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Variation of Characteristic Parameter of a Single Microstripline with Metal Strip Width and Frequency

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ABSTRACT

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In the age of digital electronics, computer technology, information technology and artificial intelligence, the knowledge systems have been changed a lot in a style which is beyond human imagination from large scale and bulky system to a miniaturized small scale like micro and nano size. The whole globe has been shrinked into small integrated chips which contain thousands of micro and nano components which can make too much smart and for sensing systems. The bulky, costly and lossy wave guides and coaxial cables have been replaced by light weight, miniaturized size, inexpensive and easily replaceable planar transmission structures with the advent of micro wave integrated circuits (MIC'S) workable in high giga hertz frequency range. These are the outcome of planer transmission line technology. The simple and most significant transmission structures are stripline, microstripline and their variants have been proved to be significant in transmitting the signals from one place to remote corner of the world. microstripline is the modified form of stripline and is most simple and useful in giga hertz range of frequency from 20 – 30 GHZ. The present work aims at the study of variation of characteristic parameters such as characteristics impedance and phase velocity with width of metal strip and operating frequency.

Keywords : Microstripline, Stripwidth, Frequency and Characteristics Parameters.

I. INTRODUCTION

The two parallel wire transmission line structure, coaxial line & wave guide have become useless now-a-days due to their bulky size, heavy cost and power losses in gigahertz range of frequency. The planar transmission line (2-dimensional) technology has been developed due to advent of microwave integrated circuits (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 and easy to fabricate etc.

In the giga hertz range of frequency stripline, microstripline and their variants have been proved to be significant in transmitting the signals. Among these, microstripline is simple and open structure. It is easy to fabricate and less lossy.

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 – 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.

The presents work aims at the study of characteristics impedance and phase velocity along with their formulation and their variations with width of metal strips and frequency of the wave travelling through microstrip line.

Actually microstripline is a modified form of stripline. It is an open structure easy to employ. A microstripline consists of a narrow conductor strip on one side of a dielectric substrate and the other side being completely metalized to serve as a ground plane. The microstrip structure may be derived from the stripline configuration by removing the top ground plane and upper laminates shown in fig-1. The electric and magnetic field configurations are shown in fig-2.

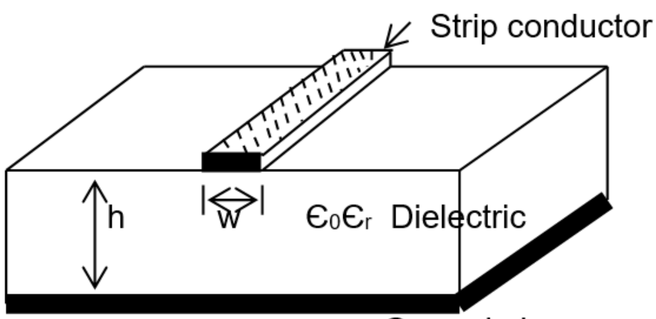


Fig-1 Microstripline (QUASI-TEM Mode)

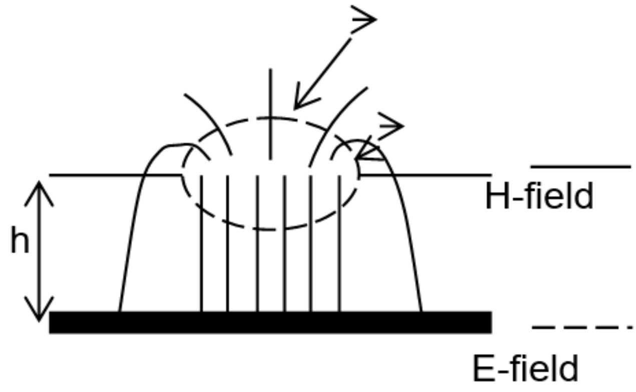


Fig-2 Microstripline Field configuration

Although the structure is open, the radiation problem is avoided by using high dielectric constant substrate. The substrate commonly employed has permittivity ϵ_r= 2.50 for fused quartz which is used here for the present study.

In the case of microstripline the energy propagates both in the dielectric substrate below the strip and in the air region above it. Fraction of power flowing through metal the stripwidth (w) and therefore the effective dielectric constant depends on the microstrip width. Thus the guide wavelength becomes the function of the characteristic parameters such as impedance and phase velocity of the microstripline.

Formulation of characteristics parameters of microstripline

The study of characteristic impedance and phase velocity are the important parameters which to be studied for the present study. The formulation of these parameters is based on methods of conformal transformation in which microstripline can be converted into parallel plate capacitors. If z_0 denotes the characteristics impedance and c_p denotes capacitance of parallel plate geometry and V_p denoted the phase velocity of the wave passing through the microstripline.

These are related by the equation

$$Z_o = 1/V_P C_P \quad \text{---------- (1)}$$

Where,

V_P = phase velocity of the wave traveling along the microstrip line.

C_P = capacitance per unit length of the line.

The capacitance of the line is the result of the combination of different components.

These are:

C_{PP} = parallel plate capacitance between lower surface of the microstrip and the ground plane and is given by

$$C_{PP} = [\epsilon_{reff} / c.\eta] . (w/h) \quad \text{---------- (2)}$$

C_{PPU} = capacitance between the upper surface of the microstrip and the ground plane which is expressed as

$$C_{PPU} = (2/3) [\epsilon_{reff} / c.\eta] . (w/h) \quad \text{---------- (3)}$$

.C_f = the fringing capacitance at the edges of the microstrip and is expressed

$$C_f = [\epsilon_{reff} / c.\eta] . (2.7/\text{Log}4h/t) \text{---------- (4)}$$

Where,

w = Microstrip width

ϵ_{reff} = The effective dielectric constant 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.

Thus the total capacitance (C_P) of the isolated microstrip structure is expressed as

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

$$\text{or } C_p = (\epsilon_{reff} / c.\eta) (w/h) + (2/3) (\epsilon_{reff} / c.\eta) (w/h) (\epsilon_{reff} / c.\eta).(2.7/\text{Log}4h/t) \quad \text{---------- (5)}$$

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

$$V_P = c / \sqrt{\epsilon_{reff}} \quad \text{---------- (6)}$$

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

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

Where,

ϵ_r = relative dielectric constant.

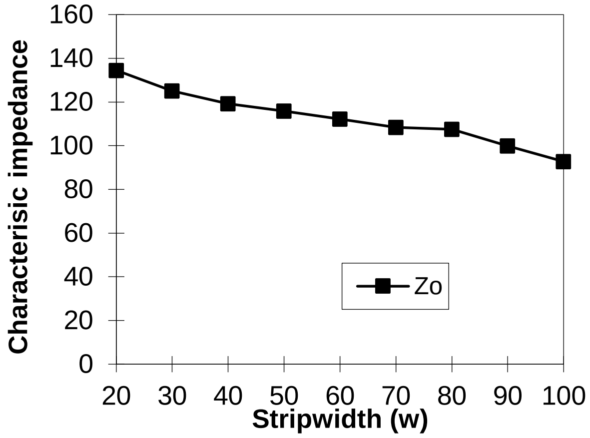
From equations (1), (5) and (6), we get

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

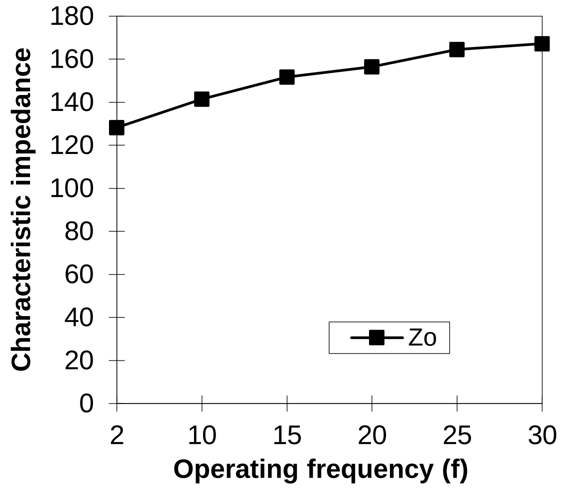
The calculations made on the basis of this expression give the characteristics impedance, the propagation constant and other transmission parameters of a single microstrip structure

Variation of Characteristic Impedance with Metal Strip Width

The characteristic impedance for single microstripline structure depends on the metal strip width for given frequency and dielectric substrate. It has been computed for different stripwidth keeping height, permittivity and frequency fixed. The graph has been plotted keeping strip width on x-axis and characteristic impedance on y-axis as shown in graph-1.



Graph-1



Graph-2

It has been concluded that the flow of energy is larger for wider strip than for narrower strip. It has been observed that the characteristic impedance decreases with increase of stripwidth. Further it has been also observed that the rate of decrease for narrow strip is larger than for wider strip. The characteristic impedance change rate becomes smaller and smaller for wider strip. It is due to larger concentration of electric flux lines below the wider strip within dielectric substrate. This information is useful for design of microstripline structure.

Study of Variation of Characteristic Impedance for Single Microstripline with Operating Frequency

The characteristic impedance for single microstripline is the function of operating frequency. It increases with increase of frequency. It has been computed for different frequencies for given stripwidth and dielectric substrate.

Graph has been also plotted keeping frequency on x-axis and characteristic impedance on y-axis as shown in graph-2. It has been concluded that for higher frequency flow of energy is smaller than for lower frequency. This has been utilized for designing different striplines in different frequency ranges.

II. DISCUSSION AND CONCLUSION

The results as plotted on graph indicate that the characteristic impedance of single microstripline decreases with increase of metal strip width. Also the characteristic impedance increases with increase of operating frequency at slower rate. The characteristic factor such as phase velocity for single stripline also decreases with increase of operating frequency. The increase of characteristic impedance with increase of operating frequency indicates larger concentration of energy through the dielectric substrate. For lower range of frequency the flow of energy is larger as velocity of wave travelling through the microstripline.

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