Experiment No. 3 ANALYSIS OF MICROSTRIP LINE

Aim:

To observe and understand the effect of variation of W/h on the characteristic impedance of a microstrip line.

Software requirements:

Software- AWR TXLINE
Operating System- Windows 7 and above

Theory:

A microstrip line consists of a single ground plane and a thin strip conductor on a low-loss dielectric substrate above the ground plate. Since the size of the microwave solid-state devices is very small (of the order 0.008–0.08 mm3), the technique of signal input to these devices and extracting output power from them uses microstrip lines on the surface on which they can be easily mounted. Figure (a) shows a typical cross section of a microstrip line.

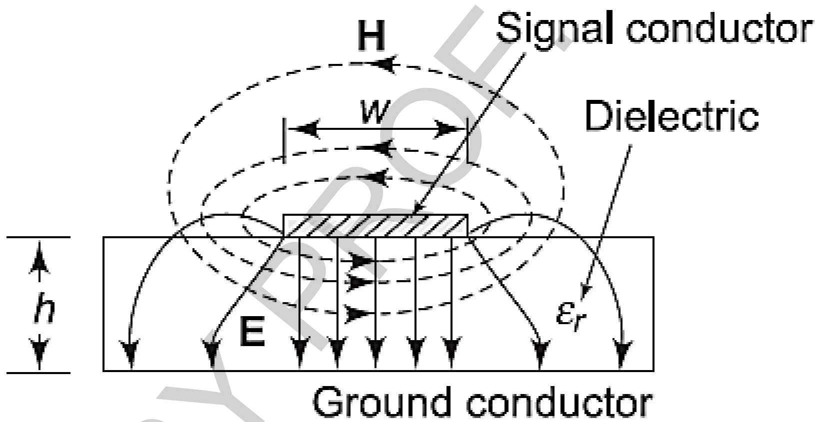

Fig.-(a) Typical cross section of a microstrip line

Due to absence of a top ground plate and the dielectric substrate above the strip, the electric field lines remain partially in the air and partially in the lower dielectric substrate. This makes the mode of propagation not pure TEM but what is called quasi-TEM. Due to open structure and any presence of discontinuity, the microstrip line radiates electromagnetic energy. The radiation loss is proportional to the square of the frequency. The use of thin and high dielectric materials reduces the radiation loss of the open structure where the fields are mostly confined inside the dielectric.

Effective Dielectric Constant

Since the propagation field lines in a microstrip lie partially in air and partially inside the homogenous dielectric substrate, the propagation delay time for a quasi-TEM mode is related to an effective dielectric constant ε_{eff}, given by

$$\varepsilon_{\mathrm{eff}} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[\left(1 + \frac{12h}{w}\right)^{-1/2} + 0.04\left(1 - \frac{w}{h}\right)^2\right]; w/h \le 1$$

$$\varepsilon_{\mathrm{eff}} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{12h}{w}\right)^{-1/2}; w/h \gg 1$$

where, ε_r is the relative dielectric constant of the substrate material.

Characteristic Impedance and Guide Wavelength

The characteristic impedance of microstrip lines can be expressed by

$$Z_0 = \frac{60}{\sqrt{\varepsilon_{\mathrm{eff}}}} \ln\left[\frac{8h}{w} + \frac{w}{4h}\right] \text{ohm, } w/h \le 1$$

$$Z_0 = \frac{376.7}{\sqrt{\varepsilon_{\mathrm{eff}}}\left[\frac{w}{h} + 1.4 + 0.667 \ln\left(\frac{w}{h} + 1.444\right)\right]} \text{ohm; for } w/h > 1$$

$$Z_0 = \frac{376.7}{\sqrt{\varepsilon_{\mathrm{eff}}}} \frac{h}{w} \text{ ohm; for } w/h \gg 1$$

The guide wavelength for the propagation of quasi-TEM mode is given by

$$\lambda_g = \frac{\lambda_0}{\sqrt{\varepsilon_{\mathrm{eff}}}}$$

The commonly used substrate materials for strip and microstrip lines are polytetrafluoroethylene (PTFE)/Teflon, RT Duroid 5880, alumina, and sapphire, etc., whose electrical characteristics are given in Table 1. Alumina is most widely used for frequencies up to 20 GHz. At higher frequencies, sapphire is used.

Table 1: Properties of substrate materials

Material	ε_r	*tan δ*
PTFE/glass	2.2	0.0002–0.0005
RT/Duroid 5880	2.26	0.001
Alumina	9.6 – 10	0.0002–0.0005
Sapphire	9.4	0.0001
GaAs	11–13	0.0016
Si	12	0.015

Numerical Example:

For a microstrip line operating at 10 GHz, dielectric constant = 4.4 (glass epoxy), loss tangent = 0.025, physical length = 100 mm, substrate height = 0.2 mm, thickness = 35 um, demonstrate the effect of variation of W/h on the characteristic impedance of a microstrip line.

Observation Table:

W (mm)	W/h	Z_0 (ohm)		W (mm)	W/h	Z_0 (ohm)
0.2	1			1.8	9	
0.4	2			2	10	
0.6	3			2.2	11	
0.8	4			2.4	12	
1	5			2.6	13	
1.2	6			2.8	14	
1.4	7			3	15	
1.6	8			3.2	16	

Output:

(Students are required to attach the graphical representation illustrating effect of variation of W/h on characteristic impedance of a microstrip line).

Conclusion:

By performing this experiment, we observe that as W/h goes on increasing, the characteristic impedance of a microstrip line keeps on reducing as expected in accordance with theoretical formula for Z_0 of microstrip line.