Lecture 12

Planar Transmission Lines

- First step to fabricate microwave integrated circuit
- it can be fabricated by thin film or photo lithographic techniques.
- it is available in various configurations such as strip lines, microstrip, slot line, coplanar lines etc.

Stripline

Conventional stripline is a balanced line in which a flat conducting strip is placed symmetrically between two large ground planes, with the space between the ground planes (GP) filled with a homogeneous dielectric.

Soln of 2D Laplace eqn subject to B.C.

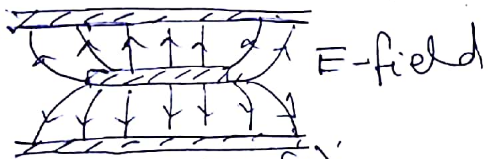


Fig (c)

Fig (d)

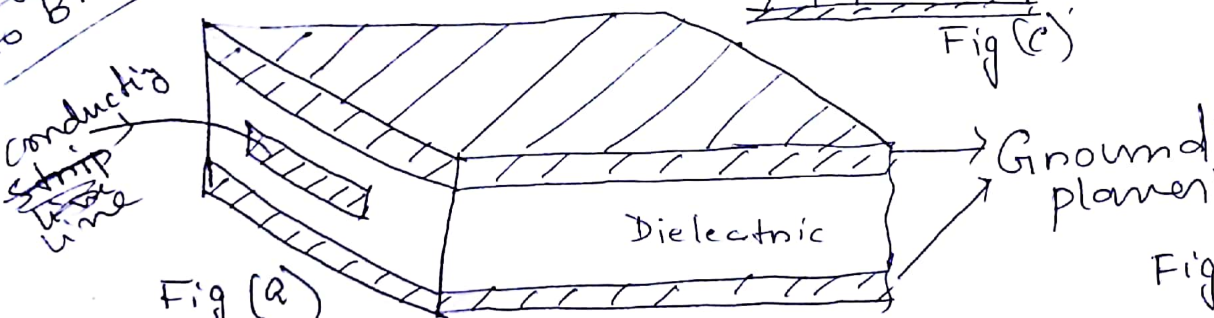


Fig (a)

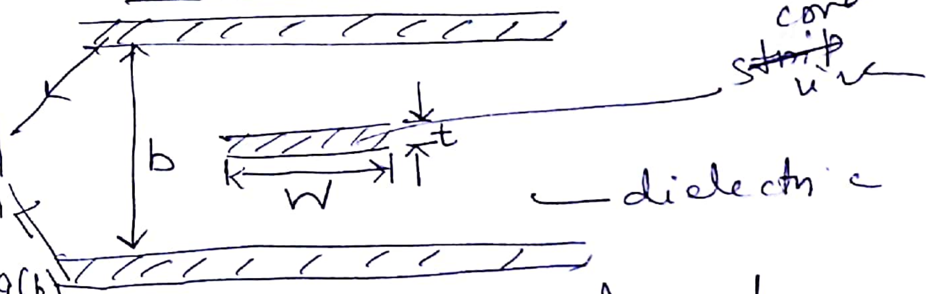


Fig (b)

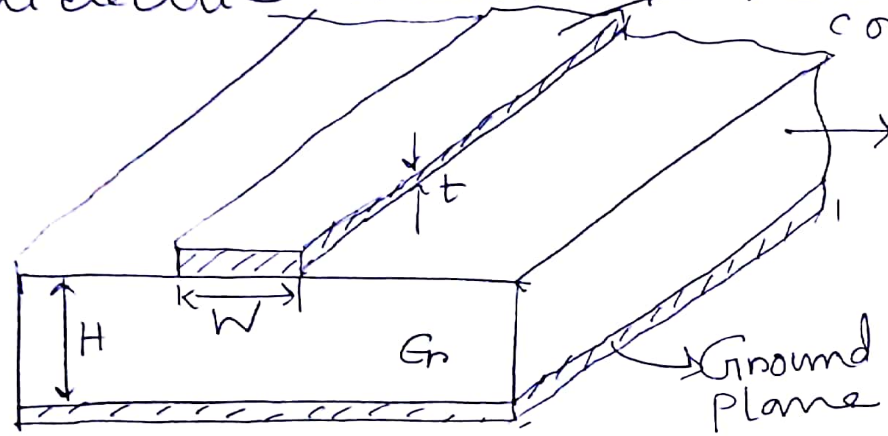
TEM mode — GP at zero potential ~~w.r.t~~ — field line concentrated near central conductor.

characteristic eqn of line $Z_0 = \frac{1}{V_p \cdot C}$; V_p = phase velocity along stripline $= \frac{V_0}{\sqrt{\epsilon_r}}$ — velocity in free space

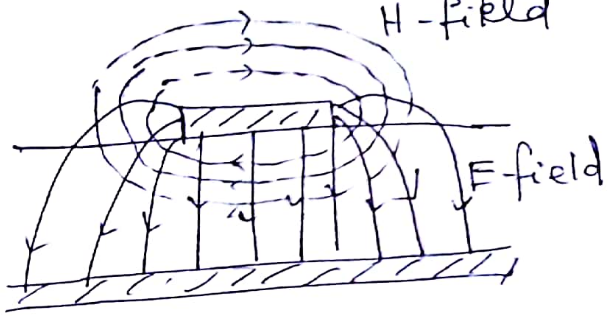
C = shunt capacitance of unit length of the line; relative ~~die~~ permittivity of dielectric medium

Microstrip lines

Open transmission line that consists of a strip conductor and a ground plane separated by a dielectric medium



Why popular?

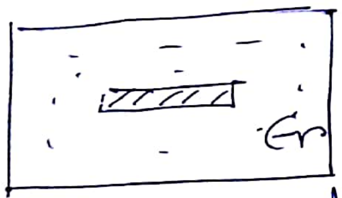


quasi - TEM

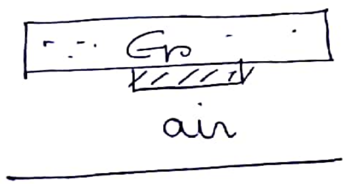
W = width of the upper conducting strip
H = Height of the dielectric substrate
t = thickness of the upper conducting strip
Gr = relative dielectric const of the substrate

three major factors for selecting dielectric

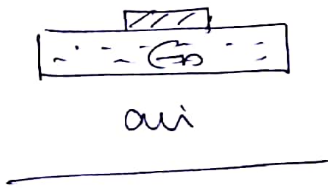
properties of dielectric substrate



Embedded microstrip line

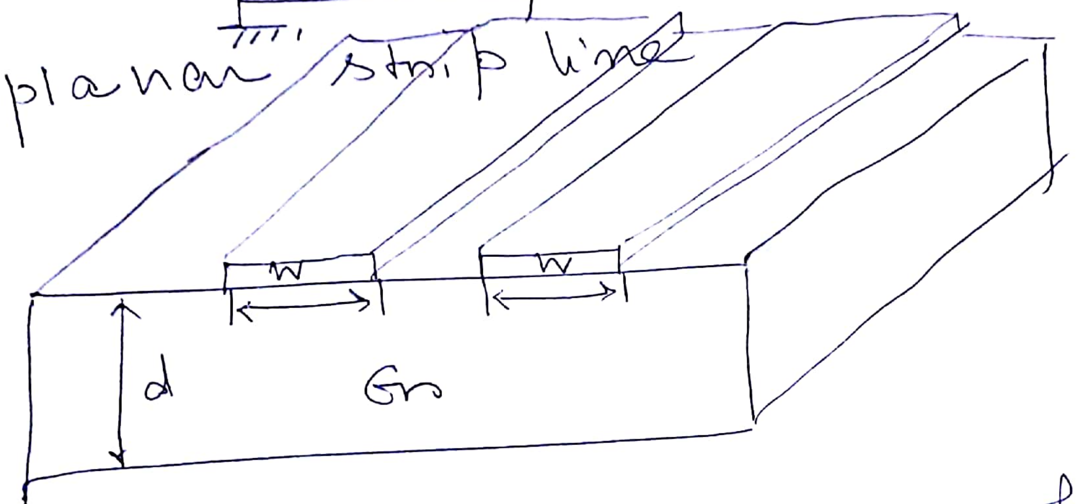


Inverted microstrip line

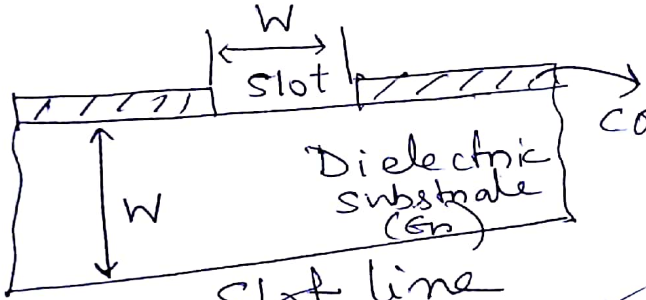


suspended microstrip

coplanar strip line

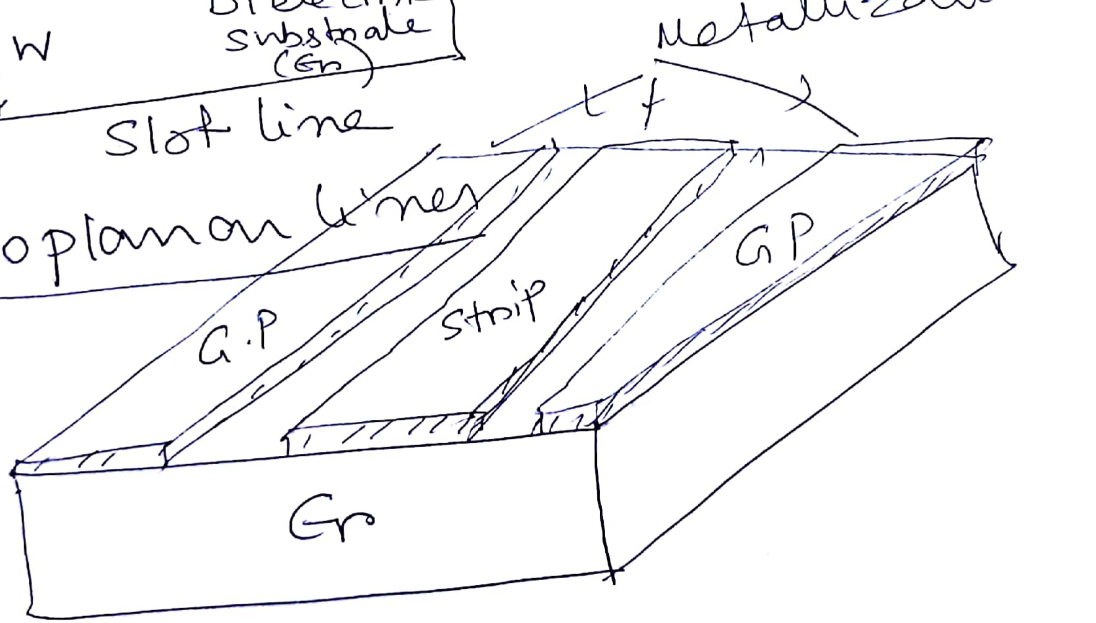


SLOT LINE : It consists of a slot on a gap between two conducting strips on a dielectric substrate.



Slot line

Coplanar lines



CPW feed.

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.

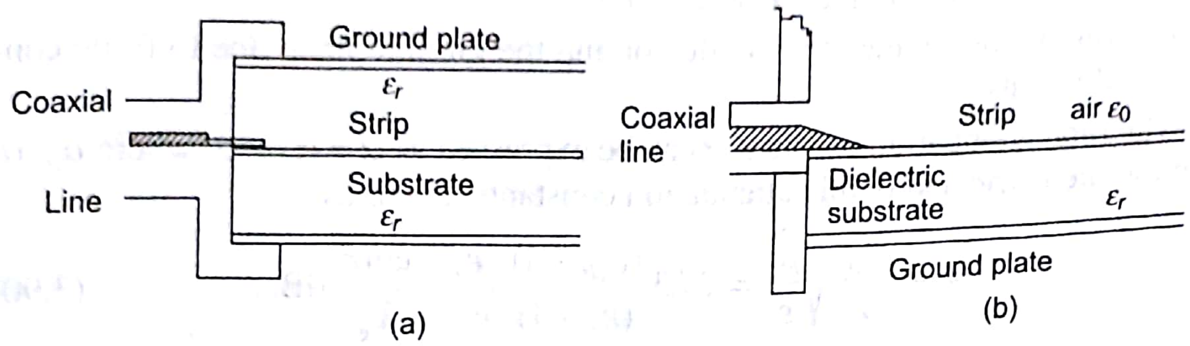


Fig. 3.19 *Strip line launcher connector (a) Strip line connector (b) Microstrip line connector*

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

$$\varepsilon_{\text{eff}} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[\left(1+\frac{12h}{W}\right)^{-1/2} + 0.04\left(1-\frac{W}{h}\right)^2\right];\ W/h \le 1 \quad (3.84)$$

$$\varepsilon_{\text{eff}} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1+\frac{12h}{W}\right)^{-1/2};\ W/h \gg 1 \quad (3.85)$$

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

$$Z_0 = \frac{60}{\sqrt{\varepsilon_{\text{eff}}}}\ln\left[\frac{8h}{W} + \frac{W}{4h}\right] \text{ ohm, } W/h \le 1 \quad (3.86)$$

$$Z_0 = \frac{376.7}{\sqrt{\varepsilon_{\text{eff}}}\left[\frac{W}{h} + 1.4 + 0.667\ln\left(\frac{W}{h} + 1.444\right)\right]} \text{ ohm; for } W/h > 1 \quad (3.87)$$

$$Z_0 = \frac{376.7}{\sqrt{\varepsilon_{\text{eff}}}}\frac{h}{W} \text{ ohm; for } W/h \gg 1 \quad (3.88)$$

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

$$\lambda_g = \lambda_0/\sqrt{\varepsilon_{\text{eff}}} \quad (3.89)$$

The characteristic impedance for a microstrip line vs W/h with ε_r as a parameter is plotted in Fig. 3.20. It is seen that the value of Z_0 decreases with increase of W/h and also with increase of ε_r.

When a pure TEM mode is assumed to exist, the method of conformal transformation may be used for the calculation of capacitance in the case of microstrip also. Because of the mixed dielectric configuration the analysis is carried out in two stages. First the capacitance is calculated for a uniform dielectric microstrip line. This result is then extended to cover the real microstrip case simply by replacing the 'uniform' dielectric constant ε_r by the 'effective' dielectric constant ε_{eff}. The concept of effective dielectric constant is explained in Fig. 10.6 (b). Wheeler (1965) has given a conformal transformation useful for microstrip analysis and derived micro-strip design formulas based on that. These consist of two different relations for wide ($W/h > 2$) and narrow ($W/h < 2$) microstrip lines because of the different approximations used. Recently (Wheeler, 1977) an empirical relation that covers both the ranges has been reported and may be written as

$$\frac{W}{h} = 8\frac{\{[\exp Z_0\sqrt{\varepsilon_r+1}/42.4-1](7+4/\varepsilon_r)/11+(1+1/\varepsilon_r)/0.81\}^{1/2}}{\exp\{(Z_0\sqrt{\varepsilon_r+1}/42.4)-1\}} \qquad ...(10.14)$$

Relation (10.14) is suitable for design (or synthesis). For analysis it may be reversed and put in the following form

$$Z_0 = \frac{42.4}{\sqrt{\varepsilon_r+1}}\ln\left\{1+\left(\frac{4h}{W}\right)\left[\left(\frac{14+8/\varepsilon_r}{11}\right)\left(\frac{4h}{W}\right)\right.\right.$$

$$\left.\left.+\sqrt{\left(\frac{14+8/\varepsilon_r}{11}\right)^2\left(\frac{4h}{W}\right)^2+\frac{1+1/\varepsilon_r}{2}\pi^2}\right]\right\} \qquad ...(10.15)$$

Effective dielectric constant may be found by evaluating an additional value of Z_0 for $\varepsilon_r = 1$. We have

$$\varepsilon_{eff} = \left(\frac{Z_0(\varepsilon_r=1)}{Z_0}\right)^2 \qquad ...(10.16a)$$

Alternatively, an empirical expression (Schneider, 1969) gives ε_{eff} directly in terms of ε_r, W and h. This may be written as

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}\left(1+\frac{10h}{W}\right)^{-1/2} \qquad ...(10.16b)$$

Variation of microstrip characteristic impedance with W/h is shown in Fig. 10.7. It may be noted that for microstrip lines, the phase velocity v_p is given by

$$v_p = c/\sqrt{\varepsilon_{eff}} \qquad ...(10.17)$$

Since ε_{eff} is a function of W and h, the phase velocity and hence the guide wavelength depends upon the line impedance also. This factor has to be taken into account while designing microstrip circuits.