Power Divider dan Coupler (2)

TTG4D3 – Rekayasa Gelombang Mikro

Oleh

Budi Syihabuddin – Erfansyah Ali

Outline

- 4 Port Coupler

4-Port Coupler

- Symetric

$$S = \begin{bmatrix} 0 & \alpha & j\beta & 0 \\ \alpha & 0 & 0 & j\beta \\ j\beta & 0 & 0 & \alpha \\ 0 & j\beta & \alpha & 0 \end{bmatrix}$$

- Anti-Symetric

$$S = \begin{bmatrix} 0 & \alpha & \beta & 0 \\ \alpha & 0 & 0 & -\beta \\ \beta & 0 & 0 & \alpha \\ 0 & -\beta & \alpha & 0 \end{bmatrix}$$

LOSSLESS???

School of Electrical Engineering

Directional Coupler

c = koefisien Coupling

$$S = \begin{bmatrix} 0 & \alpha & j\beta & 0 \\ \alpha & 0 & 0 & j\beta \\ j\beta & 0 & 0 & \alpha \\ 0 & j\beta & \alpha & 0 \end{bmatrix}$$

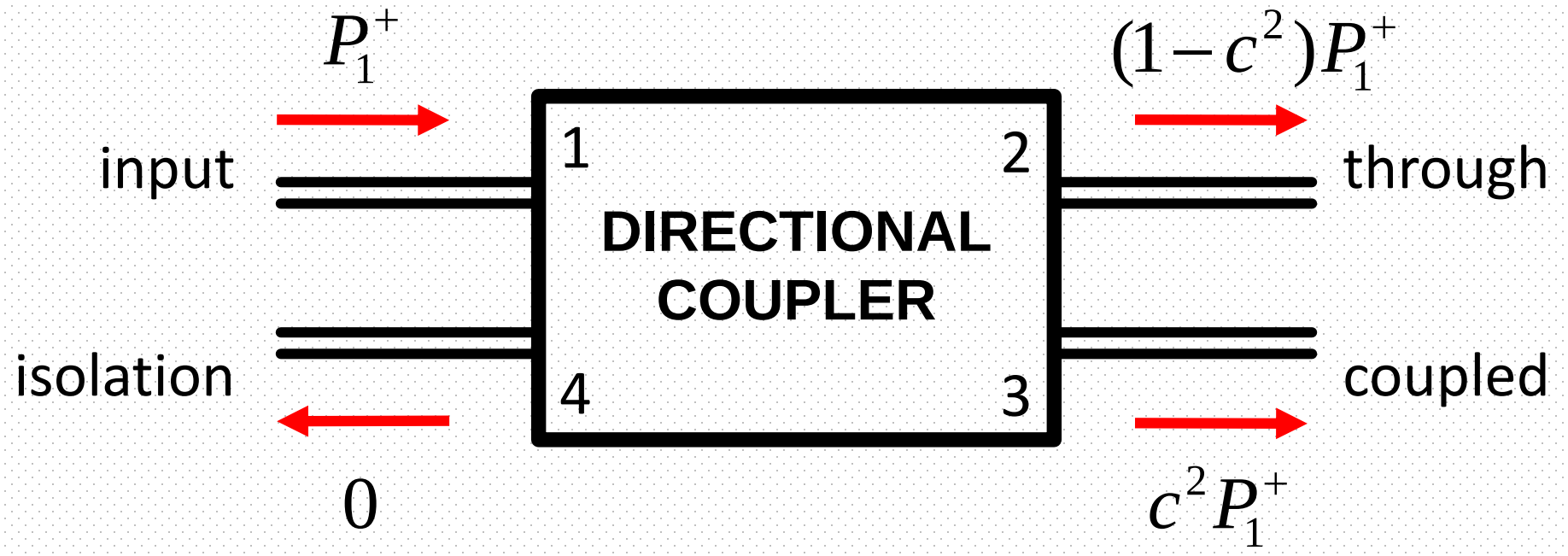
$$S = \begin{bmatrix} 0 & \sqrt{1-c^2} & jc & 0 \\ \sqrt{1-c^2} & 0 & 0 & jc \\ jc & 0 & 0 & \sqrt{1-c^2} \\ 0 & jc & \sqrt{1-c^2} & 0 \end{bmatrix}$$

$$\alpha = \sqrt{1-\beta^2}$$

School of Electrical Engineering

Directional Coupler (2)

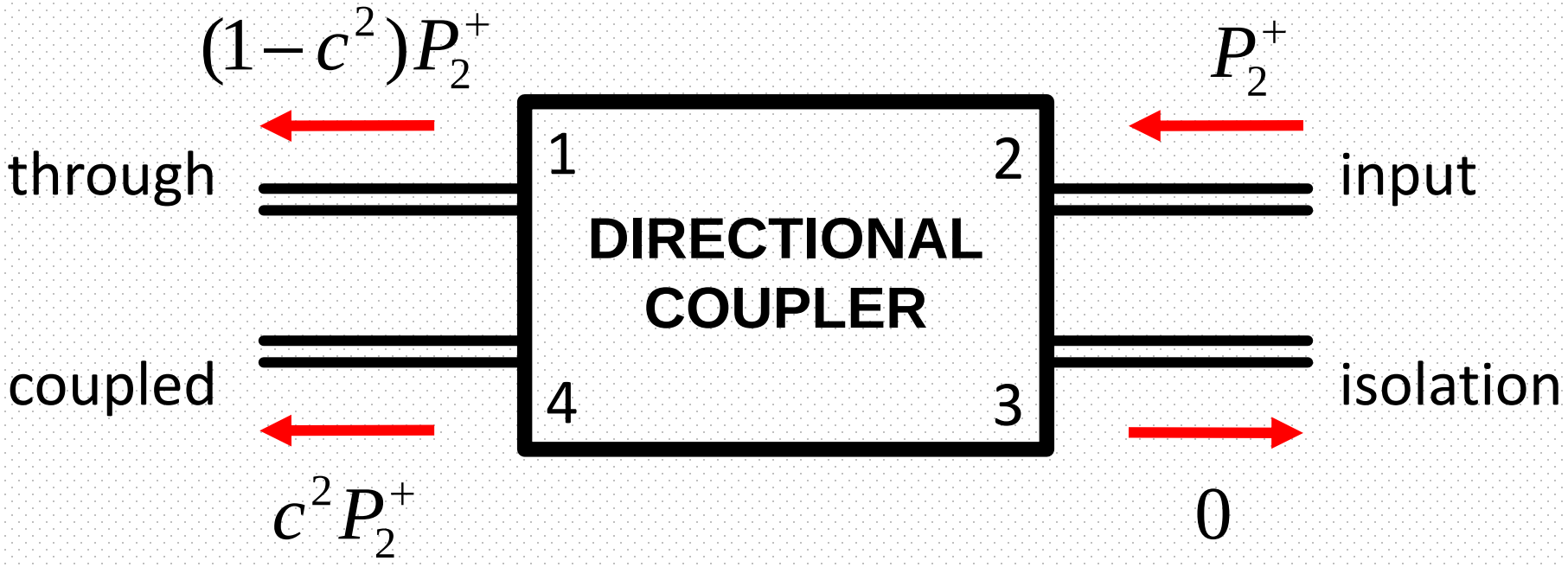
Jika input pada port - 1



School of Electrical Engineering

Directional Coupler (3)

Bagaimana Jika input pada port – 2?



School of Electrical Engineering

Directional Coupler (4)

- Jadi..

input	through	coupled	isolation
Port-1	Port-2	Port-3	Port-4
Port-2	Port-1	Port-4	Port-3
Port-3	Port-4	Port-1	Port-2
Port-4	Port-3	Port-2	Port-1

Directional Coupler (5)

- Non-ideal Directional Coupler

$$S = \begin{bmatrix} S_{11} & S_{21} & jc & S_{41} \\ S_{21} & S_{11} & S_{411} & jc \\ jc & S_{41} & S_{11} & S_{21} \\ S_{41} & jc & S_{21} & S_{11} \end{bmatrix}$$

Directional Coupler (6)

- Coupling (C)

$$C(dB) = 10\log_{10}\left[\frac{P_1^+}{P_3^-}\right] = -10\log_{10}\left|jc\right|^2$$

- Directivity (D)

$$D(dB) = 10\log_{10}\left[\frac{P_3^-}{P_4^-}\right] = 10\log_{10}\left[\frac{\left|jc\right|^2}{\left|S_{41}\right|^2}\right]$$

- Isolation (I)

$$I(dB) = 10\log_{10}\left[\frac{P_1^+}{P_4^-}\right] = -10\log_{10}\left[\left|S_{41}\right|^2\right]$$

$$I(dB) = C(dB) + D(dB)$$

School of Electrical Engineering

Directional Coupler (7)

- Mainline Loss (ML)

$$ML(dB) = 10\log_{10}\left[\frac{P_1^+}{P_2^-}\right] = -10\log_{10}\left[|S_{21}|^2\right]$$

- Coupling Loss (CL)

$$CL(dB) = -10\log_{10}\left[1-|jc|^2\right]$$

- Isolation (I)

$$IL(dB) = ML(dB) - CL(dB)$$

School of Electrical Engineering

Quadrature Hybrid

Simetrik

$$S = \begin{bmatrix} 0 & \alpha & \beta & 0 \\ \alpha & 0 & 0 & -\beta \\ \beta & 0 & 0 & \alpha \\ 0 & -\beta & \alpha & 0 \end{bmatrix}$$

Anti-simetrik

$$S = \begin{bmatrix} 0 & \alpha & j\beta & 0 \\ \alpha & 0 & 0 & j\beta \\ j\beta & 0 & 0 & \alpha \\ 0 & j\beta & \alpha & 0 \end{bmatrix}$$

School of Electrical Engineering

90 Degrees Hybrid Coupler

$$S = \begin{bmatrix} 0 & \alpha & \beta & 0 \\ \alpha & 0 & 0 & -\beta \\ \beta & 0 & 0 & \alpha \\ 0 & -\beta & \alpha & 0 \end{bmatrix}$$

jika

$$\alpha = \frac{-j}{\sqrt{2}}$$

$$j\beta = \frac{-1}{\sqrt{2}}$$

maka

$$S = \begin{bmatrix} 0 & -j/\sqrt{2} & -1/\sqrt{2} & 0 \\ -j/\sqrt{2} & 0 & 0 & -1/\sqrt{2} \\ -1/\sqrt{2} & 0 & 0 & -j/\sqrt{2} \\ 0 & -1/\sqrt{2} & -j/\sqrt{2} & 0 \end{bmatrix}$$

Matched
Lossless
Resiprok

School of Electrical Engineering

90 Degrees Hybrid Coupler

$$S = \begin{bmatrix} 0 & -j/\sqrt{2} & -1/\sqrt{2} & 0 \\ -j/\sqrt{2} & 0 & 0 & -1/\sqrt{2} \\ -1/\sqrt{2} & 0 & 0 & -j/\sqrt{2} \\ 0 & -1/\sqrt{2} & -j/\sqrt{2} & 0 \end{bmatrix}$$

Contoh :
Jika daya sebesar 10mW masuk ke port 3, berapa daya yang keluar di port 1 dan port 4?

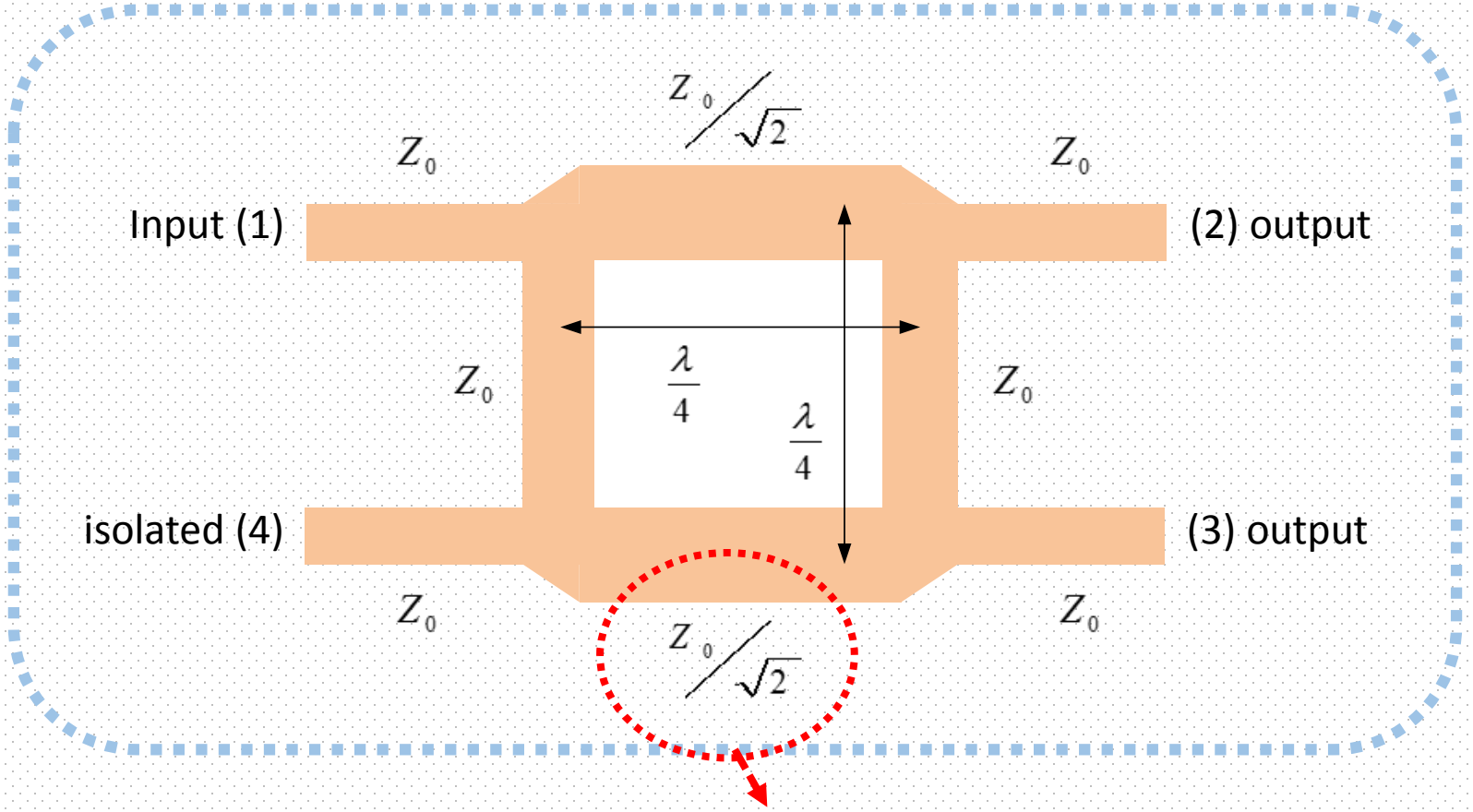
$$V_1(z,t) = \frac{|V_{03}^-|}{\sqrt{2}} \cos(\omega_0 t + \beta z)$$

$$V_4(z,t) = \frac{|V_{03}^-|}{\sqrt{2}} \sin(\omega_0 t + \beta z)$$

Magnitude pada port-1 dan port-4 sama, tetapi fasanya berbeda 90 derajat

School of Electrical Engineering

Quadrature Coupler



Mirip dengan wilkinson power divider yang menggunakan λ/4

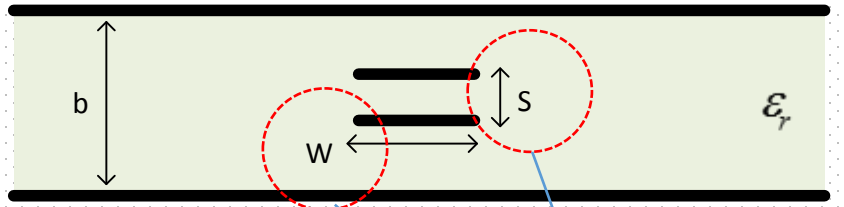
Coupled-Line Directional Coupler

Quadrature hybrid adalah coupler 3dB, bagaimana membuat coupler dengan coupling yang lebih kecil? Seperti 10dB, 20dB atau 30dB?

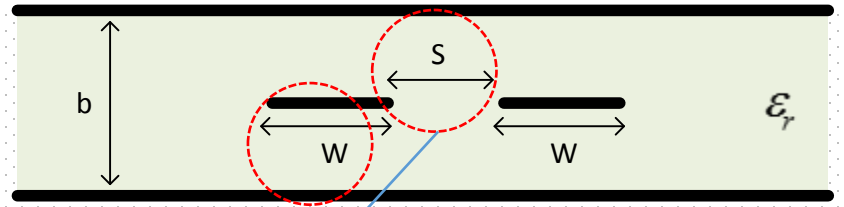
Dengan menggunakan Coupled-Line!

Coupled-Lines Coupler

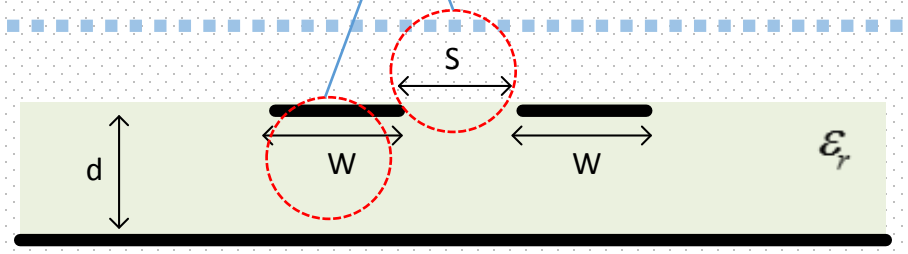
Coupled-Line - Stacked



Coupled-Line - Planar



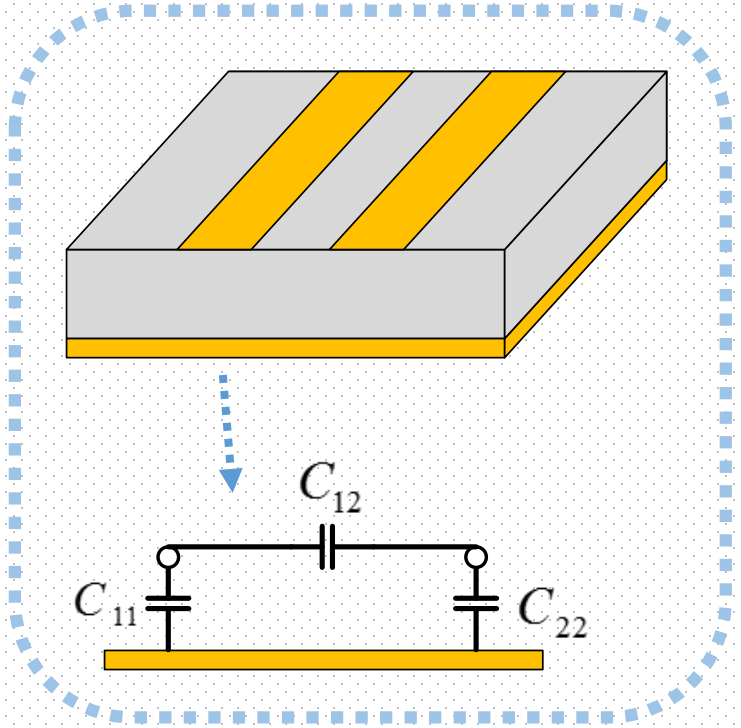
- 2 saluran transmisi yang didekatkan satu sama lain akan mengkopling daya satu sama lain
- Kedekatan ini akan memodifikasi medan elektromagnetik (juga arus dan tegangan) juga impedansi saltrans



Coupled Microstrip

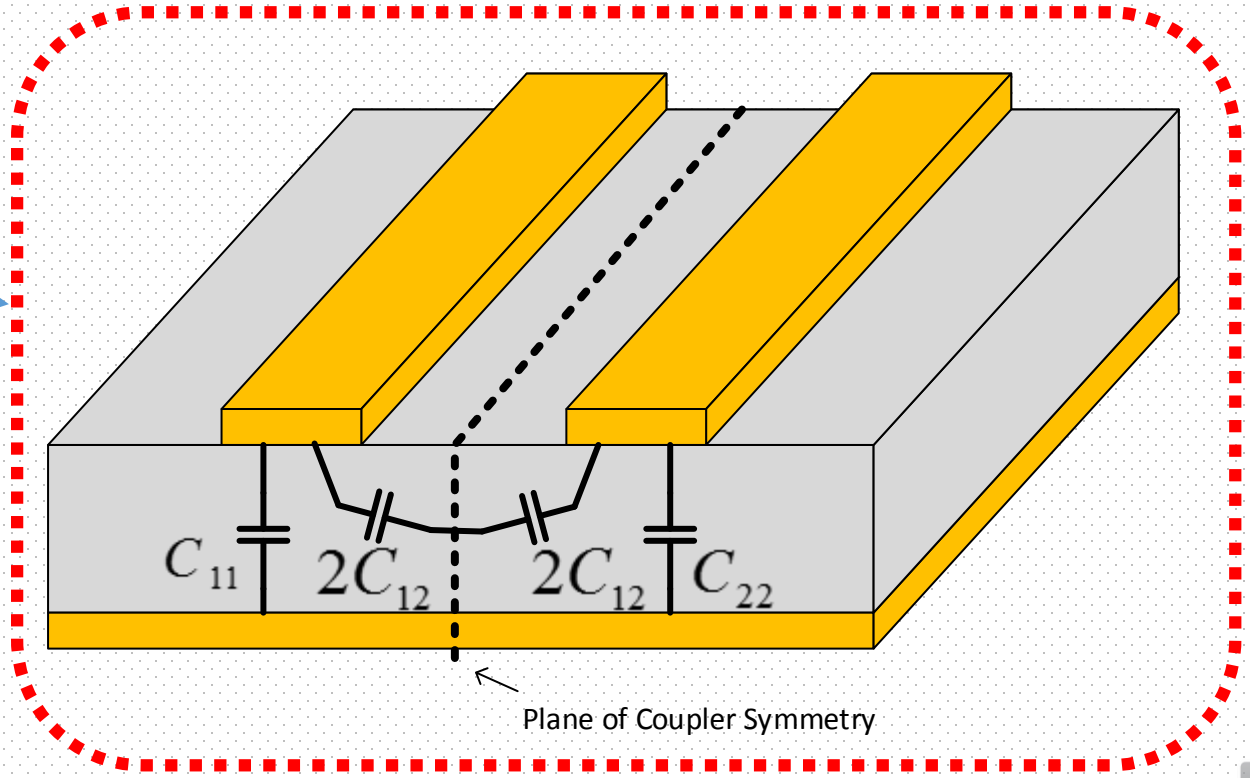
School of Electrical Engineering

Quadrature Coupler



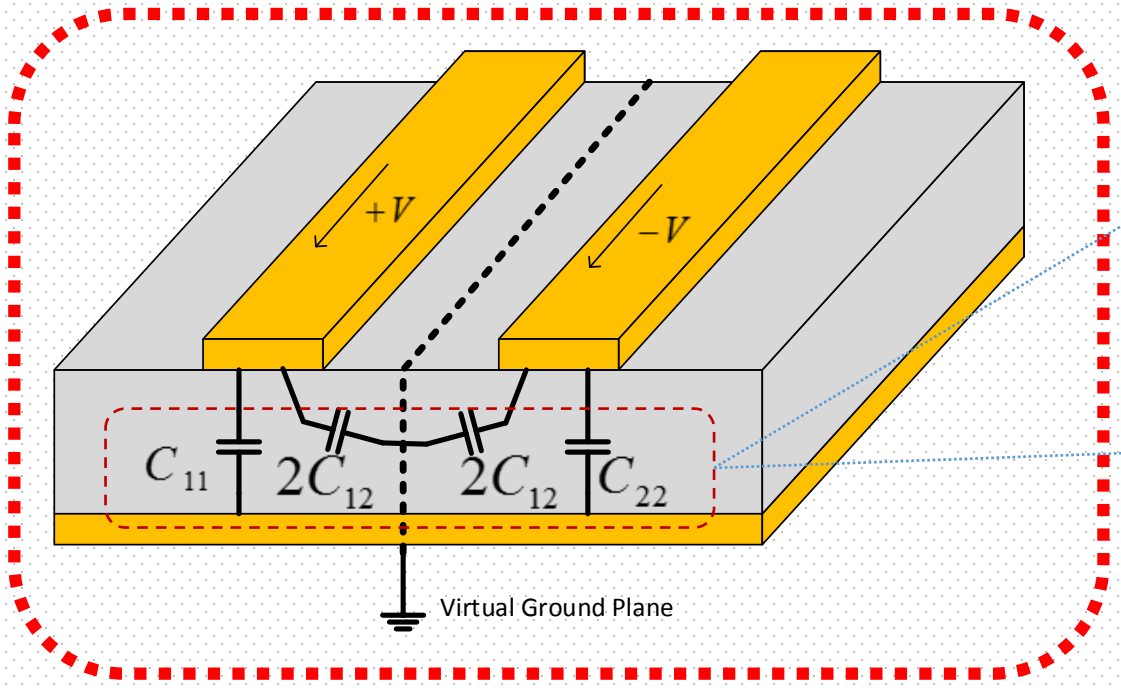
Jika 2 saltran identik, maka $C_{11} = C_{22}$

Rangkaian identik, simetrik, bisa dianalisa dengan odd/even analysis.



Quadrature Coupler

Odd Mode : Gelombang/tegangan datang sepanjang saltran berlawanan, megnitude sama, tapi fasa berbeda 180 derajat.



Kapasitansi persatuan panjang

$$C_0 = C_{11} + 2C_{12} = C_{22} + 2C_{12}$$

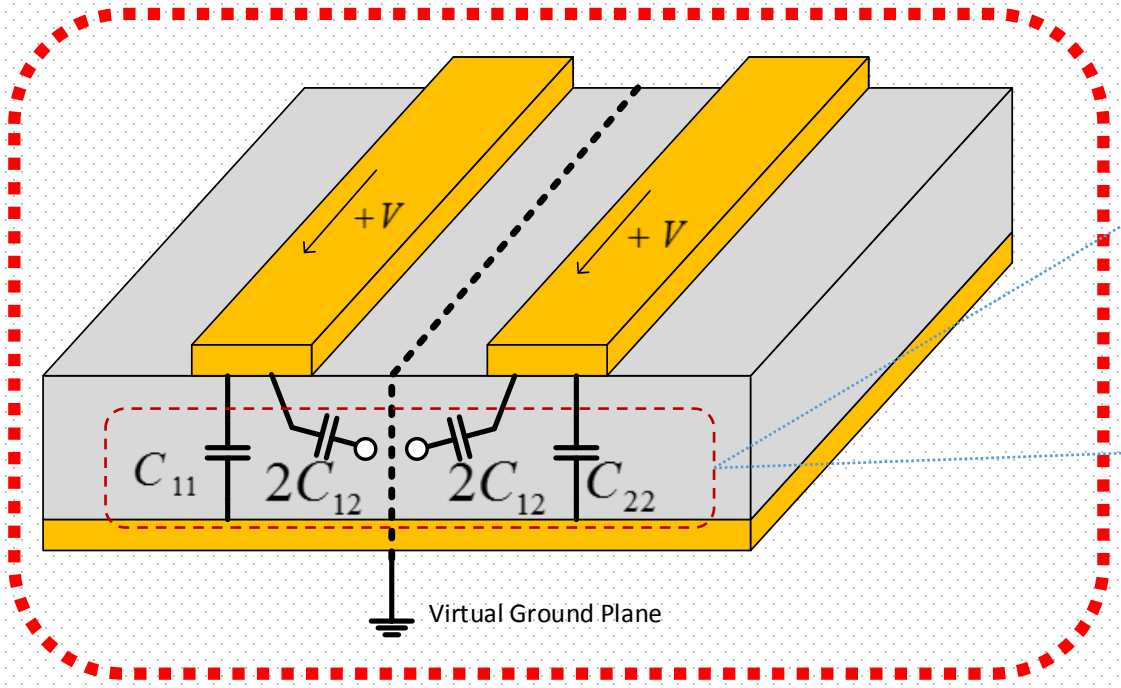
Impedansi Karakteristik

$$Z_0^o = \sqrt{\frac{L}{C_o}}$$

School of Electrical Engineering

Quadrature Coupler

Even Mode : Gelombang/tegangan datang sepanjang saltran sebanding, magnitude dan fasa sama



Kapasitansi persatuan panjang

$$C_0 = C_{11} = C_{22}$$

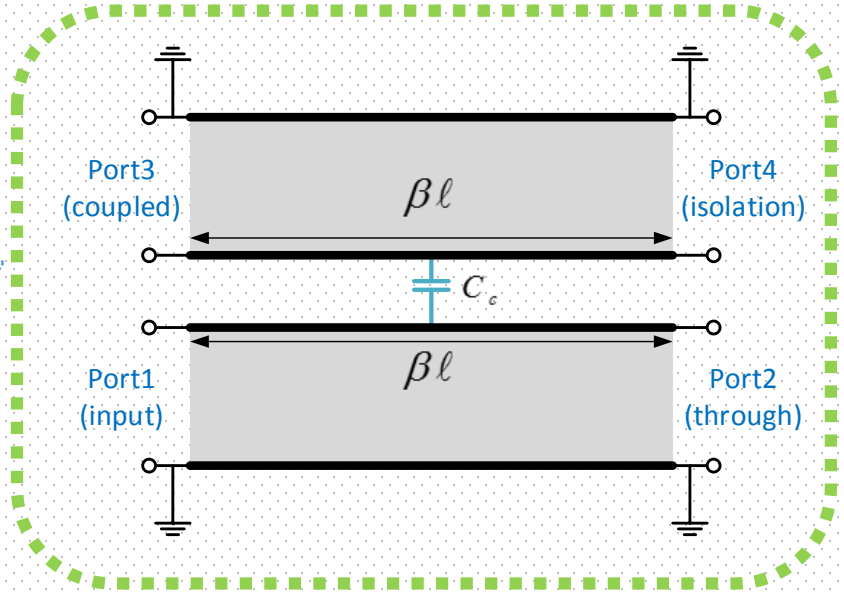
Impedansi Karakteristik

$$Z_0^e = \sqrt{\frac{L}{C_e}}$$

School of Electrical Engineering

Quadrature Coupler

$$S = \begin{bmatrix} 0 & -j\sqrt{1-c^2} & c & 0 \\ -j\sqrt{1-c^2} & 0 & 0 & c \\ c & 0 & 0 & -j\sqrt{1-c^2} \\ 0 & c & -j\sqrt{1-c^2} & 0 \end{bmatrix}$$



$$Z_0^e = Z_0\sqrt{\frac{1+c}{1-c}}$$

$$Z_0^o = Z_0\sqrt{\frac{1-c}{1+c}}$$

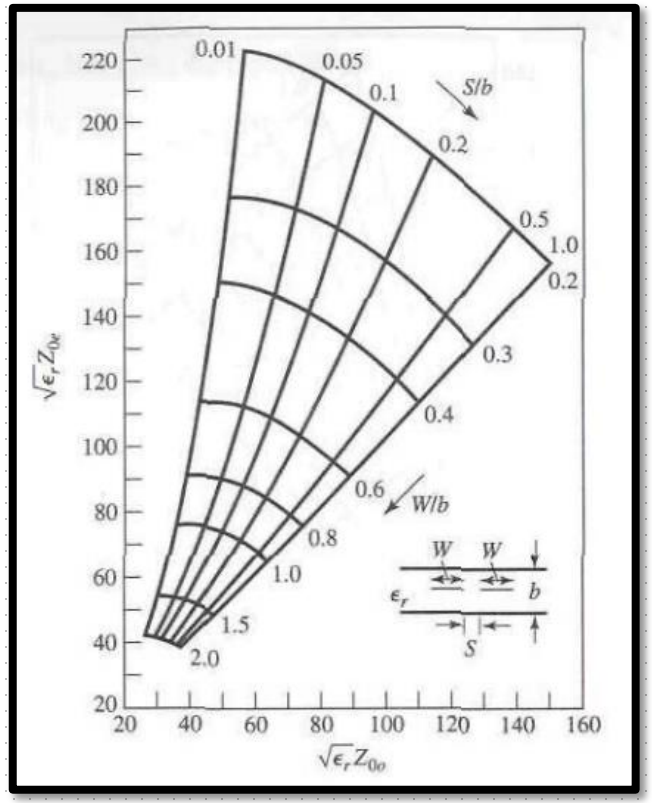
$$Z_0^e Z_0^o = Z_0$$

$$c = \frac{Z_0^e - Z_0^o}{Z_0^e + Z_0^o}$$

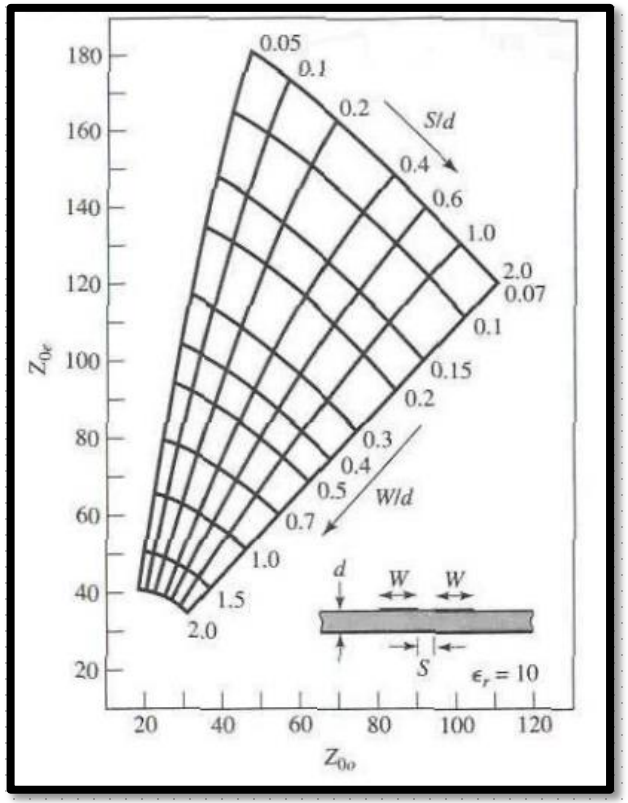
School of Electrical Engineering

Quadrature Coupler

Edge-Coupled Striplines



Coupled Microstrip Lines



School of Electrical Engineering

Contoh : Single Section Coupler Design

Design a 20 dB single section coupled line coupler in stripline with a 0,158 cm ground plane spacing, dielectric constant of 2,56. a characteristic impedance of 50 ohm and center frequency of 3 GHz.

Penyelesaian - Quadrature Coupler

1

Cari coupling vactor!

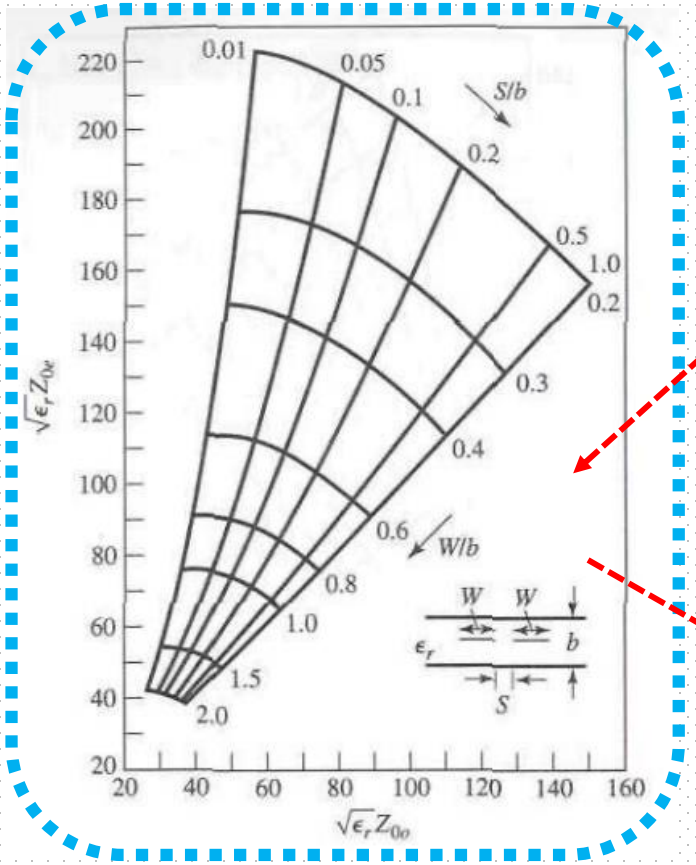
$$C = 10^{-20/20} = 0{,}1$$

2

Cari Z_0 even/odd

$$Z_{0e} = 50\sqrt{\frac{1{,}1}{0{,}9}} = 55{,}28\Omega$$

$$Z_{0o} = 50\sqrt{\frac{0{,}9}{1{,}1}} = 45{,}23\Omega$$



3

Gunakan grafik

$$\sqrt{\varepsilon_r} Z_{0e} = 88{,}4$$

$$\sqrt{\varepsilon_r} Z_{0o} = 72{,}4$$

4

$$W/b = 0{,}72$$

$$S/b = 0{,}34$$

5

$$W = 0{,}72b = 0{,}114cm$$

$$S = 0{,}34b = 0{,}054cm$$

School of Electrical Engineering

180 Degrees Coupler

4 Port 3dB

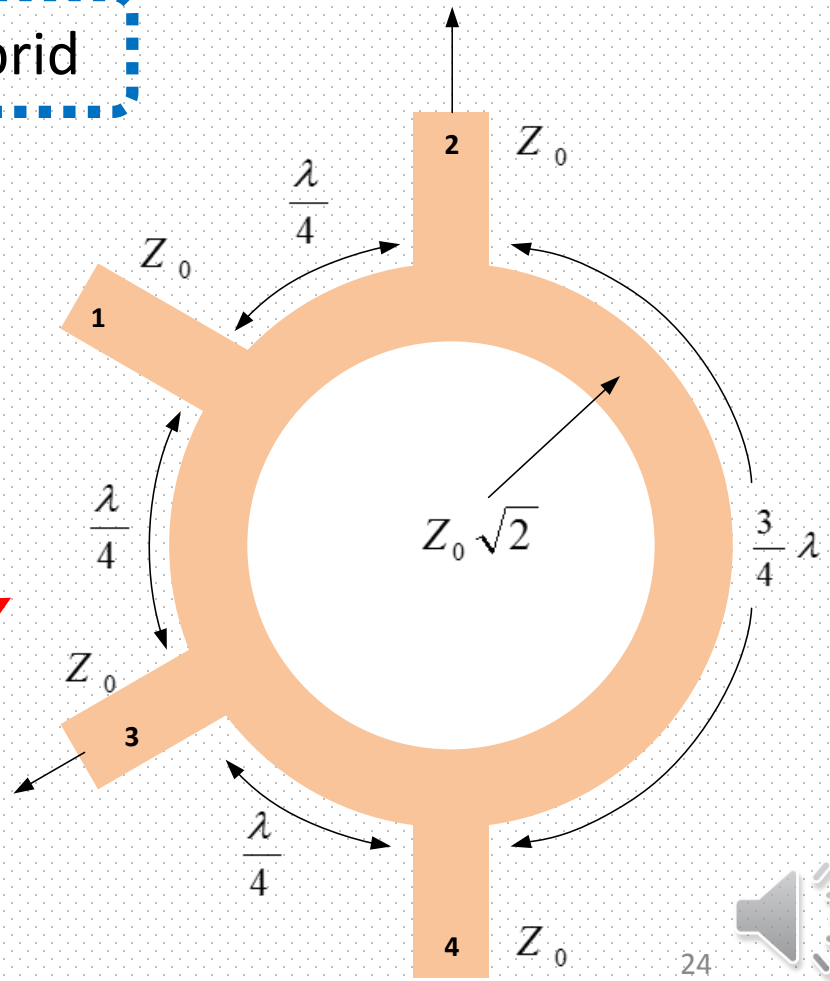
Symetric

90 Degrees Hybrid

Anti - Symetric

180 Degrees Hybrid

Ring hybrid,
rat-race hybrid,
Magic-T



School of Electrical Engineering

Contoh : Single Section Coupler Design

$$S = \begin{bmatrix} 0 & \alpha & \beta & 0 \\ \alpha & 0 & 0 & -\beta \\ \beta & 0 & 0 & \alpha \\ 0 & -\beta & \alpha & 0 \end{bmatrix}$$

Matched
Lossless
Resiprok

$$S = \begin{bmatrix} 0 & 1/\sqrt{2} & 1/\sqrt{2} & 0 \\ 1/\sqrt{2} & 0 & 0 & -1/\sqrt{2} \\ 1/\sqrt{2} & 0 & 0 & 1/\sqrt{2} \\ 0 & -1/\sqrt{2} & 1/\sqrt{2} & 0 \end{bmatrix}$$

School of Electrical Engineering

Referensi

- Microwave Engineering 3rd Edition, David M. Pozar

Terima Kasih