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Analysis of L and C Band Wave Guide Junctions

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ABSTRACT:

Antenna plays an important role in radar and communication applications for transmitting and receiving purpose. For most of the applications, desired specifications like polarization, impedance, VSWR and radiation pattern characteristics are required.The radiated fields should have polarization purity. In such cases slot coupled junctions are useful.

In the present work, H plane Tee junctions through coupling are considered and the analysis is made to obtain admittance characteristics as a function of frequency for two H plane Tee junction wave guides with different dimensions. The results are numerically computed by varying the slot width and slot inclination. The concepts of self-reaction and discontinuity in modal currents of the main guide as well as Tee arm are used in the analysis. The variation of admittance, coupling, and VSWRfor L-band and C-band H-plane Tee junctions are presented which are very much useful for the array designer.

KEYWORDS:*slot coupled junction, admittance, discontinuity in modal current, self –reaction.*

I. INTRODUCTION:

H-Plane Tee junction is a three port device. The main guide containing two ports and the coupled arm contains third port.In power division applications, to divide the power equally into two main ports Shunt Tees are usually preferred when fed through shunt port. In the present work H-Plane Tee junctions 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 and the main guide are coupled usually by a longitudinal slot. However, the coupling can be made by inclined slot in the narrow wall of main guide. This coupling system will provided additional design parameters for the array designer i.e. waveguide dimensions and slot dimensions. Literature on Longitudinal slot coupled shunt Tee wave guides is available, but a few researchers reported on inclined slot coupled wave guide shunt Tee. In case of open ended slot arraysradiation pattern will be distorted because of mutual coupling exists between the slots.In array applications, cross polarized components can be suppress by slot coupled shunt Tees which in turn reduces mutual coupling between slots.

The analysis of different slots and wave guides is presented by many researchers [1-5].Raju et al. reported how to obtain a desired radiation pattern for a wave guide array by suppressing cross polarization and to reduce mutual coupling between the slots [6]. To obtain equivalent impedance parameters as seen from primary waveguide, Variational approach and power stored in the wave guide are considered by Oliver[7] Using self-reaction and discontinuity in modal current approach by considering inclined slots in the narrow wall of rectangular waveguide admittance characteristics and resonant length of slot are formulated byPandharipande [8]. Oliner [9] presented impedance properties of different types of slots using equivalent circuit and variational method, by taking into account slot with thickness and without thickness. Fields are produced by Discontinuities in Waveguides walls. Discontinuity Electric and Magnetic Fields equivalent represents Discontinuity in modal Currents [10] . The coupled slots are present either in the narrow wall or broad wall of a rectangular waveguide, mostly coupled slots are resonant. Watson [11] explained the laws of guide coupling in terms of the manner in which impedance is transferred and the position of the slot center in coupled guide into feed guide at the same position. Hsu et al. [12] obtained admittance properties of the inclined slots in the narrow wall and possible resonant length. The analysis includes the internal power storage in evanescent modes in the waveguides. Raju et al [13] has reported on Admittance of inclined Slots in narrow wall of rectangular waveguide that are sufficiently wide as a function of frequency and variation of resonant length as a function of slot width. Raju et al. [14] has investigated a rectangular aperture excited by a rectangular waveguide and its admittance characteristics as a function of slot length and slot width are obtained. Inclined slots in the narrow wall of rectangular waveguide admittance characteristics and resonant length of slot are formulated using self-reaction and discontinuity in modal current approach by Das et al [15].

II. ANALYSIS FOR ADMITTANCE CHARACTERISTICS:

The electric field in a vertical slot in narrow wall of rectangular waveguide is horizontally directed, hence they do not radiate. 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 L-band Shunt Tee and C-band Shunt Tee are determined from self-reaction and discontinuity in modal current []. The analysis considered in two parts: first 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 admittance as a function of resonant slot length. The result is numerically obtained for varied slot widths and slot inclination. Consider L-band and C-band waveguide shunt Tee coupled through an inclined slot of length 2L and width 2w, on the narrow wall as shown in Fig.1.

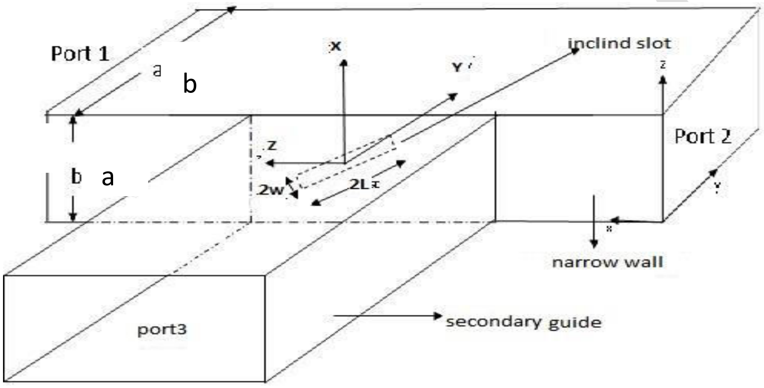

Fig.1 Inclined slot coupled waveguide shunt Tee

The analysis for admittance characteristics is obtained 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 [6]. 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.

As shown in fig (1) aand b are narrow wall and broad wall dimensions of primary and secondary rectangular wave guide. For C-band a= 3.48 cm, b=1.57cm and for L-band a= 16.5 cm, b=8.2cm. An inclined slot in the narrow wall of coupled junction of two different standard waveguides with slot length 2L and width 2W.

2.1 Self-reaction equations in H plane Tee junction coupled through inclined slot:

The Electric field in aperture plane of slot is replaced by an equivalent magnetic current, the total self-reaction $\langle q,q\rangle$of this magnetic current, with magnetic Fields produced by this magnetic current. The admittance seen by primary guide can be expressed as

$$Y_T = -\frac{(I.I)}{\langle q,q\rangle} \qquad (1)$$

Where $I$is discontinuity in modal current.

Expression for self- reaction is given by [1]

$$\langle q,q\rangle = -\int_{V} \mathbf{H}.\mathbf{M}\, dv (2)$$

where **H**is magnetic field and **M**is magnetic current. V is the coupled volume.

In present work Self-reaction $\langle q,q\rangle$ is determined separately for the two guides. The self -reaction $\langle q,q\rangle_1$in primary guide is longitudinal component of magnetic current, the self-reaction $\langle q,q\rangle_2$in primary guide is transverse component of magnetic current, the self-reaction $\langle q,q\rangle_3$in secondary guide, obtained from the modal expansion of the magnetic field in the coupled guide, is given by [5]., The shunt admittance loading on the primary guide due to the slot coupled shunt Tee can be expressed as the total self-reaction is equal to the sum of self-reactance$\langle p,p\rangle_1$, $\langle q,q\rangle_2$and $\langle q,q\rangle_3$.Hence, the equivalent network parameter will be

$$\langle q,q\rangle = \langle q,q\rangle_1 + \langle q,q\rangle_2 + \langle q,q\rangle_3 (3)$$

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

$$Y_T = Y_1 + Y_2 + Y_3 \quad (4)$$

2.2 Self-reaction due to longitudinal component of magnetic current in primary wave guide$\langle q,q\rangle_1$:

The Electric field $\overline{E_S}$ in aperture plane of slot of fig1 is related to equivalent magnetic Current ***M*** by the relation

$$\boldsymbol{M} = \overline{E_S} X \overline{u_n}$$

where$\overline{u}_n$ is unit vector normal to the aperture plane

The field distribution in the slot is assumed to be of form given by [1]

$$\overline{E_S} = \overline{u_x} E_m sink(p)$$

$$\text{For} \frac{a}{2} - W \le |x'| \le \frac{a}{2} + W \text{ and } -L \le |z'| \le L \text{ ; p=} L - |z'|$$

whereE_m is maximum Electric field, $\overline{u_x}$ is unit vector along x direction and K=2π/λ. λ is wave length. 2L is length of slot and 2W is width of slot.

From the fig.1 that$\overline{u_n} = \overline{u_y}$. Hence the magnetic current due to slot is in z direction. From the knowledge of magnetic field and magnetic current, it is possible to evaluate self -reaction required for obtaining expression for equivalent network. The self -reaction has been defined in (2) in the form of volume integral. Since magnetic current is distributed over the surface, the volume integral in the self–reaction reduced to surface integral. Taking the image in the wall y=b into account, the expression for self-reaction

takes the form $\langle q,q\rangle_1 = -\int \boldsymbol{H}.2\boldsymbol{M}\, ds$

By integrating and simplifying the above expression, The expression for the self-reaction for the longitudinal component of the slot magnetic current in primary wave guide will be

$$\langle q,q\rangle_1 = 2Q sin^4\theta \sum_{m=0}^{\infty}\sum_{n=1}^{\infty} E1.G1.D1\left[\frac{\sin(nR)}{(nR)}\right]\left[0.5(1+e^{-2F2}) - \cos(F1)\langle 2e^{-F2} - \cos(F1) + \frac{\gamma_{01}}{k}\sin(F1)\rangle\right]^2 \quad (5)$$

where$R = \frac{\pi W \sin\theta}{a}$;$Q = \frac{j2k^2 V_m{}^2}{\mu_0 \omega ab}$,$\gamma_{01} = \left[\left(\frac{m\pi}{b}\right)^2 + \left(\frac{n\pi}{a}\right)^2 - (k)^2\right]^{\frac{1}{2}}$;F1=$kL\sin\theta$;
F2=$\gamma_{01}L\sin\theta$;G1=$cos^2 m\pi$; D1=$cos^2\frac{n\pi}{2}$;E1=$\frac{\epsilon_m\epsilon_n}{\gamma_{01}(k^2+\gamma_{01}{}^2)}$.

Similarly, the expression for the self-reaction for the transverse component of the slot magnetic current in primary wave guide will be

$$\langle q,q\rangle_2 = QH1^2\sum_{m=0}^{\infty}\sum_{n=1}^{\infty}\frac{\epsilon_m}{(\gamma_{01}{}^2)}G1.G2.[G3]^2\left[cos\left(\frac{n\pi LH1}{a}\right) - \cos(F1)\right]^2\left[2H1 + \frac{e^{-2H1.H2}}{H2} - \frac{1}{H2}\right] \quad (6)$$

where H1=$cos\theta$; H2=$\gamma_{01}w$, G2=$sin^2\frac{n\pi}{2}$; G3=.$\left[\frac{1}{k^2-\left(\frac{n\pi}{a}\right)^2}\right]$

The expression for the self-reaction in coupled wave guide reduced to
For the coordinates shown in fig.1 the variables are related as

$$X = x' + \left(\frac{a}{2}\right) \quad \text{and} \quad z = z' + \left(\frac{b}{2}\right); \quad k = 2\pi/\lambda.$$

From formulation given by [1] and using the relations above the normalized vectors for electric ($\bar{E}^e_{mn}$) and magnetic ($\bar{E}^m_{mn}$) are found. The electric and magnetic voltages are given

$$V^e_{mn} = \int_{-w}^{w}\int_{-L}^{L}\bar{E}_S\bar{E}^{-e}_{mn}\,dx'\,dz'$$

$$V^m_{mn} = \int_{-w}^{w}\int_{-L}^{L}\bar{E}_S\bar{E}^{-m}_{mn}\,dx'\,dz'$$

whereE_m is maximum Electric field, and k=2π/λ . λ is wave length. a and b are narrow wall and broad wall dimensions of feed and coupled guide. From the knowledge of [6] the expressions for modal voltages are obtained.

The field distribution in the aperture plane of slot is assumed having length 2Land width 2Wgiven by

$$\overline{E_S} = \overline{u_x} E_m sink(p)$$

for -L≤ $|z'| \leq L$ and -W≤ $|x'| \leq W$

whereE_m is maximum Electric field, $\overline{u_x}$ is unit vector along x direction and k=2π/λ. λ is wave length. 2L is length of slot and 2W is width of slot and $V_m=2WE_m$

The electrical field distribution in the aperture plane of slot can represent by an equivalent magnetic current. The self-reaction$\langle p, p\rangle_3$of the magnetic current **M** in coupled guide given by

$$\langle q, q\rangle_3 = -\iint \boldsymbol{H}.\boldsymbol{M}\, dx'\, dz'$$

The self- reaction$\langle p, p\rangle_3$is reduced to

$$\langle q, q\rangle_3 = 2\sum_{m=0}^{\infty}\sum_{n=1}^{\infty}(Y_0)_{mn}^{e}\,(V_{mn}^{e})^2 + 2\sum_{m=0}^{\infty}\sum_{n=1}^{\infty}(Y_0)_{mn}^{m}\,(V_{mn}^{m})^2 (7)$$

where$(Y_0)_{mn}^{e} = \frac{\gamma_{01}}{j\omega\mu_0}$; $(Y_0)_{mn}^{m} = \frac{j\omega\epsilon}{\gamma_{01}}$

2.3 EXPRESSION FOR MODAL DISCONTINUITY CURRENT:

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

$$I = -J1.A1.A2.A3\left(\cos\beta_{01}\frac{L}{2} - \cos k\frac{L}{2}\right)\frac{\sin A4}{A4} (8)$$

Here A1= $\left(\frac{2}{ab}\right)^{\frac{1}{2}}$;A2=$\frac{\pi}{b\beta_{01}}$; A3=$\frac{k}{{\beta_{01}}^2-k^2}$; A4=$\beta_{01}\frac{w}{2}$;$Y_{01} = \frac{\beta_{01}}{\omega\mu_{01}}$;$J1 = 2jY_{01}V_m$ and $\beta_{01} = \sqrt{k^2 - \left(\frac{\pi}{b}\right)^2}$

2.4EXPRESSION FOR ADMITTANCE LOADING:

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

$$y = \frac{Y_T}{Y_{01}}$$

WhereY_{01} is characteristic wave admittance for dominant mode.

$$y = g_n + jb_n (9)$$

Whereg_n is the normalized conductance and b_n is the normalized susceptance

2.5 EXPRESSION FOR COUPLING AND VSWR:

Using power balanced condition the radiated power in dB coupled to free space is given by

$$C_0 = \frac{4g_n^2}{[X1]} \text{ where } X1 = [(2+g_n)^2 + b_n^2] \quad (10)$$

The VSWR in terms of reflection coefficient is given by

$$\text{VSWR} = \frac{1+|\rho|}{1-|\rho|} \quad (11)$$

wherereflection coefficient$\rho = \frac{1-y}{1+y}$

III. RESULTS:

Using the normalized admittance presented above in expression (9), the variations of normalized conductance, normalized susceptance, using the expression (10) the variation of coupling and using the expression(11) the variation of VSWRare numerically computed at the central frequency of L-band and C-band wave guides. For the slot inclination of $\theta=30^0,35^0$, $40^0,45^0,50^0$ the resonant lengths of the slot 2L=10.6cm, 11.0cm, 11.4cm, 11.8cm, 12.0cm for L-band are obtained respectively. For slot width of 0.1 cm,0.2 cm,0.3 cm the variation of conductance, susceptance, coupling andVSWR as a function of frequency are presented in figs.2, 4, 6. Similarly for C-bandfor the slot inclination of $\theta=30^0,35^0$, $40^0,45^0,50^0$ the resonant lengths of the slot 2L=2.0 cm,2.1cm,2.2cm,2.3cm and2.3cm are obtained respectively. For slot width of 0.1 cm, 0.2 cm, 0.3 cm the variation of conductance, susceptance, coupling and VSWR as a function of frequency are presented in figs.3, 5,7.

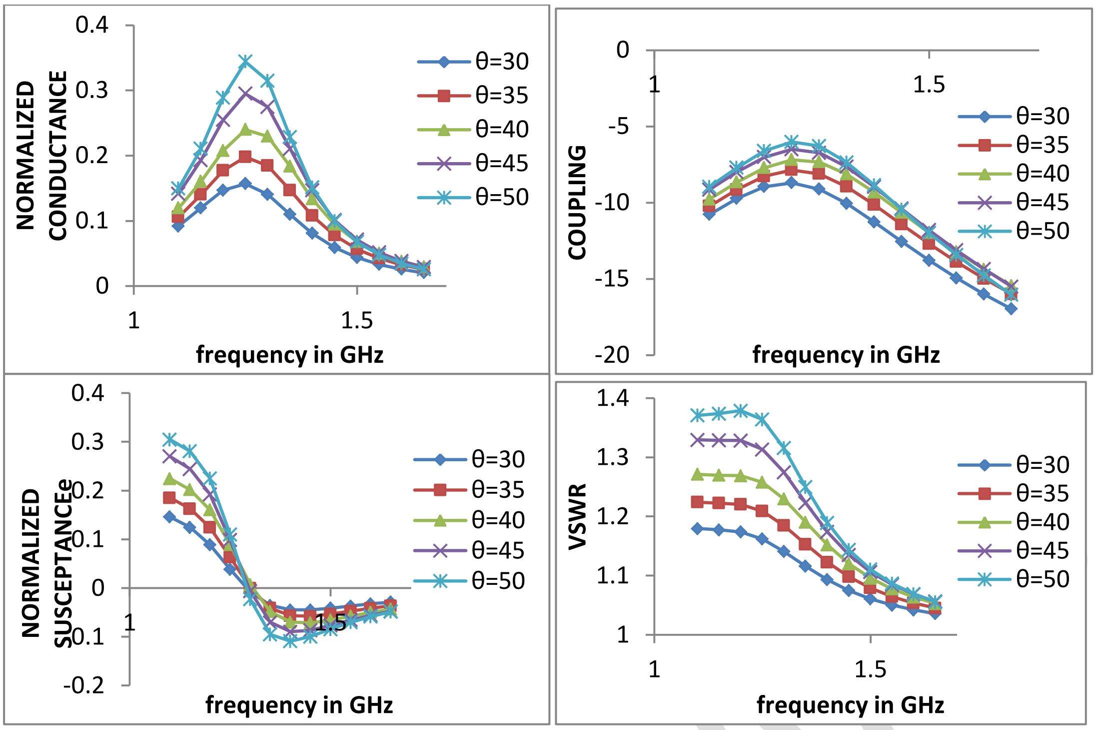

Fig.2.Variation in conductance, susceptance, coupling and VSWR as a function of frequency for L-band, with slot width 0.1cm and slot inclination θ= $30^0,35^0,40^0,45^0,50^0$

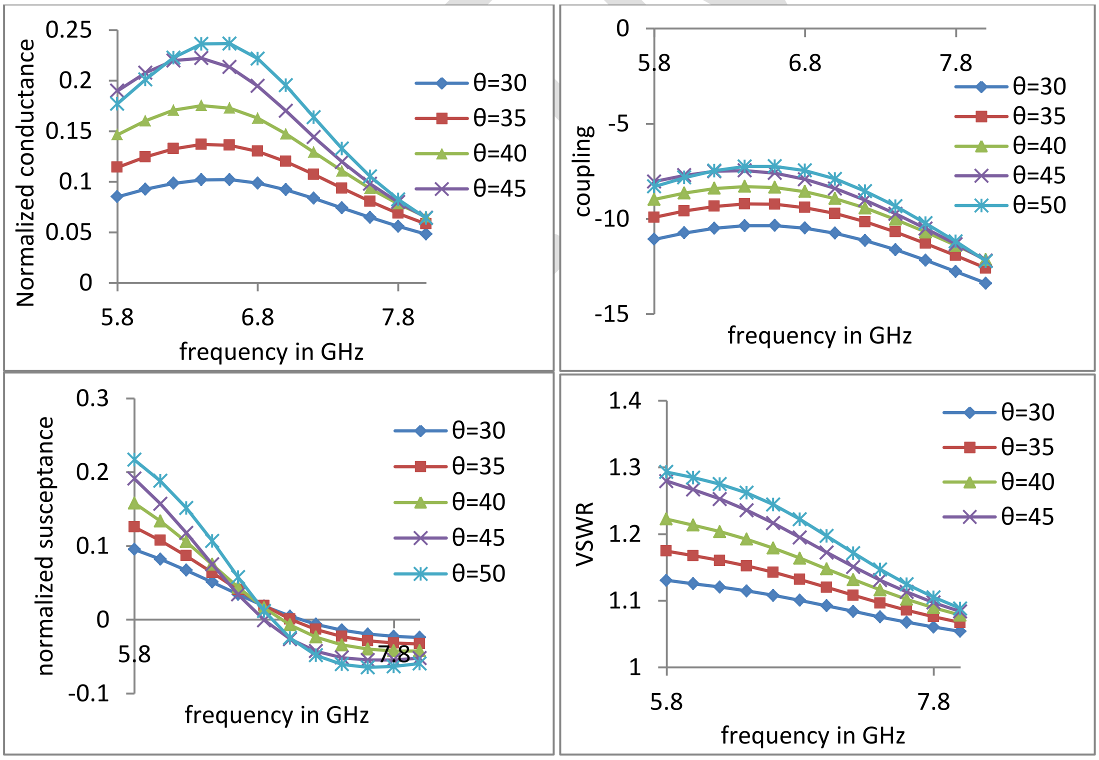

Fig.3.Variation in conductance, susceptance, coupling and VSWR as a function of frequency of C band with slot width 0.1cm and slot inclination θ= $30^0,35^0,40^0,45^0,50^0$

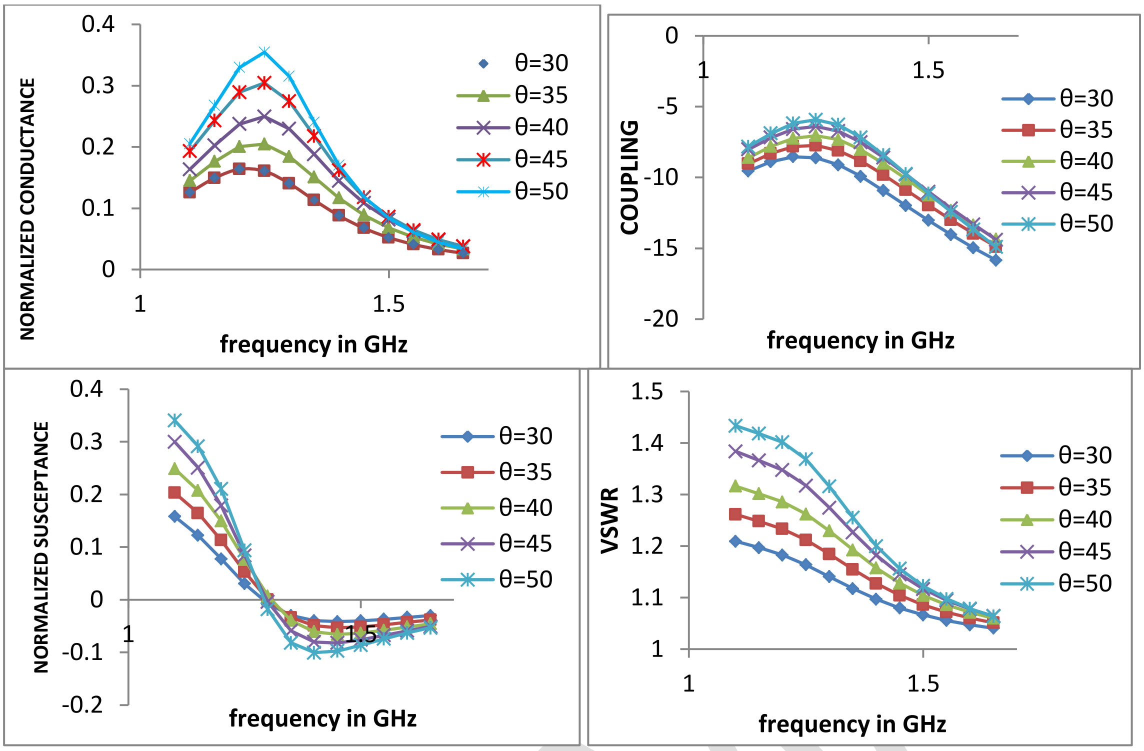

Fig.4.Variation in conductance, susceptance, coupling and VSWR as a function of frequency for **L-band**, with slot width 0.2cm and slot inclination θ= 30^0,35^0,40^0,45^0,50^0

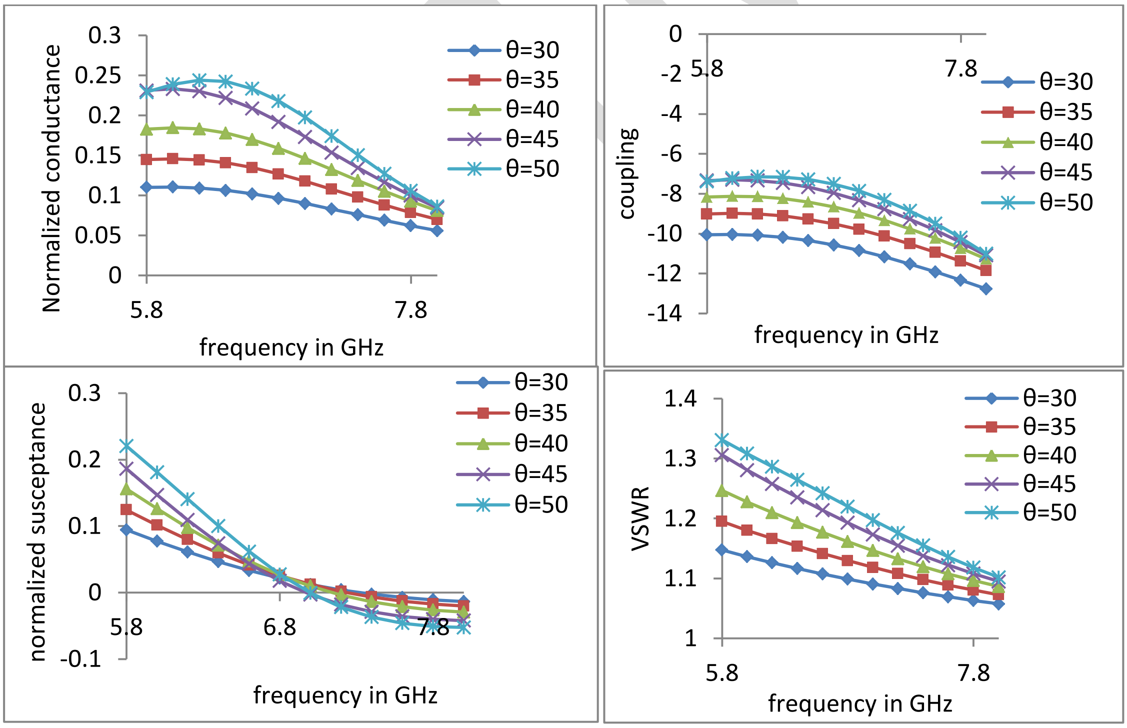

Fig.5.Variation in conductance, susceptance, coupling and VSWR as a function of frequency of **C band** with slot width 0.2cmand slot inclination θ= 30^0,35^0,40^0,45^0,50^0

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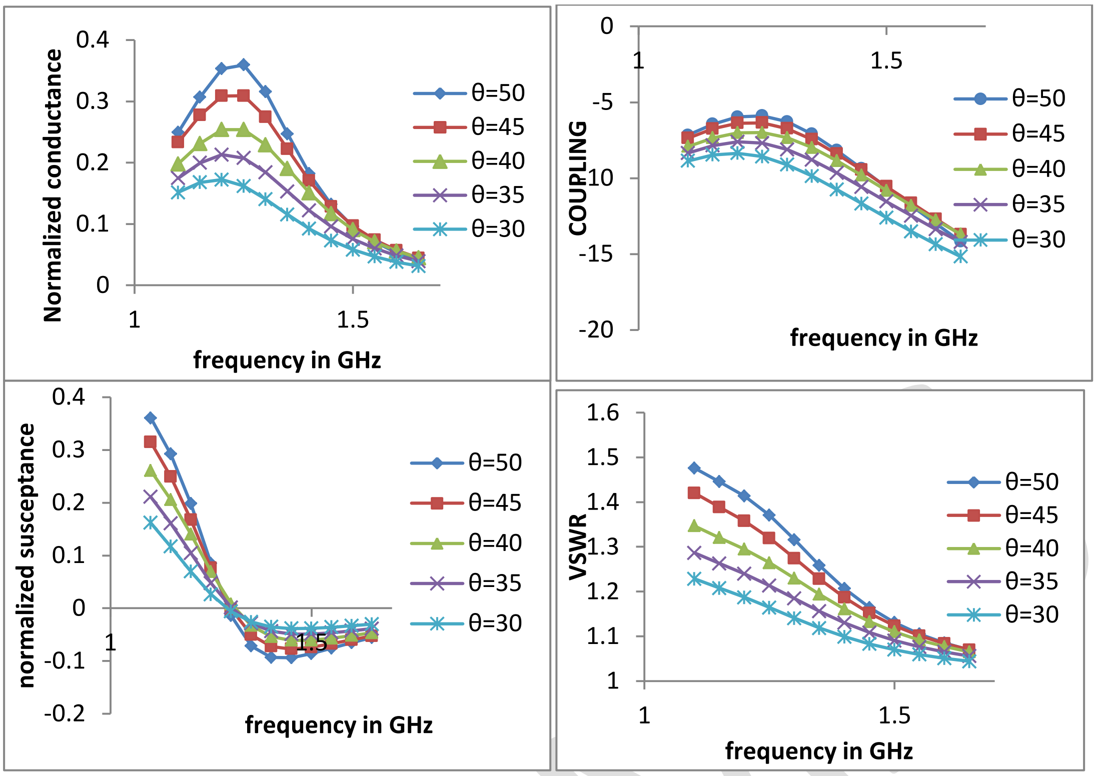

Fig.6.Variation in conductance, susceptance, coupling and VSWR as a function of frequency for L-band, with slot width 0.3cm and slot inclination θ= $30^0,35^0,40^0,45^0,50^0$

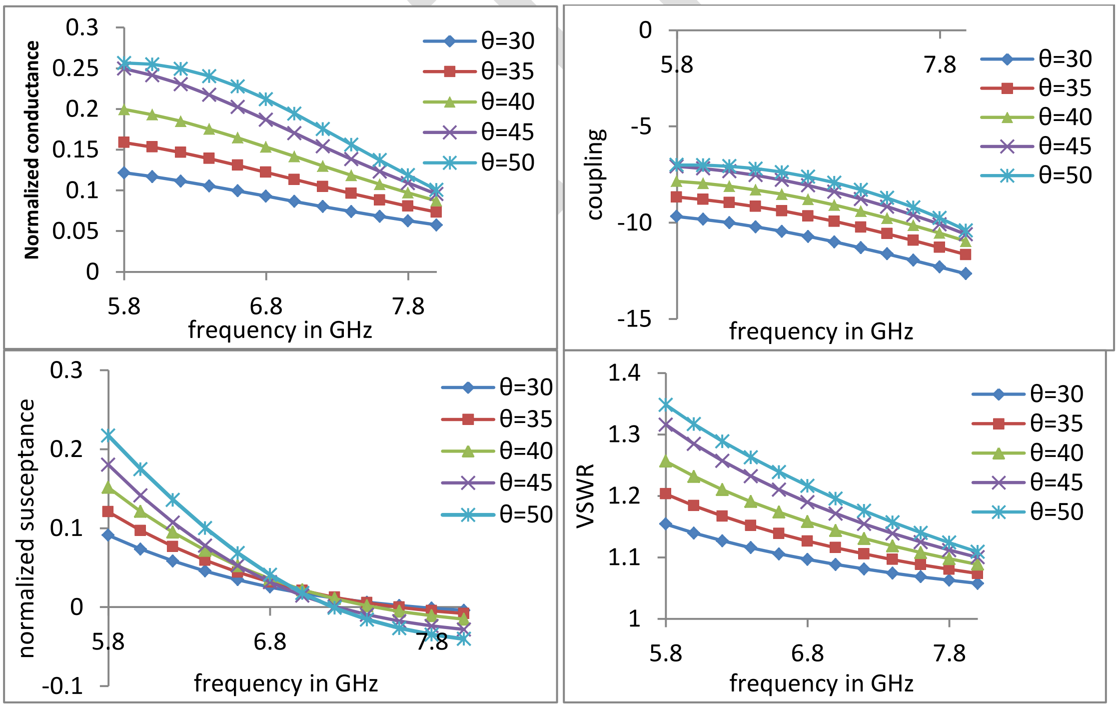

Fig 7 Variation in conductance, susceptance, coupling and VSWR of C-band as a function of frequency for slot width 0.3cm and slot inclination θ= $30^0,35^0,40^0,45^0,50^0$

IV. CONCLUSIONS:

It is found from the results that the conductance has a variation over a range of 0.02 and 0.4 for L-band junction.However, for C-band junction g_n has highest value of about 0.24. In both the cases, peak has shifted to the left of resonant frequency. Coupling is found to be higher than for L-band than C-band junction for the same slot parameters. In both the cases, VSWR has the highest value 1.5. The results presented in the paper are useful for the array design for a specified radiation pattern.

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