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Analysis of H-Plane Tee Junction Formed ByS and X Band Wave Guides

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Abstract:*Many researchers investigated admittance characteristics of standard and nonstandard rectangular wave guides with slots in one of the walls i.e. either broad wall or narrow wall. The analysis of longitudinal slots in the narrow wall of wave guide is available in literature. However,No literature is available on inclined slot in the narrow wall of coupled junction of two waveguides of different bands. From the knowledge of admittance characteristics, the new coupling method provides additional design parameters for the designer.*
In the present work, the analysis of admittance characteristics, coupling and VSWRas a function of frequency and antenna parameters like width and inclination of slot arepresented. The self-reaction and discontinuity modal current concepts have been used to obtain admittance characteristics.Theresults of the theoryare compared with that of practical.
Keywords:*admittance, discontinuity in modal current, inclined slot, self-reaction, wave guide*

I. Introduction:

Slot in a rectangular wave guide radiates depending on location and orientation. An array of slots in a wave guide are very useful in many applications due to its compact size and space occupied is less.Depending on the application requirement, longitudinal or transverse slot in the walls of wave guide have been used to produce perpendicular or parallel polarized radiation pattern. However, longitudinal slot in the broad wall or transverse slot in narrow wall will not radiate. Inclined slot in the wave guide radiate cross polarized component. But EMI problems will arise, if cross polarized component radiated into free space. Slot coupled junctions suppress these cross polarized componentThis new junction provides vertical polarized waves.

With a variety of geometry, the analysis of different slots is reported by many researchers [1-4]. Results on studies of impedance characteristics of slots are reported.Toobtain a desired radiation pattern using nonstandard dimensions, a wave guide array to suppress cross polarization have been designedby Raju.et al[5].Das et al[6] has developed A method to find admittance and resonant length of an inclined slot in a narrow wall of a rectangular wave guide. Also derived an expression to find admittance of the slot using angular spectrum ofplane wave and discontinuity in modal current.Oliner A A[7] has carried out an analysis, by using variation approach and considering stored power in wave guide,to obtain equivalent impedance parameters as seen from primary wave guide. Powen Hsu et al [8]has reported data onAdmittance of an inclined slot in a narrow wall of a rectangular wave guide as a function of slot length and inclination but slot enters into broad wall on both sides. Internal power stored in the evanescent modes in the wave guide is taken care.Marcuvitzet al [9] has developed the concept of discontinuity in modal current by equivalent electric and magnetic fields discontinuity. Fields will be produced whenever there is discontinuity in narrow or broad wall. John et al [10] has presented a full wave analysis method for an array comprised of edge slots.Using finite element boundary integral equation method fields in the slot are calculated and spectral domain moment method is used for the effects of external wave guide structure. Cheng - Geng Jan [11] presented method of moments analysis for slot in rectangular wave guide. It is found that for resonant slots the amplitude is sinusoidal with small tilt,were as aperture field is almost constant. From the field distribution the characteristics like conductance, susceptance and resonant length of slot can be estimated.

In the present paper two different standard wave guides are coupled through an inclined slot in the narrow wall of primary wave guide and intensive work has been done to determine admittance characteristics, coupling and VSWR as a function of slot inclination and width. The concept of self-reaction and discontinuity modal current concepts have been used to obtain admittance characteristics. Spectrum of plane waves approach has been used for analysis.

II. Formulation

As shown in fig (1) a_1 and b_1 are narrow wall and broad wall dimensions of primary rectangular wave guide.a_2 andb_2 are narrow wall and broad wall dimensions of secondary rectangular wave guide. An inclined slot in the narrow wall of coupled junction of two different standard waveguides with slot length 2L and width 2W .θ is the angle of inclination of slot from vertical axis. The slots admittance characteristics are analyzed using s and elf-reaction and discontinuity in modal current. using TE and TM mode field concepts, slot radiators are analyzed

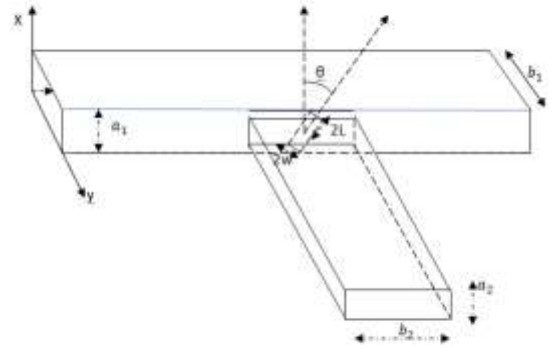


Fig1 rectangular wave guide junction coupled through inclined slot in the narrow wall

2.1 Self Reaction

The equivalent network parameter is given by [9] the expression of the form (8).In present work Self-reaction <a, a> is determined separately for the two guides. The self -reaction $\langle a,a\rangle_{f1}$in primary guide is longitudinal component of magnetic current, the self-reaction $\langle a,a\rangle_{f2}$in primary guide is transverse component of magnetic current, the self-reaction $\langle a,a\rangle_{f3}$in secondary guide, obtained from themodal expansion of the magnetic field in thecoupled guide, is given by [14]. In the general µcase of two dissimilar guides, the total self-reaction is equal to the sum of self-reactance$\langle a,a\rangle_{f1}$, $\langle a,a\rangle_{f2}$and$\langle a,a\rangle_{f3}$.

Hence, the equivalent network parameter will be

$$<a, a>=\langle a,a\rangle_{f1}+\langle a,a\rangle_{f2}+\langle a,a\rangle_{f3}$$

The expression for shunt impedance loading on the primary guide due to slot coupled matched terminated Tee arm will be

$$Z_T = -\frac{\langle a,a\rangle}{I_c I_c} = -\frac{\langle a,a\rangle_{f1}}{I_c I_c} - \frac{\langle a,a\rangle_{f2}}{I_c I_c} - \frac{\langle a,a\rangle_{f3}}{I_c I_c} \quad \text{----------} \quad (1)$$

$$Z_T = Z_1 + Z_2 + Z_3$$

The expression for the self-reaction for the longitudinal component of the slot magnetic currentin primary wave guide will be

$$\langle a,a\rangle_{f1} = \frac{j4k^2V^2 sin^4\theta}{\mu_0 \omega a_1 b_1} \sum_{m=0}^{\infty}\sum_{n=1}^{\infty} \frac{\epsilon_m \epsilon_n}{\gamma_{01}(k^2+{\gamma_{01}}^2)} cos^2 m\pi . cos^2 \frac{n\pi}{2} \left[\frac{\sin(nP)}{(nP)}\right]^2$$

$$\left[0.5\left(1+e^{-2\gamma_{01} L \sin\theta}\right) - \cos(kLsin\theta)\langle 2e^{-\gamma_{01} L\sin\theta} - \cos(kL\sin\theta) + \frac{\gamma_{01}}{k}\sin(kL\sin\theta)\rangle\right]$$

$$\text{Where} P = \frac{\pi W \sin\theta}{a_1} \quad \text{----------------------} \ (2)$$

The expression for the self-reaction for the transvers component of the slot magnetic current in primary wave guide will be

$$\langle a,a\rangle_{f2} = \frac{j2k^2V^2cos^2\theta}{\mu_0 \omega a_1 b_1} \sum_{m=0}^{\infty}\sum_{n=1}^{\infty} \frac{\epsilon_m}{({\gamma_{01}}^2)} cos^2 m\pi . sin^2\frac{n\pi}{2}\left[\frac{1}{k^2-\left(\frac{n\pi}{a_1}\right)^2}\right]^2 \left[cos\left(\frac{n\pi Lcos\theta}{a_1}\right) - \cos(kLsin\theta)\right]^2 \left[2cos\theta + \frac{e^{-2\gamma w cos\theta}}{\gamma_{01} w} - \right.$$

$$1\gamma 01w \text{----------------------} \ (3)$$

The expression for the self-reaction in coupled wave guide reducedto

$$\langle a,a\rangle_{f3} = 2\sum_{m=0}^{\infty}\sum_{n=1}^{\infty}(I)_{mn}^{e}\ (E_{mn}^{e})^2 + 2\sum_{m=0}^{\infty}\sum_{n=1}^{\infty}(I)_{mn}^{m}\ (E_{mn}^{m})^2 \quad \text{-------------} \ (4)$$

$$\text{Where}(I)_{mn}^{e} = \frac{\gamma_{01}}{j\omega\,\mu_0}; (I)_{mn}^{m} = \frac{j\omega\in}{\gamma_{01}} \text{ and} \gamma_{01} = \left[\left(\frac{m\pi}{b_1}\right)^2 + \left(\frac{n\pi}{a_1}\right)^2 - (k)^2\right]^{\frac{1}{2}}$$

And modal voltages are given by[6]

$$E_{mn}^{e} = \frac{V}{2\pi}\left[\frac{a_2 b_2 \in_m \in_n}{m a_2{}^2 + n b_2{}^2}\right]^{\frac{1}{2}}\left[\left(\frac{m\pi}{b_2}cos\theta + \frac{n\pi}{a_2}sin\theta\right)(coskL - cosAL)\frac{2k}{k^2 - A^2}\frac{sinBw}{Bw}sin\overline{m+n}\frac{\pi}{2} + \left(\frac{m\pi}{b_2}cos\theta - \frac{n\pi}{a_2}sin\theta\right)(coskL - cosCL)\frac{2k}{k^2 - C^2}\frac{sinDw}{Dw}sin\overline{m-n}\frac{\pi}{2}\right]$$

$$E_{mn}^{m} = \frac{-V}{\pi}\left[\frac{a_2 b_2}{m a_2{}^2 + n b_2{}^2}\right]^{\frac{1}{2}}\left[\left(\frac{n\pi}{a_2}cos\theta - \frac{m\pi}{b_2}sin\theta\right)(coskL - cosAL)\frac{2k}{k^2 - A^2}\frac{sinBw}{Bw}sin\overline{m+n}\frac{\pi}{2} + \left(\frac{n\pi}{a_2}cos\theta + \frac{m\pi}{b_2}sin\theta\right)(coskL - cosCL)\frac{2k}{k^2 - C^2}\frac{sinDw}{Dw}sin\overline{m-n}\frac{\pi}{2}\right]$$

Where $A = \frac{m\pi}{b_2}cos\theta + \frac{n\pi}{a_2}sin\theta$

B= $\frac{n\pi}{a_2}sin\theta - \frac{m\pi}{b_2}cos\theta$

C = $\frac{n\pi}{a_2}cos\theta - \frac{m\pi}{b_2}sin\theta$

D = $\frac{n\pi}{a_2}sin\theta + \frac{m\pi}{b_2}cos\theta$

2.2 Expressions for modal discontinuity Current:

The expression for discontinuity in modal current [9]can be reduces to

$$I_C = -2jY_{01}V\left(\frac{2}{a_1 b_1}\right)^{1/2}\frac{\pi}{b_1\beta_{01}}\frac{k}{\beta_{01}^2 - k^2}\left(\cos\beta_{01}\frac{L}{2} - \cos k\frac{L}{2}\right)\frac{\sin\beta_{01} w/2}{\beta_{01} w/2} \text{ -------------- (5)}$$

Here $Y_{01} = \frac{\beta_{01}}{\omega\mu_{01}}$ and $\beta_{01} = \sqrt{k^2 - \left(\frac{\pi}{b_1}\right)^2}$

2.3 ExpressionforAdmittance loading:

The normalized shunt admittance is related to normalized impedance by the relation and can be calculated from the knowledge of self-reactionand discontinuity in modal current

$$Y = g_n + jb_n = \frac{1}{z_T} = \frac{1}{r + jx} \text{ ------------------- (6)}$$

2.4 Expression for Coupling and VSWR:

A slot in the waveguide wall produces a discontinuity in modal current, giving rise to shunt type of equivalent giving rise to admittance parameters.The transmission matrix of the shunt admittance parameters [3]is given by

$$\begin{bmatrix} c_1^+ \\ c_1^- \end{bmatrix} = \begin{bmatrix} 1 + Y/2 & Y/2 \\ -Y/2 & 1 - Y/2 \end{bmatrix}\begin{bmatrix} c_2^+ \\ c_2^- \end{bmatrix}$$

When port2 of guide1is terminated with matched load $c_2^- = 0$

The reflection coefficient seen by port1 is given by

$$\tau = \frac{\mathbf{1} - \boldsymbol{Y}_{LN}}{\mathbf{1} + \boldsymbol{Y}_{LN}} \text{ Where } Y_{LN} = 1 + Y$$

Using power balanced condition the radiated power coupled to free space is given by [12]

C $=4g_n^2/[(2 + g_n)^2 + b_n^2]$ ---------------------------(7)

The coupling in dB taking correction into account

$$C_{dB} = 10\log_{10}[4g_n^2/((2+g_n)^2+b_n^2)] - 8.686\alpha t$$

Wherecorrection factor $\alpha = \left[\left(\frac{\pi}{2L}\right)^2 - k^2\right]^{\frac{1}{2}}$andtis wall thickness of wave guide.

The VSWR in terms of reflection coefficient is given by [5]

$$VSWR = \frac{1+|\tau|}{1-|\tau|} \text{ --------------------------- (8)}$$

III. Results

From the obtained resonant length, normalized conductance, normalized susceptance, coupling and VSWR are numerically computed as a function of frequency, from expressions (1),(6),(7) and (8).Results are shown fora$_1$=3.48cm,b$_1$=7.24cm, a$_2$=1.016 cm, b$_2$=2.286 cm, for slot length 2L=1.6cm, for slot width 2W= 0.05, 0.1, 0.15, 0.2,0.3for slot inclinations θ=30^0,35^0,40^0,45^0 and 50^0 in fig (2), fig(3), fig(4), fig(5), fig(6) respectively,

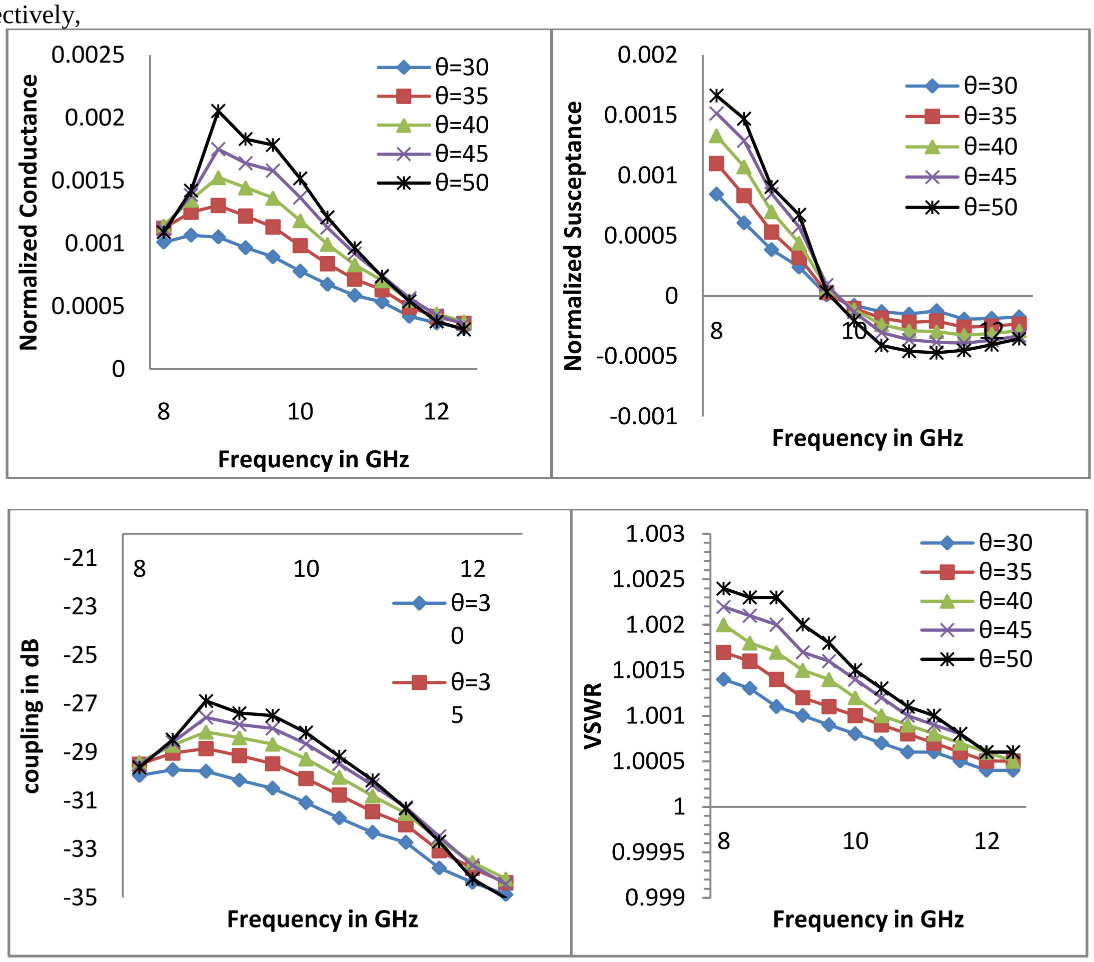


Fig (2)Variation of conductance, susceptance, coupling and VSWR as a function of frequency with slot length2L=1.6cm, slot width=0.05cm and slot inclination θ =30^0, 35^0, 40^0, 45^0, 50^0

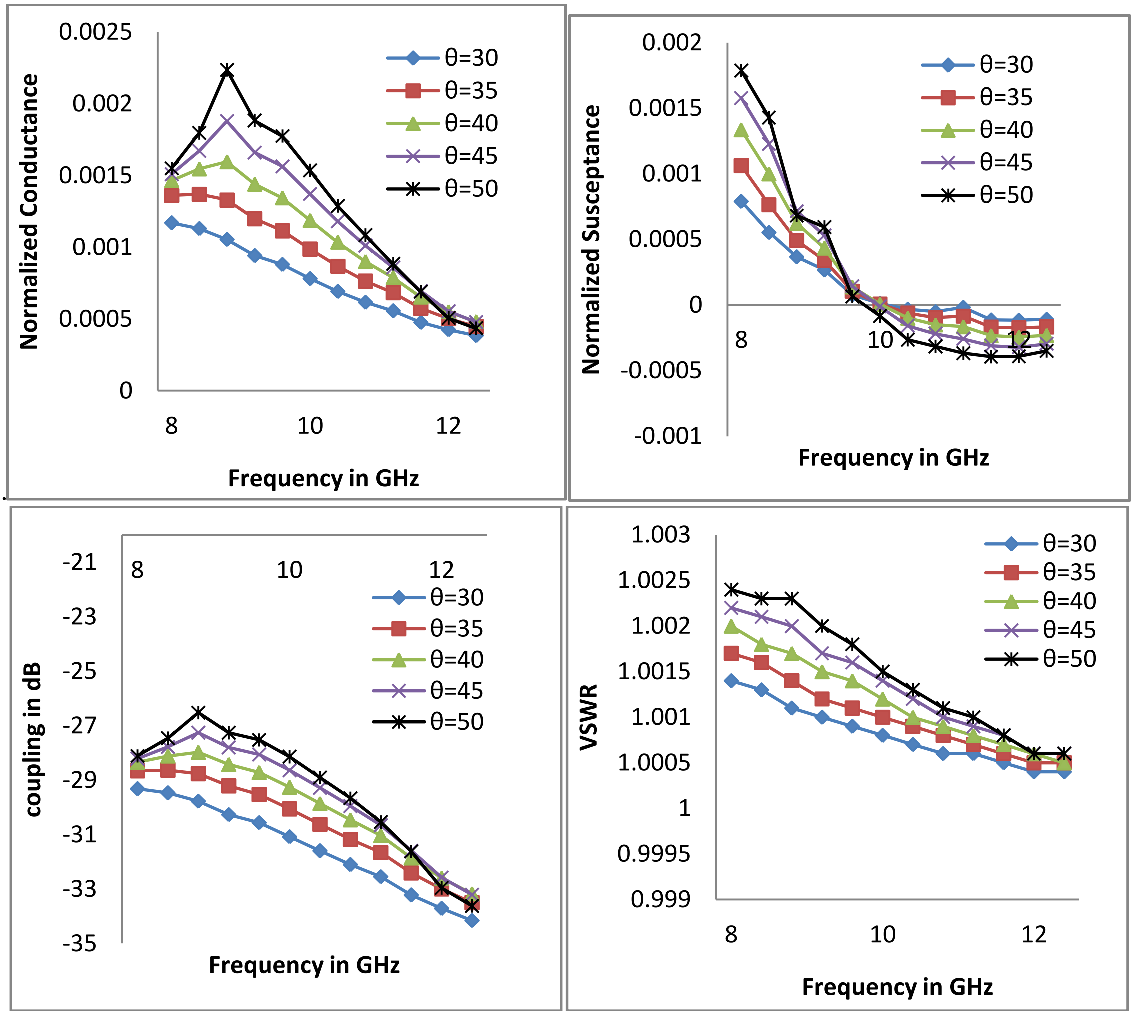
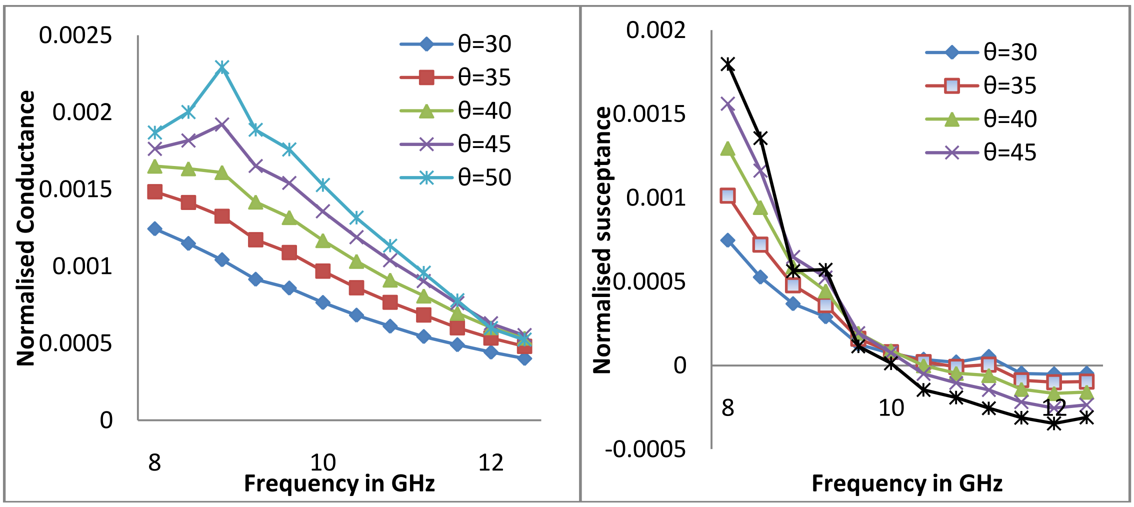


Fig (3) Variation of conductance, susceptance, coupling and VSWR as a function of frequency with slot length2L=1.6cm, slot width=0.1cm and slot inclination θ =$30^0, 35^0, 40^0, 45^0, 50^0$



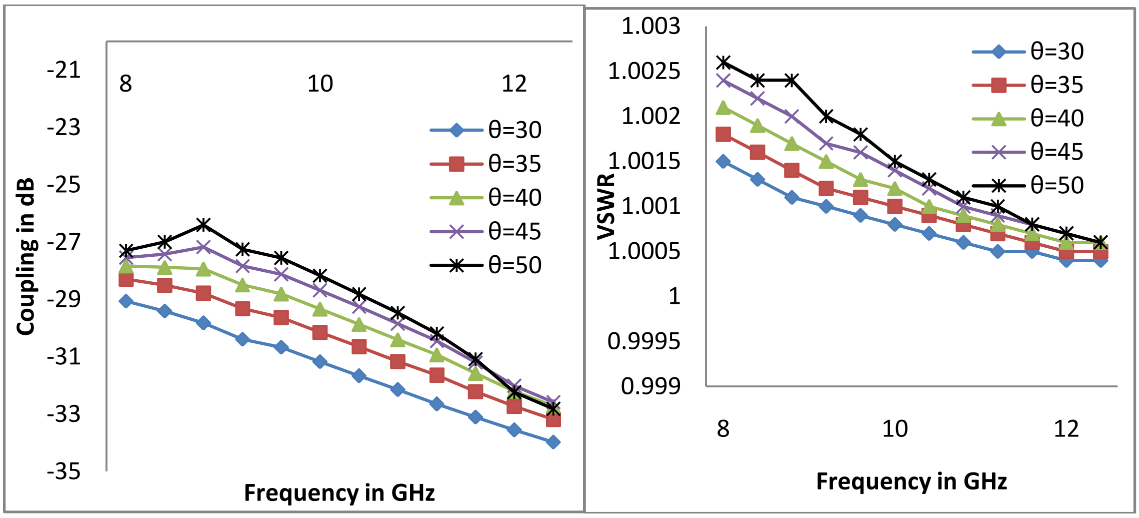


Fig (4) Variation of conductance, susceptance, coupling and VSWR as a function of frequency with slot length2L=1.6cm, slot width=0.15cm and slot inclination $\theta = 30^0, 35^0, 40^0, 45^0, 50^0$

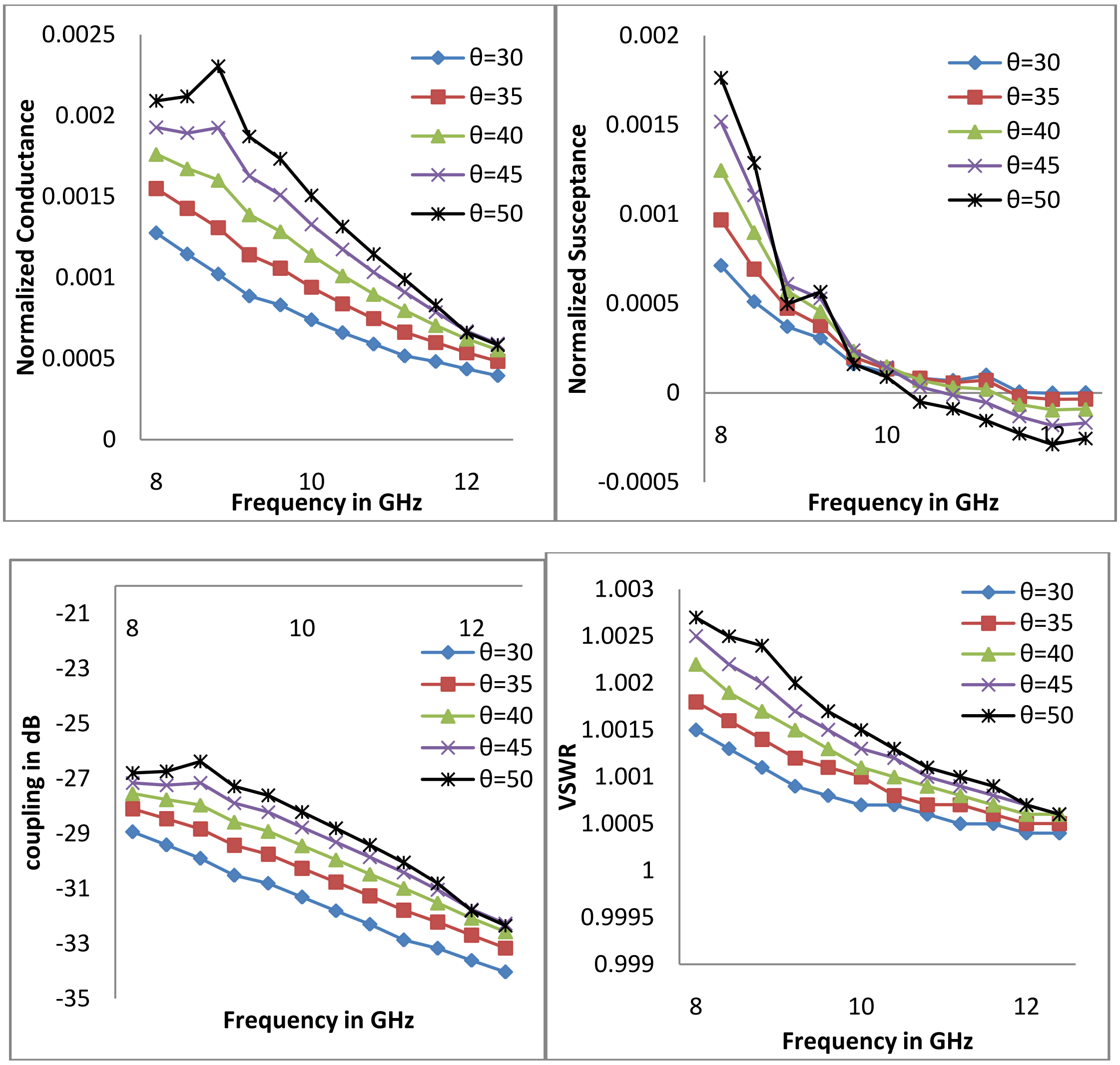


Fig (5) Variation of conductance, susceptance, coupling and VSWR as a function of frequency with slot length2L=1.6cm, slot width=0.2cm and slot inclination $\theta = 30^0, 35^0, 40^0, 45^0, 50^0$

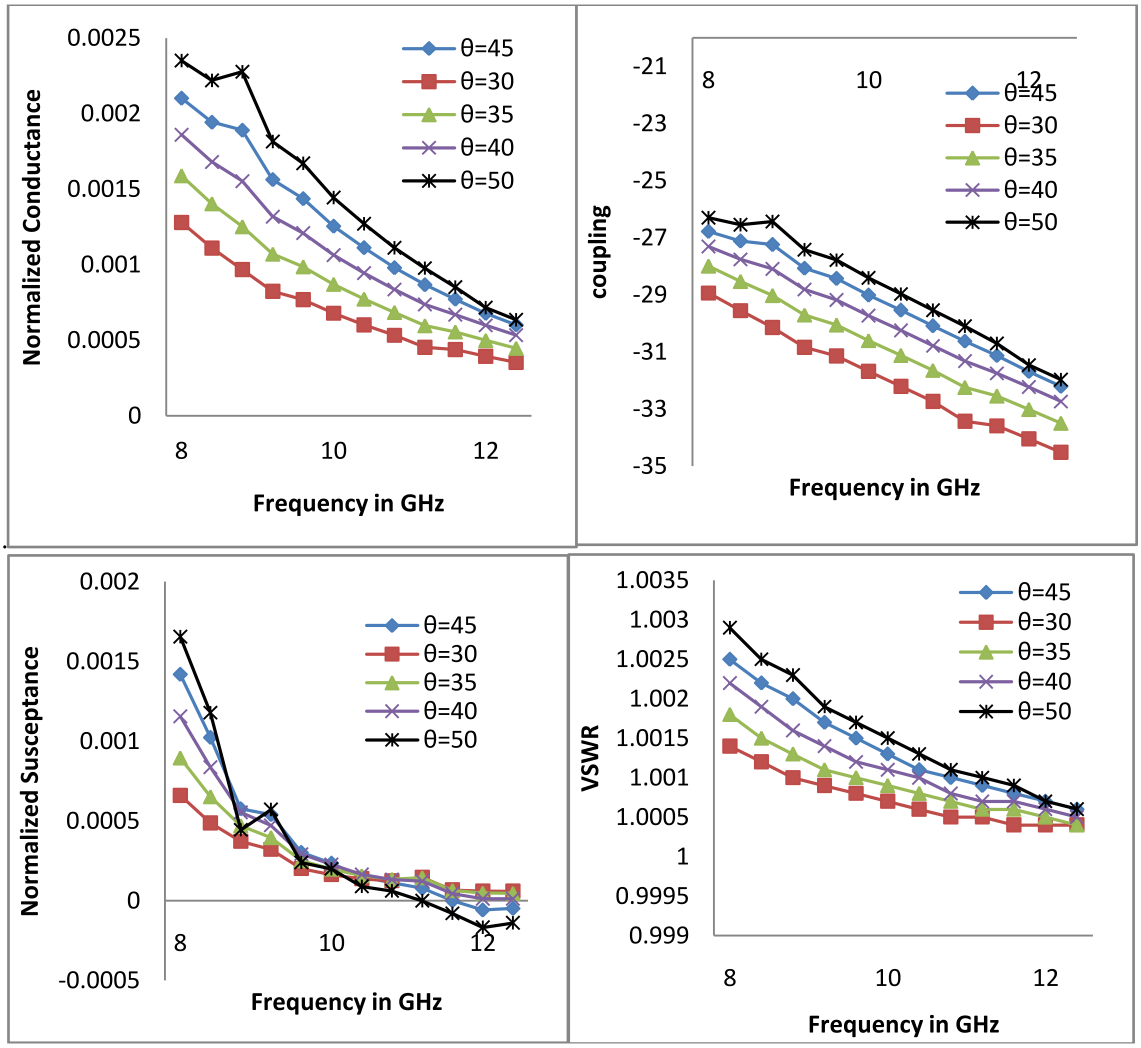


Fig (6) Variation of conductance, susceptance, coupling and VSWR as a function of frequency with slot length2L=1.6cm, slot width=0.3cm and slot inclination $\theta = 30^0, 35^0, 40^0, 45^0, 50^0$

IV. Conclusions

It is evident from the resultswave guide junction made of s band and x band wave guide. The results are found to be very interesting. Using MATLab the variation of normalized conductance and normalized susceptance is found to depend on frequency, slot length, slot width and slot inclination. The results on coupling indicate that power coupled from primary to secondary at around mid-frequency of band. VSWR found to exhibit small variation over the entire frequency .Slot inclination also found to influence .The results presented in this papermake it possible to design such junctions very easily.

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