THE QUADRATURE (90°) HYBRID

SINGLE-BOX BRANCHLINE COUPLER

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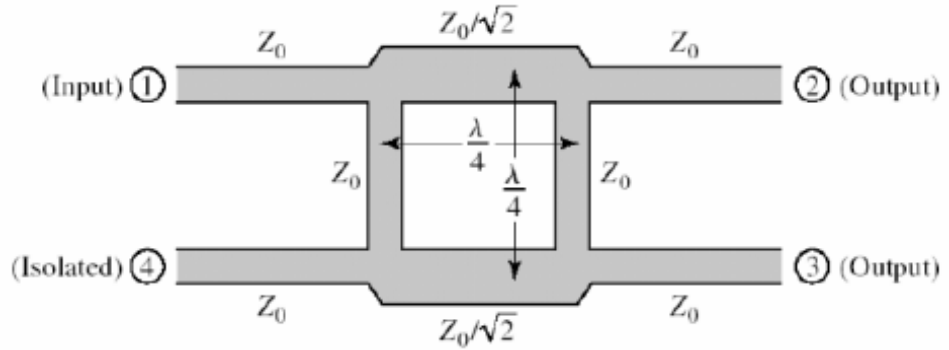
ECE597 Project 2

Four Port Network: Quadrature (90°) Hybrid

Quadrature (90 degree) Hybrid:

- Directional Coupler
- Symmetric Coupler
- Coupling Factor = 3 dB



Directional Coupler:

- Lossless
- reciprocal
- matched-four port network

Symmetric Coupler:

- 90 degree phase shift
- $\phi = \theta = \frac{\pi}{2}$

Scattering Parameters Matrix

Coupling Factor: $-20\log_{10}\beta = 3\ dB$

$$\beta = \alpha = \frac{1}{\sqrt{2}}$$

$$[S] = \begin{bmatrix} 0 & \alpha & j\beta & 0 \\ \alpha & 0 & 0 & j\beta \\ j\beta & 0 & 0 & \alpha \\ 0 & j\beta & \alpha & 0 \end{bmatrix} \longrightarrow [S] = \frac{1}{\sqrt{2}} \begin{bmatrix} 0 & 1 & j & 0 \\ 1 & 0 & 0 & j \\ j & 0 & 0 & 1 \\ 0 & j & 1 & 0 \end{bmatrix}$$

Normalized Circuit

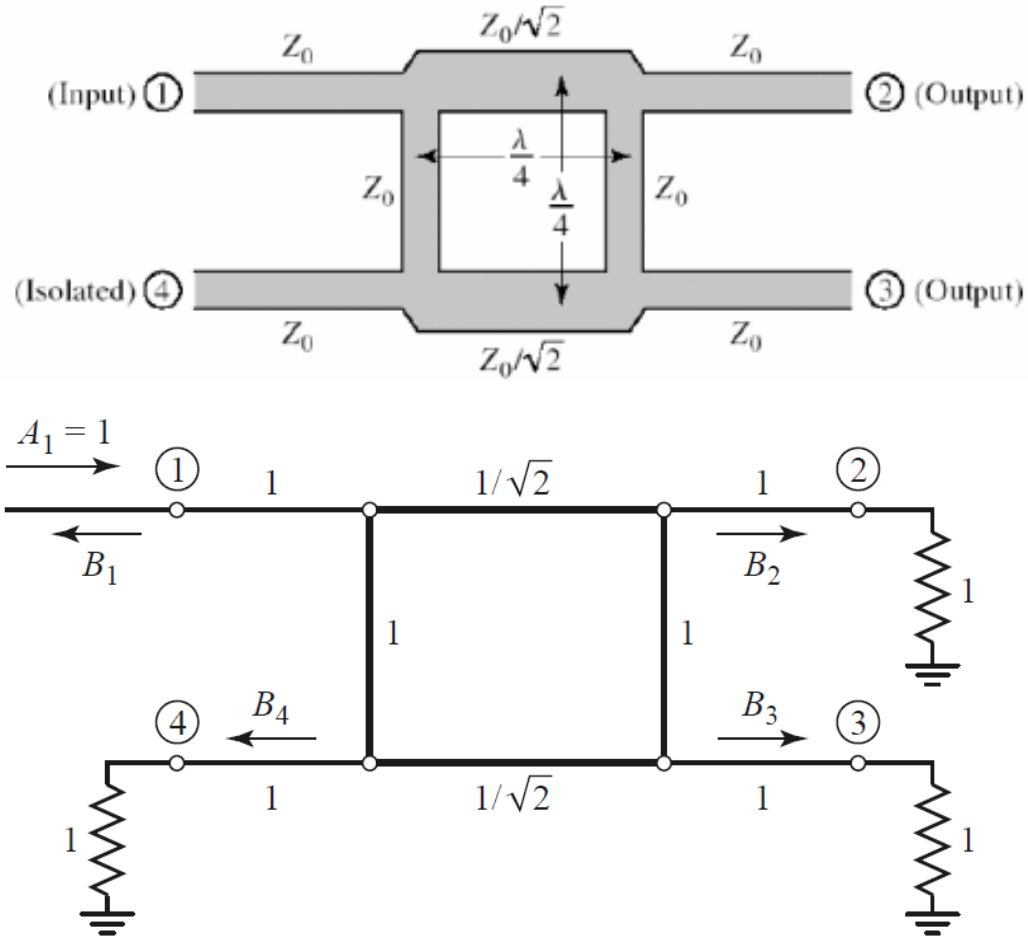


Figure 7.22 Normalized Form

Even Mode Analysis

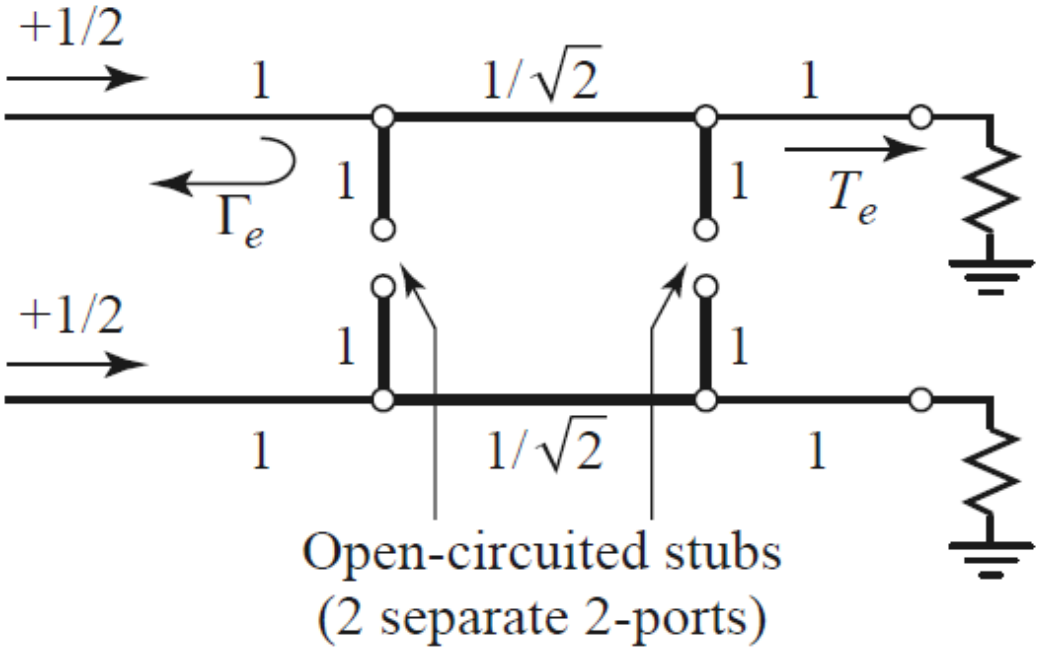


Figure 7.23(a) Even Mode

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix}_e = \underbrace{\begin{bmatrix} 1 & 0 \\ j & 1 \end{bmatrix}}_{\substack{\text{Shunt} \\ Y = j}} \underbrace{\begin{bmatrix} 0 & j/\sqrt{2} \\ j\sqrt{2} & 0 \end{bmatrix}}_{\substack{\lambda/4 \\ \text{Transmission} \\ \text{line}}} \underbrace{\begin{bmatrix} 1 & 0 \\ j & 1 \end{bmatrix}}_{\substack{\text{Shunt} \\ Y = J}} = \frac{1}{\sqrt{2}} \begin{bmatrix} -1 & j \\ j & -1 \end{bmatrix}$$

$$\Gamma_e = \frac{A + B - C - D}{A + B + C + D} = 0,$$

$$T_e = \frac{2}{A + B + C + D} = \frac{-1}{\sqrt{2}}(1 + j).$$

Odd Mode Analysis

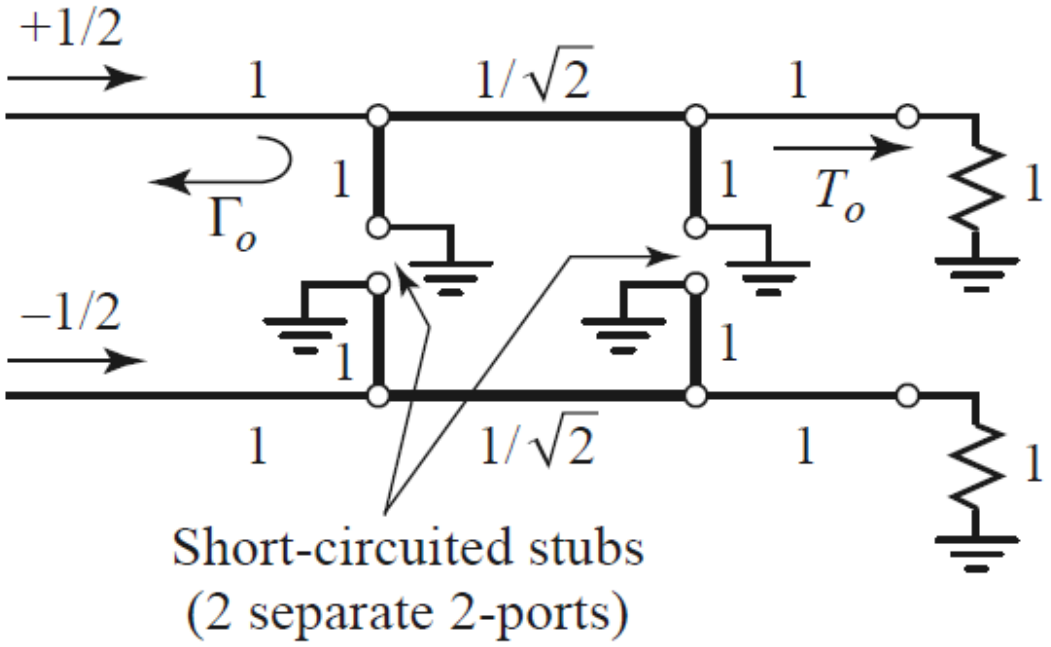


Figure 7.23(b) Odd Mode

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix}_o = \underbrace{\begin{bmatrix} 1 & 0 \\ -j & 1 \end{bmatrix}}_{\substack{\text{Shunt} \\ Y = j}} \underbrace{\begin{bmatrix} 0 & j/\sqrt{2} \\ j\sqrt{2} & 0 \end{bmatrix}}_{\substack{\lambda/4 \\ \text{Transmission} \\ \text{line}}} \underbrace{\begin{bmatrix} 1 & 0 \\ -j & 1 \end{bmatrix}}_{\substack{\text{Shunt} \\ Y = J}} = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & j \\ j & 1 \end{bmatrix}$$

$$\Gamma_o = 0,$$

$$T_o = \frac{1}{\sqrt{2}}(1 - j).$$

Normalized Circuit

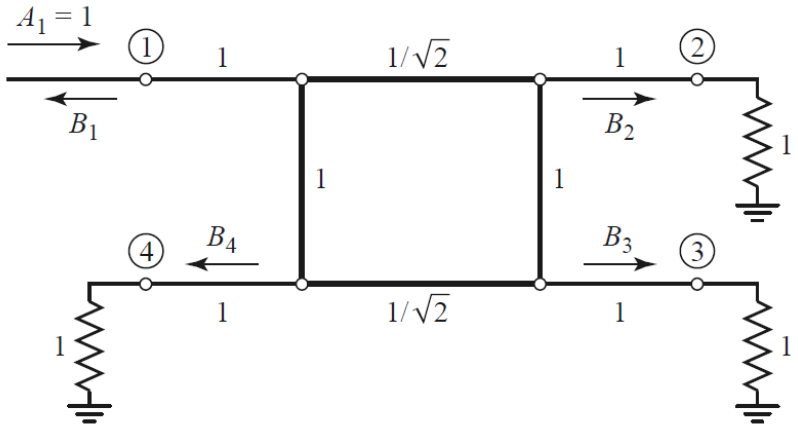


Figure 7.22 Normalized Form

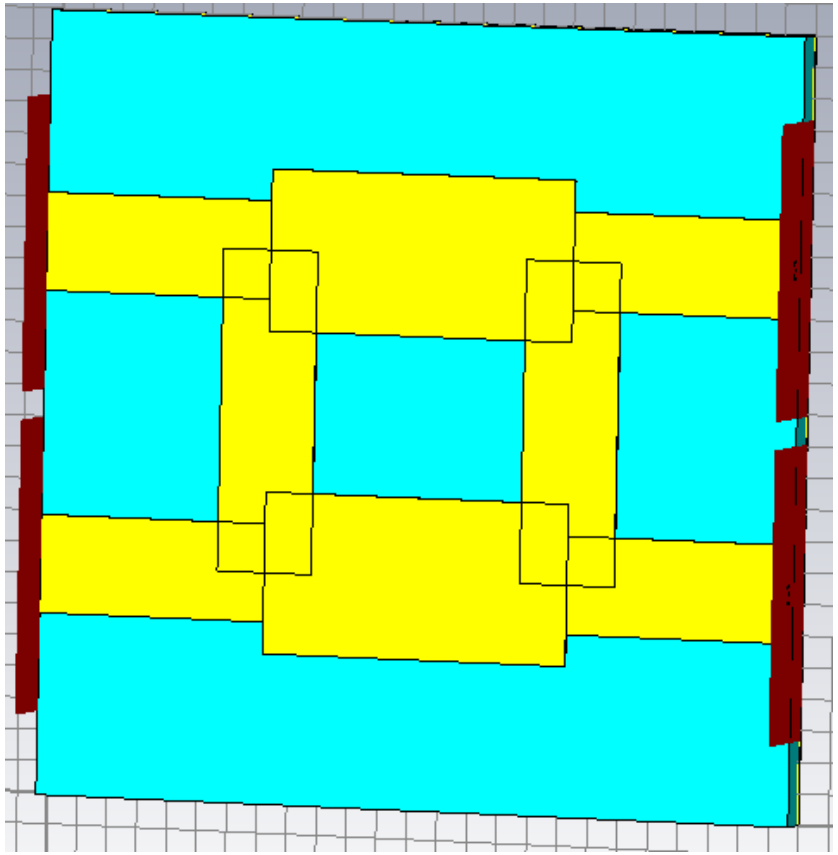
$$B_1 = \frac{1}{2}\Gamma_e + \frac{1}{2}\Gamma_o = 0 \qquad \text{(port 1 is matched),} \tag{7.67a}$$

$$B_2 = \frac{1}{2}T_e + \frac{1}{2}T_o = -\frac{j}{\sqrt{2}} \qquad \text{(half-power, } -90^\circ \text{ phase shift from port 1 to 2),} \tag{7.67b}$$

$$B_3 = \frac{1}{2}T_e - \frac{1}{2}T_o = -\frac{1}{\sqrt{2}} \qquad \text{(half-power, } -180^\circ \text{ phase shift from port 1 to 3),} \tag{7.67c}$$

$$B_4 = \frac{1}{2}\Gamma_e - \frac{1}{2}\Gamma_o = 0 \qquad \text{(no power to port 4).} \tag{7.67d}$$

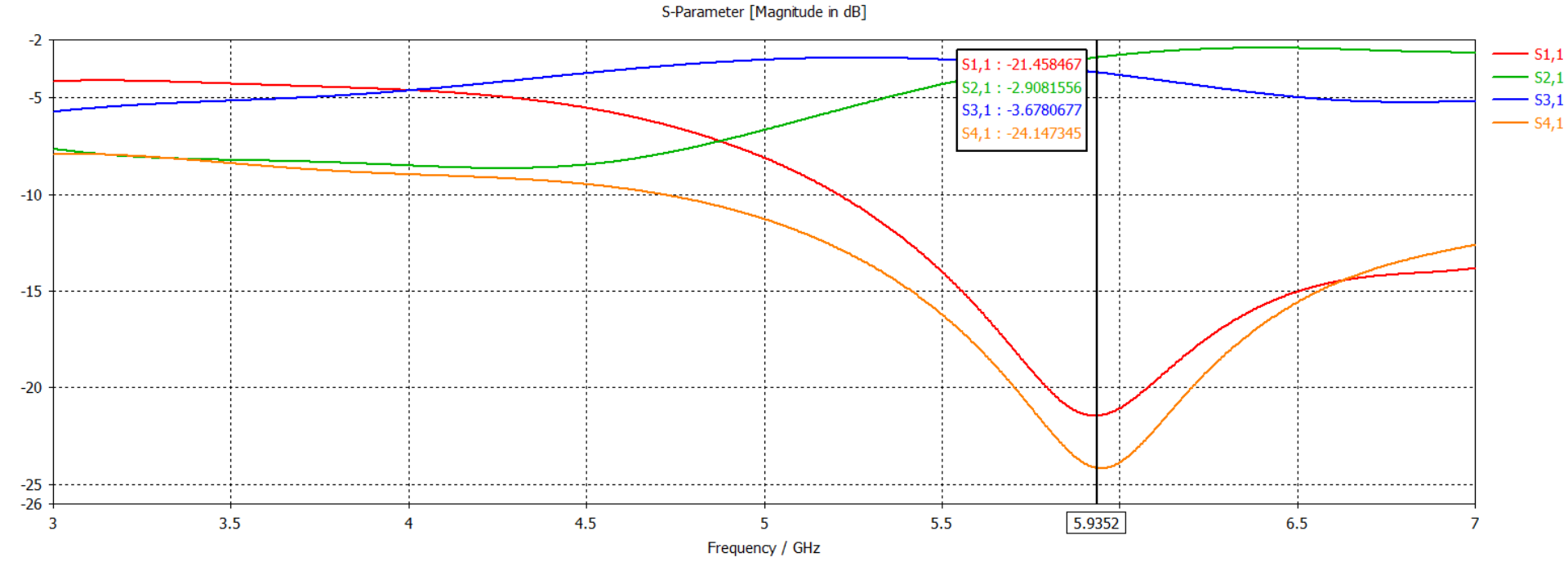
Design Modeling



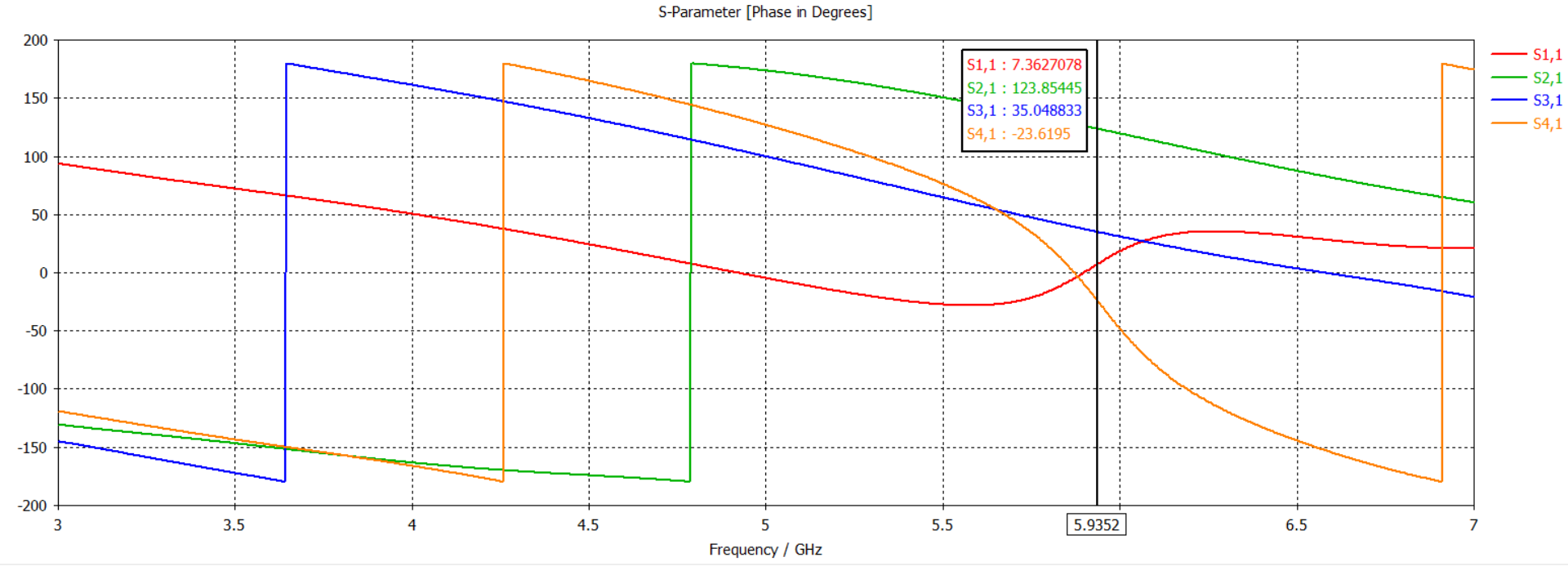
Lines	Width (mm)	Length (mm)
50Ω Line	5.15	10.059
35.36Ω Line	3.13	10.266

$$d = 1.160mm$$
$$\epsilon_r = 2.55$$

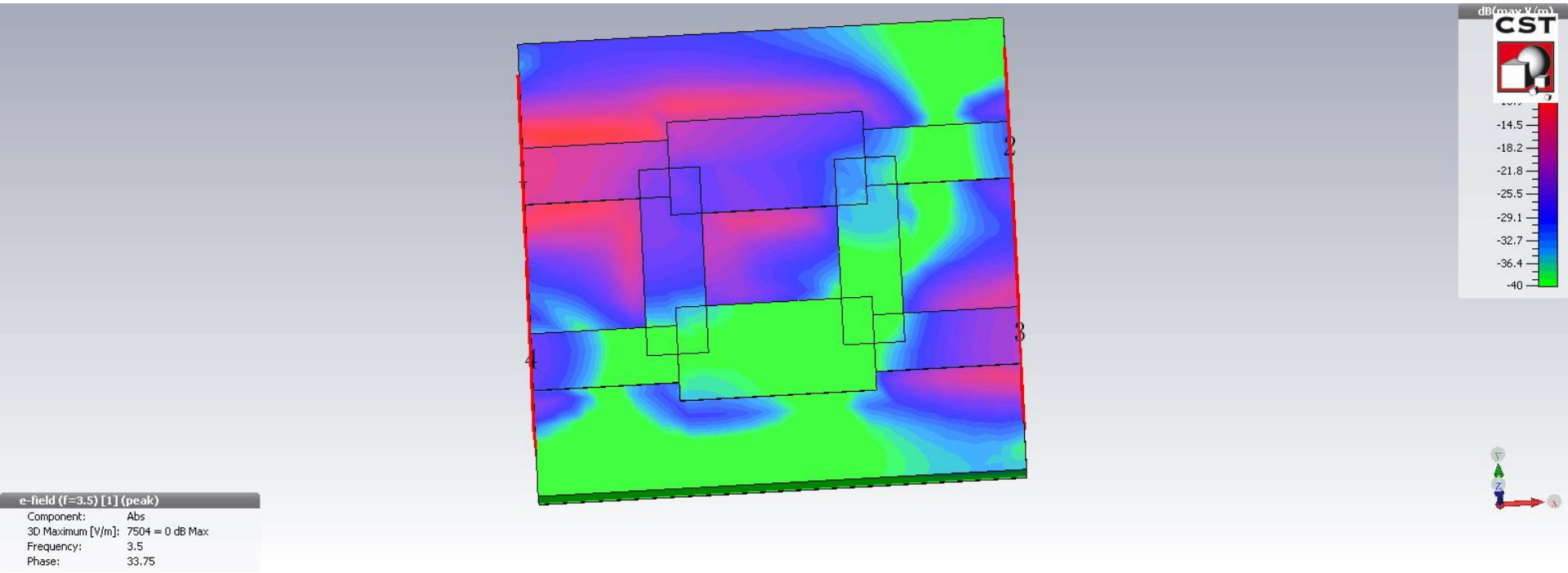
CST Simulation



CST Simulation

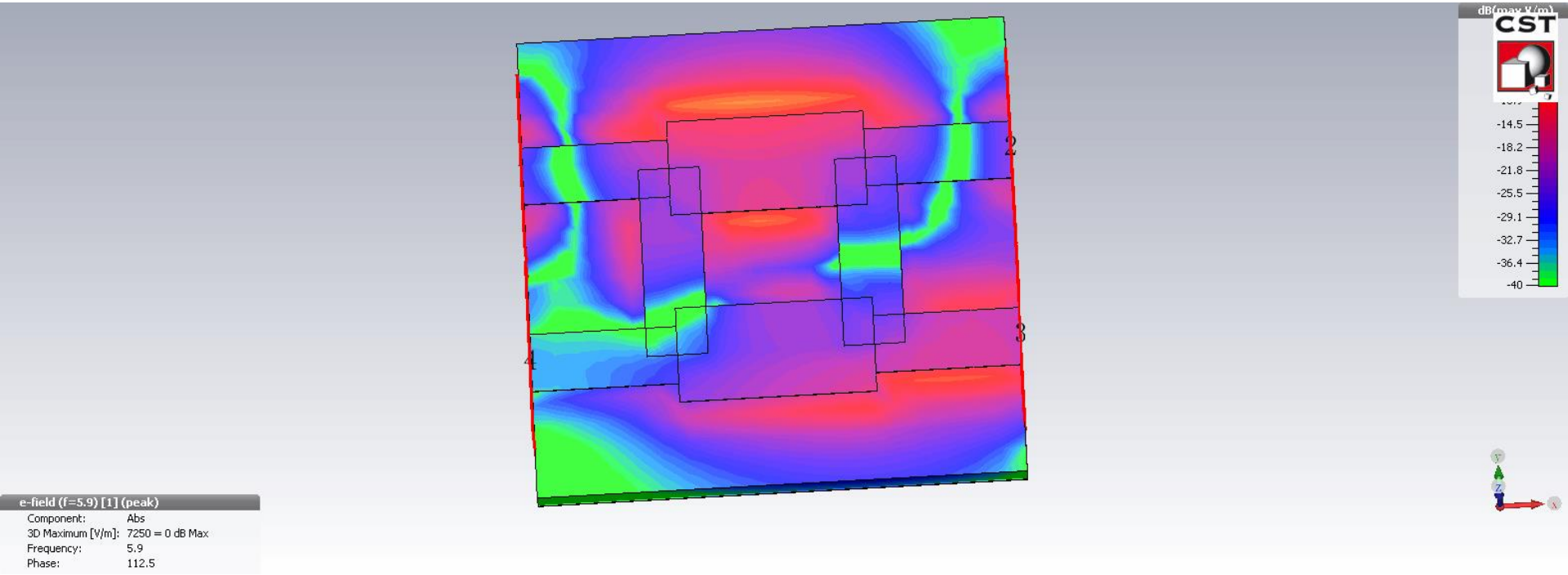


Surface Current Animation



@ 3.5 GHz

Surface Current Animation



@ 5.9 GHz

Citations

[1] David M. Pozar, *Microwave Engineering*. Hoboken: John Wiley & Sons, Inc, 2011.

[2] Stuart M. Wentworth, *Applied Electromagnetics: Early Transmission Lines Approach*. Hoboken: John Wiley & Sons, Inc, 2006.

[3] "Microstrip Line Calculator." *InfoSphere*. [Online]. Available: *http://www1.sphere.ne.jp/i-lab/ilab/tool/ms_line_e.htm*