Formulation of the Characteristic Parameters of single Microstriplines

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Abstract :

There are different structures for the propagation of electromagnetic power in different modes. Also there are various devices for sending message or signals from one place to another place. After development of microwave integrated circuit, the old transmission systems such as two parallel wires transmission lines, waveguides, coaxial lines etc has been revolutionized with the introduction of miniaturized microwave planar transmission structures. These planar transmission structures are too much attractive and characterized by conducting thin metal strip, large ground plane and multilayer insulation. When two metal strip parallel to each other enclose proximity on a dielectric substrate supported by a metal plate, natural coupling exist between them. In present paper formulation of the characteristic parameters of single microstripline will be carried out. This study is necessary for design of stripline, filters, circulators and directional coupler.

Key words : Phase velocity, characteristic impedance, permittivity, substrate, propagation constant, guide wavelength.

1. Introduction

The poiner workers like H.A. Wheeler employed conformal mapping technique to study the properties of parallel strip geometry by considering TEM mode of propagation. Microstriplines which is subject of present paper and modified version of parallel strip geometry is an open structure and is also inhomogeneous in nature. Supports quasi TEM mode of wave propagation. The quasi TEM mode means partly TEM and partly non TEM mode. How ever at lower frequency range the mode of propagation closely pure TEM-mode.

Wheeler calculated capacitance, phase velocity and characteristic impedance of single and coupled striplines. In addition various others methods have been adopted for such studies. In this paper formulation of characteristic parameters will be carried out and using this technique formulation of self inductance will be performed for its study analytically. This uses the computer aided techniques which is convenient approach for the analysis of single microstripline in the quasi static limit in lower GHz frequency range.

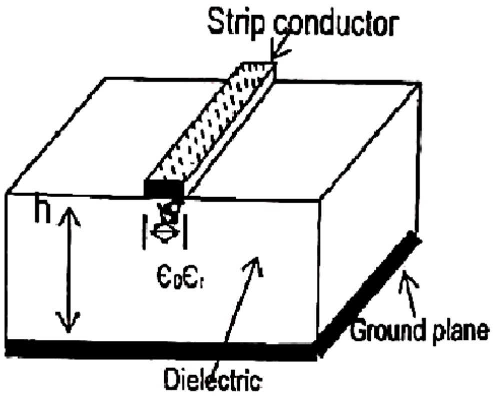
Different work has been done in recent years on the numerical calculation of the characteristic of microwave stripline, microstriplines, slotlines, suspended and inverted striplines and microstriplines using different dielectric substrates and different frequency ranges. Several empirical expressions have been developed by different authors on the basis of which useful models have been proposed for single and coupled microstriplines to study the characteristics parameters. Several types of microstriplines circuits have been developed and there characteristics have been studied for the various modes of propagation through these microstriplines.

The present paper is devoted to the study of formulation of the problems using computers aided design (CAD) techniques developed by S.K. Kaul and exhaustive computational work is also involved for the study of characteristic parameters of the microstripline. The important characteristic parameters are characteristic impedance, propagation constant, phase velocity and guide wavelength etc.

2. Single Microstripline Structure

Microstripline is the simplest and open structure. It consists of a narrow metal strip on one side of a dielectric substrate other side of which is metallised to serve as a ground plane. Microstriplines is also called an open stripline shown in Fig. 1a. The electric and magnetic field lines are confined in the vicinity of the metal strip with large concentration inside the substrate & small in the air region as shown in Fig. 1 (b).

Modes of propagation in microstripline are only quasi transverse electric and magnetic (TEM). Thus the theory of TEM coupled lines applied only approximately. Radiation loss in microstripline is a problem, particularly at such discontinuities as short circuit posts, corners and so on. However, the use of thin high dielectric materials considerably reduces the radiation loss of the open strip. A microstripline has an advantage over the balanced striplines because the open strip has better interconnection features and easier fabrication. Several researchers have analyzed the circuit of a microstripline mounted on an infinite dielectric substrate over an infinite ground plane. Numerical analysis of microstriplines, however requires large digital computers whereas microstriplines problems can generally be solved by conformal transformations without requiring complete numerical calculations. The microstriplines structure shown in fig. (1c) consists of different components.



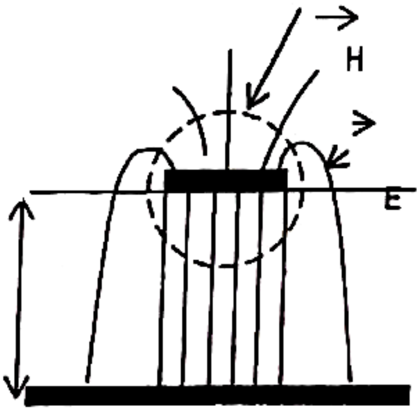


Fig. 1(a) : Microstripline (QUASI-TEM Mode) **Fig. 1(b)** : Microstripline Field configuration

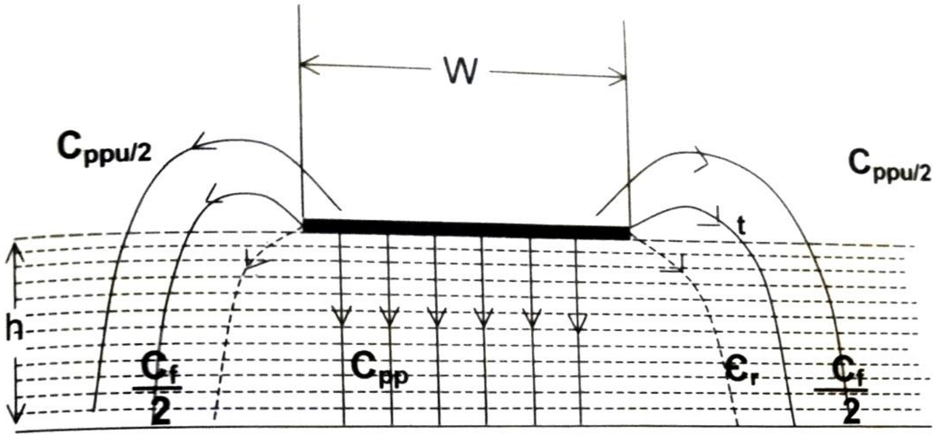


Fig. (1c) : Isolated conductor field configuration

3. Mathematical formulation for the characteristic parameters of single microstriplines

The characteristic impedance of TEM transmission line is given by

$$Z_0 = 1/v_P C_P \tag{1}$$

where, v_P = phase velocity of the wave travelling along the transmission structure

C_P = capacitance per unit length of the structure

Different components of microstripline structure as shown in Fig. (1c) are as follows

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

$$C_{PP} = [\in_{re}/c\eta][\omega/h] \tag{2}$$

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

$$C_{PPU} = (2/3)[\in_{re}/c\eta][\omega/h] \tag{3}$$

(iii) C_f = Fringing capacitance of the edges of the microstrip and the ground plane which is expressed as

$$C_f = [\in_{re}/c\eta](2.7/\log 4h/t) \tag{4}$$

where ω = microstrip width

$\in_{re}$ = the effective permittivity of the medium

h = height of the substrate

c = velocity of light in free space = 3×10^8 m/s

η = Free space impedance = 377 Ω

t = microstrip thickness

combining equation (2), (3) and (4), the total capacitance (C_P) per unit of the structure is expressed as

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

$$C_P = [\in_{re}/c\eta][\omega/h] + (2/3)[\in_{re}/c\eta][\omega/h] + [\in_{re}/c\eta](2.7/\log 4h/t) \tag{5}$$

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

For wide strip, $\in_{re} \cong \in_r$

and for narrow strip

$$\in_{re} = (\in_r + 1)/2$$

where $\in_r$ = relative permittivity

using this expression we can also calculated other characteristic parameters of transmission line e.g., propagation constant, phase velocity and guide wavelength.

4. Effective Permittivity ($\in_{re}$)

In the microstrip structure which resembles a parallel plate capacitor the electric flux is concentrated in the substrate below the stripline and also in the medium surrounding the strip. So the effective permittivity is written to a second approximation as

$$\in_{re} = [(\in_r + 1)/2].[1 + (\in_r - 1)/(\in_r + 1)][In(\pi/2) + 1]/\in_r \, In(4/\pi)]/In(8h/\omega)] \quad (6)$$

Schneider further modified this expression

$$\in_{re} = [(\in_r + 1) + 2] + [(\in_r - 1)/2][1 + (10h/\omega)]^{-1/2} \quad (7)$$

Which is suitable for narrow as well as wide strip.

But in case of very narrow microstrip line the electric flux is equally shared by air and the substrates such that at this extreme the $\in_{re}$ is nearly equal to $\in_r$.

5. Formulation of phase velocity

When microstrip source is connected to the strip line, wave starts flowing. The velocity with which the wave propagates is called phase velocity which is the function of the geometry of the striplines, height of the dielectric substrate and effective permittivity. The relation between phase velocity and effective permittivity is given for TEM mode as

$$C_P = c/\sqrt{\in_{re}}$$

where c = velocity of the wave in free space = 3×10^8 m/s

6. Conclusion

From the above discussion of the results in different sections it can be concluded that formulation of characteristic parameters such as characteristic impedance, phase velocity, guide wavelength, etc are very important to study of microstripline. The result shows that our study for the calculation of characteristic impedance and its variation as

(i) Characteristic impedance of single microstripline must be vary with the width (w) of microstripline

(ii) Characteristic impedance of single microstripline also vary with height of dielectric substrate.

These result provide useful information and greater tool for design and analysis of various microstripline devices, filters, directional coupler, etc. Thus this study can provide useful tool for the further study for microstripline devices.

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