# Transmission Line Geometries

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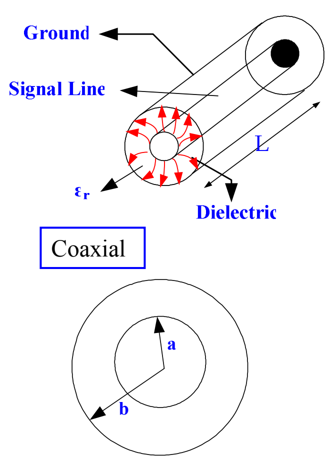
**RF/MW Circuits – I**

Powerpoint slides originally prepared by B. Lakshminarayanan.

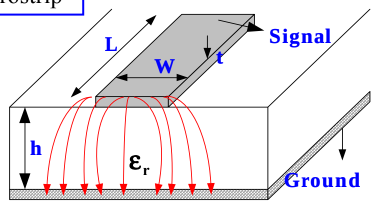
## Transmission Lines - Coaxial




- Typical: $1 \le \varepsilon_r \le 2.2$
  - $1\text{mm} \le b \le \ldots$
- TEM mode: $$Z_0 = \frac{\sqrt{\mu/\varepsilon}\,\ln\left(b/a\right)}{2\pi}$$ $$V_p = \frac{c}{\sqrt{\varepsilon_r}} = \lambda_g f$$
- When dimensions become "electrically large" non-TEM modes can propagate. They are dispersive. Above "cut-off" frequency ($f_c$)
- Keep a, b, $\varepsilon_r$ small for high $f_c$ $$f_c = \frac{c\left(\frac{2}{a+b}\right)}{2\pi\sqrt{\varepsilon_r}}$$

# Transmission Lines - Microstrip

Microstrip



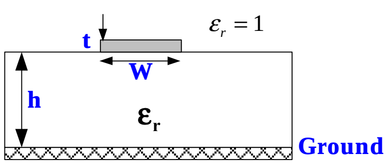

- Typical: $1 \le \varepsilon_r \le 13.1$
  - $0.1mm \le h \le 2.5mm$
  - $0.5\mu m \le h \le 35\mu m$

  (100GHz) (10GHz)
- Microstrip is not a pure TEM mode if $\varepsilon_r \ge 1$ but close to TEM (called quasi-TEM) if $h << \lambda$.
- Pure TEM exists only in homogeneous medium



# Microstrip (cont'd)

- Effective dielectric constant:
  - If microstrip were embedded in a uniform medium and had same $Z_0$ and $V_p$ as in non-uniform medium then the equivalent dielectric constant will be $\varepsilon_{re}$

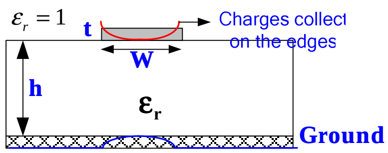



$$\varepsilon_{re} = \frac{\varepsilon_r + 1}{2} + correction\ factor$$

$$V_p = \frac{c}{\sqrt{\varepsilon_{re}}}; \quad \beta = \frac{\omega}{V_p} = \frac{2\pi}{\lambda_g} \quad \text{for quasi TEM mode!!!}$$

- Equations for $Z_0$ and $\varepsilon_{re}$ (or $\varepsilon_e$) ⇒ page 144-145 (Pozar 3rd edition). Look in **Transmission Lines and Waveguides** Chapter

# Microstrip (cont'd)




- Higher order modes:
  - When microstrip dimensions become electrically large, higher order modes will propagate ($f_{c,TE1}$, $f_{c,TR}$)

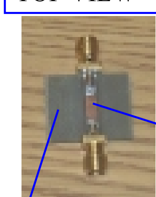
$$f_{c,TE1} = \frac{c}{4h\sqrt{\varepsilon_r - 1}} \qquad f_{c,TR} = \frac{c}{\sqrt{\varepsilon_r}\left(2W + 0.8h\right)}$$

- Keep $f < f_{c,TE1}$ and $f_{c,TR}$
- Loss: Conductor, dielectric, and radiation ⇒ all increase with frequency



# Some pictures

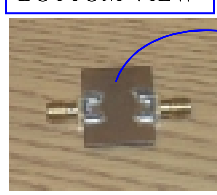
TOP VIEW



SIGNAL

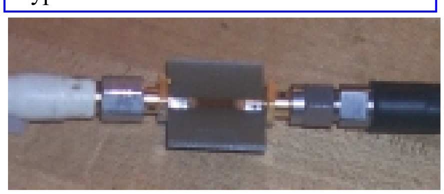
DIELECTRIC

BOTTOM VIEW

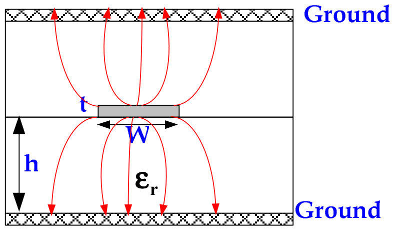


GROUND PLANE

Typical connection for measurement



# Stripline

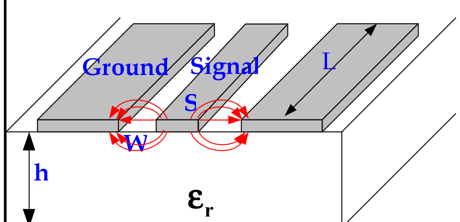



- Homogenous medium ⇒ non-dispersive ⇒ TEM mode of propagation

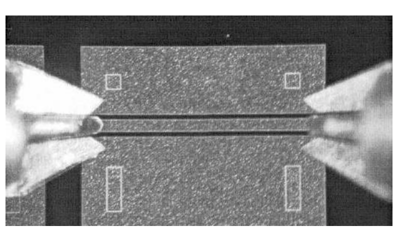
$$V_p = \frac{c}{\sqrt{\varepsilon_r}}$$



# Coplanar Waveguide




Coplanar Waveguide (CPW)



TOP VIEW

- Less dispersive than microstrip
- Easy to connect to ground
- $Z_0$ decreases as S/(S+2W) increases and as $\varepsilon_r$ increases
- Very good for mm-wave design
- To prevent higher order modes propagation, keep

$$S + 2W < \left(\frac{\lambda_g}{10}\right) \qquad \varepsilon_{re} = \frac{\varepsilon_r + 1}{2}$$