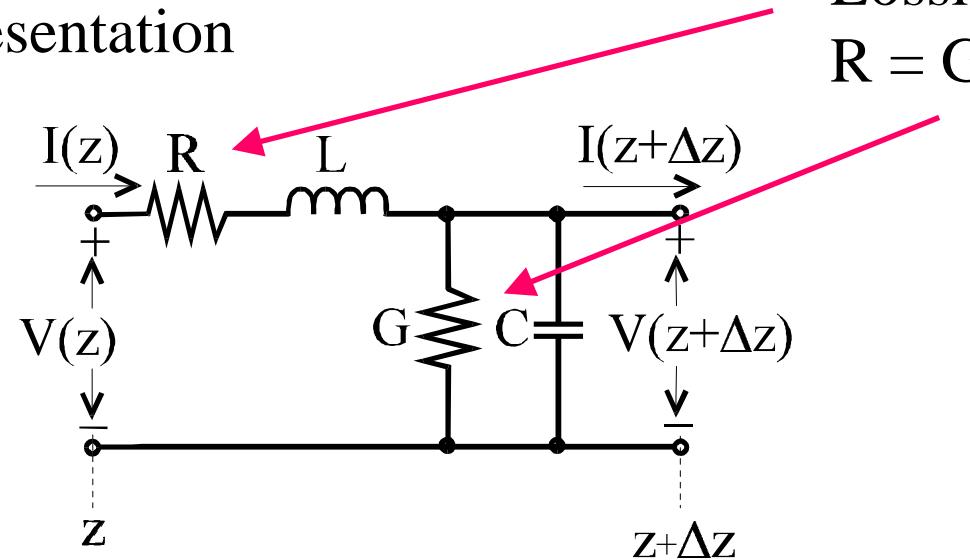


# Lossless Transmission Line Model

- Line representation

Lossless implies:  
 $R = G = 0!$



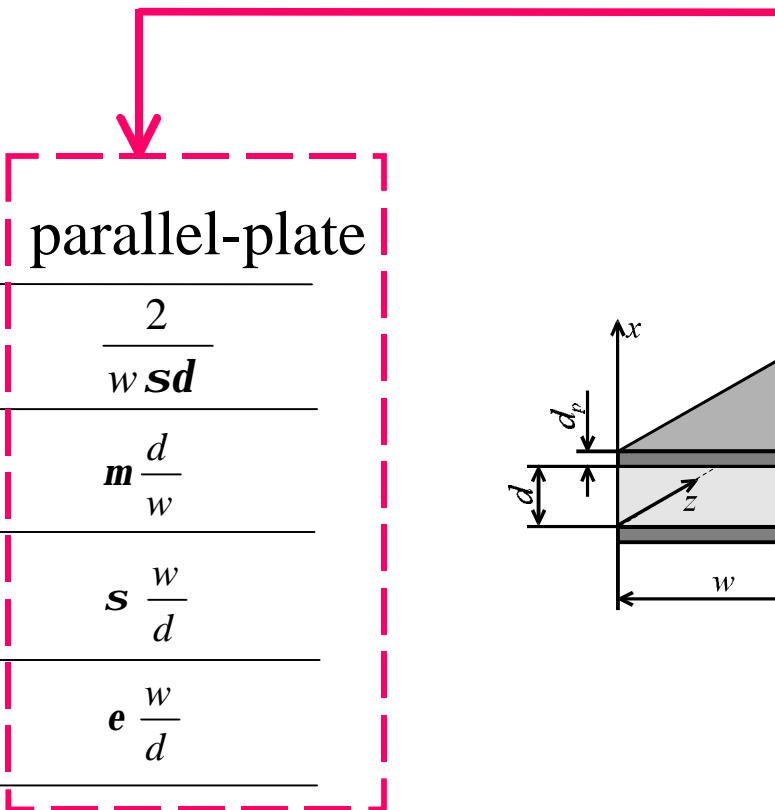
Characteristic impedance:

$$Z_0 = \sqrt{\frac{(R + jwL)}{(G + jwC)}}$$

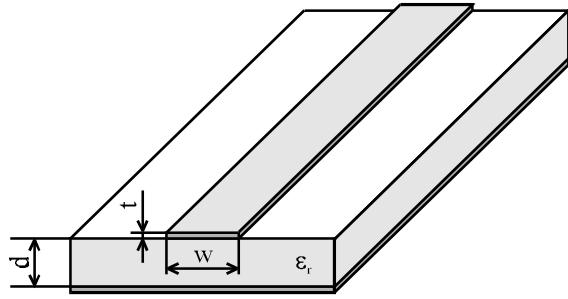
**Note:**  $R, L, G, C$  are given per unit length and depend on geometry

# Transmission Line Parameters for different line types

	2-wire	coax	parallel-plate
R	$\frac{1}{pasd}$	$\frac{1}{2psd} \left( \frac{1}{a} + \frac{1}{b} \right)$	$\frac{2}{w \mathbf{s} d}$
L	$\frac{\mathbf{m}}{p} ch^{-1} \left( \frac{D}{2a} \right)$	$\frac{\mathbf{m}}{2p} \ln \left( \frac{b}{a} \right)$	$\mathbf{m} \frac{d}{w}$
G	$\frac{ps}{ch^{-1}(D/(2a))}$	$\frac{2ps}{\ln(b/a)}$	$\mathbf{s} \frac{w}{d}$
C	$\frac{pe}{ch^{-1}(D/(2a))}$	$\frac{2pe}{\ln(b/a)}$	$\mathbf{e} \frac{w}{d}$

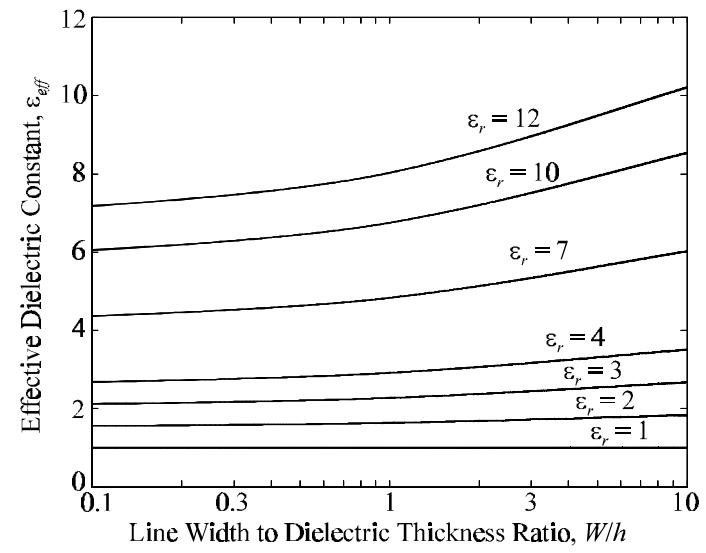
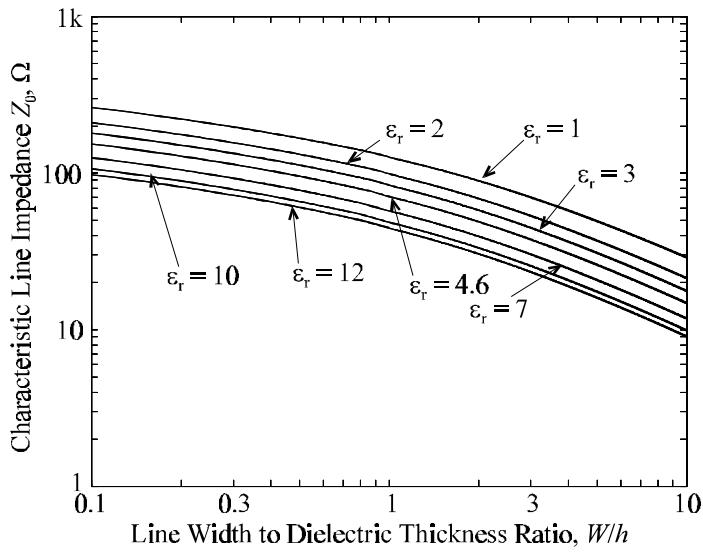


# Microstrip line

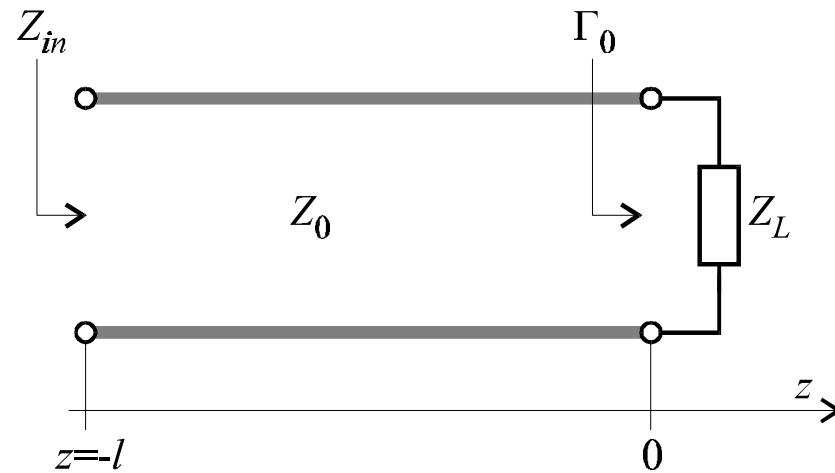


$$Z_0 = \frac{\sqrt{m_0 / e_0}}{2p \sqrt{e_{eff}}} \ln\left(8 \frac{h}{W} + \frac{W}{4h}\right), W/h < 1$$

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



## What is a voltage reflection coefficient?



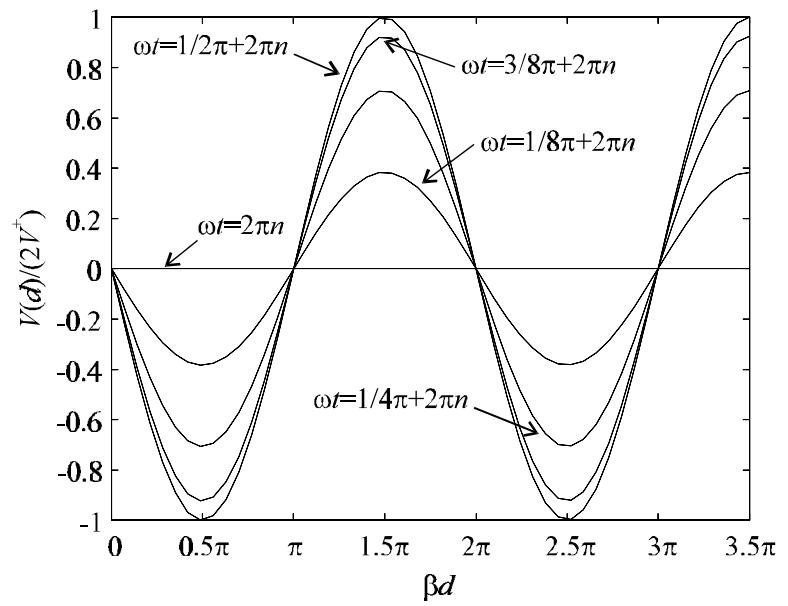
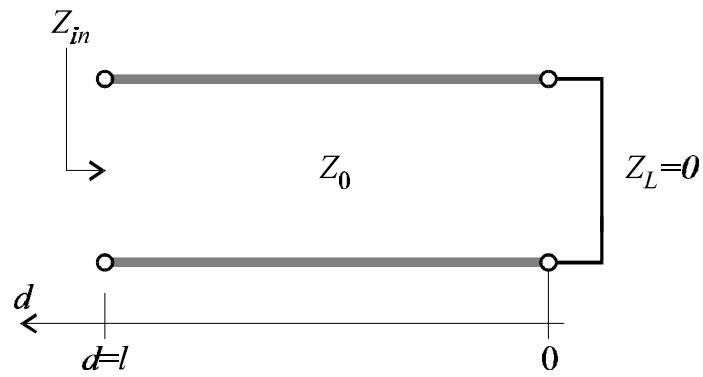
Reflection coefficient  
at the load location

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

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

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

# Standing Waves

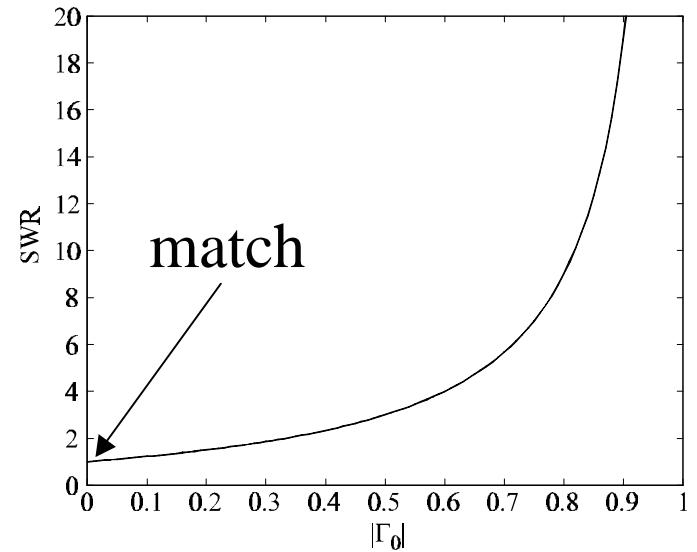


$$V(d) = V^+ (e^{+jbd} - e^{-jbd})$$

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

## 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)