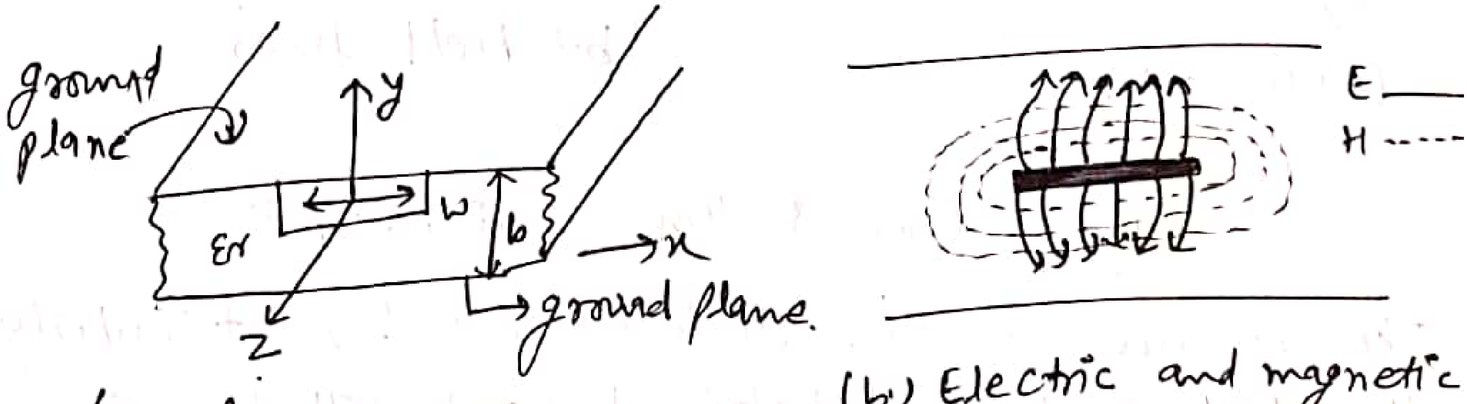
Q.(1)(b) PLANAR TRANSMISSION LINES:-

→ **Striplines:-** Stripline is a planar type of transmission line that lends itself well to microwave Integrated circuitry and photolithographic technique. The transmission line that were used generally were coaxial, waveguide or parallel strip line circuits. for recent years stripe type can be fabricated by employing printed circuit technologies (Photolithography, etching etc) and are easily integrated with other passive and active microwave devices. Geometry of stripline is shown in fig. A thin conducting strip of w is centered between two wide conducting ground planes of separation b and the entire region b/w the ground planes is filled with a dielectric.



(a.) Geometry

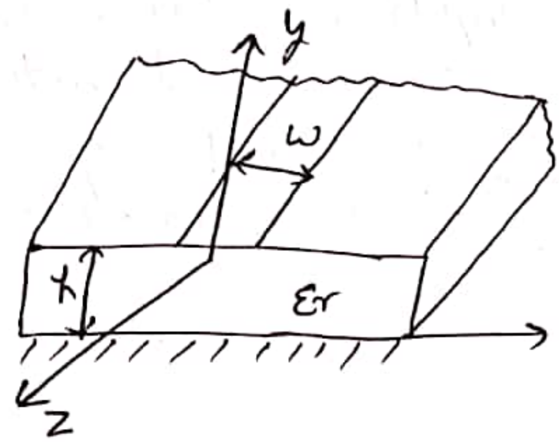
(b.) Electric and magnetic field lines

fig:- Stripline transmission line.

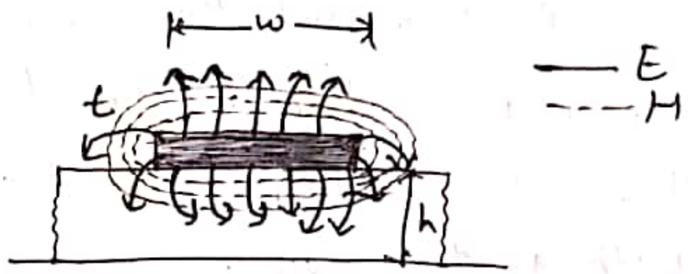
Stripline is conducted by etching the center conductor on a grounded substrate of the same thickness. It uses a planner geometry which implies that the characteristic of the line can be determined from the dimensions in a single plane.

→ Microstripline :-

Microstripline is one of the most popular types of planar transmission lines, primarily because it can be fabricated by photolithographic processes and is easily integrated with other passive and active circuits. It is asymmetric stripline in which a conductor of ~~which~~ width 'w' is printed on a thin, grounded dielectric substrate of thickness h and relative permittivity ϵ_r. The geometry of microstrip line is shown in fig.



(a.) Geometry



(b.) field lines

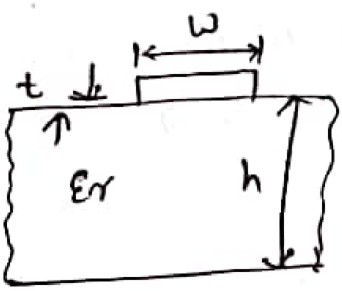
Fig.:- Cross section of microstrip lines

The presence of the dielectric, and particularly the fact that the dielectric does not fill the air region above the strip, complicates the behavior and analysis of microstrip line. Unlike stripline where all the fields are contained within a homogeneous dielectric region, microstrip has some of it's field lines in the dielectric region, concentrated b/w the strip conductor and the ground plane and some fraction in air above the substrate.

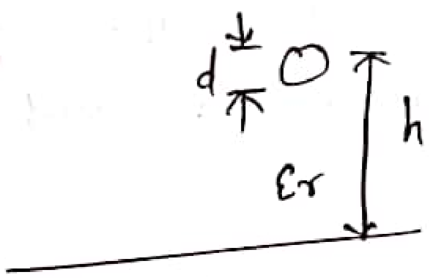
→ Characteristic Impedance of microstripline:-

In microstrip line the circuit inter connection can be made easily since they can be fabricated by automated digital techniques and they provide the required uniform signal path.

The characteristic impedance of a microstrip-line is a function of stripline width, stripline thickness, the distance between the line and ground plane, and the homogeneous dielectric constant of the board material.



(a.) micro strip line



(b.) A wire over ground line

fig:- Comparison of micro strip line and wire over ground

Various methods were developed to calculate the characteristics impedance of the microstrip line but comparative or the most convenient method was indirect method in which microstrip line is considered to be a wire over ground.

The characteristic impedance of wire over ground transmission line is given by -

$$Z_0 = \frac{60}{\sqrt{\epsilon_r}} \ln \frac{4h}{d} \quad \text{for } h >> d \qquad —(1.)$$

Where ε_r = dielectric constant

h = the height from the center of the wire to the ground plane.

d = diameter of the wire.

→ **Effective dielectric constant (ε_{eff}):-**

Since some of the field lines are in the dielectric region and some are in air, one might suspect that the actual value of dielectric constant of the micro-strip line must lie somewhere between 1 and ε_r which is termed as the effective dielectric constant ε_{eff} of the microstrip line and satisfies the relation

$1 < \varepsilon_{eff} < \varepsilon_r$.

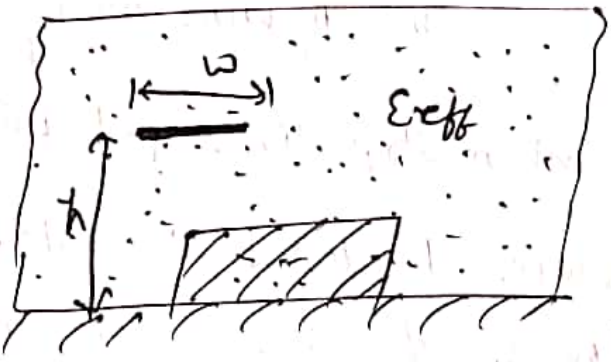


Fig.:- Equivalent geometry of micro strip line.

For a homogeneous medium the propagation delay time per unit length is -

$$\tau_d = \sqrt{\mu \epsilon} \qquad (2)$$

Where μ = permeability of medium.

ϵ = permittivity of medium

∴ for free space propagation delay is —

1(a) $\tau_{df} = \sqrt{\mu_0 \epsilon_0} = 3.333\ ns/m$ or $1.016\ ns/ft$ —— (3)

Where $\mu_0 = 4\pi \times 10^{-7}\ H/m$ or $3.83 \times 10^{-7}\ H/ft$

$\epsilon_0 = 8.854 \times 10^{-12}\ f/m$ or $2.69 \times 10^{-12}\ F/ft$

This relation was -

$$\epsilon_{re} = 0.475\epsilon_r + 0.67 \quad \text{—— (4)}$$

Where ϵ_r = relative dielectric constant

ϵ_{re} = effective relative dielectric constant

There are also other many relations which can be used to calculate characteristic impedance and effective microstrip permittivity as a function of the dimensions and substrate permittivity. The cross section microstripline as shown in fig. is rectangular. The rectangular conductor of width w and thickness t can be transformed into an equivalent circular conductor by an empirical equation -

$$d = 0.67w\left(0.8 + \frac{t}{w}\right) \quad \text{—— (5)}$$

Where d = diameter of the wire over ground

w = width of microstrip line

t = thickness of microstrip line

on substituting eqn. (4) for the dielectric constant and eqn. (5) for the equivalent diameter in eqn. (1)

$$Z_0 = \frac{60}{\sqrt{0.475\varepsilon_r + 0.67}} \ln \frac{4h}{0.67w\left(0.8 + \frac{t}{w}\right)} \quad (6.)$$

$$Z_0 = \frac{87}{\sqrt{\varepsilon_r + 1.41}} \ln \left(\frac{5.97h}{0.8w + t}\right) \text{ for } (h < 0.8w) \quad (6.)$$

~~Where ε_r~~

The characteristic impedance for wide microstrip line $(w \gg h)$ is –

$$Z_0 = \frac{h}{w}\sqrt{\frac{\mu}{\varepsilon}} = \frac{h}{w}\frac{377}{\sqrt{\varepsilon_r}} \quad (w \gg h) \quad (7)$$

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

$$\lambda_g = \frac{\lambda_0}{\sqrt{\varepsilon_{eff}}} \quad (8.)$$

→ Limitations of micro strip :-

1. Most of the field in microstrip is concentrated in the dielectric substrate, a slight change in ε_r is due to temperature variation or both to batch variation changes the impedance and guide wavelength considerably.

2. Ckt dimensions at high frequencies are comparatively quite small, this leads to the fabrications problems.

3. As frequency is increased the substrate becomes thin but this makes Q very low.

4. As frequency is increased the conductors losses increases. It can ~~can~~ safely be used in the range upto about 50 GHz.

→ Parallel Striplines :-

A parallel stripline consists of two perfectly parallel conducting strips separated by a perfect dielectric slab of uniform thickness. The schematic diagram of parallel strip line is shown in fig.

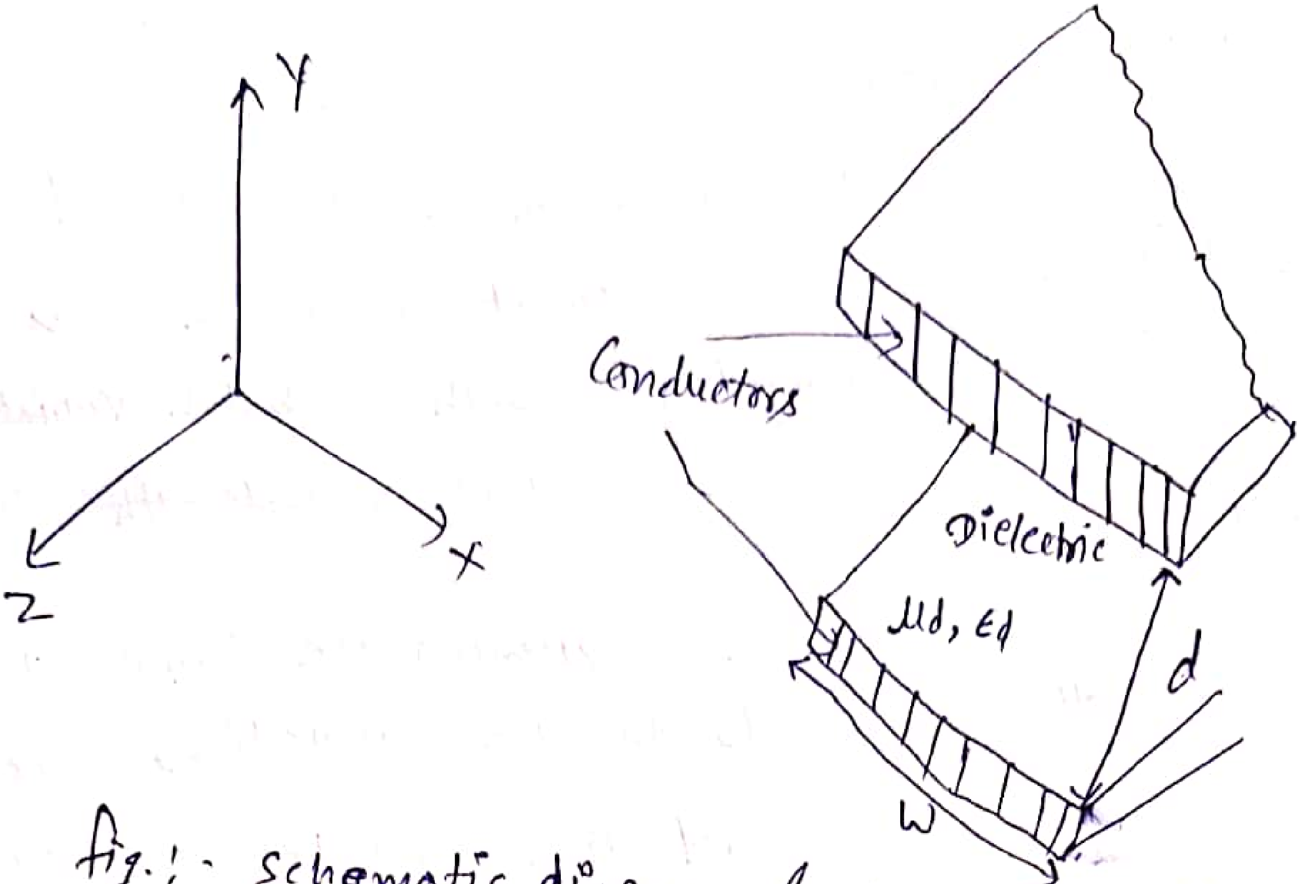


fig:- schematic diagram of parallel stripline

Here the two parallel strip has width greater then the distance b/w then ($w >> h$) and thickness t ($w >> t$). The relative permittivity and permeability of the dielectric slab placed b/w these two parallel strip is ϵ_d and μ_d respectively. It can support a TEM mode, since it is similar to two conductor transmission line. The field pattern is shown in fig.

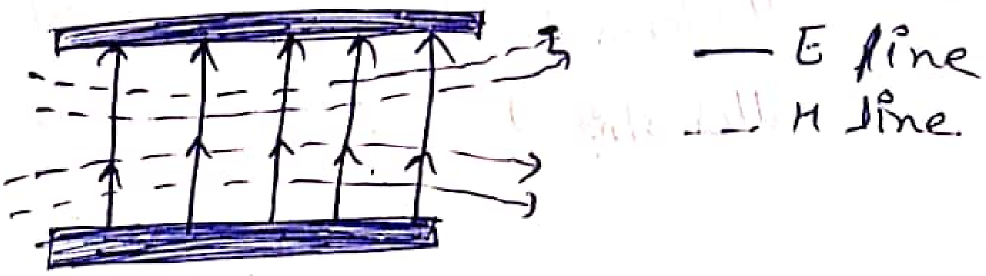


fig:- TEM field pattern in parallel stripline

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→ Distributed parameters:-

Here we assumed the electric field is in y-dirⁿ, magnetic field is in x-dirⁿ and wave is propagating in +z-dirⁿ. If the width w is much larger than the separation distance d, the fringing capacitance is negligible. Then the eqⁿ for the inductance along the two conducting strip can be given as –

$$L = \frac{\mu_c d}{w} \; H/m$$

where μ_c → permeability of the conductor.

The capacitance b/w two conducting strips can be expressed as –

$$C = \frac{\epsilon_d w}{d} \; F/m.$$

where ϵ_d → Permittivity of dielectric slab.

At high frequencies the maximum current charge gets accumulated at the surface this leads to surface resistance leading to some losses. The series resistance for both strips is given by –

$$R = \frac{2R_s}{w} = \frac{2}{w}\sqrt{\frac{\pi f \mu_c}{\sigma_c}} \; \Omega/m$$

where $R_s = \sqrt{\frac{(\pi f \mu_c)}{\sigma_c}}$

R_s → is the conductor surface resistance

The shunt conductance of the striplines is—

$$G = \frac{\sigma_d w}{d} \ \mho/m$$

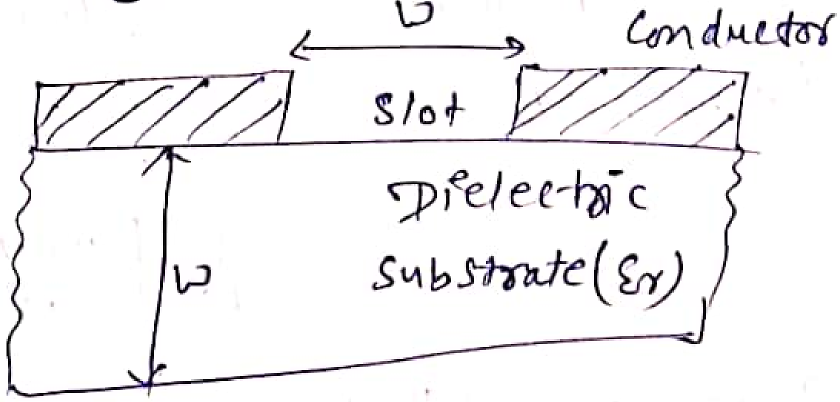
Here σ_d → Conduction of dielectric substrate.

→ **Slot lines:-**

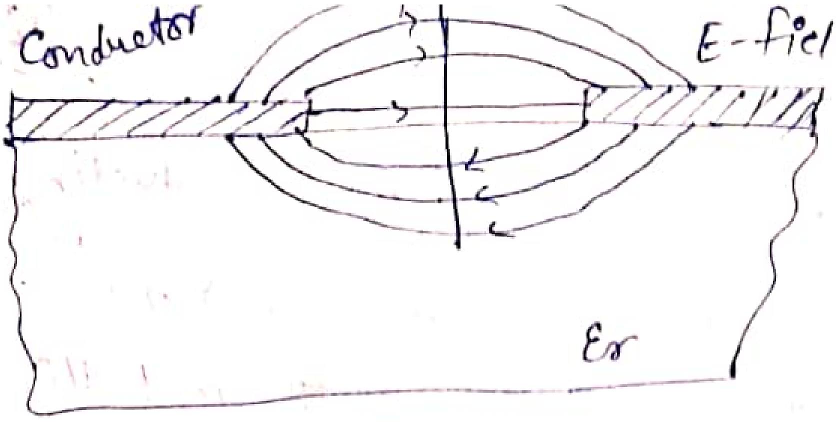
It consists of a slot or a gap b/w two conducting strips on a dielectric substrate as shown in fig. The electric and magnetic field lines are shown in fig. (a.) and (b.)

main features of a slot line are:-

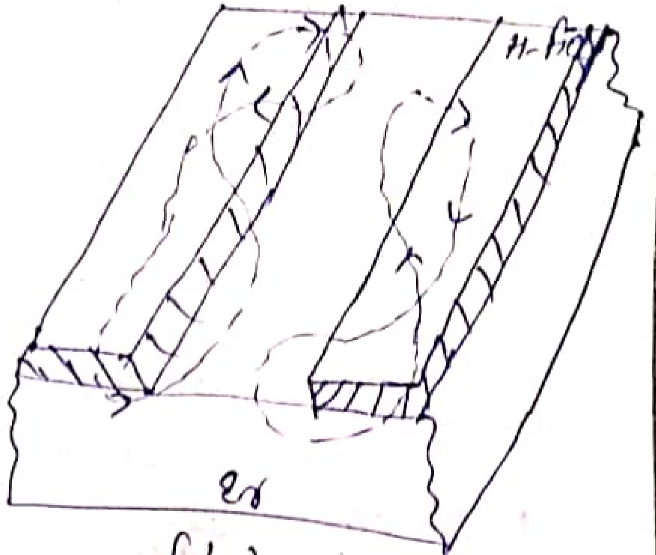
1. As both the conductors are in one plane and therefore shunt mounting of components across the line is very convenient than microstrip.
2. Higher impedance can be easily realized by increasing the slot widths than a microstrip



Slot line.



(a)



(b.)

fig. (a.) E-field in slot line, (b.) H-field in slot line.

③ In a slot line variation of Z_0 and λ_0/λ_g with frequency are larger than microstrip.

④ Resonance isolator can be designed by properly selecting a location in the slot line where the magnetic field is circularly polarized.

⑤ The substrate concentrates the field density b/w the plates, suppressing higher order modes.

⑥ It is easy to fabricate because it requires only single sided board etching.

The disadvantages of slot line is that –

① Its Q factor is low, so it is relatively lossy.

② the field configuration deviates greatly from TEM.