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Study of Inductive Reactance of a Micro Strip Line Structure with The Spacing Between Two Metal Strip

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ABSTRACT

The Present Paper aims at the study of inductive property developed due to propagation of electromagnetic waves through the structure and its dependence on the spacing between two metal strip and other factors. Due to interaction of electron beam with electromagnetic waves, kinetic energy of electron is increased. Microwaves have become very powerful experimental tools for study of some of the basic properties of materials. There are different structures for the propagation of electromagnetic powers in different modes. The Microwave Integrated circuits (MIC'S) have changed the systems in the present days by replacing large scale waveguides and co-axial component arrays to small light weight assemblies. These introduced microwave striplines, microslotlines, coplanar strip lines and coplanar waveguide etc.

Keywords : Microstripline, Capacitance, Stripwdth, Geometry of strip

I. INTRODUCTION

With the advent of microwave integrated circuits, the older transmission structures like two parallel wire lines, waveguide and co-axial line have been revolutionized with the introduction of miniaturized microwave planar transmission structure. The two parallel wire transmission lines are the simplest structure for microwave signal but these are very much lossy in giga hertz range of frequency. To minimize the losses & to reduce the size & cost new technology known as planar transmission line technology has been developed with the advent of microwave integrated circuits (MIC's). The two parallel wire transmission etc. Structure coaxial lines, wave guide have because obsolete now days due to their bulky size, heavy cost and power losses in gigahertz range of frequency. Technology have been developed due to advent of microwave integrated circuit (MIC's) owing to certain special features and characteristics such as: Miniaturized size, Reduced weight, Low cost, Minimum power consumption, Low dissipation of power, easily replaceable, Easy to fabricate.

II. MATERIALS AND METHOD

Microstripline consists of a metal strip fixed on one side of a dielectric substrate whose other side is metalized to serve as ground plane. The substrate material should be of suitable permittivity having low loss tangent and the operating frequency ranges from 2 GHz – 30 GHz. For maximum circuit size reduction, the dielectric substrate material has been selected having relative permittivity of the order of two or higher. But due to smaller loss tangent or low dissipation factor fused quartz like substrate is preferably used. As shown in figure 1.

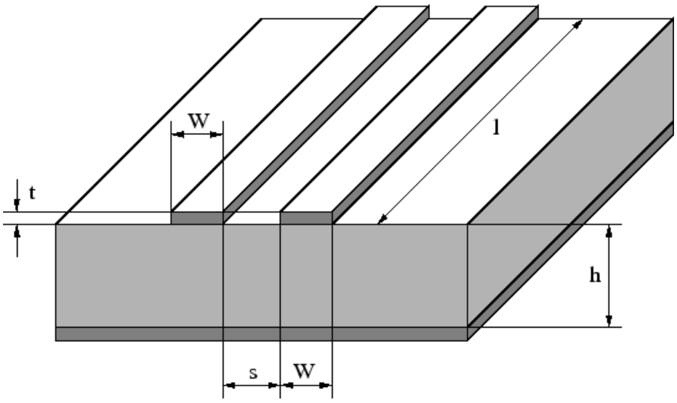

Figure 1: Microsterip line structure

The present work aims at the study of inductive reactance and its variations with spacing between two metal strips. This involves the study of the study of characteristics impedence and phase velocity and their variations with spacing between two metal strips. This required some mathematical formulation based on conformal transformation technique developed by wheeler, Schwartz man and others.

III.RESULTS AND DISCUSSION

The characteristic impedance of TEM transmission line is given by

$$Z_o = 1/V_P C_P \qquad ----- 1$$

Where, V_P= phase velocity of the wave traveling along the transmission structure.

C_P= capacitance per unit length of the structure.

In case of microstriplines structure shown in fig .1consists of different components as indicated in the figure. These components are as follows:

(i) C_{PP} = Parallel plate capacitance between lower surface of the microstrip and the ground plane and is given by

$$C_{PP} = [\epsilon_{re}/C\eta] \,.\, (w/h) \qquad ---- 2$$

(ii) C_{PPU} = Parallel plate capacitance between the upper surface of the microstrip and the ground plane which is expressed as

$$C_{PPU} = (2/3)\,[\epsilon_{re}/C\eta] \,.\, (w/h) \qquad ------ 3$$

C_f = the fringing capacitance at the edges of the microstrip and the ground plane which is expressed as

(iii) $$C_f = [\epsilon_{re}/C\eta] \,.\, (2.7/\mathrm{Log}4h/t) \qquad ------ 4$$

Where,

W	=	microstrip width
ϵ_{re}	=	The effective permittivity of the medium
h	=	height of the substrate

η = free space impedance = 377 Ω

C = the velocity of light in free space = 3.0×10^8 m/sec

t = microstrip thickness.

Combining equations 2, 3, 4 the total capacitance (C_P) per unit of the structure is expressed as

$$C_P = C_{PP} + C_{PPU} + C_f$$

Or,

$$C_P = (\epsilon_{re} / C\eta)(w/h) + (2/3)(\epsilon_{re} / C\eta)(w/h)(\epsilon_{re} / C\eta).(2.7/\text{Log}4h/t) \quad \text{----- } 5$$

This is the expression of the capacitance of the microstrip structure in terms of its geometric parameters.

The phase velocity V_P can be calculated by the formula

$$V_P = C/\sqrt{\epsilon_{re}} \quad \text{------ } 6$$

For wide strip, $\epsilon_{re} \approx \epsilon_r$, and

For narrow strip, $\epsilon_{re} \approx (\epsilon_r + 1) / 2$

Where ϵ_r = relative permittivity.

From equations 1, 5, and 6 we get,

$$Z_o = (\eta/\sqrt{\epsilon_{re}})[1/[(w/h)+(2w/3h)+(2.7/\text{Log}4h/t)]] \quad \text{---- } 7$$

Using his expression, we can also calculate other characteristic parameters of transmission line e.g., propagation constant, phase velocity and guide wavelength.

Microstripline supports TEM mode of propagation. Although it is true that bulk of energy is transmitted along the microstripline with field distribution closely resembling TEM-mode. It is usually referred to as a quasi-TEM mode. The field distribution is quite complicated. The fields have been analysed by a number of workers using various static technique in the analysis process characteristic impedance and phase velocity are computed which are further employed in calculating the self inductance. The characteristic impedance is related with primary and secondary line constants as

$$Z_0 = \sqrt{\frac{R + j\omega L}{G + j\omega C}} \quad \text{--------------------8}$$

At microwave frequency and for low loss

$$Z_0 = \sqrt{\frac{L}{C}} \quad \text{--------------9}$$

Where,

C = Capacitance of the stripline transmission structure

L = Self inductance for low loss stripline transmission structure.

Alternate expression for characteristic impedance for such structure is given as

$$Z_0 = V_P . L \quad \text{--------------- } 10$$

From equation 3,

$$L = Z_0 / V_P$$

Knowing the value of characteristic impedance of the microstripline transmission structure and phase velocity of the wave passing through the structure, Self inductance of the structure can be determined. This property of the structure is due to change of magnetic flux linked with the structure which is owing to the presence of magnetic flux and energy flowing through it.

If $\omega = 2\pi f$, then inductive reactance $X = \omega L = 2\pi f L$ where f=operating frequency.

The inductive reactance is the property of the structure developed due to wave propagation and presence of magnetic flux. this is a lossless parameter but produces hindrance to the flow of electromagnetic power and its due to energy observe by the structure. The study of variation of inductive reactance is the aim of present paper.

Table No. 1: Study of variation of self-inductance with spacing between two metal strip

f = 2 GHz, h = 100 mils, t = 0.02 mils, ϵ_r = 3.78(fused quartz), c = 3 x 10^8 m/sec

1 mil = 2.54 x 10^{-5} meter.

Stripwidth w (mils)	Characteristic Impedance Z_0 (Ω)	Phase velocity V_p x 10^8 m/sec	Self-Inductance (L) x 10^{-7} H	Inductive reactance(ohm)
15	135.12	1.88	7.38	9.254
30	103.64	1.86	5.75	7.207
45	92.85	1.84	5.22	6.541
60	84.54	1.82	4.79	6.001
75	81.22	1.81	4.46	5.587

Study of Variation of Inductive Reactance With Spacing Between Two Metal Strip:

Result obtained shows that for given frequencies and dielectric material inductive reactance decreases with increase of spacing between two metal strip. This shows larger concentration of field lines below the strip and greater amount of power flow. The result is shown in table 1 related graphs in graph no.1.This concludes that for wider strip the rate of variation of inductive reactance with strip width w is always the same. This idea is very useful for a designer to design microstripline of given inductive reactance for lower dissipation and larger selectivity.

Graph No. 1: Study of variation of self inductance with spacing between two metal strip

f = 2 GHz, h = 100 mils, t = 0.02 mils, ϵ_r = 3.78(fused quartz), c = 3 x 10^8 m/sec

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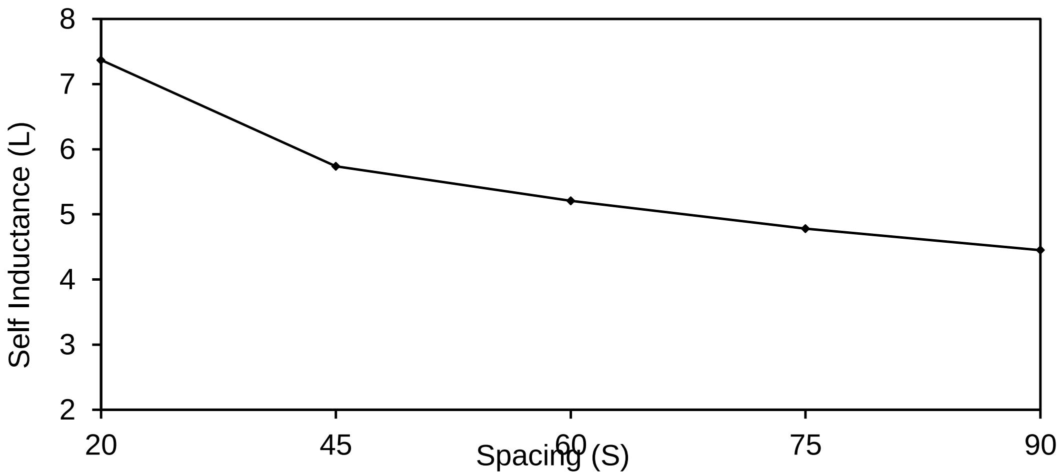

IV. CONCLUSION

The study of variation of Inductive reactance has been performed by varying the spacing between two metal strip, which shows a sharp decrease in inductive reactance with increase of spacing of metal strip. This indicates the inductive reactance is larger for narrower strip and smaller for wider strip. This concludes that the flow of power is larger for wider metal strip & smaller for narrower strip. This work has the scope of future work also. The results obtained in the present work are in close agreement with the theoretical and experimental results obtained by Delinger, Getsinger and Wheelar.

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