Power Divider dan Coupler (1)

TTG4D3 – Rekayasa Gelombang Mikro

Oleh

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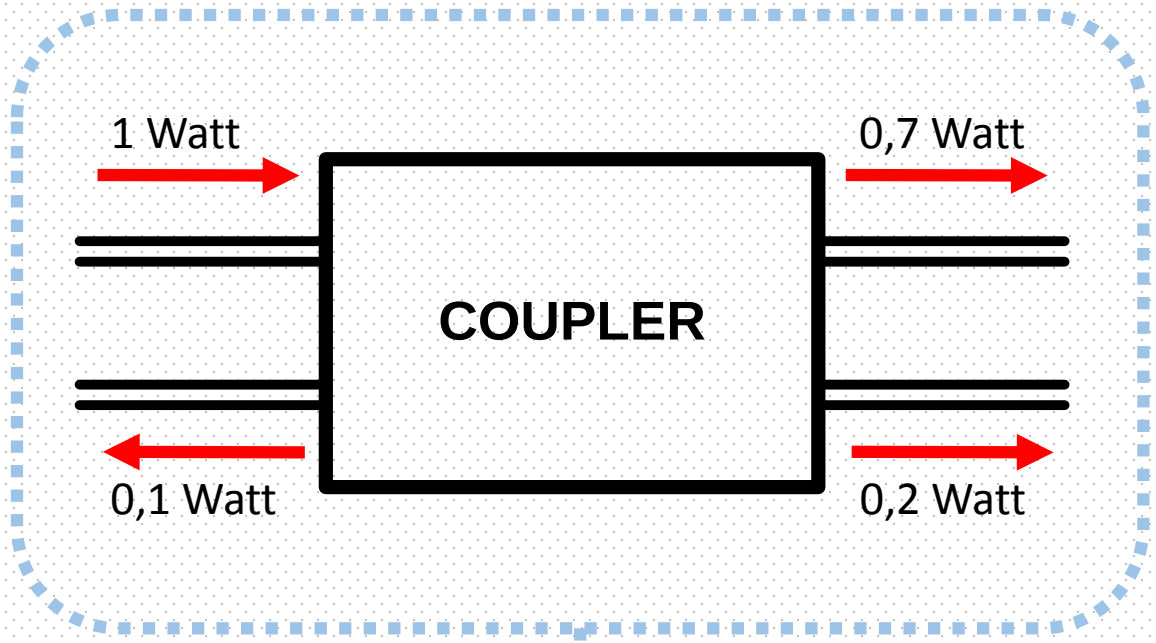
Outline

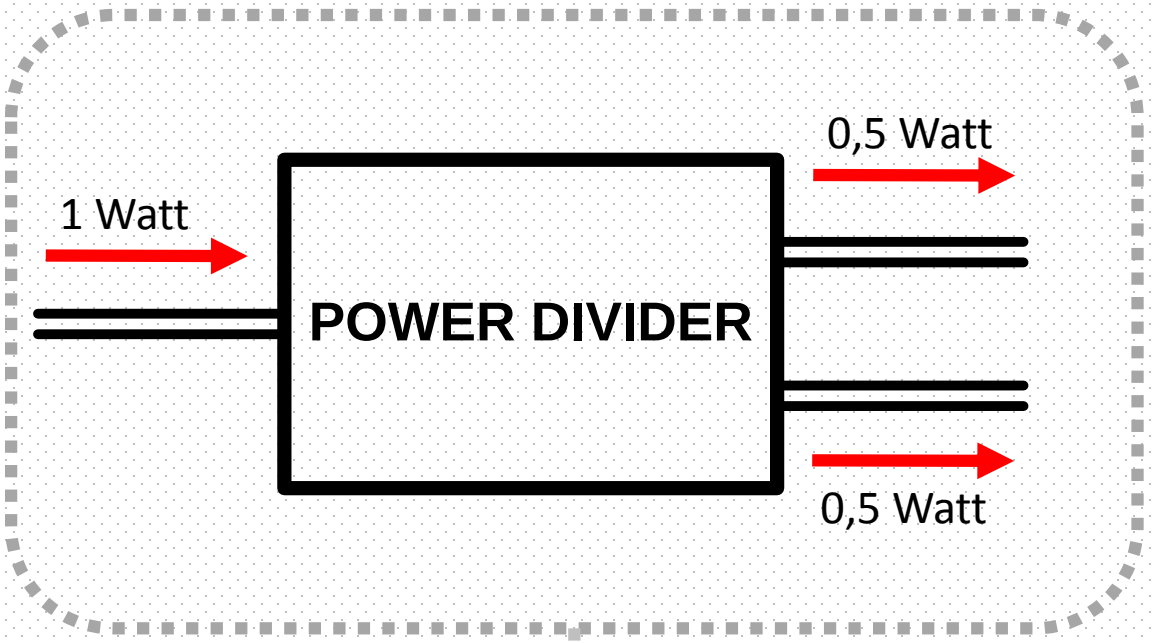
- 3 Port Power Divider
  - Resitive Power Divider
  - Lossless Power Divider
  - T-Junction Power Divider
  - Wilkinson Power Divider
  - Circulator

Pendahuluan

- Bagaimana cara membagi daya dengan komponen gelombang mikro?



4 Port



3 Port

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Sifat Divider dan Coupler

- Rangkaian 3-Port (T-Juntions)
  - Secara ideal, coupler 3 port harus matched, lossless dan resiprok.

1. Lossless :

$$\sum_{k=1}^{N} S_{ki} S_{ki}^{*} = 1 \qquad \sum_{k=1}^{N} S_{ki} S_{kj}^{*} = 0 \qquad \text{Utk } i \neq j$$

2. Matched :

$S_{11} = S_{22} = S_{33} = 0$; tidak ada pantulan pada port input.

2. Resiprok :

Matrix Parameter S, simetris.

3-Port Coupler (1)

Matrix Parameter S

$$[S]=\begin{bmatrix} S_{11} & S_{12} & S_{13} \\ S_{21} & S_{22} & S_{23} \\ S_{31} & S_{32} & S_{33} \end{bmatrix}$$

Diasumsikan : Device adalah komponen pasif dan terbuat dari isotropic material.

Syarat 3-Port Coupler : Matched, Resiprok dan Lossless.

- Matched → $S_{11} = S_{22} = S_{33} = 0$
- Resiprok → $S_{21} = S_{12}$; $S_{31} = S_{13}$; $S_{23} = S_{32}$

$$[S]=\begin{bmatrix} 0 & S_{21} & S_{31} \\ S_{21} & 0 & S_{32} \\ S_{31} & S_{32} & 0 \end{bmatrix}$$

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3-Port Coupler (2)

- Matrix S matched dan Resiprok

$$[S] = \begin{bmatrix} 0 & S_{21} & S_{31} \\ S_{21} & 0 & S_{32} \\ S_{31} & S_{32} & 0 \end{bmatrix}$$

- Jika diharapkan 3-Port Coupler bersifat lossless, maka :

$$|S_{21}|^2 + |S_{31}|^2 = 1 \qquad S_{31}^* S_{32} = 0$$

$$|S_{21}|^2 + |S_{32}|^2 = 1 \qquad S_{21}^* S_{32} = 0$$

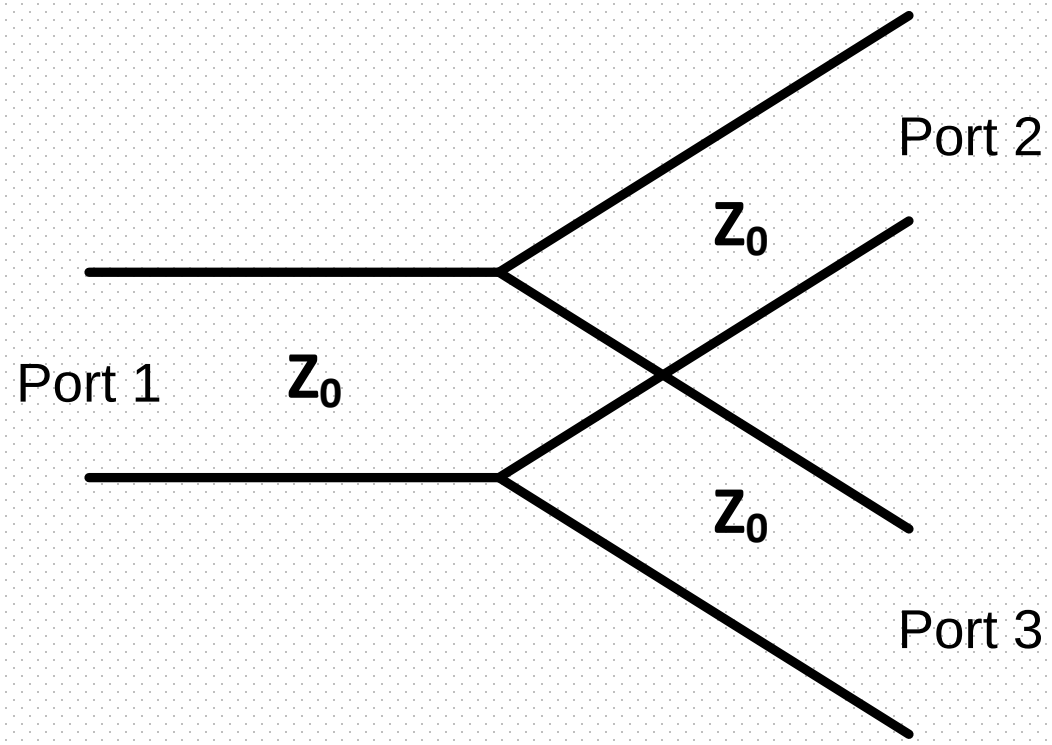
$$|S_{31}|^2 + |S_{32}|^2 = 1 \qquad S_{21}^* S_{31} = 0$$

- Sulit mencari solusi dari 9 variable dengan 6 persamaan!!

Kesimpulan (1)

- Komponen 3-Port Coupler yang bersifat Matched, Resiprok dan Lossless sulit untuk direalisasikan.

Contoh (1)



Cek apakah rangkaian tersebut bersifat Matched? Lossless? Resiprok?

$$S = \begin{bmatrix} -1/3 & 2/3 & 2/3 \\ 2/3 & -1/3 & 2/3 \\ 2/3 & 2/3 & -1/3 \end{bmatrix}$$

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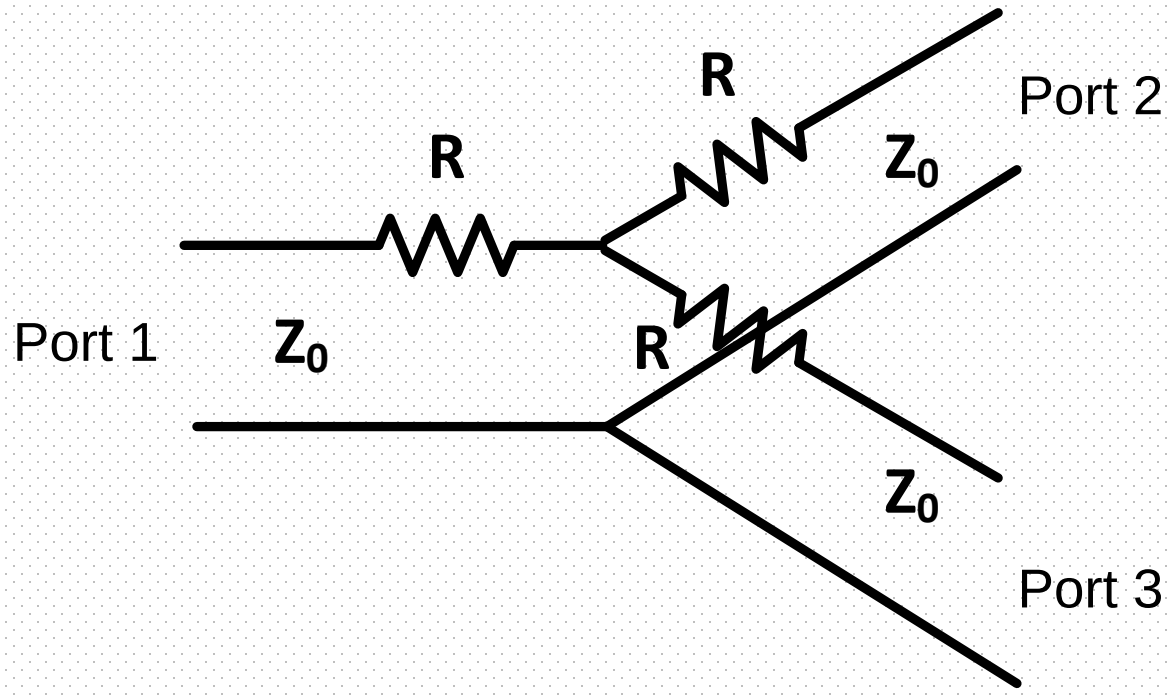
Contoh (2)



Cek apakah rangkaian tersebut bersifat Matched? Lossless? Resiprok?

$$S = \begin{bmatrix} 0 & 3/5 & 3/5 \\ 3/5 & 0 & 3/5 \\ 3/5 & 3/5 & 0 \end{bmatrix}$$

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Kesimpulan (2)

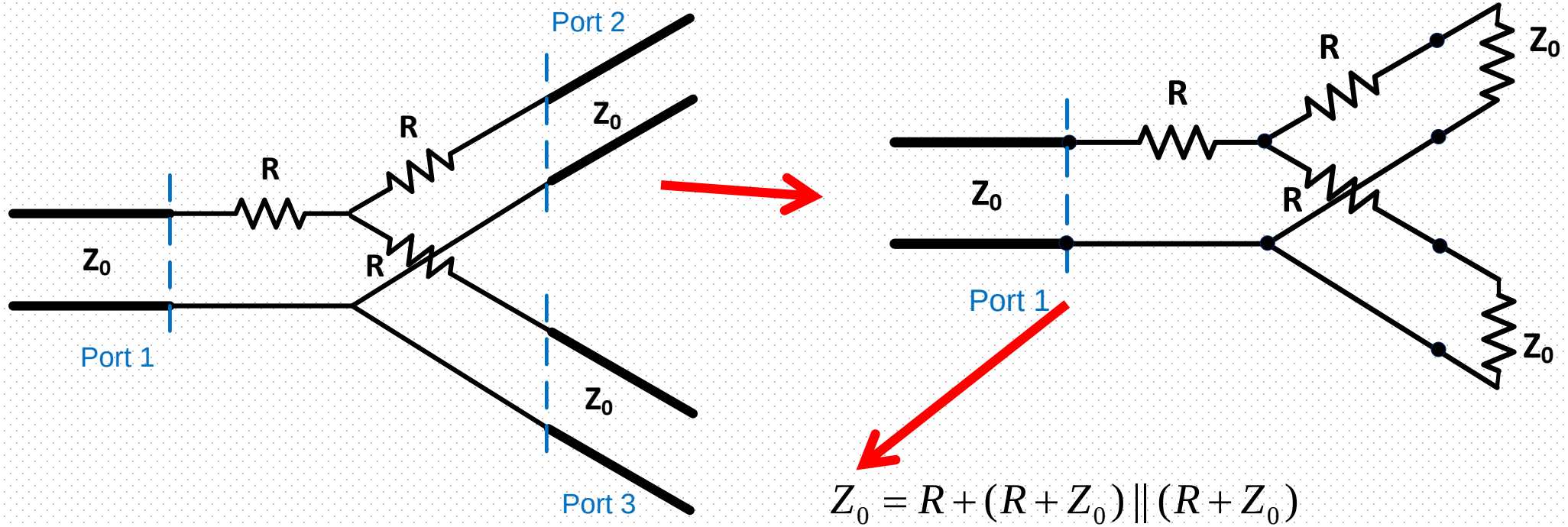
- Dengan menggunakan 3-Port, dapat dibuat 3-Port Coupler yang bersifat lossless dan resiprok atau 3-port Coupler yang matched dan resiprok bahkan mathed dan lossless tapi tidak resiprok.
- Dari beberapa percobaan sebelumnya, dengan menggunakan 3-Port, **tidak dapat** dibuat 3-Port Coupler yang bersifat matched, lossless dan resiprok.

T-Junction Coupler

→Diinginkan matched dan lossless utk 3 port coupler→ tapi sulit utk 3 port, bahkan mustahil.

1. Lossless Divider → lossless, reciprok, tapi gak match.
2. Resitive Divider → lossy tapi resiprok dan match
3. Circulator → matched dan (ideally) lossy, gak resiprok
4. Wilkinson Divider → mirip resitif power divider, matched dan resiprok, tapi lossy. Tapi lossy ini tidak muncul ketika membagi daya, jadi seolah2 daya bisa dibagi tanpa redaman (loss).

Resitive Divider (1)



$$Z_0 = R + (R + Z_0) \| (R + Z_0)$$

$$= R + \frac{R + Z_0}{2}$$

$$= 1{,}5R + \frac{Z_0}{2}$$

Port – 1 akan matched jika :

$$R = \frac{Z_0}{3}$$

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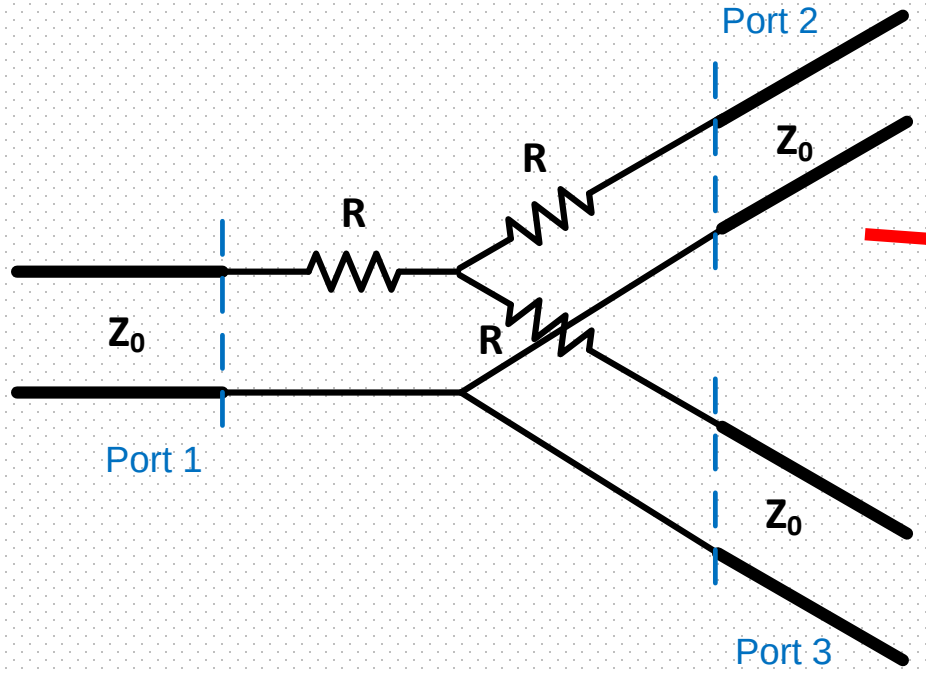
Resitive Divider (2)



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

Lossy

Matched

Resiprok

Bagaimana dengan daya tiap port? Dari daya yang masuk pada Port – 1, total daya yang keluar Port – 2 dan Port – 3 hanya ½ daya input port – 1. ¼ pada Port – 2 dan ¼ pada Port – 3. sisanya terserap oleh divider

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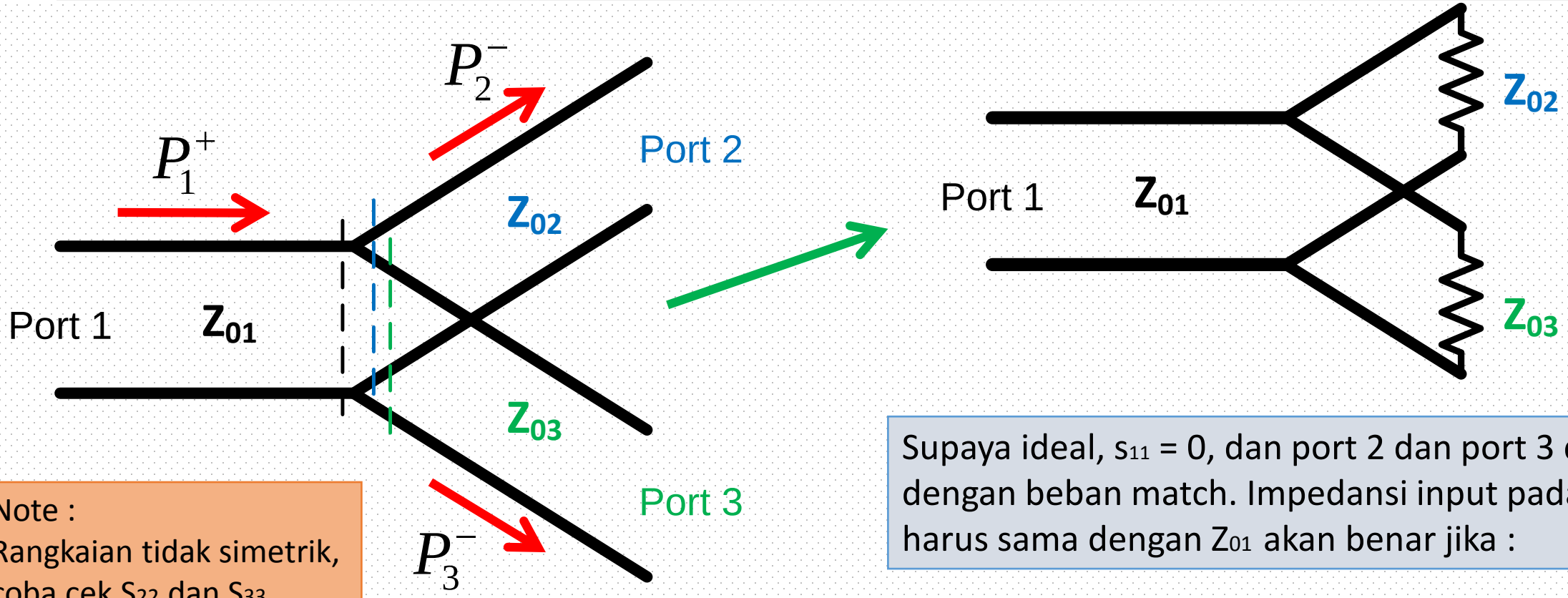
Lossless Power Divider (1)



Note :
Rangkaian tidak simetrik, coba cek S_{22} dan S_{33}, apakah bernilai nol??

Supaya ideal, $s_{11} = 0$, dan port 2 dan port 3 dibebani dengan beban match. Impedansi input pada port-1 harus sama dengan Z_{01} akan benar jika :

$$Z_{01} = \left(\frac{1}{Z_{02}} + \frac{1}{Z_{03}} \right)^{-1} = \frac{Z_{02} Z_{03}}{Z_{02} + Z_{03}}$$

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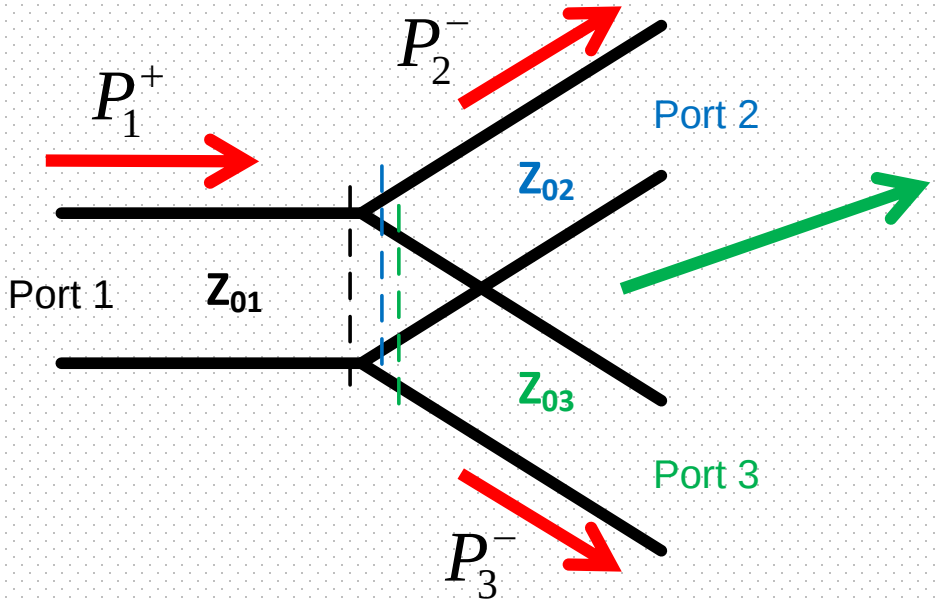
Lossless Power Divider (1)



Lossless, karena tidak ada komponen bersifat resitif.

$$P_1^+ = P_2^- + P_3^-$$

Daya yg datang (dan diserap) jika $S_{11} = 0$

Daya yang diserap pada port 2 dan port 3 jika dibebani dengan beban matched

Kecuali Z_{02} dan Z_{03} bernilai sama, daya yang mengalir ke port 2 dan port 3 tidak akan sama. Sehingga diperoleh ratio pembagi (divission ratio) α :

$$\alpha = \frac{P_2^-}{P_3^-} = \frac{Z_{03}}{Z_{02}}$$

Jika diinginkan $S_{11} = 0$ dengan ratio pembagi (divission ratio) α tertentu, maka :

$$Z_{02} = Z_{01}\left(1 + 1/\alpha\right)$$

$$Z_{03} = Z_{01}\left(1 + \alpha\right)$$

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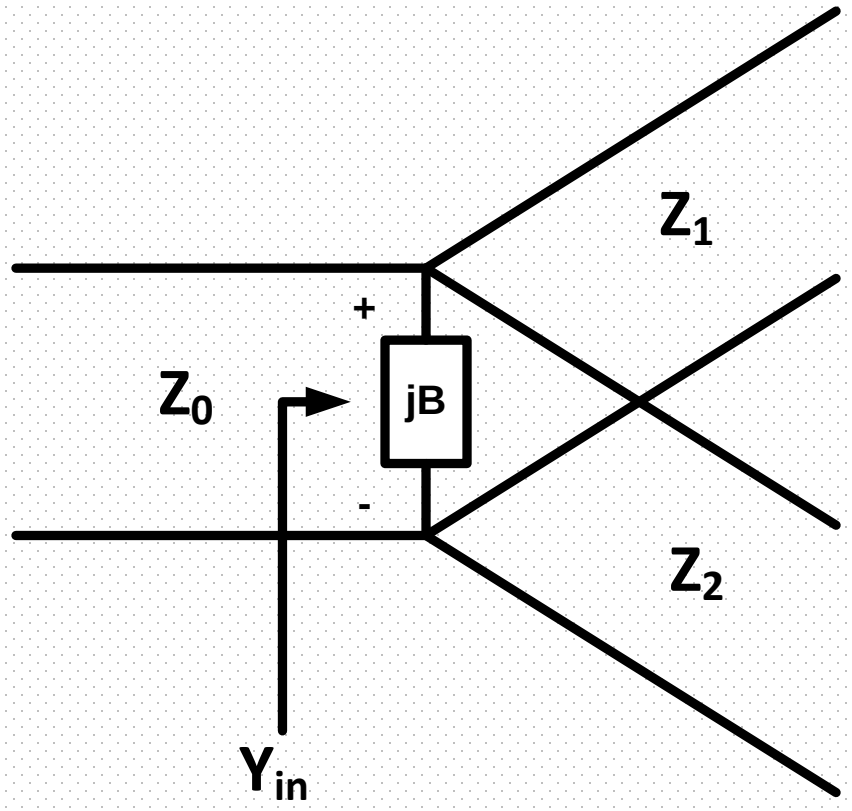
Contoh : T-Junction Power Divider

- A lossless T-Junction power divider has a source impedance of 50 ohm. Find theoutput characteristic impedances so the input power is divided in a 2:1 ratio. Compute the reflection coefficients

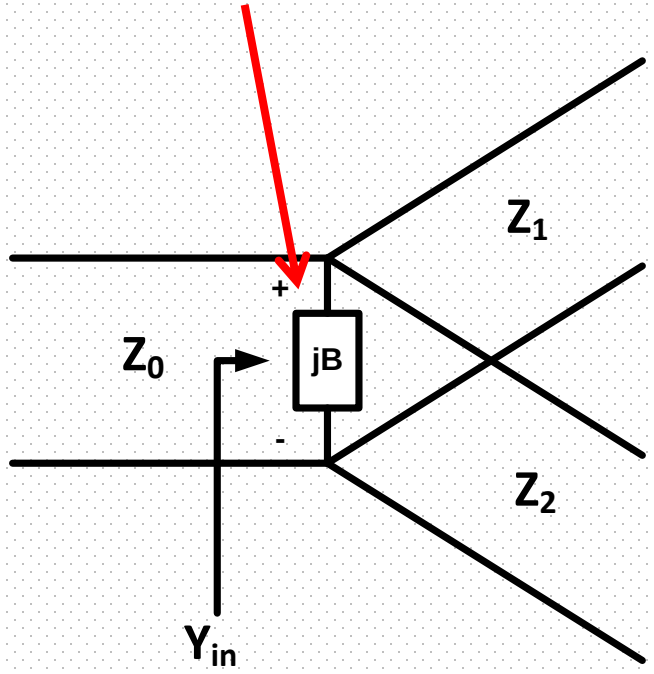


Contoh : T-Junction Power Divider

Jika tegangan pada sambungan adalah V_0 , daya input divider tersebut adalah :

$$P_{in} = \frac{1}{2}\frac{V_0^2}{Z_0}$$

$$Z_{in} = 75 \| 150 = 50\Omega$$



$$P_1 = \frac{1}{2}\frac{V_0^2}{Z_1} = \frac{1}{3}P_{in}$$

$$Z_1 = 3Z_0 = 150\Omega$$

$$Z_2 = \frac{3Z_0}{2} = 75\Omega$$

$$P_2 = \frac{1}{2}\frac{V_0^2}{Z_2} = \frac{2}{3}P_{in}$$

Koefisien pantul port 2 thd port 1 dan port 3 thd port 1??

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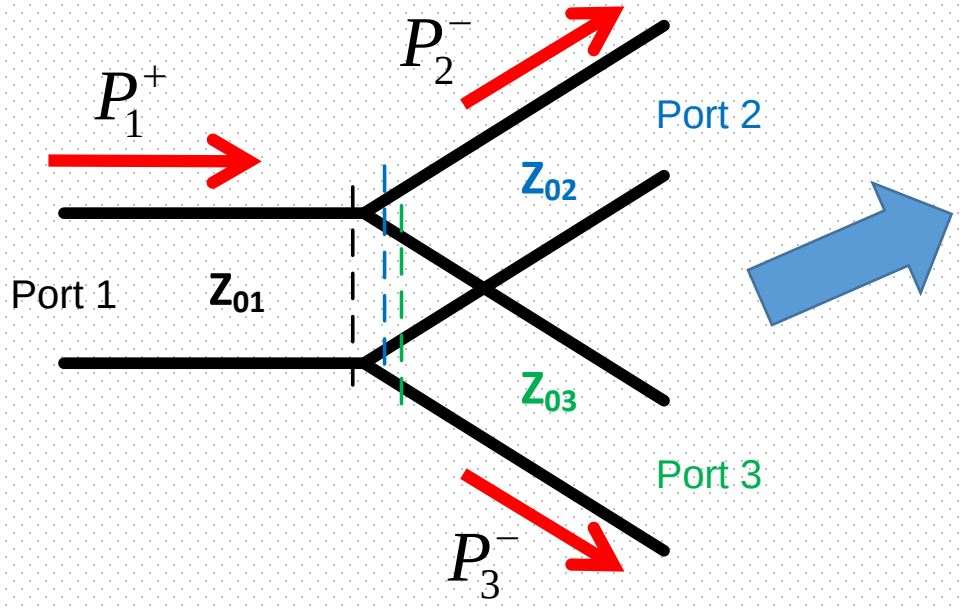
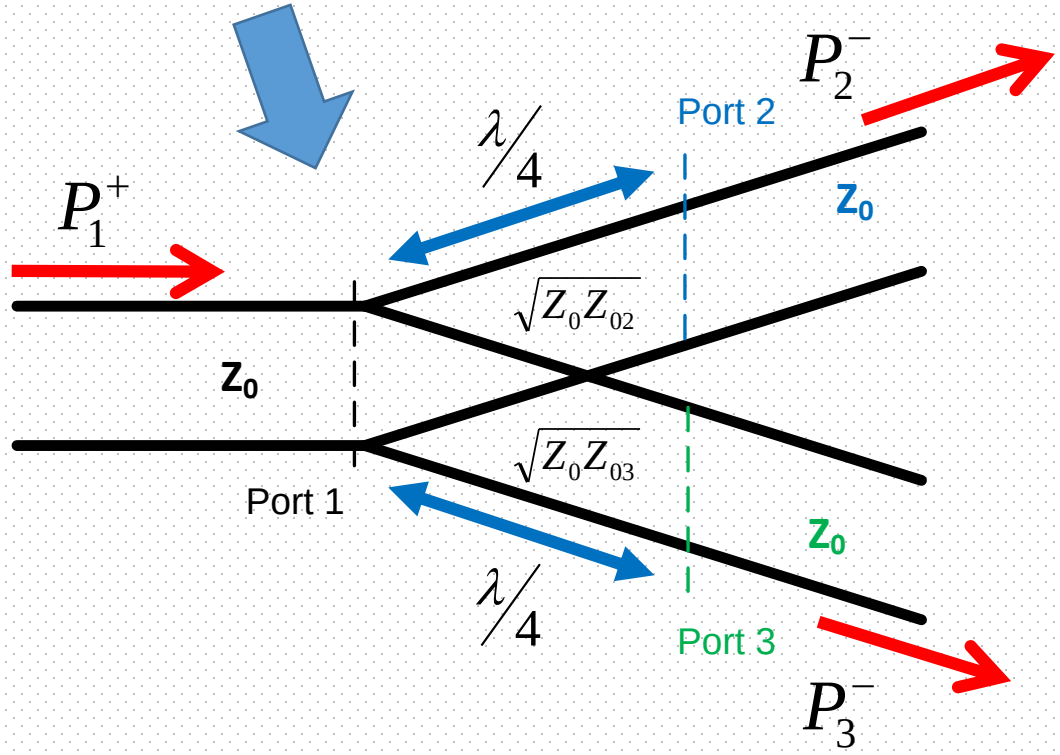
Contoh : T-Junction Power Divider



Q : bukankah diinginkan impedansi karakteristik tiap port sama? $Z_{01} = Z_{02} = Z_{03} = Z_0$??
A : Betooll!!, secara praktis bisa disisipkan penyepadan, seperti ¼ λ pada port 2 dan port 3.



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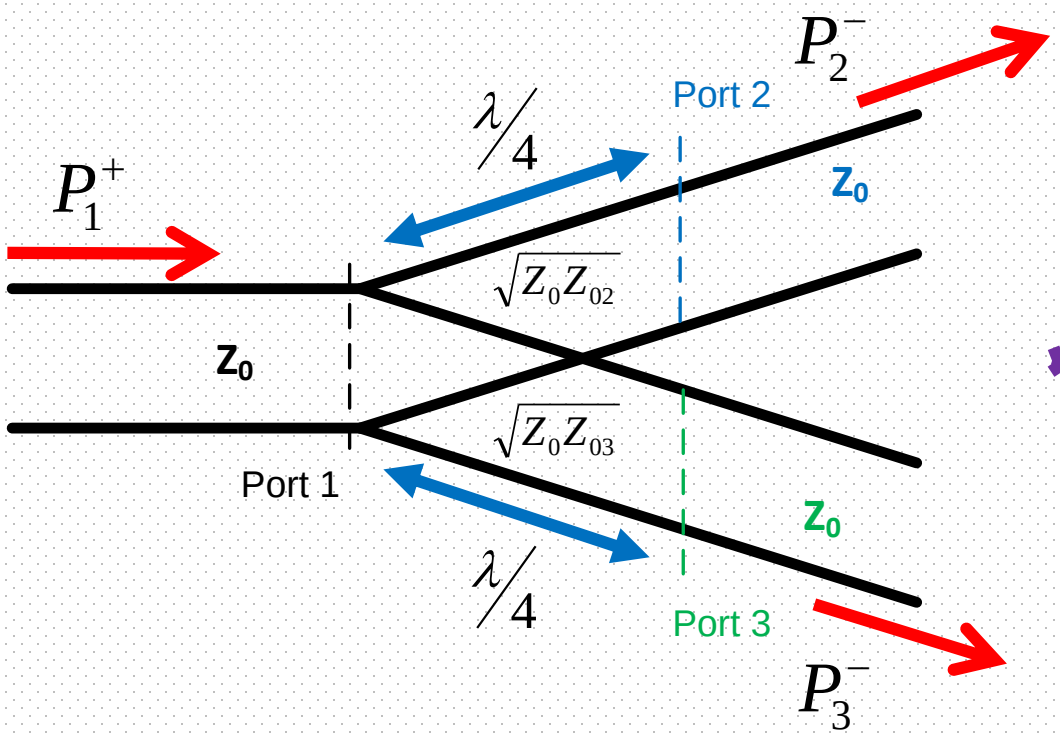
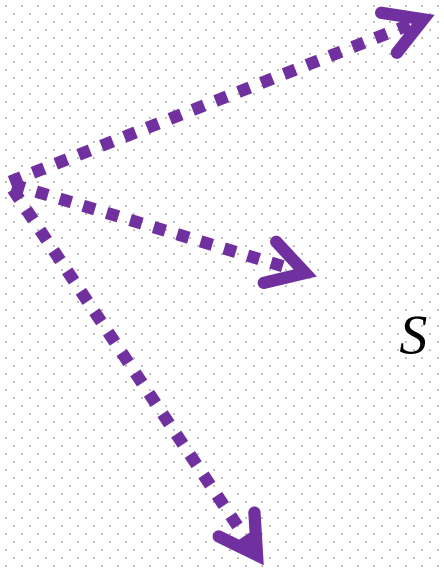
Contoh : T-Junction Power Divider





Tapi ingat, penyepadanan ini akan membuat divider bekerja hanya di satu frekuensi.

$$S = \begin{bmatrix} 0 & -j/\sqrt{2} & -j/\sqrt{2} \\ -j/\sqrt{2} & S_{22} & S_{23} \\ -j/\sqrt{2} & S_{32} & S_{33} \end{bmatrix}$$

S_{22} , S_{23} , S_{32} , S_{22} , tergantung dari ratio pembagi (divission ratio) α

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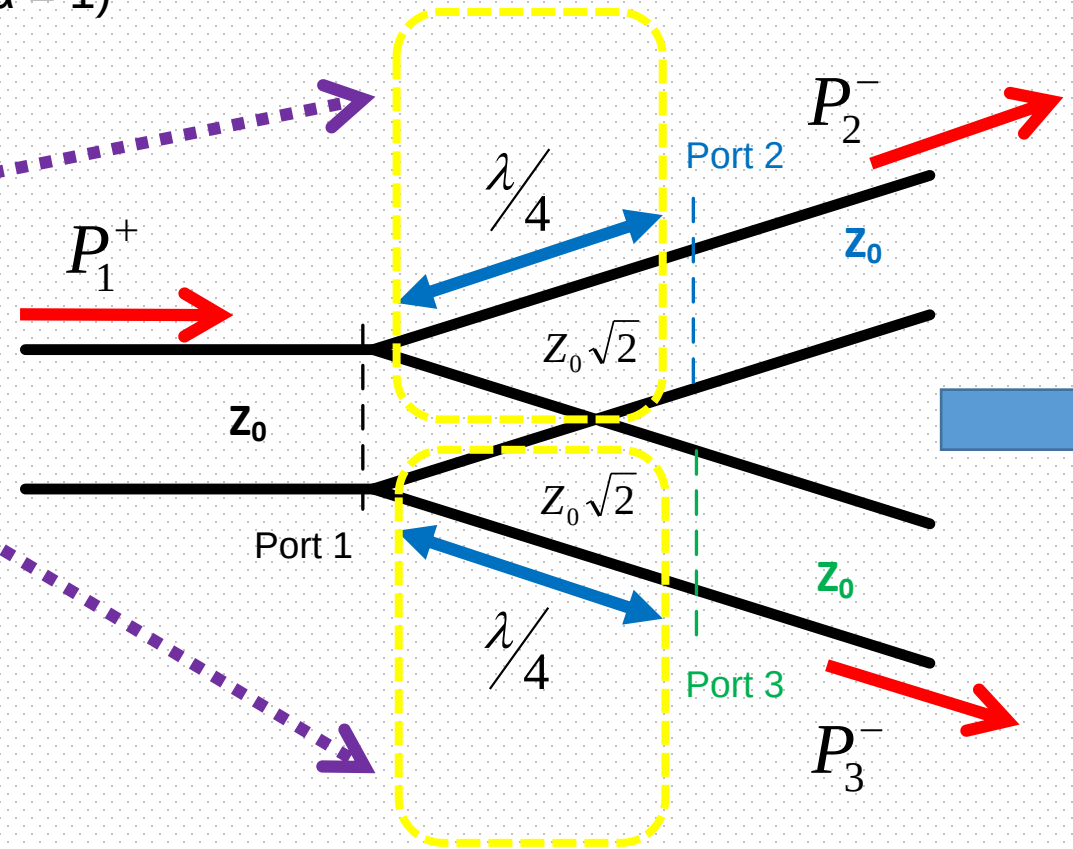
Contoh : T-Junction Power Divider

Jika diinginkan divider 3dB (i.e α = 1)

$$\sqrt{Z_{02}} = \sqrt{Z_{03}} = 2Z_{01}$$



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

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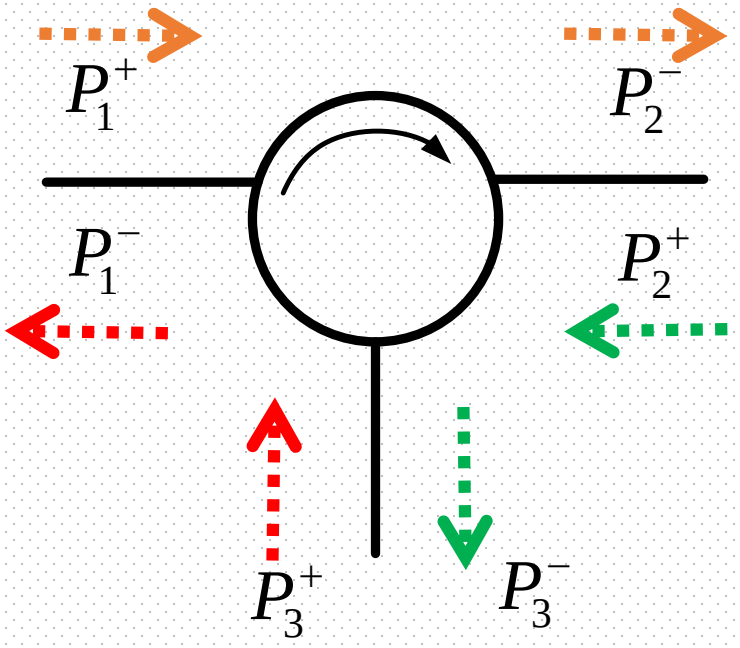
Circulator



Jika dicatu port 2, akan keluar di port 1. bagaimana jika dicatu port 1? Apakah keluar di port 2? Bagaimana jika dicatu port 3?

$$S = \begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}$$

- Matched
- Lossless
- Tidak Resiprok

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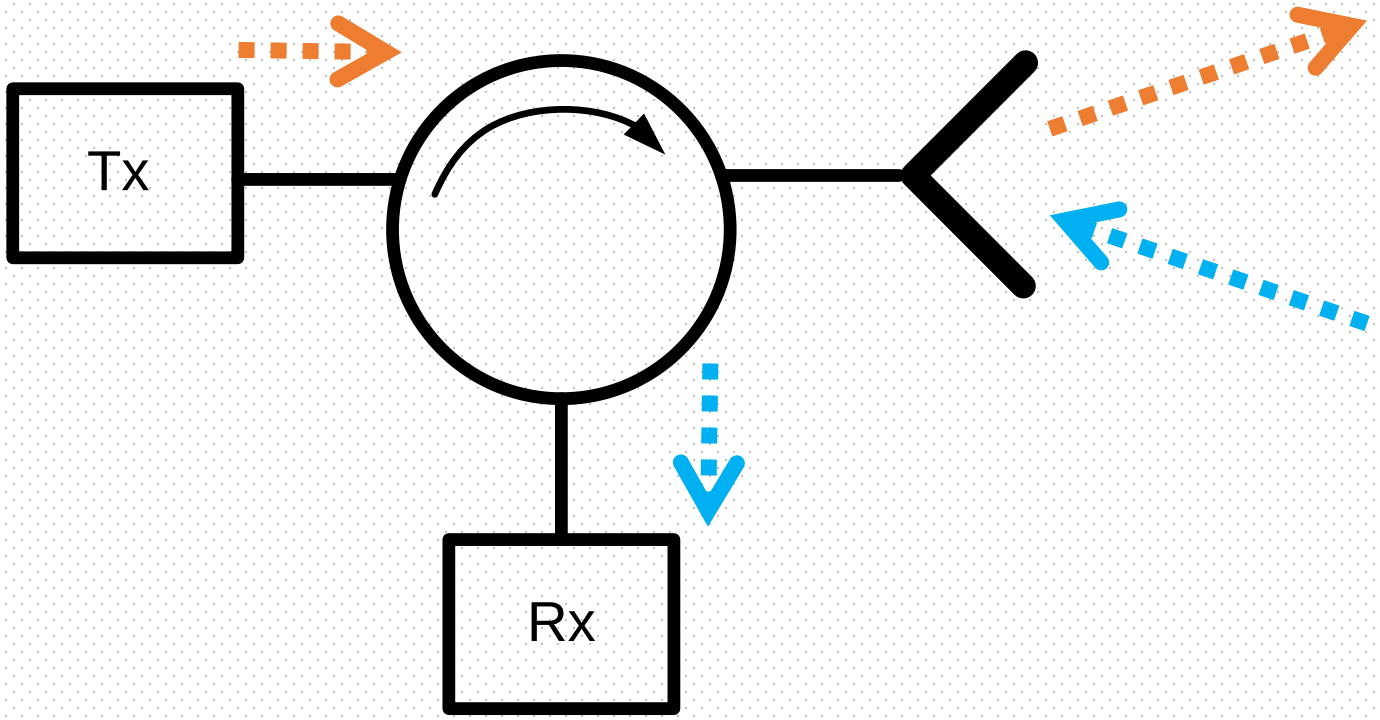
Circulator



Wilkinson Power Divider

→Most popular power divider

→Very similiar to a lossless 3dB divider, but has one additional component.

→even/odd analysis to analyze its performance.

$$S_{23} = S_{32} = 0$$

$$S_{22} = S_{33} = 0$$

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

$$|S_{11}|^2 + |S_{21}|^2 + |S_{31}|^2 = 1$$

$$P_2^- = |S_{21}|^2 P_1^+ = \frac{P_1^+}{2}$$

$$P_3^- = |S_{31}|^2 P_1^+ = \frac{P_1^+}{2}$$

Mendekati power divider 3dB ideal

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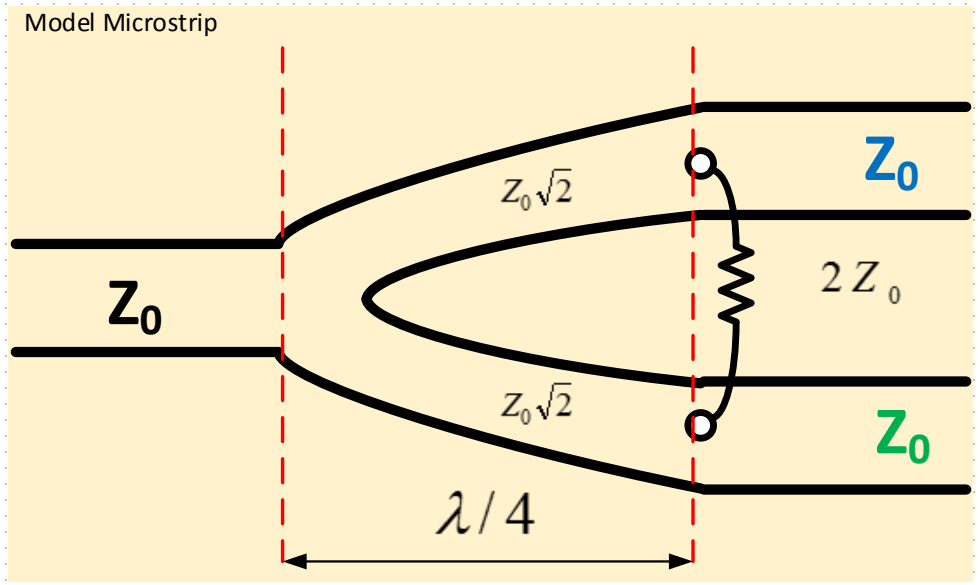
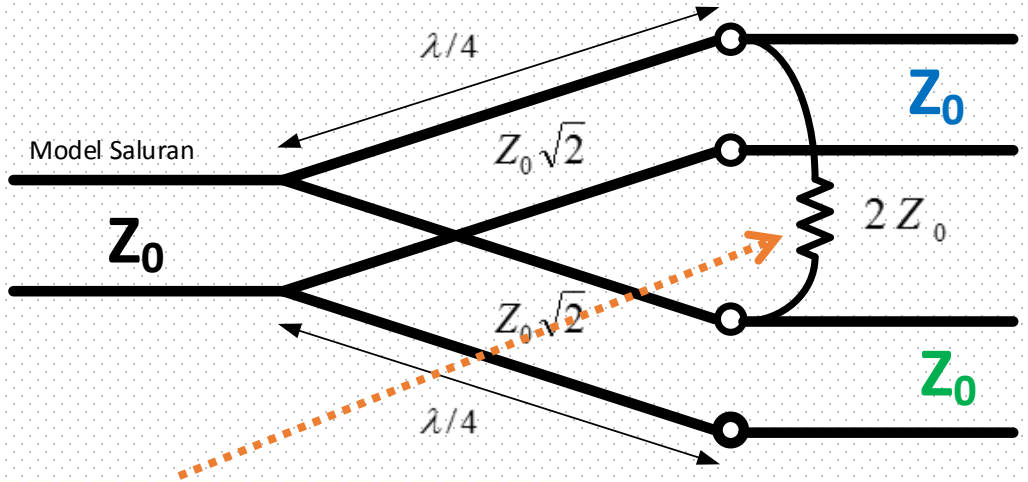
Wilkinson Power Divider

Bagaimana cara menbuat Wilkinson Power Divider?





Dengan menyisipkan resistor sebesar $2Z_0$ antara port 2 dan port 3

Port 2 dan port 3 menjadi matched

Port 2 dan port 3 menjadi terisolir (isolated) satu sama lain

λ/4 membuat wilkinson power divider menjadi narrow band (pita sempit)

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Referensi

- Microwave Engineering 3rd Edition, David M. Pozar

Terima Kasih