Lecture 1

Tamer Mostafa Abuelfadl
Email: tamer@eng.cu.edu.eg

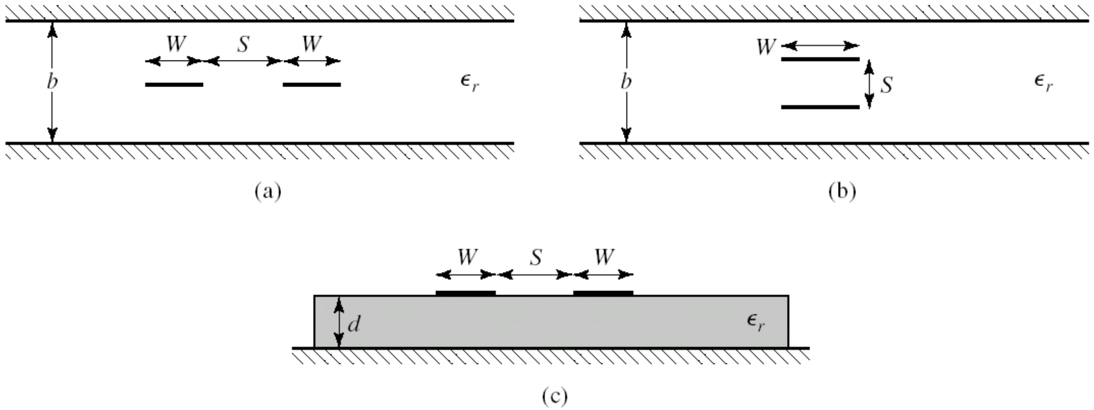
Components and Filters
Topics and References

- Directional coupler
  - Coupled line theory
  - Coupled line coupler
  - 180 degrees Hybrid
- Microwave filters:
  - Low pass filter
  - Band pass filter
  - Band stop and band pass filters

Reference: D. M. Pozar, *Microwave Engineering,* Wiley, 2011.

Coupled Line Theory

Various coupled transmission line geometries. (*a*) Coupled stripline (planar, or edge coupled). (*b*) Coupled stripline (stacked, or broadside-coupled). (*c*) Coupled microstrip.



- A three-wire coupled transmission line and its equivalent capacitance network

Even and Odd Mode Analysis

- Even mode capacitance

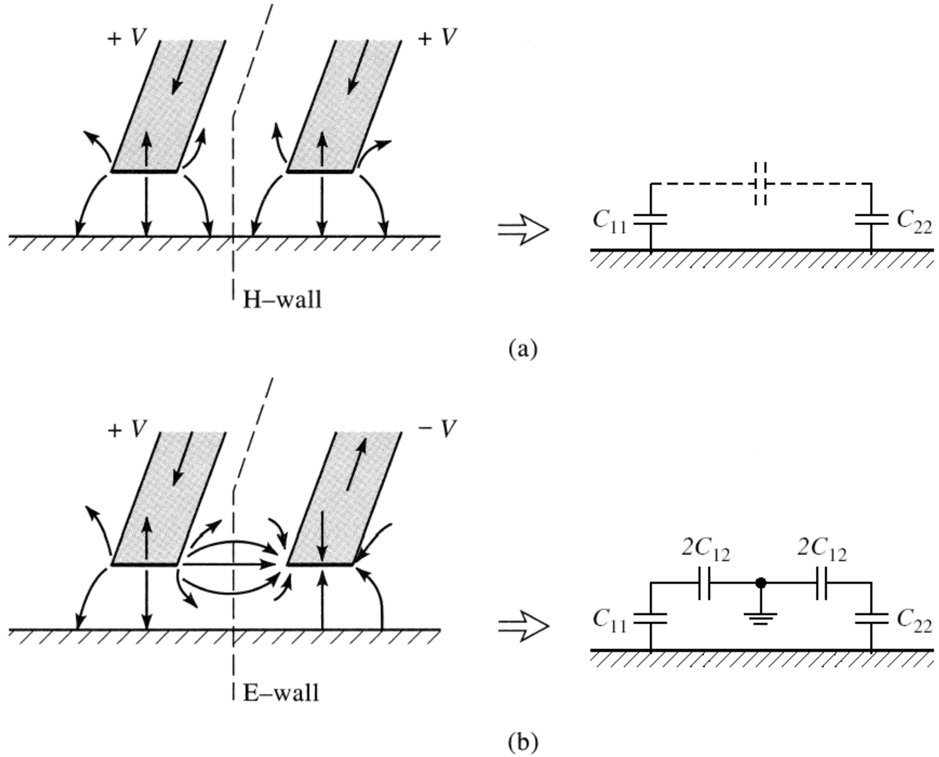
$$C_e = C_{11} = C_{22}$$

$$Z_{0e} = \sqrt{\frac{L}{C_e}} = \frac{1}{v_p C_e}$$

- Odd mode

$$C_o = C_{11} + 2C_{12} = C_{22} + 2C_{12}$$

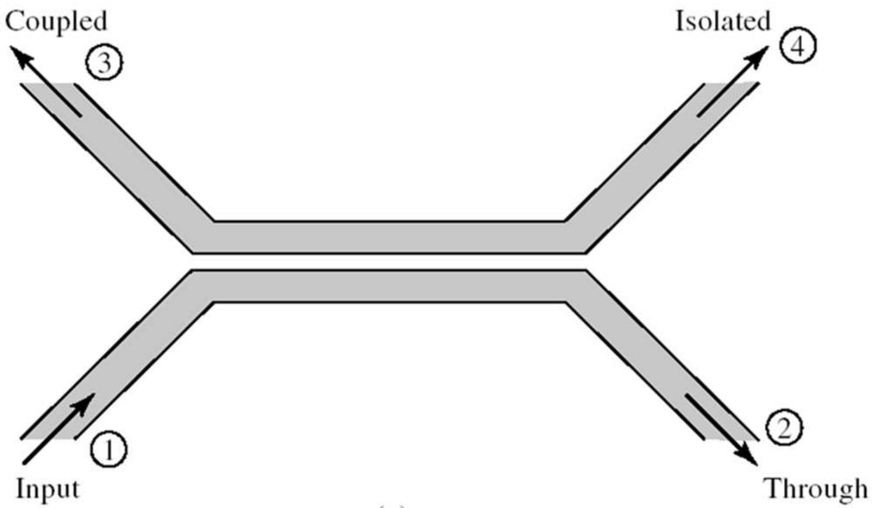
$$Z_{0o} = \frac{1}{v_p C_o}$$



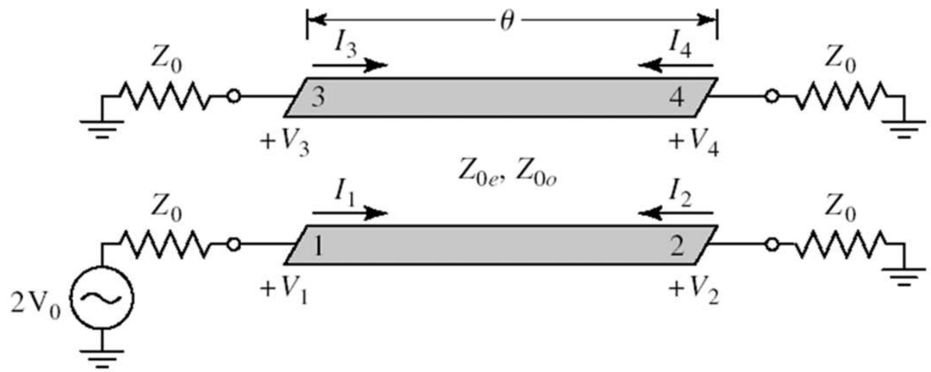
It should be clear that $C_e < C_o$, hence $Z_{0e} > Z_{0o}$.

Design of Coupled Line Couplers

- A single-section coupled line coupler.
  - (*a*) Geometry and port designations.
  - (*b*) The schematic circuit.

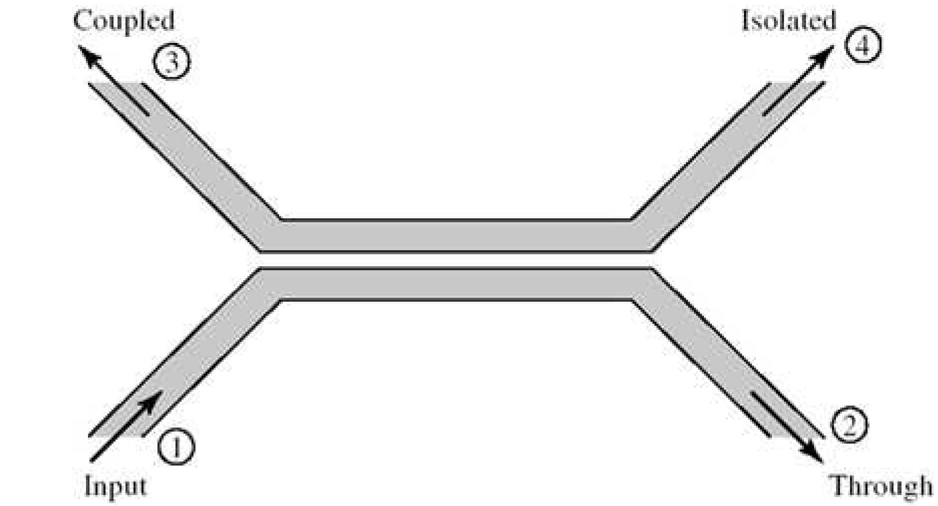


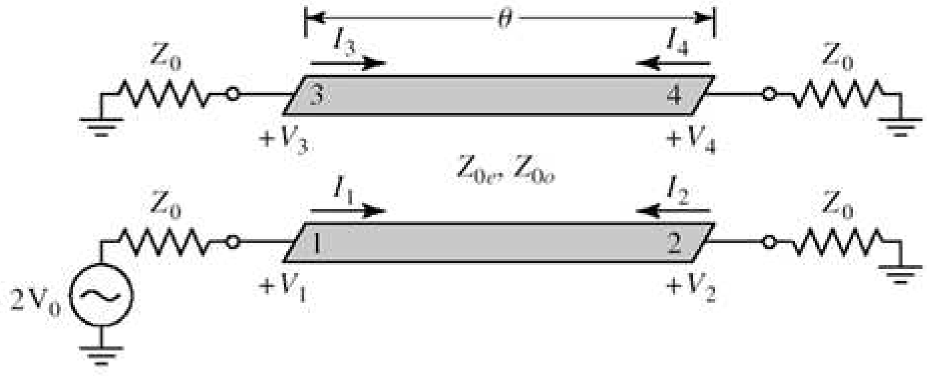
(a)



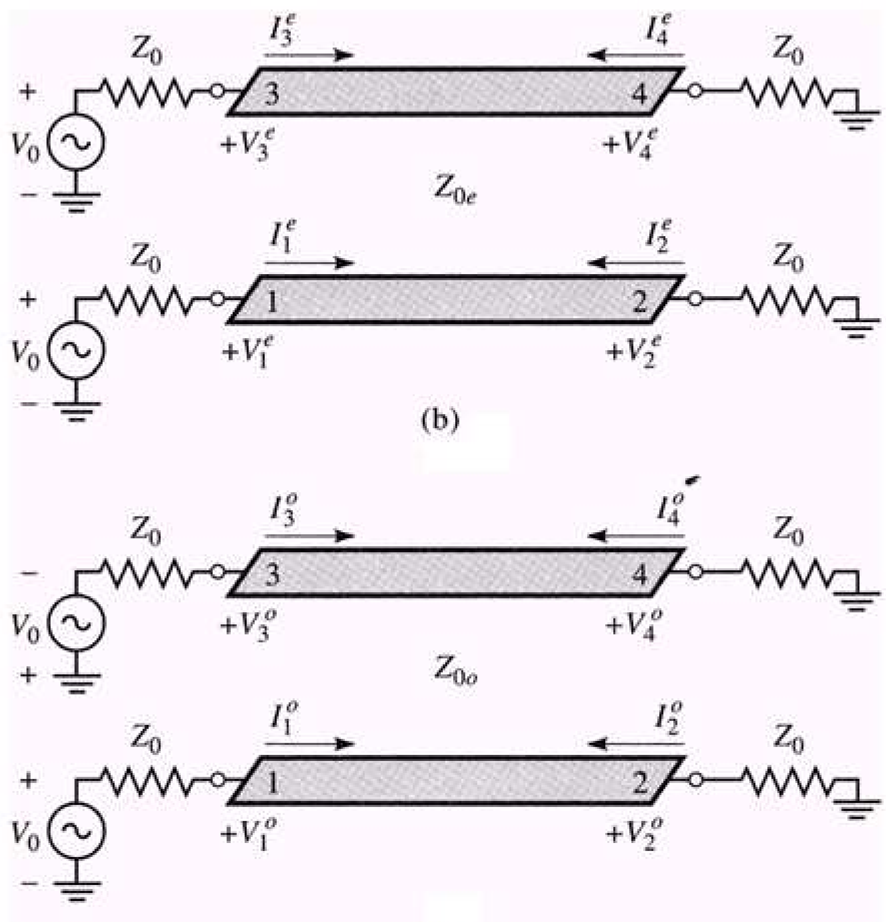
(b)

Decomposition of the coupled lines into even and odd modes





(a)



(c)

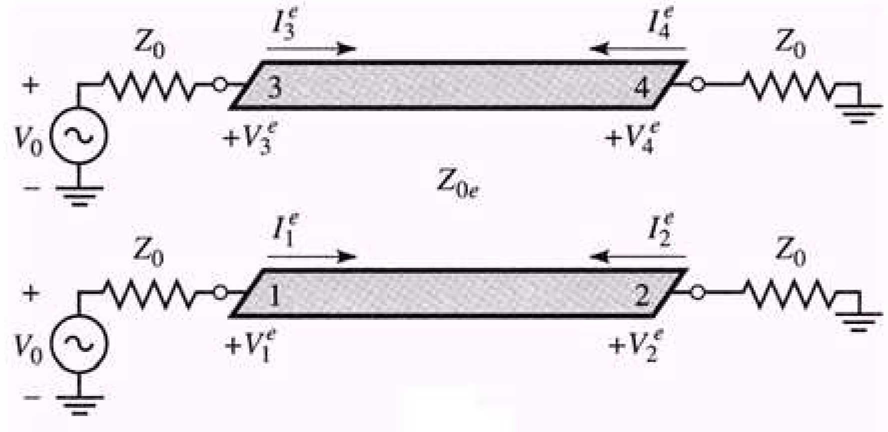
Circuit (a) is the superposition of the even mode (b) and odd mode (c)

Even mode circuit

- $I_1^e = I_3^e, I_2^e = I_4^e$
- $V_1^e = V_3^e, V_2^e = V_4^e$

$$Z_{in}^e = Z_{0e}\frac{Z_0 + jZ_{0e}\tan\theta}{Z_{0e} + jZ_0\tan\theta}$$

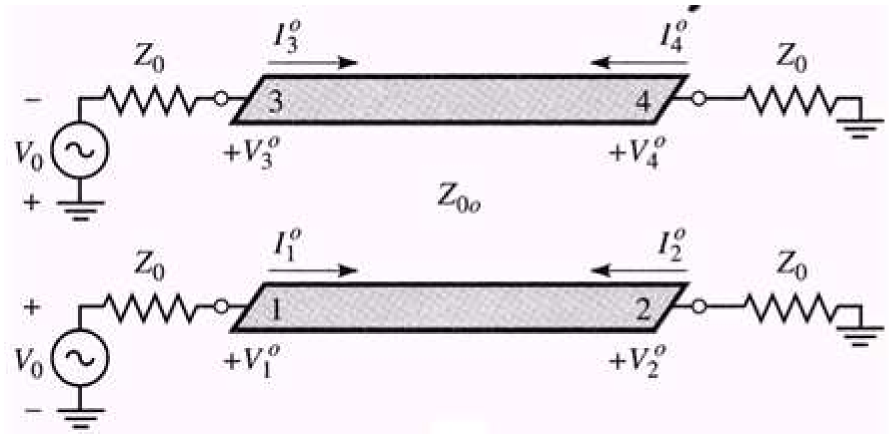
$$V_1^e = V_0\frac{Z_{in}^e}{Z_{in}^e + Z_0}$$



- $I_3^o = -I_1^o, I_4^o = -I_2^o$
- $V_3^o = -V_1^o, V_4^o = -V_2^o$

$$Z_{in}^o = Z_{0o}\frac{Z_0 + jZ_{0o}\tan\theta}{Z_{0o} + jZ_0\tan\theta}$$

$$V_1^o = V_0\frac{Z_{in}^o}{Z_{in}^o + Z_0}$$



$$Z_{in} = \frac{V_1}{I_1} = \frac{V_1^e + V_1^o}{I_1^e + I_1^o} = \frac{Z_{in}^o\left(Z_{in}^e + Z_0\right) + Z_{in}^e\left(Z_{in}^o + Z_0\right)}{Z_{in}^e + Z_{in}^o + 2Z_0} = Z_0 + \frac{2\left(Z_{in}^e Z_{in}^o - Z_0^2\right)}{Z_{in}^e + Z_{in}^o + 2Z_0}$$

- If we let $Z_0 = \sqrt{Z_{0e} Z_{0o}}$,

$$Z_{in}^e = Z_{0e}\frac{\sqrt{Z_{0o}} + j\sqrt{Z_{0e}}\tan\theta}{\sqrt{Z_{0e}} + j\sqrt{Z_{0o}}\tan\theta} \qquad Z_{in}^o = Z_{0o}\frac{\sqrt{Z_{0e}} + j\sqrt{Z_{0o}}\tan\theta}{\sqrt{Z_{0o}} + j\sqrt{Z_{0e}}\tan\theta}$$

So that $Z_{in}^e Z_{in}^o = Z_{0e} Z_{0o} = Z_0^2$ and reduces,

$$Z_{in} = Z_0$$