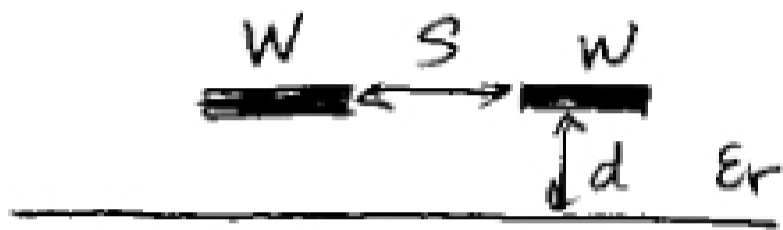
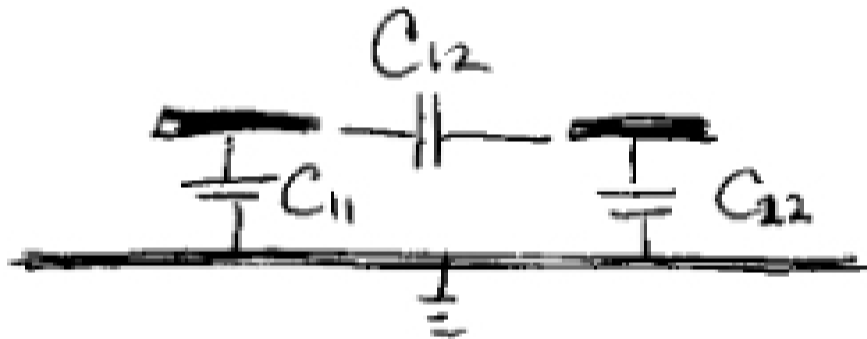


Begin of Coupled Lines:

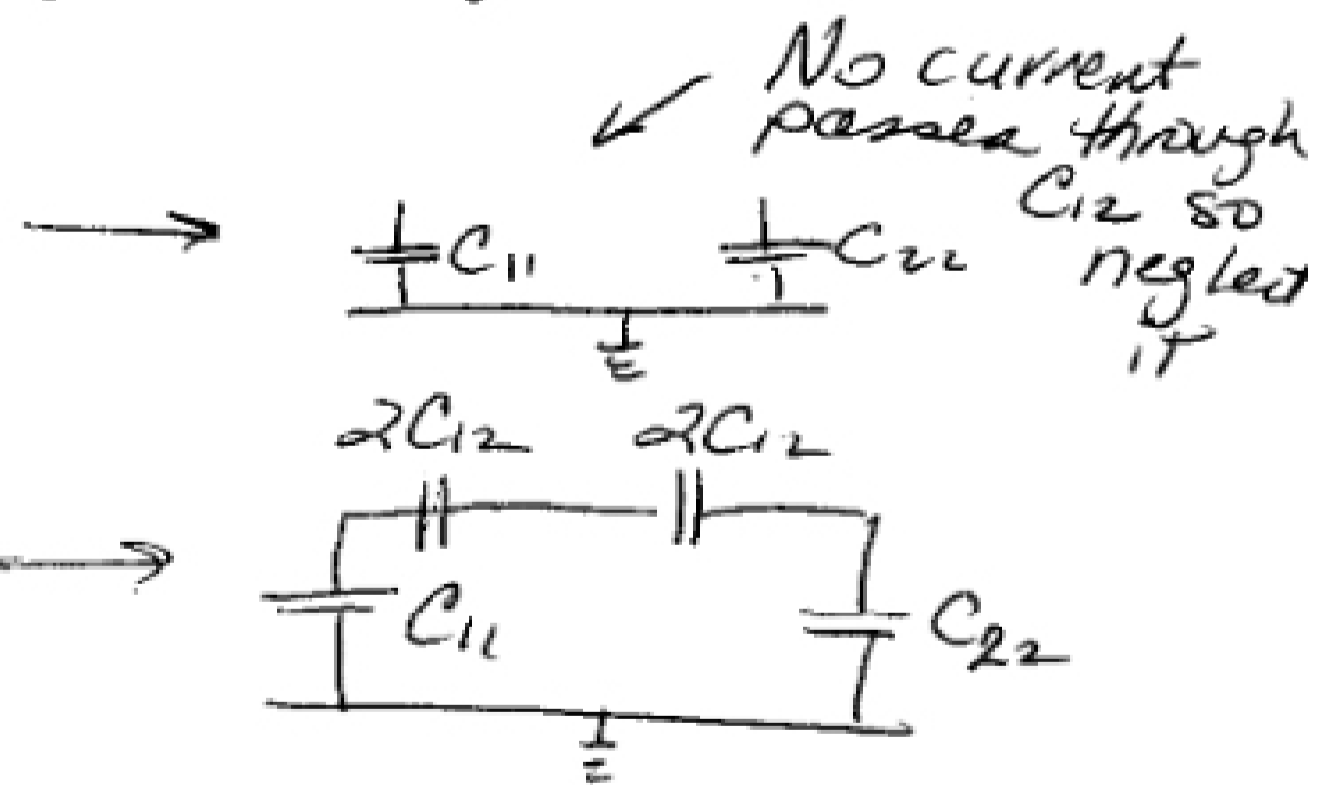
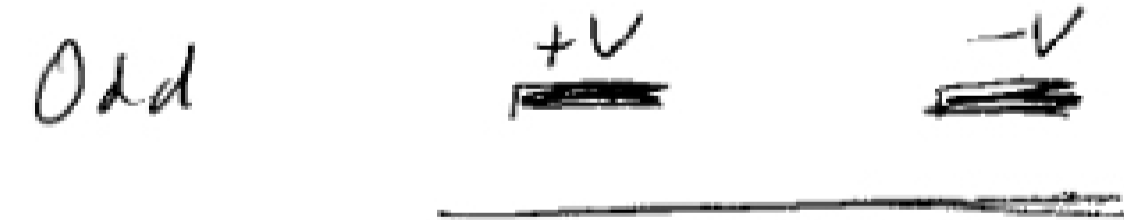


Assume TEM Propagation (perfect for stripline, not perfect for microstrip)

Model Capacitive Coupling



Divide Into Even & Odd Modes



For Even Mode

$$C_e = C_{11} = C_{12} \quad (\text{if lines are same size})$$

$$Z_{oe} = \sqrt{\frac{L}{C_e}} = \frac{\sqrt{LC_e}}{C_e} = \frac{1}{v_p C_e}$$

For Odd Mode

$$C_o = C_{11} + 2C_{12} = C_{22} + 2C_{12} \quad (\text{if same size line})$$

$$Z_{oo} = \frac{1}{v_p C_o}$$

Any source: Superposition of even + odd modes

To find actual values of Z_{oe} and Z_{oo} , need to find capacitances. This is generally done numerically — see handout.

Coupler Design

$$Z_{in} = \frac{V_1}{I_1} = \frac{V_1^e + V_1^o}{I_1^e + I_1^o}$$



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

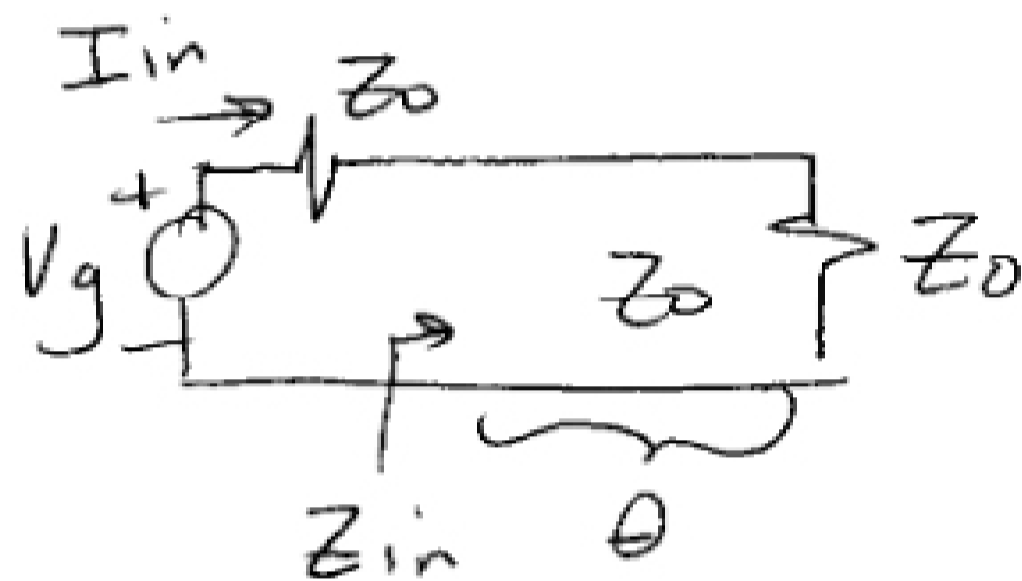
$$Z_{in}^o = Z_{oo} \frac{Z_0 + jZ_{oo} \tan \theta}{Z_{oo} + jZ_0 \tan \theta}$$

$$V_i^o = V_g \frac{Z_{in}^o}{Z_{in}^o + Z_0}$$

$$V_i^e = V_g \frac{Z_{in}^e}{Z_{in}^e + Z_0}$$

$$I_i^o = \frac{V_g}{Z_{in}^o + Z_0}$$

$$I_i^e = \frac{V_g}{Z_{in}^e + Z_0}$$



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

Want $Z_{in} = Z_0$ (matched)

$$\text{Let } (Z_0)^2 = (Z_{in}^o Z_{in}^e)$$

this defined impedances of lines

$$Z_{in}^e = Z_{oe} \frac{\sqrt{Z_{oo}} + j\sqrt{Z_{oe}} \tan \theta}{\sqrt{Z_{oe}} + j\sqrt{Z_{oo}} \tan \theta}$$

$$Z_{in}^o = Z_{oo} \frac{\sqrt{Z_{oe}} + j\sqrt{Z_{oo}} \tan \theta}{\sqrt{Z_{oe}} + j\sqrt{Z_{oe}} \tan \theta}$$

$$Z_{in} = Z_0$$