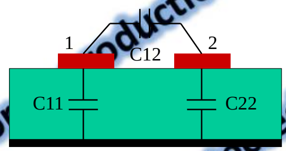
Coupled Microstrip Lines



Self and mutual capacitances

Odd Mode

Even Mode

Characteristics of Symmetric Coupled Microstrip Lines

Even mode excitation

$$\rho_e^1 = C_{11}V_e^1 + C_{12}(V_e^1 - V_e^2)$$
$$\rho_e^2 = C_{21}(V_e^2 - V_e^1) + C_{22}V_e^2$$
$$\text{with } V^1 = V^2 = 1 \Rightarrow \rho_e^1 = C_{11} \text{ and } \rho_e^2 = C_{22}$$

Odd mode excitation

$$\rho_o^1 = C_{11}V_o^1 + C_{12}(V_o^1 - V_o^2)$$
$$\rho_o^2 = C_{21}(V_o^2 - V_o^1) + C_{22}V_o^2$$
$$\text{with } V^1 = 1 \text{ and } V^2 = -1 \Rightarrow \rho_o^1 = C_{11} + 2C_{12} \text{ and } \rho_o^2 = -2C_{21} - C_{22}$$

The subscripts:
- e ⇨ even
- o ⇨ odd
- a ⇨ air substrate

$$C_{11} = \rho_e^1 \,,\; C_{22} = \rho_e^2 \,,\; C_{12} = (\rho_o^1 - \rho_e^1)/2 \,,\; C_{21} = -(\rho_o^2 + \rho_e^2)/2$$

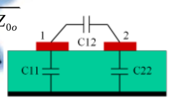
Characteristics of Symmetric Coupled Microstrip Lines

$$\rho_{e,o}^1 = C_{11}V_{e,o}^1 + C_{12}(V_{e,o}^1 - V_{e,o}^2) \,,\; \rho_{e,o}^2 = C_{21}(V_{e,o}^2 - V_{e,o}^1) + C_{22}V_{e,o}^2$$
$$\Downarrow$$
$$C_{11} = \rho_e^1 \,,\; C_{22} = \rho_e^2 \,,\; C_{12} = (\rho_o^1 - \rho_e^1)/2 \,,\; C_{21} = -(\rho_o^2 + \rho_e^2)/2$$

$$Z_{0e} = \frac{|V|}{c\sqrt{\rho_e \rho_{ae}}} \;,\; Z_{0o} = \frac{|V|}{c\sqrt{\rho_o \rho_{ao}}} \Rightarrow Z_0 = \sqrt{Z_{0e}\, Z_{0o}}$$

$$v_e = c\sqrt{\frac{\rho_{ae}}{\rho_e}} \;,\; v_o = c\sqrt{\frac{\rho_{ao}}{\rho_o}}$$

$$\text{Coupling factor} \Rightarrow k = 20\log_{10}\left[\frac{C_{12}}{C_{11} + C_{12}}\right]$$



The subscripts:
- e ⇨ even
- o ⇨ odd
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Procedure to Compute The Symmetric Coupled Microstrip Line Parameters

Sep # 1
Assign the potential for **even mode** excitation. Solve for the potential distribution with **dielectric material**. Calculate the charges with $V^1 = V^2 = 1 \Rightarrow \rho_e^{1,2}$

Step # 2
Replace the dielectric with **free space**. Solve for the potential distribution. Calculate the charges with $V^1 = V^2 = 1 \Rightarrow \rho_{ae}^{1,2}$

Step # 3
Repeat step # 1 with the **odd mode** excitation $V^1 = 1, V^2 = -1 \Rightarrow \rho_o^{1,2}$

Step #4
Repeat step #2 with the **odd mode** excitation $V^1 = 1, V^2 = -1 \Rightarrow \rho_{ao}^{1,2}$

Step #5
Solve for the capacitances (4 equations in 4 unknowns) based on $\rho_e^{1,2}, \rho_o^{1,2}$

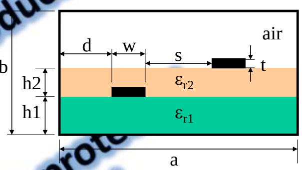
Step #6
Calculate the phase velocities, impedance and coupling coefficient based on expressions in the previous slide.

Assignment

For the shown cross-section of a shielded coupled microstrip geometry, assuming that there is no variation along the z direction, use the FD technique, non-uniform discretization, iterative procedure with coefficients to evaluate the following parameters:

a) Characteristic impedances (odd and even modes)
b) Phase velocities (odd and even modes)
c) The electric coupling between the two microstrip lines
d) Potential distribution for the complete cross-section of the problem with dielectric substrate for the two modes (Provide a 3D plot for each mode)

e) Provide comments and error analysis (choice of spatial increment, number of iterations, order of FD approximation, etc..). Assume a reference solution based on the matrix solution method.
f) For the even mode with dielectric material, report the CPU time used for computing the potential distribution and the CPU time for computing the charge on one of the strips.



a = 10, b =5.5 , d =3 , w = 1, s=2, h1 =1.5, h2 =1.0, t =.05 , ε_{r1} =12 , ε_{r2} =6

All dimensions are in cm.

End of Lecture