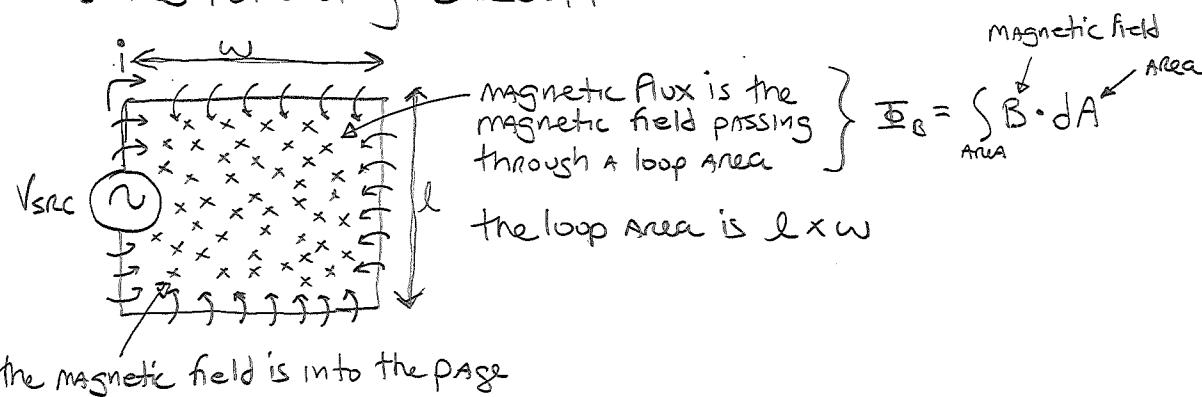


Return Currents - Practical Considerations

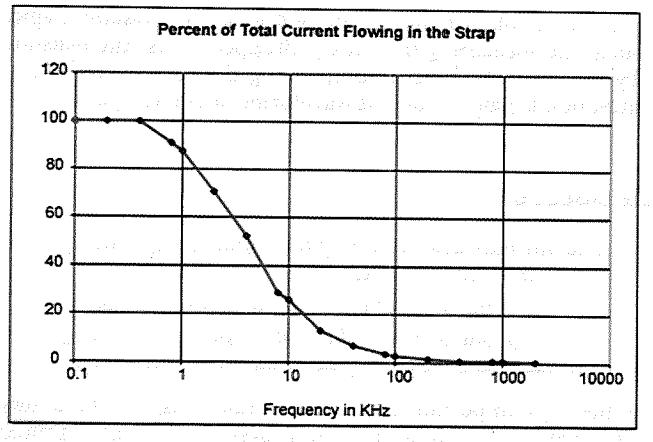
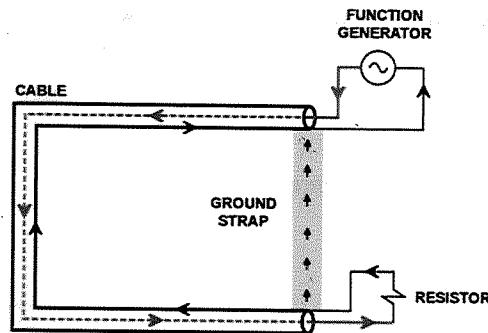
Consider the following circuit:



- If we induce a time-varying current in the loop, there will be a time-varying magnetic flux induced in the loop that creates a voltage that is in opposition to the source (back emf.)
- The loop Area is the primary physical factor that effects the inductive opposition.
- The degree of opposition caused by the inductor is inductive impedance.
- The inductance is a constant of proportionality that expresses how much opposition occurs with a given current. $L = \frac{\Phi_B}{I}$
- Thus, a greater loop Area increases Φ_B , which increases inductance. Since $X_L = 2\pi f L$, at higher frequencies, return currents will follow the path of least impedance.
- You cannot have an inductor without a loop of current!
- For a loop: $L = \mu_0 R \ln\left(\frac{8R}{r} - 2\right)$; R = Radius of loop r = Radius of wire L = inductance $\mu_0 = 1.257 \times 10^{-6}$ H/meter

Example T-Line Structures - Practical Considerations

Return currents flow through the path of least impedance.



There are 2 paths for the return current to take.

At low frequencies $Z = R + j\omega L$ is dominated by R ; return via ground strap mostly.

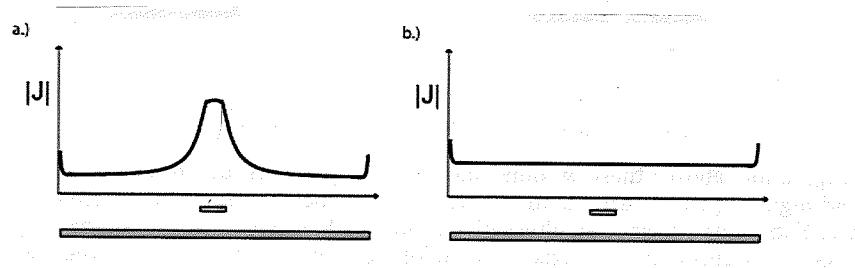
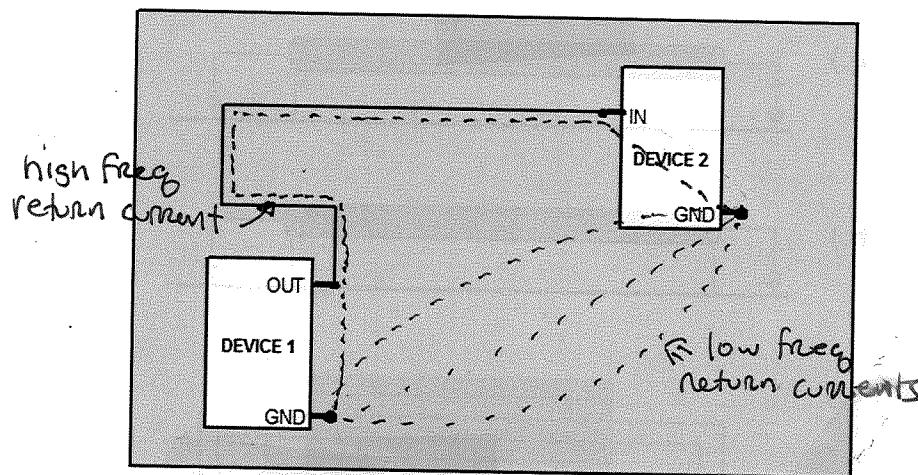
At high frequencies the path through the strap forms a large loop area.

This forms a larger "L" than the small area within the coax.

Return currents at high frequency will flow along the insine of the coax shield.

Return Currents (cont.)

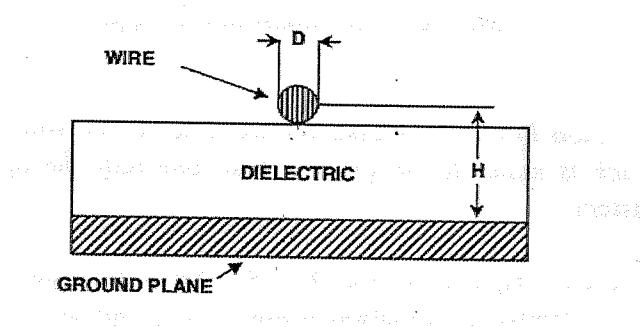
The same scenario occurs on a PCB. Consider the following:



Ground Plane Current Density

- High Frequencies (MHz + above)
- Low Frequencies (kHz + below)

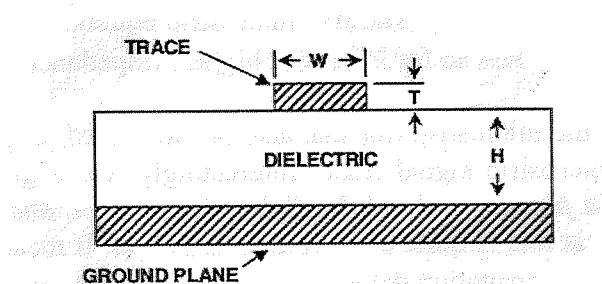
Example T-Line Structures



(Dimensions in mils (.001")
(FROM IPC-2141A)

- | How do $\zeta + L$ vary with the different geometries?
- | Calculate w/formulas?
- | Think: parallel plate, loop Area (ζ) (L)

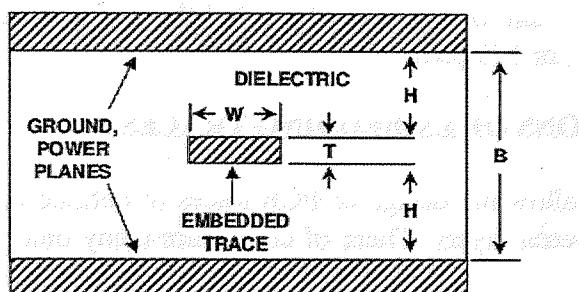
Wire microstrip (wire over groundplane)



Microstrip

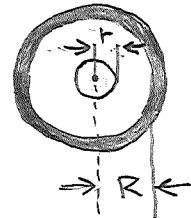
For 20 mil trace width, 1 oz Cu, Ant
10 mil dielectric (FR-4) $\approx 50\Omega$
for 75Ω , change $W = 8.3$ mils

$$Z_0(\Omega) = \frac{87}{\sqrt{\epsilon_r + 1.41}} \ln \left[\frac{5.98H}{(0.8W+T)} \right]$$



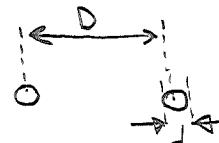
embedded microstrip or stripline

Simple Line Structures



$$Z_0 = 60 \frac{\ln\left(\frac{R}{r}\right)}{2\pi\epsilon_r}$$

Coaxial Cable



$$Z_0 = 276 \log_{10} \left(\frac{D}{d} \right)$$

Twin Lead

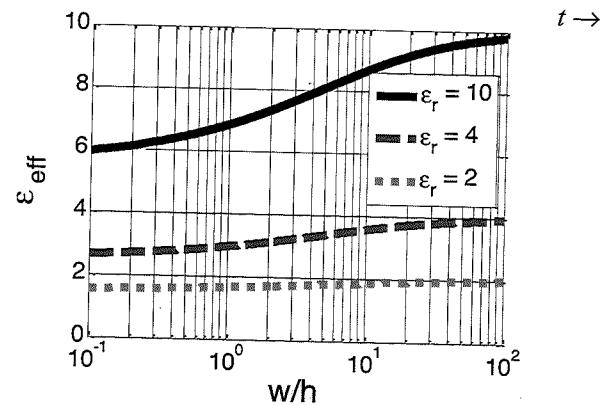
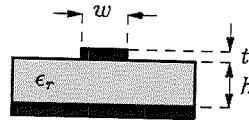
for Air dielectric & $D \gg d$

- All these formulas are approximations and are about $\pm 10\%$ accurate.
- "Eyeballing" Z_0 is all about cross-sectional area
- See www.eeweb.com/toolbox

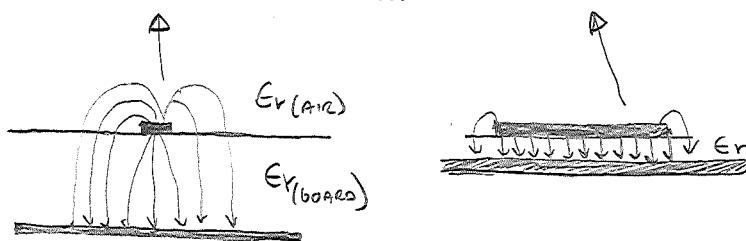
Practical Considerations

Microstrip – Effective Dielectric Constant

$$\epsilon_{\text{eff}} \approx \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \frac{1}{\sqrt{1 + 10 h/w}}$$



$t \rightarrow 0$

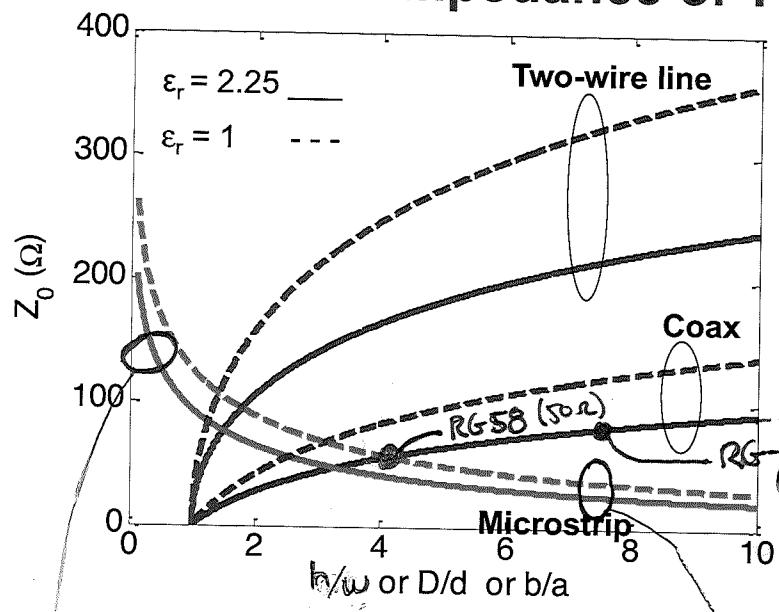


As the dielectric constant of a board goes up, the trace width has more of an impact on the effective dielectric constant.

Practical Considerations - Manufacturing Issues

6

Characteristic Impedance of TLs



Two-wire line $\frac{D}{d} = 15$ ($\#1b + D = 0.75$)
300 ohm twin lead (#22 + .3 = D)

1 oz Cu, $w=5$ mil, $h=63$ mil, 147 ohm

Board becoming very thick

1 oz Cu, $w=30$ mil, $h=6$ mil, 22 ohm
Traces very wide