ESTIMATION AND CHARACTERISTIC OF THE EFFECTIVE DIELECTRIC CONSTANT OF MICROSTRIP LINE USING QUASI STATIC ANALYSIS

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Abstract-

In this paper we propose the estimation of the characteristic impedance and the effective dielectric constant of microstrip line using quasi static analysis and performances are predicted using theoretical analysis. Numerically efficient and accurate formulae based on the quasi static method for the analysis of microstrip line structures are presented. The analysis formulas for microstrip line are derived and verified with Matlab. Characteristic Impedance of microstrip line for different normalized strip width as well as for different effective permittivity is under consideration in this work.

***Keywords* -** Microstrip line, Quasi –static, Effective Permittivity.

INTRODUCTION

The microstrip is the printed circuit version of a wire over a ground plane, and so it tends to radiate as the spacing between the ground plane and the strip increases. The microstrip line is widely used as planer transmission for RF and Microwave circuits due to its planar nature, ease of fabrication, ease of integration with solid-state devices, good heat sink, and good mechanical support. In today's modern communication industry and with the trend towards operation at X-band, Microstrip transmission lines are one of the most popular types of planar transmission lines. Microstrip line has been used extensively in microwave as well as transmission line for wide range application. Transmission system usually requires a portable and a probable system suited to less or lossless energy transmission, primarily because of its relative ease of fabrication and its simple integration with other passive and active microwave devices. Microstrip transmission line playing a major role to transport the total amount of energy fed at one point to another. It possess many advantages like mounting active device on top of Microstrip line, high frequency response, high-speed digital PCB designs where signals need to be routed from one part of the assembly to another with minimal distortion, and avoiding high cross-talk and radiation. Motivated by these inherent advantages, main concern is led towards the analysis of Microstrip line especially the variation of characteristic impedance of Microstrip line with various transmission line parameter, effective permittivity. Throughout the years, Microstrip transmission lines structures are the most common option used to realize microwave, radar and other communication devices. Due to its numerous advantages over the other transmission lines, the microstrip transmission lines have achieved importance and generated interest to microwave integrated circuit designers for many years.

STRUCTURE AND FORMULATION

Microstrip line comprising a conducting strip separated from a ground plane by a dielectric layer known as the substrate, which is shown in figure 1.

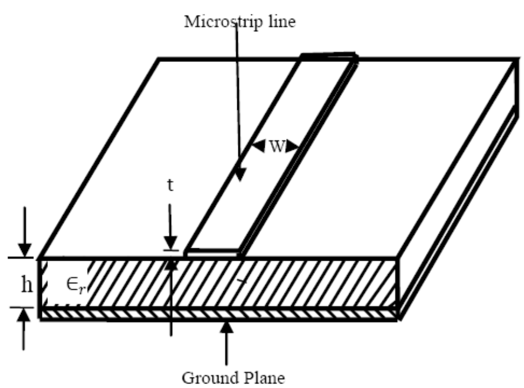


Figure 1: Microstrip line

In microstrip, the stripline and ground plane are located on opposite sides of the substrate. Because of the coupling of electromagnetic fields, a pair of coupled lines can support two different modes of propagation known as odd and even modes. These modes have different characteristics impedances. The velocity of propagation of these two modes is equal**,** when the lines are imbedded within an infinite homogeneous dielectric medium. But for coupled microstrip lines involving in homogeneous medium**,** a part of the field extends into the air above the substrate. This fraction is different for the two modes of coupled lines. Consequently, the effective dielectric constants are not equal for the two modes. When the two conductors of a coupled line pair are identical we have a symmetrical configuration. This symmetry is very useful for simplifying the analysis and design of such coupled lines. If the two lines do not have the same dimension, the configuration is called asymmetric. This paper aims to provide the reader with a comprehensive analysis of all fundamental concepts related to the open symmetrical coupled microstrip transmission lines.

ANALYSIS BY QUASI STATIC

A Microstrip line can be quasi-statically analyzed by the use of elliptical integral formulae. It consists in transforming the geometry of the PCB into another conformation.

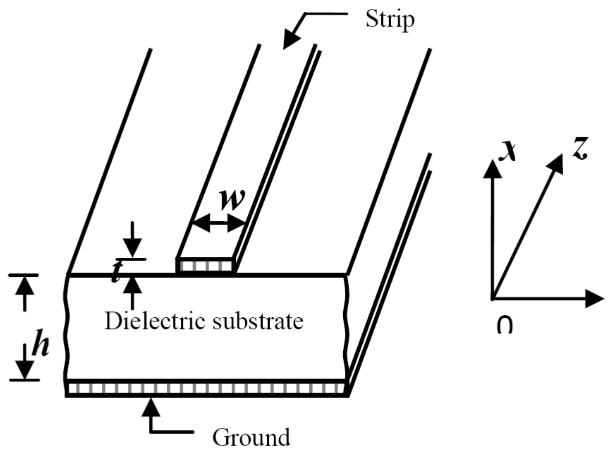


Figure 2: Symmetric diagram of microstrip line

Where *h* is the hight of substrate, *t* is thickness of microstrip line, *W* is slot width of microstrip line. One of the most challenging problems associated with this configuration arises from the fact that the small strip is not immersed in a single dielectric. On one side there is the board dielectric, and on the top is usually air. The technique that has been developed to handle this challenge uses, the concept of effective relative dielectric constant, $\in_{eff}$. This value represents some intermediate value between the relative dielectric constant of the board material, $\in_r$, and that of air (assumed equal to 1) that can be used to compute microstrip parameters as though the strip were completely surrounded by material of that effective relative dielectric constant. One obvious advantage of the microstrip structure is the "open" line which makes it very easy to connect components. Aside from the difficulty of calculating the value of $\in_{eff}$, there is another important effect. It is clear that $\in_{eff}$ will depend on both *W* and *h*. Hence, the phase velocity along the microstrip will depend on these parameters. Assuming the relative permeability of all materials in the line design is well approximated by $\mu_r = 1$, the phase velocity will be given by

$$v_p = \frac{c}{\sqrt{\in_{eff}}} \qquad \text{..............................(1)}$$

Since the characteristic impedance Z_o of the line will also depend on these parameters, every time we need to design a microstrip with a new characteristic impedance, we will be faced with the additional complication of having to deal with a change in phase velocity (or delay time) and consequently of the wavelength of waves on that microstrip. To get an idea of the range of ε_{eff}, consider the cases of a very wide width W and then a very narrow width W.

$$maximum\ \in_{eff} = \in_r \qquad \text{.......................................(2)}$$

Eqn. (2) is in the form of an "effective" microstrip width (W_e), which is used to replace W.

For a wide microstrip, nearly all of the electric field lines will be concentrated between the metal planes, similar to the case of a parallel plate capacitor, and for narrow width W the electric field lines will be about equally divided between the air and the board dielectric so that:

$$maximum\ \in_{eff} = \frac{1}{2}\left(\in_r + 1\right) \qquad \text{.......................................(3)}$$

This gives a range:

$$\frac{1}{2}\left(\in_r + 1\right) \le \in_{eff} \le \in_r \qquad \text{.......................................(4)}$$

Several different equations have been developed for use in calculating characteristic impedance for microstrip design. Probably the most useful are the following which are reported to be accurate to within about 1%.

$$Z_0 = \frac{60}{\sqrt{\varepsilon_{eff}}} \ln\left(8\frac{h}{W} + \frac{W}{4h}\right) \qquad \text{...............................(5)}$$

Where

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[\left(1 + 12\frac{h}{W}\right)^{\frac{1}{2}} + 0.04\left(1 - \frac{W}{h}\right)^2\right] for\ \frac{W}{h} \le 1 \qquad \text{..............................(6)}$$

$$Z_0 = \frac{120\Pi}{\sqrt{\varepsilon_{eff}}\left[\frac{W}{h} + 1.393 + 0.667\ln\left(\frac{W}{h} + 1.444\right)\right]} \qquad \text{.......................................(7)}$$

Where

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[\left(1 + 12\frac{h}{W}\right)^{-\frac{1}{2}}\right] for\ \frac{W}{h} \ge 1 \qquad \text{.......................................(8)}$$

These are relatively equations for the calculation of characteristic impedance, given W, h, and ε_{eff}. However, the more useful calculation involves determination of the W/h ratio, given a required characteristic impedance. Here, then, is the design challenge since the equations are transcendental for the W/h parameter. Now, modify to the above equations which is a consequence of considering the finite thickness (t) of the microstrip. This modification is in the form of an "effective" Microstrip width (W_e), which is used to replace W in those equations:

$$W_e = W + \frac{t}{\pi}\left[1 + \ln\left(\frac{2h}{t}\right)\right] \; for \frac{W}{h} \geq \frac{1}{2\pi} \qquad \text{...(9)}$$

$$W_e = W + \frac{t}{\pi}\left[1 + \ln\left(\frac{4\pi W}{t}\right)\right] \; for \frac{W}{h} \leq \frac{1}{2\pi} \qquad \text{.......................................(10)}$$

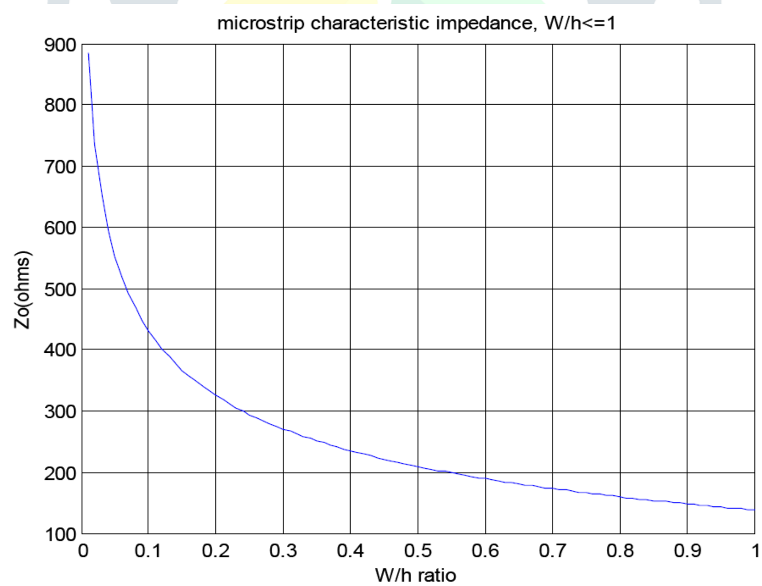
RESULT AND DISCUSSION

a.) CHARACTERISTIC IMPEDANCE V/S NORMALISED STRIP WIDTH

Normalized strip width is known as ratio of width of Microstrip line and height of the substrate. The graph represents the variation of characteristic impedance with normalized strip width for substrate is chosen to be of glass fiber.

1.1 Normalized strip width when $w/h \leq 1$

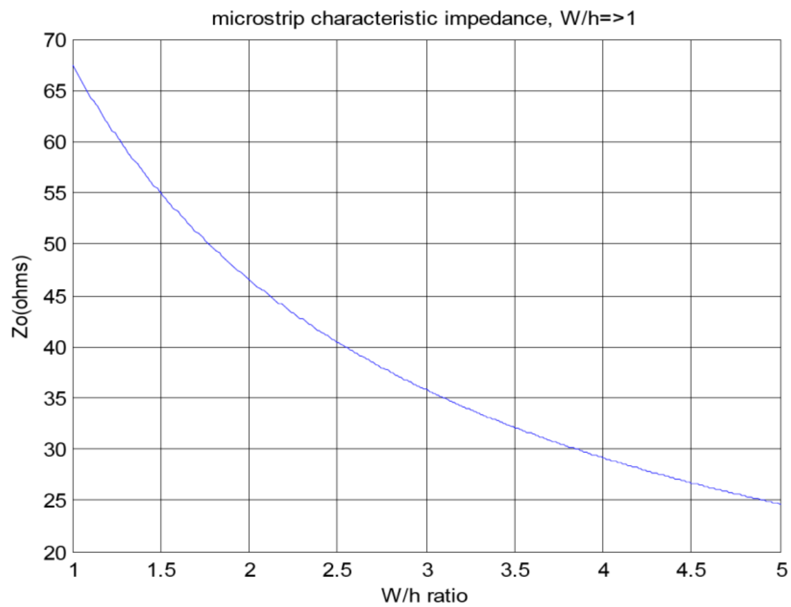
Graph 1.1 shows the variation of characteristic impedance with normalized strip width.



Graph1.1. variation of characteristic impedance v/snormalized strip width

1.2 Normalized strip width when $w/h \geq 1$

Grap1.2 shows the variation of characteristic impedance with normalized strip width.



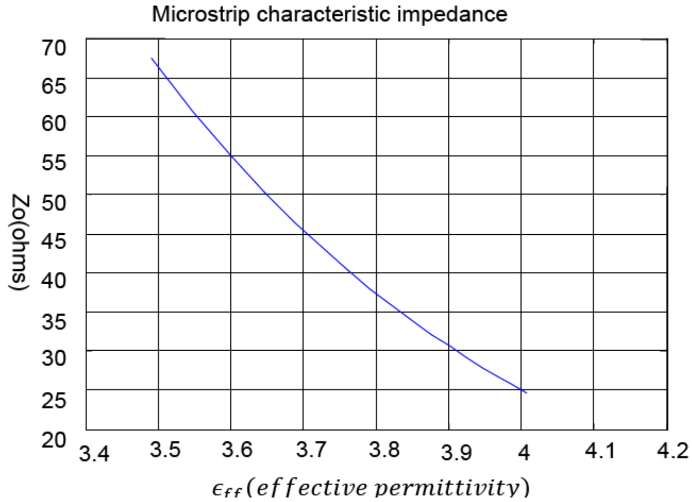
Graph1.2. variation of characteristic impedance v/s normalized strip width

As seen in both the above graph, that when normalized strip width is kept between 1 to 5, then the characteristic impedance decreases with increases in normalized strip width. But when the same normalized strip width is kept between 0 to 1 then there is a sudden and rapid decrease in characteristic impedance

b) CHARACTERISTIC IMPEDANCE V/S EFFECTIVE PERMITIVITY

2.1 Effective permittivity for $w/h \geq 1$

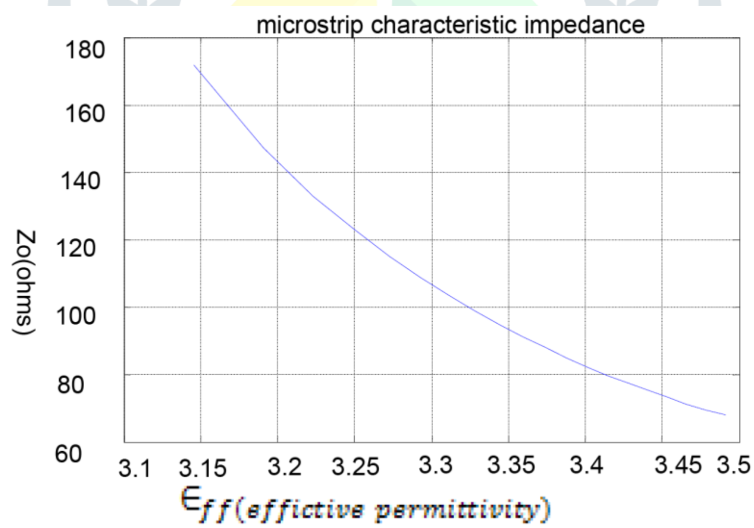
Graph 2.1 shows the variation of characteristic impedance with different value of effective permittivity. In this graph it is clear that, as we increase the effective relative permittivity, the value of characteristic impedance decreases when the value of normalized strip width is greater than equal to 1.



Graph2.1: variation of characteristic impedance v/s effective permittivity

2.2 Effective permittivity for $^{w}/_{h} \leq 1$

Figure 4.4 shows the variation of characteristic impedance with different value of effective permittivity. In the graph it is clear that, as we increase the effective relative permittivity, the value of characteristic impedance decreases when the value of normalized strip width is less than equal to 1.



Graph2.2: variation of characteristic impedance v/s effective permittivity

The characteristic impedance of any type of transmission line decreases with increase in relative permittivity and can be expressed by using formula from transmission line is given by

$$Z_0 = \sqrt{\frac{R + j\omega L}{G + j\omega C}} \qquad ....(11)$$

Where,

R = Resistance per unit length,

L = Inductance per unit length

G = Conductance per unit length

C = Capacitance per unit length

Form the above mention formula, the condition arises $R \times C = L \times G$ for distortion less transmission line. Since there is no wires or long conducting element L and G cannot be changed so it is very evident from the above condition that only R and C can be inversely proportional to each other as C is dependent on relative permittivity and R can be treated as characteristic impedance it can be knuckled with the fact that whenever C Increases R decreases.

CONCLUSION

Work has been done to demonstrate the utility of microstrip line and its advantages especially energy is to be transferred from one point to another, in a very compact and efficient form. A simple and inexpensive method also known as quasi-static has been applied for calculating the characteristic impedance as well as effective permittivity. Variation of characteristic impedance for different value of normalized strip width as well as different value of effective permittivity is represented. It has been observed that characteristic impedance decreases with advancement of normalized strip width and also decreases for increasing effective permittivity. This property can be applied in microwave transmission theory to design different antenna models for different purposes along with the advantage of minimal distortion, and avoiding high cross-talk and radiation.

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