

# EE 3113

# INTRODUCTION INTO RF

# CIRCUIT DESIGN

Lecture Notes for A-term 1999

## LECTURE 5

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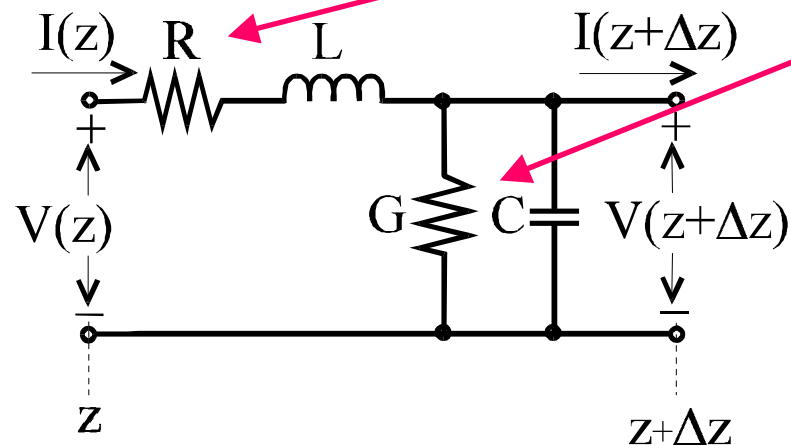
Worcester, MA

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# Lossless Transmission Line Model

- Line representation

Lossless implies:  
 $R = G = 0!$



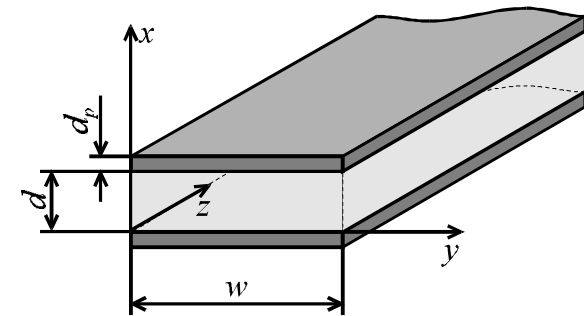
Characteristic impedance:

$$Z_0 = \sqrt{\frac{(R + j\omega L)}{(G + j\omega C)}}$$

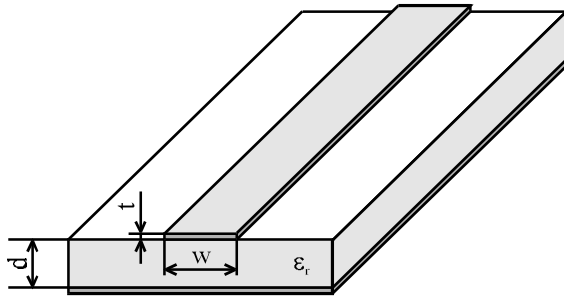
**Note:**  $R, L, G, C$  are given per unit length and depend on geometry

# Transmission Line Parameters for different line types

|   | 2-wire                                             | coax                                                         | parallel-plate    |
|---|----------------------------------------------------|--------------------------------------------------------------|-------------------|
| R | $\frac{1}{p a s d}$                                | $\frac{1}{2 p s d} \left( \frac{1}{a} + \frac{1}{b} \right)$ | $\frac{2}{w s d}$ |
| L | $\frac{m}{p} c h^{-1} \left( \frac{D}{2a} \right)$ | $\frac{m}{2p} \ln \left( \frac{b}{a} \right)$                | $m \frac{d}{w}$   |
| G | $\frac{p s}{c h^{-1} (D/(2a))}$                    | $\frac{2 p s}{\ln(b/a)}$                                     | $s \frac{w}{d}$   |
| C | $\frac{p e}{c h^{-1} (D/(2a))}$                    | $\frac{2 p e}{\ln(b/a)}$                                     | $e \frac{w}{d}$   |

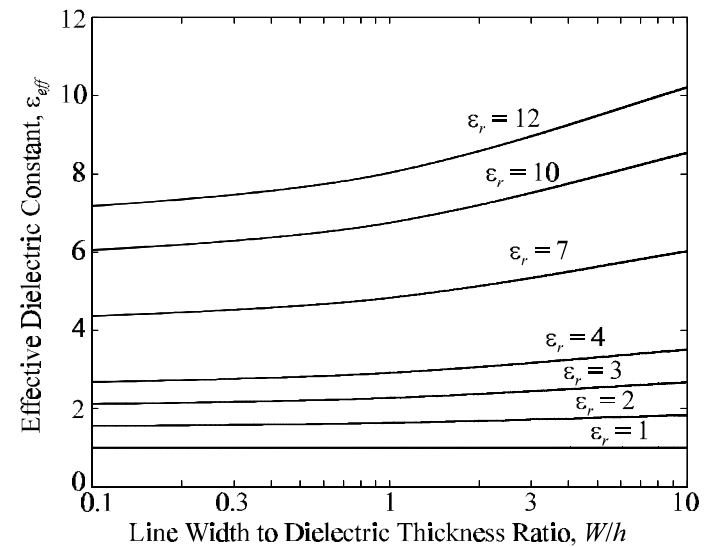
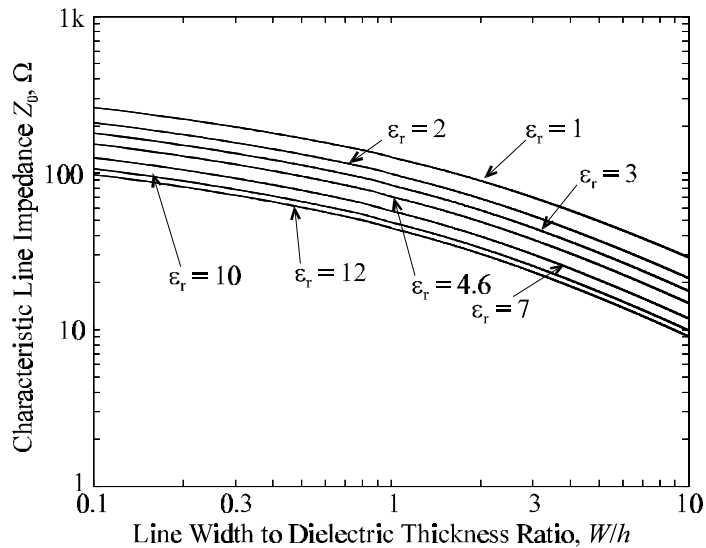


# Microstrip line

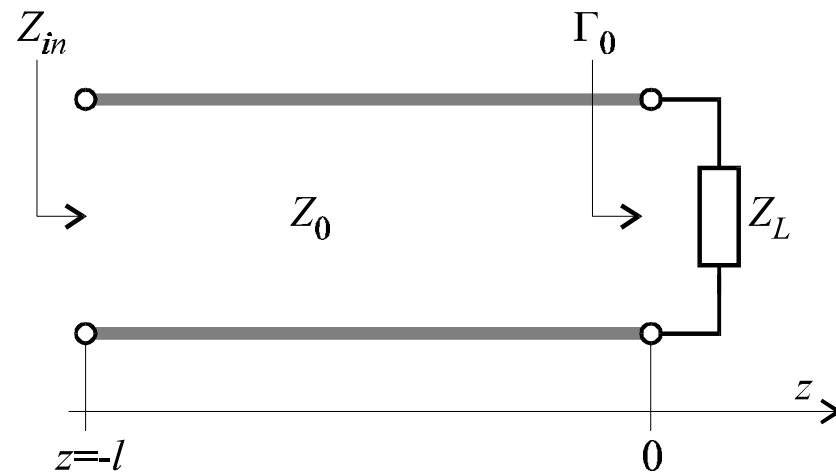


$$Z_0 = \frac{\sqrt{m_0 / e_0}}{2p \sqrt{e_{eff}}} \ln\left(8 \frac{h}{W} + \frac{W}{4h}\right), W/h < 1$$

$$e_{eff} = \frac{e_r + 1}{2} + \frac{e_r - 1}{2} [(1 + 12h/W)^{-1/2} + 0.04(1 - W/h)^2]$$



## What is a voltage reflection coefficient?



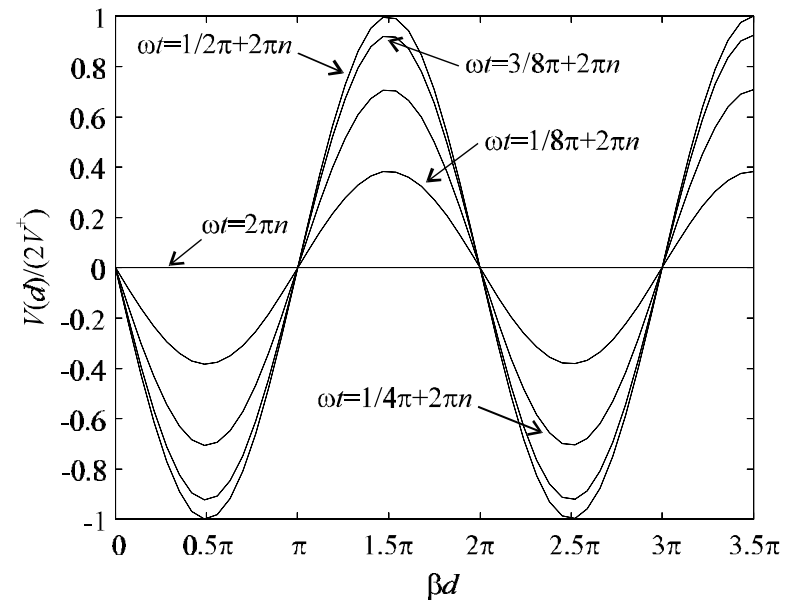
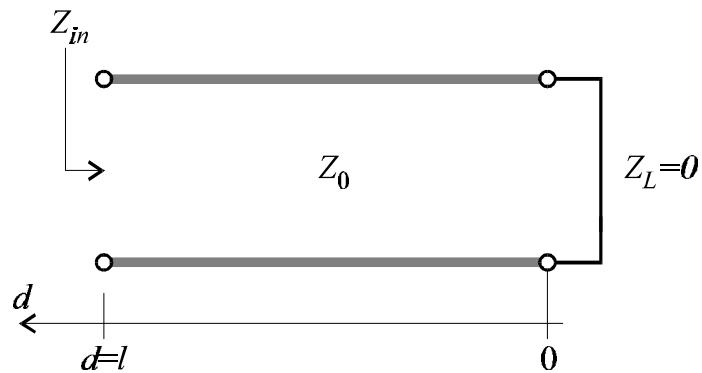
Reflection coefficient  
at the load location

$$\Gamma_0 = \frac{Z_L - Z_0}{Z_L + Z_0}$$

$\Gamma_0 = 1 \quad (Z_L \rightarrow \infty)$

$\Gamma_0 = -1 \quad (Z_L \rightarrow 0)$

# Standing Waves

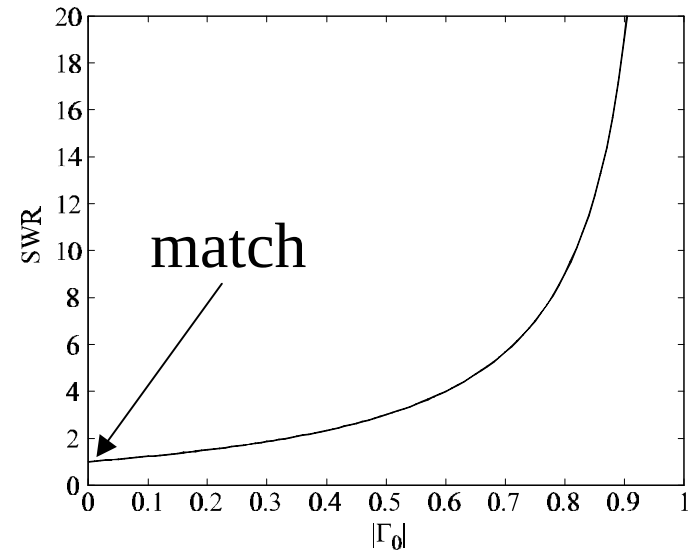


$$V(d) = V^+ (e^{+jbd} - e^{-jbd})$$

$$v(d,t) = 2V^+ \sin(bd) \cos(\omega t + p/2)$$

## Standing wave ratio

$$SWR = \frac{|V_{\max}|}{|V_{\min}|} = \frac{|I_{\max}|}{|I_{\min}|} = \frac{1 + |\Gamma_0|}{1 - |\Gamma_0|}$$



SWR is a measure of mismatch of the load to the line

SWR=1 (matched) or  $SWR \rightarrow \infty$  (total mismatch)