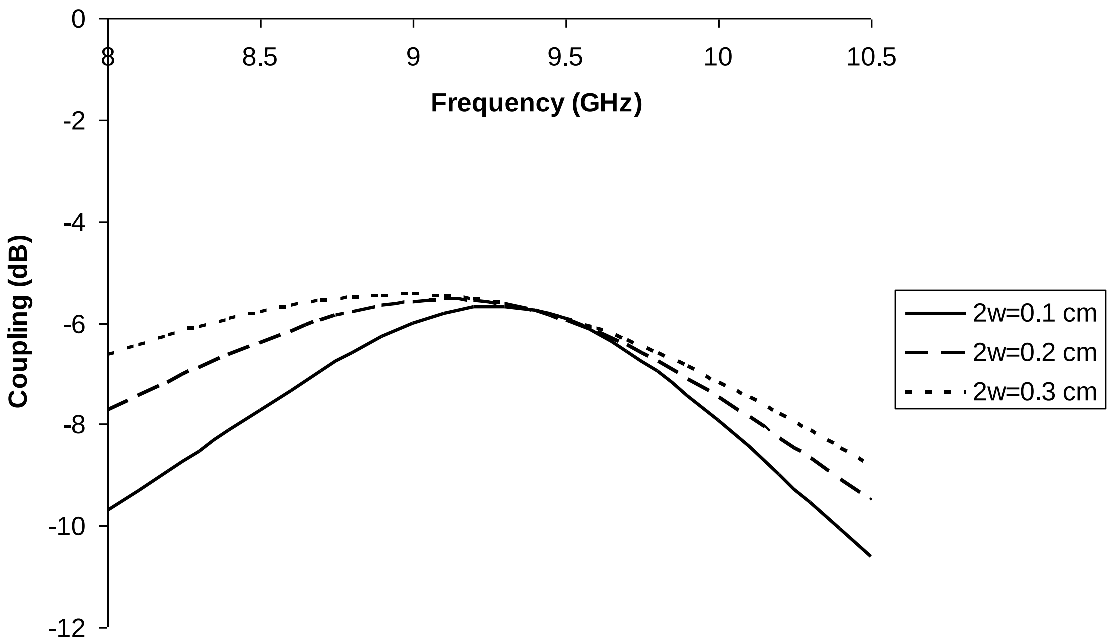

Fig.3 Variation of Coupling with Frequency for θ=70⁰

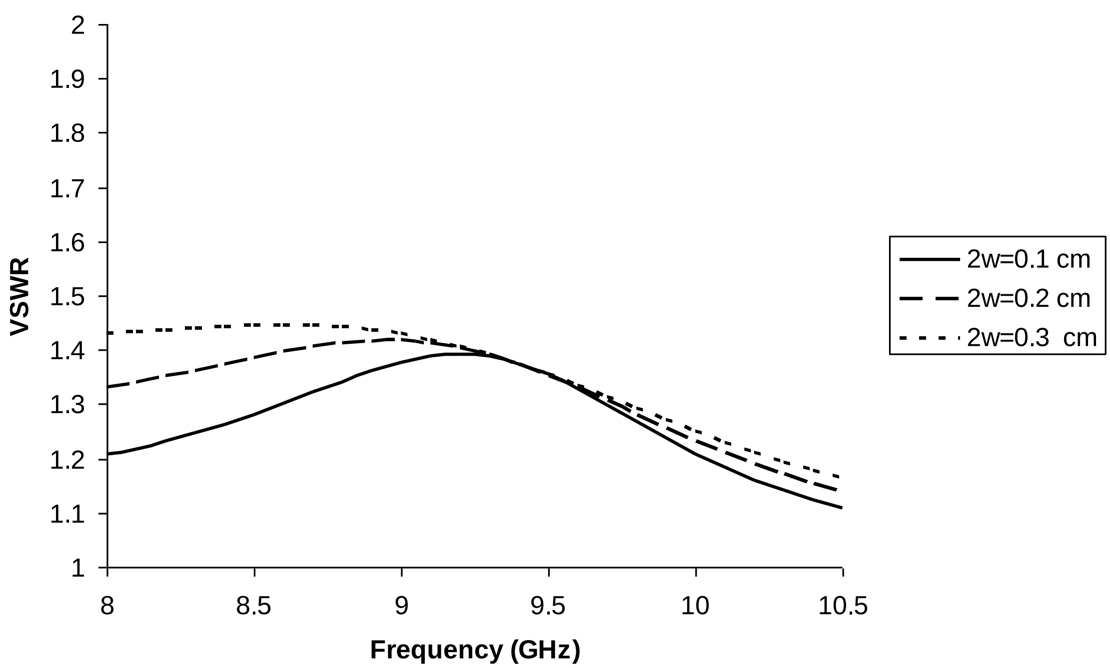

Fig.4 Variation of VSWR with Frequency for θ=70⁰

It is evident from the results that the conductance peak is occurring at a frequency slightly away from resonant frequency. This is in accordance with the change in partial distributed components of the radiators with the frequency.

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