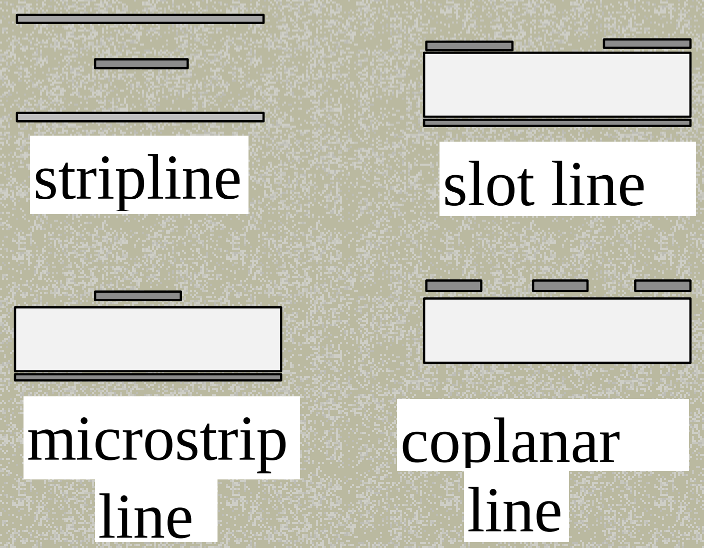
Planar Transmission Line

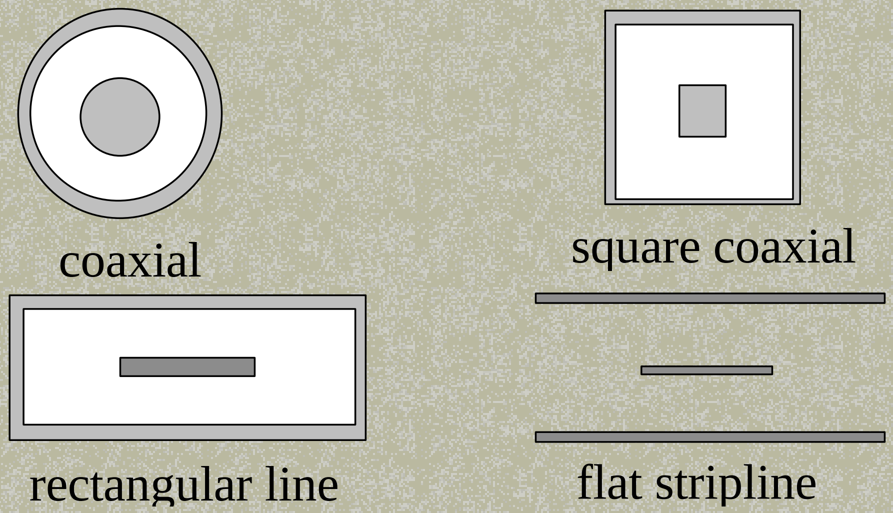
Striplines and Microstrip Lines

- various planar transmission line structures are shown here:



Striplines and Microstrip Lines

- the strip line was developed from the square coaxial

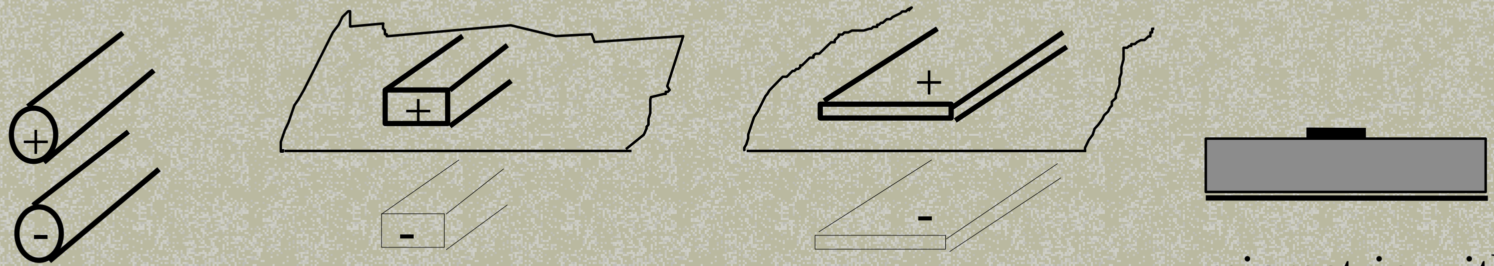


Striplines and Microstrip Lines

- since the stripline has only 1 dielectric, it supports TEM wave, however, it is difficult to integrate with other discrete elements and excitations
- microstrip line is one of the most popular types of planar transmission line, it can be fabricated by photolithographic techniques and is easily integrated with other circuit elements

Striplines and Microstrip Lines

- the following diagrams depicts the evolution of microstrip transmission line



two-wire line | single-wire above ground (with image) | microstrip in air (with image) | microstrip with grounded slab

Striplines and Microstrip Lines

- a microstrip line suspended in air can support TEM wave
- a microstrip line printed on a grounded slab does not support TEM wave
- the exact fields constitute a hybrid TM-TE wave
- when the dielectric slab become very thin (electrically), most of the electric fields are trapped under the microstrip line and the fields are essentially the same as those of the static case, the fields are quasi-static

Striplines and Microstrip Lines

- one can define an effective dielectric constant so that the phase velocity and the propagation constant can be defined as

$$v_p = \frac{c}{\sqrt{\varepsilon_e}} ----(47)$$

$$\beta = k_o \sqrt{\varepsilon_e} ---(48)$$

- the effective dielectric constant is bounded by $1 < \varepsilon_e < \varepsilon_r$, it also depends on the slab thickness d and conductor width, W

Design Formulas of Microstrip Lines

- design formulas have been derived for microstrip lines
- these formulas yield approximate values which are accurate enough for most applications
- they are obtained from analytical expressions for similar structures that are solvable exactly and are modified accordingly

Design Formulas of Microstrip Lines

- or they are obtained by curve fitting numerical data

- the effective dielectric constant of a microstrip line is given by

$$\varepsilon_r = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \frac{1}{\sqrt{1 + 12d / W}} - - - - (49)$$

Design Formulas of Microstrip Lines

- the characteristic impedance is given by
- for W/d≤1

$$Z_o = \frac{60}{\sqrt{\varepsilon_r}} \ln\left(\frac{8d}{W} + \frac{W}{4d}\right) ----(50)$$

- For W/d ≥ 1

$$Z_o = \frac{120\pi}{\sqrt{\varepsilon_r}\left[W/d + 1.393 + 0.667\ln(W/d + 1.444)\right]} --(51)$$

Design Formulas of Microstrip Lines

- for a given characteristic impedance Z_o and dielectric constant ε_r , the W/d ratio can be found as

$$W/d = \frac{8e^{A}}{e^{2A}-2} ----(52)$$ **for W/d<2**

Design Formulas of Microstrip Lines

$$W/d = \frac{2}{\pi}[B - 1 - \ln(2B-1) + \frac{\varepsilon_r - 1}{2\varepsilon_r} \times$$

- $$\{\ln(B-1) + 0.39 - \frac{0.61}{\varepsilon_r}\}] ----(53)$$ for W/d > 2
- Where $$A = \frac{Z_o}{60}\sqrt{\frac{\varepsilon_r + 1}{2}} + \frac{\varepsilon_r - 1}{\varepsilon_r + 1}(0.23 + \frac{0.11}{\varepsilon_r})$$
- And $$B = \frac{377\pi}{2Z_o\sqrt{\varepsilon_r}}$$

Design Formulas of Microstrip Lines

- for a homogeneous medium with a complex dielectric constant, the propagation constant is written as

$$\gamma = \alpha_d + j\beta = \sqrt{k_c^2 - \kappa^2}$$

$$\gamma = \sqrt{k_c^2 - \omega^2 \mu_o \varepsilon_o \varepsilon_r (1 - j \tan\delta)}$$

- note that the loss tangent is usually very small

$$\gamma = \sqrt{k_c^2 - k^2 + jk^2 \tan\delta}$$

Design Formulas of Microstrip Lines

- Note that $(1+x)^{1/2} = 1 + x/2$ where x is small
- therefore, we have

$$\gamma = \sqrt{k_c^2 - k^2} + \frac{jk^2 \tan\delta}{2\sqrt{k_c^2 - k^2}} \quad --- (54)$$

Design Formulas of Microstrip Lines

- Note that $j\beta = \sqrt{k_c^2 - k^2}$
- for small loss, the phase constant is unchanged when compared to the lossless case
- the attenuation constant due to dielectric loss is therefore given by
- $\alpha_d = \dfrac{k^2 \tan\delta}{2\beta}$ Np/m (TE or TM) (55)

Design Formulas of Microstrip Lines

- For TEM wave $k = \beta$, therefore
- $\alpha_d = \dfrac{k \tan\delta}{2}$ **Np/m (TEM) (56)**
- for a microstrip line that has inhomogeneous medium, we multiply Eq. (56) with a filling factor

$$\frac{\varepsilon_r(\varepsilon_e - 1)}{\varepsilon_e(\varepsilon_r - 1)}$$

Design Formulas of Microstrip Lines

- $$\alpha_d = \frac{k_o \sqrt{\varepsilon_e} \tan\delta}{2} \frac{\varepsilon_r(\varepsilon_e - 1)}{\varepsilon_e(\varepsilon_r - 1)} = \frac{k_o \varepsilon_r (\varepsilon_e - 1) \tan\delta}{2\sqrt{\varepsilon_e}(\varepsilon_r - 1)} \quad (57)$$
- the attenuation due to conductor loss is given by

$$\alpha_c = \frac{R_s}{Z_o W}$$

- (58) Np/m where

$$R_s = \sqrt{\omega\mu_o / (2\sigma)}$$

- R_s is called the surface resistance of the conductor

Design Formulas of Microstrip Lines

- note that for most microstrip substrate, the dielectric loss is much more significant than the conductor loss
- at very high frequency, conductor loss becomes significant

Application Potential OF MICROWAVE COMPONENTS

- Most widely used guide structures in component development are image guides.
- Best potential at freq above 60GHz
- Use of dielectric H-guide and groove-guide structures at for freq. beyond 100GHz.
- Realizing high-performance antennas.
- Feed structures for array antennas.
- Incorporation of active devices in dielectric guides is more difficult than in suspended striplines or fin lines
- Realizing dynamically controlled devices such as switches, phase shifters and attentuators.