SNS COLLEGE OF TECHNOLOGY
(An Autonomous Institution)
Sathy Main Road, Saravanampatti (Post), Coimbatore – 641 035
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Department of Electronics and Communication Engineering

COURSE NAME : OPTICAL AND MICROWAVE ENGINEERING

Topic- Two Port Network-S parameters and ABCD parameters

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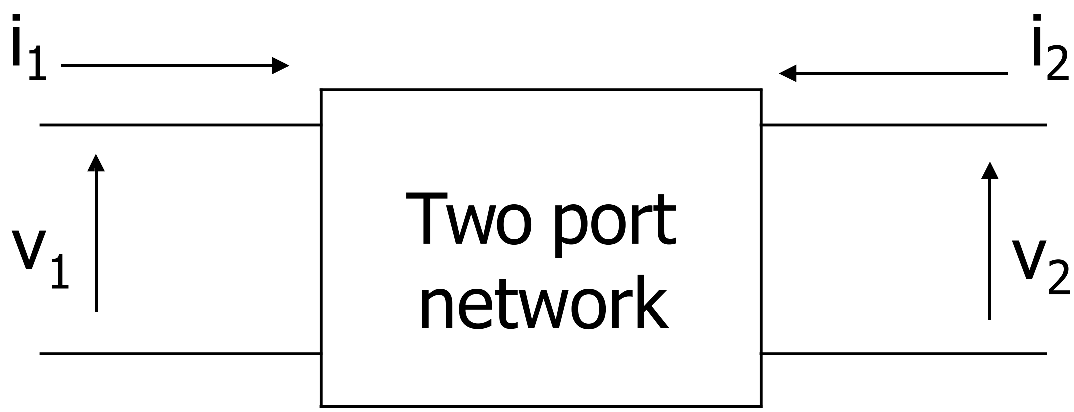
Two-Port Network

- 2-port networks are often described by using z, y, h, or ABCD parameters.



z-parameters (in Ohm)

$v_1 = z_{11}i_1 + z_{12}i_2$

$v_2 = z_{21}i_1 + z_{22}i_2$

$$\Rightarrow \begin{bmatrix} v_1 \\ v_2 \end{bmatrix} = \begin{bmatrix} z_{11} & z_{12} \\ z_{21} & z_{22} \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \end{bmatrix}$$

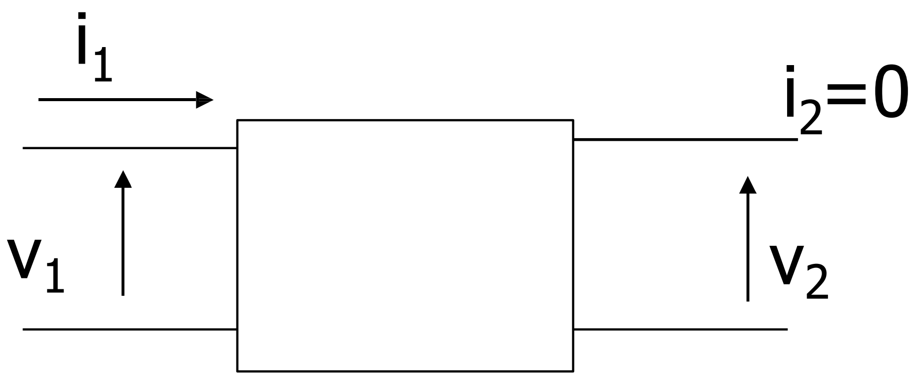
where

$$z_{11} = \left. \frac{v_1}{i_1} \right|_{i_2=0} \qquad z_{12} = \left. \frac{v_1}{i_2} \right|_{i_1=0}$$

$$z_{21} = \left. \frac{v_2}{i_1} \right|_{i_2=0} \qquad z_{22} = \left. \frac{v_2}{i_2} \right|_{i_1=0}$$

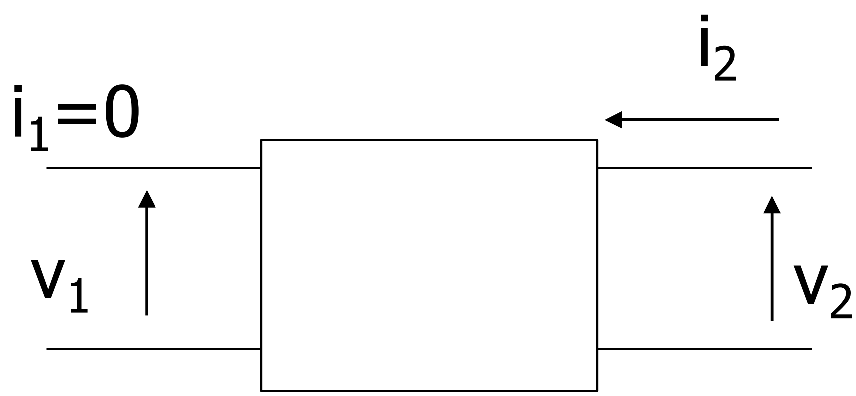
z-parameters (in Ohm)

$$z_{11} = \left.\frac{v_1}{i_1}\right|_{i_2=0}$$



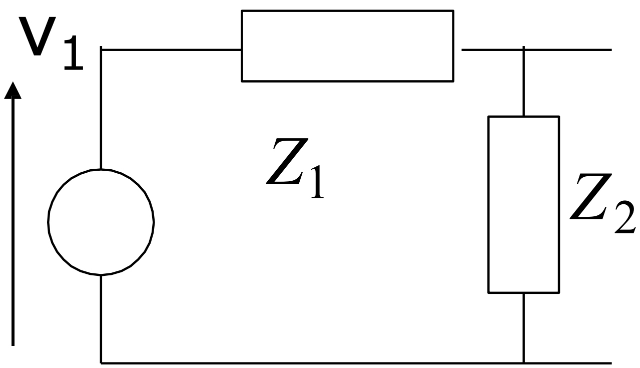
$$z_{21} = \left.\frac{v_2}{i_1}\right|_{i_2=0}$$

$$z_{12} = \left.\frac{v_1}{i_2}\right|_{i_1=0}$$



$$z_{22} = \left.\frac{v_2}{i_2}\right|_{i_1=0}$$

Example (Z-parameters)



$$z_{11} = \left.\frac{v_1}{i_1}\right|_{i_2=0} \longrightarrow i_1 = \frac{v_1}{Z_1 + Z_2}$$

$$z_{11} = Z_1 + Z_2$$

y-parameters (in Siemens)

$i_1 = y_{11}v_1 + y_{12}v_2$

$i_2 = y_{21}v_1 + y_{22}v_2$

$$\Longrightarrow \begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \end{bmatrix}$$

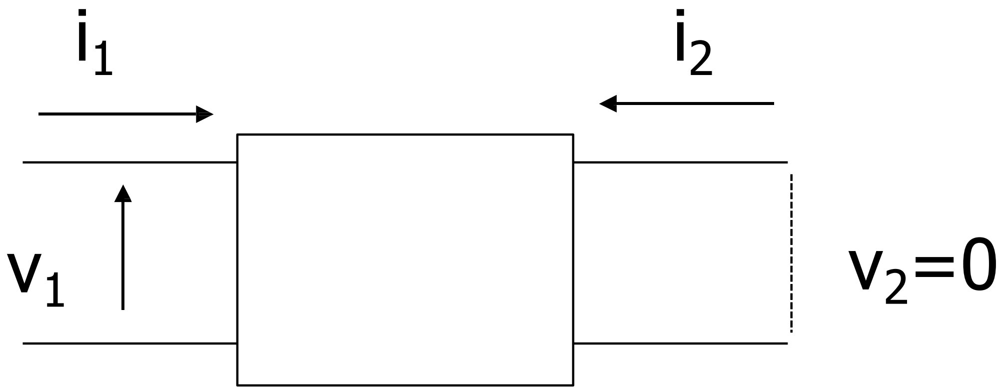
where

$$y_{11} = \left.\frac{i_1}{v_1}\right|_{v_2=0} \qquad y_{12} = \left.\frac{i_1}{v_2}\right|_{v_1=0}$$

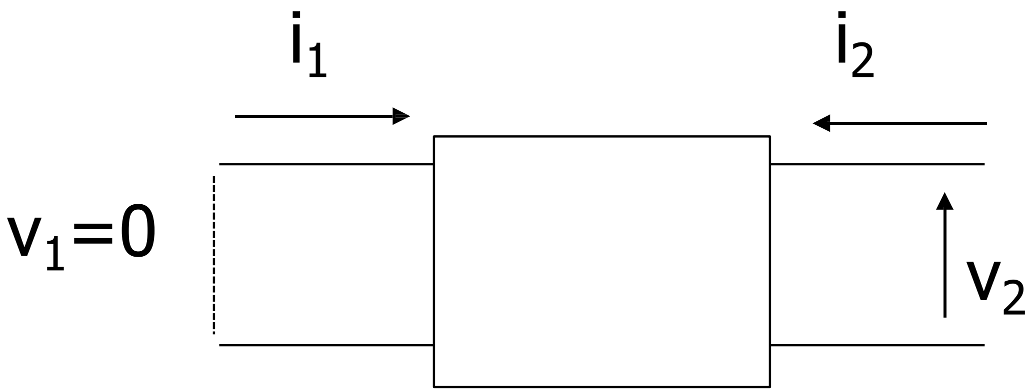
$$y_{21} = \left.\frac{i_2}{v_1}\right|_{v_2=0} \qquad y_{22} = \left.\frac{i_2}{v_2}\right|_{v_1=0}$$

y-parameters (in Siemens)

$$y_{11} = \left.\frac{i_1}{v_1}\right|_{v_2=0}$$



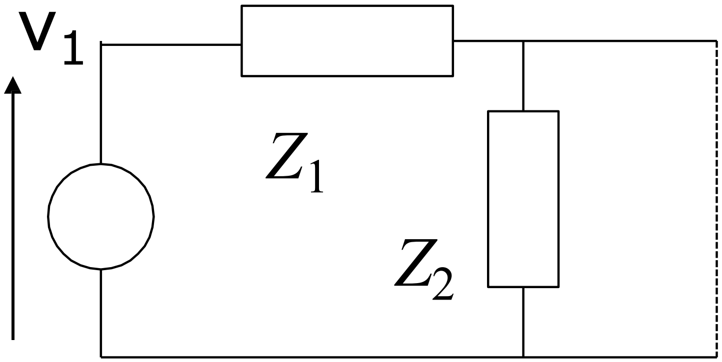
$$y_{21} = \left.\frac{i_2}{v_1}\right|_{v_2=0}$$



$$y_{12} = \left.\frac{i_1}{v_2}\right|_{v_1=0}$$

$$y_{22} = \left.\frac{i_2}{v_2}\right|_{v_1=0}$$

Example (y-parameters)



$$y_{21} = \left.\frac{i_2}{v_1}\right|_{v_2=0} \longrightarrow \quad i_2 = \frac{-v_1}{Z}$$

$$y_{21} = \frac{-1}{Z_1}$$

Conversion between z- & y- parameters

$$\begin{bmatrix} v_1 \\ v_2 \end{bmatrix} = \begin{bmatrix} z_{11} & z_{12} \\ z_{21} & z_{22} \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \end{bmatrix} \qquad \begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \end{bmatrix}$$

$$[Y] = [Z]^{-1}$$

ABCD-parameters

$$v_1 = Av_2 + B(-i_2)$$

$$i_1 = Cv_2 + D(-i_2)$$

$$\Longrightarrow \begin{bmatrix} v_1 \\ i_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} v_2 \\ -i_2 \end{bmatrix}$$

where

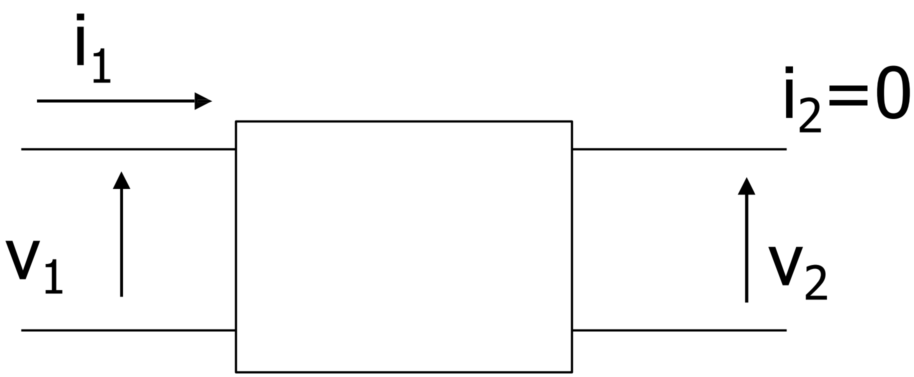
$$A = \left.\frac{v_1}{v_2}\right|_{-i_2=0} \qquad B = -\left.\frac{v_1}{i_2}\right|_{v_2=0}$$

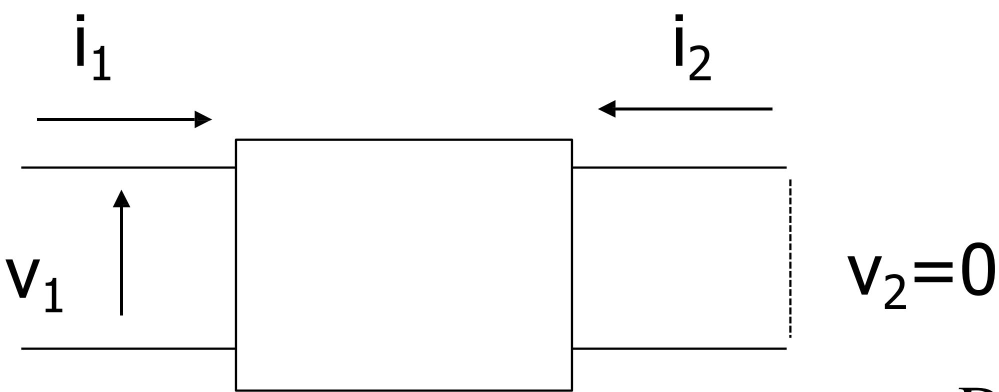
$$C = \left.\frac{i_1}{v_2}\right|_{-i_2=0} \qquad D = -\left.\frac{i_1}{i_2}\right|_{v_2=0}$$

ABCD-parameters

$$A = \left.\frac{v_1}{v_2}\right|_{-i_2=0}$$

$$C = \left.\frac{i_1}{v_2}\right|_{-i_2=0}$$

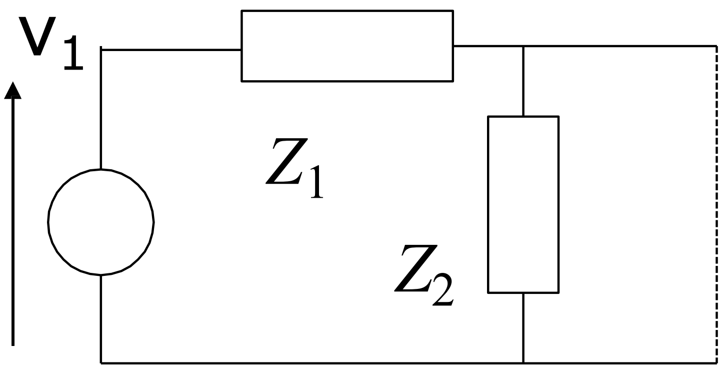




$$B = -\left.\frac{v_1}{i_2}\right|_{v_2=0}$$

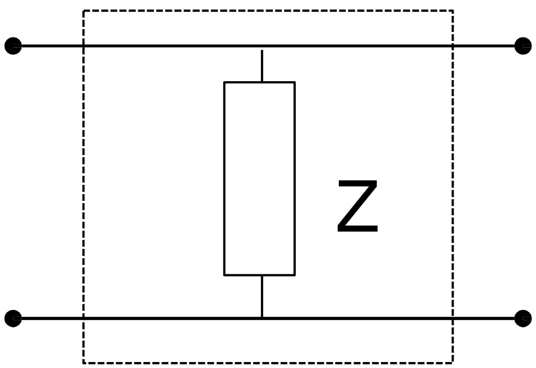
$$D = -\left.\frac{i_1}{i_2}\right|_{v_2=0}$$

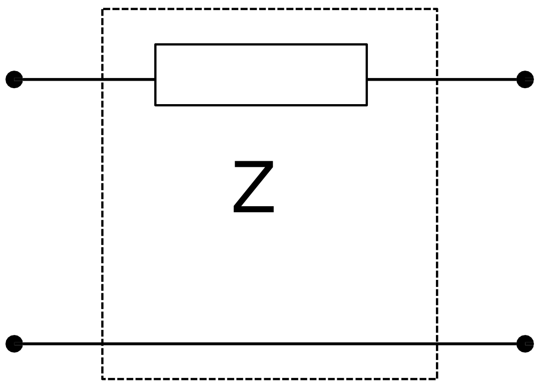
Example (ABCD-parameters)

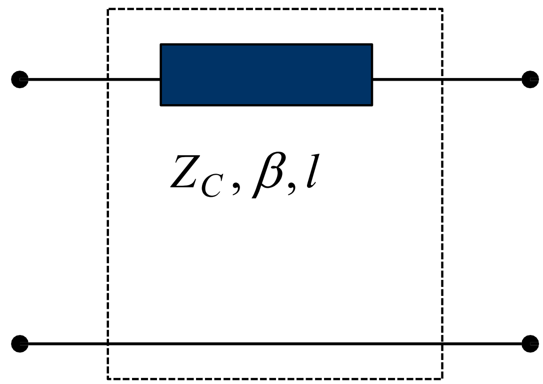


$$D = -\left.\frac{i_1}{i_2}\right|_{v_2=0} \longrightarrow \begin{array}{l} i_2 = -i_1 \\ D = 1 \end{array}$$

ABCD-(circuit examples)





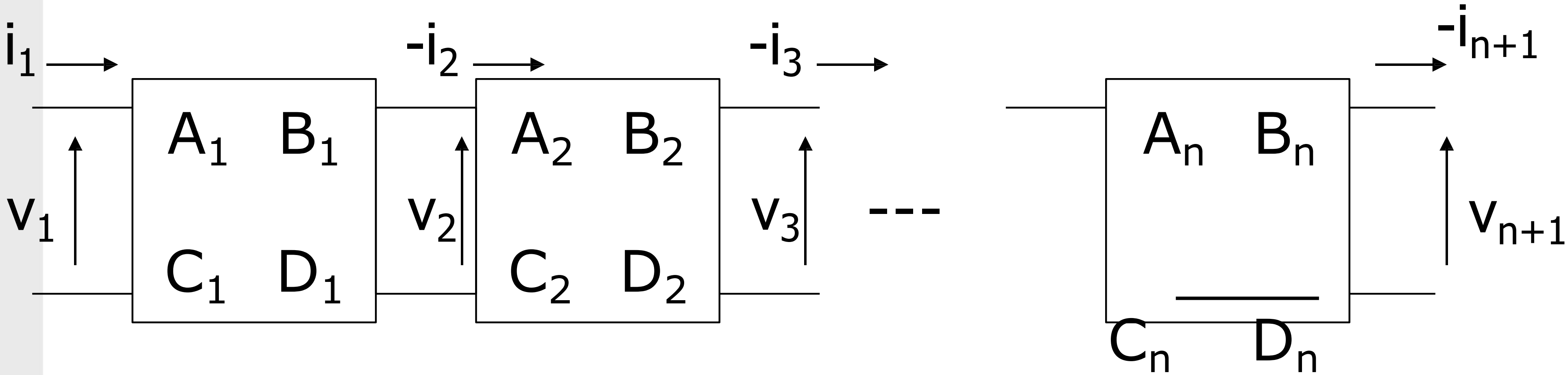


$$\begin{bmatrix} 1 & 0 \\ 1/Z & 1 \end{bmatrix}$$

$$\begin{bmatrix} 1 & Z \\ 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} \cos \beta l & jZ_C \sin \beta l \\ \dfrac{j \sin \beta l}{Z_C} & \cos \beta l \end{bmatrix}$$

ABCD-(Cascaded circuit)



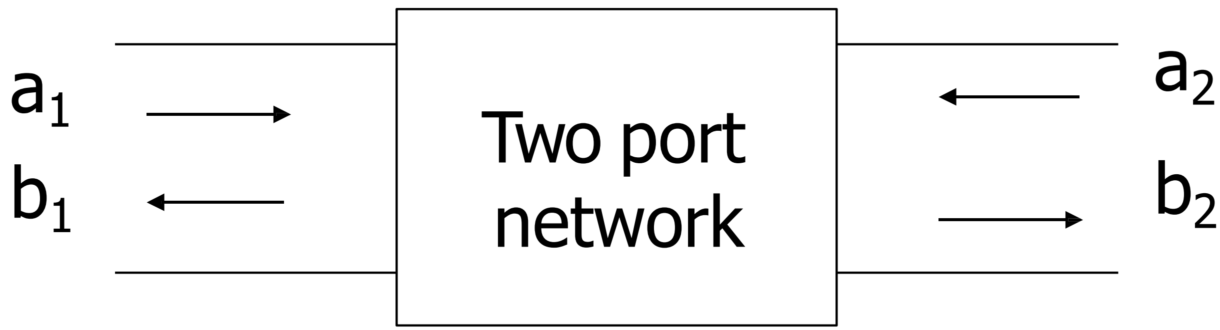
$$\begin{bmatrix} v_1 \\ i_1 \end{bmatrix} = \begin{bmatrix} A_T & B_T \\ C_T & D_T \end{bmatrix} \begin{bmatrix} v_{n+1} \\ -i_{n+1} \end{bmatrix}$$

$$\begin{bmatrix} A_T & B_T \\ C_T & D_T \end{bmatrix} = \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} \begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix} \cdots \begin{bmatrix} A_n & B_n \\ C_n & D_n \end{bmatrix}$$

Drawbacks of Y, Z parameters

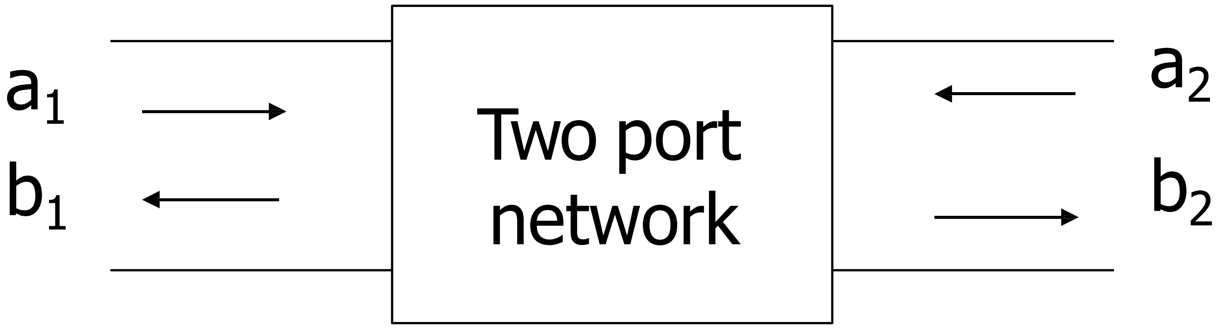
- At microwave frequency, total voltage and current are difficult to measure.
- Ideal open- and short-circuit terminations are difficult to realize.
- Active devices may oscillate under open- or short-circuit conditions.

Scattering parameters



- Incident and reflected waves are being monitored instead.
- Resistive termination is employed.
- Active devices are normally quite stable under resistive termination.

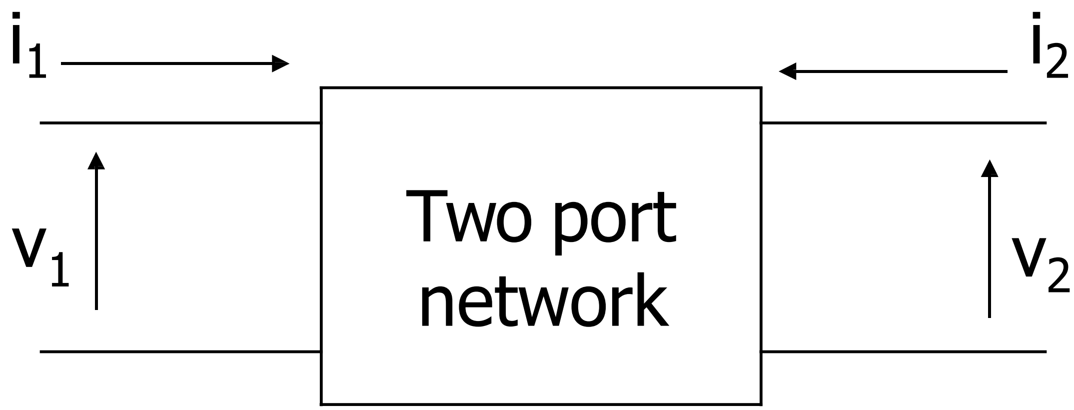
Scattering parameters



$$a_1 = \frac{v_{i,1}}{\sqrt{Z_o}} \qquad a_2 = \frac{v_{i,2}}{\sqrt{Z_o}}$$

$$b_1 = \frac{v_{r,1}}{\sqrt{Z_o}} \qquad b_2 = \frac{v_{r,2}}{\sqrt{Z_o}}$$

Waves and Total voltage/current



$$v_1 = (a_1 + b_1)\sqrt{Z_0}$$

$$v_2 = (a_2 + b_2)\sqrt{Z_0}$$

$$i_1 = (a_1 - b_1)\frac{1}{\sqrt{Z_0}}$$

$$i_2 = (a_2 - b_2)\frac{1}{\sqrt{Z_0}}$$

Scattering parameters

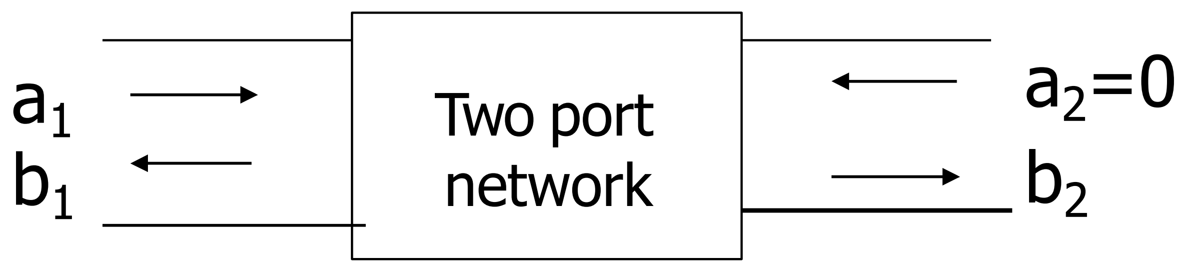
$b_1 = S_{11}a_1 + S_{12}a_2$

$b_2 = S_{21}a_1 + S_{22}a_2$

$$\Longrightarrow \begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$

Scattering parameters

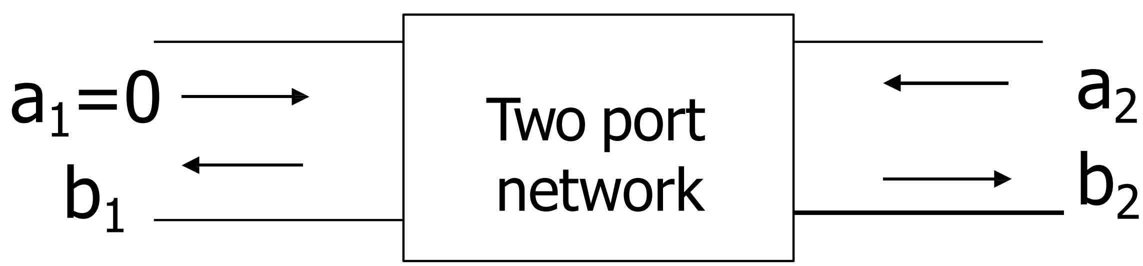
$$S_{11} = \left.\frac{b_1}{a_1}\right|_{a_2=0}$$ = reflection coefficient at port 1 with a_2=0



$$S_{21} = \left.\frac{b_2}{a_1}\right|_{a_2=0}$$ = forward transmission coefficient from port 1 to 2 with a_2=0

Scattering parameters

$$S_{12} = \left. \frac{b_1}{a_2} \right|_{a_1=0}$$ = reverse transmission coefficient from port 2 to 1 with $a_1=0$



$$S_{22} = \left. \frac{b_2}{a_2} \right|_{a_1=0}$$ = reflection coefficient at port 2 with $a_1=0$

2-port network (new terms)

Insertion loss (dB):

$$\alpha = -10\times\log\left|S_{21}\right|^{2} = -20\times\log\left|S_{21}\right|$$

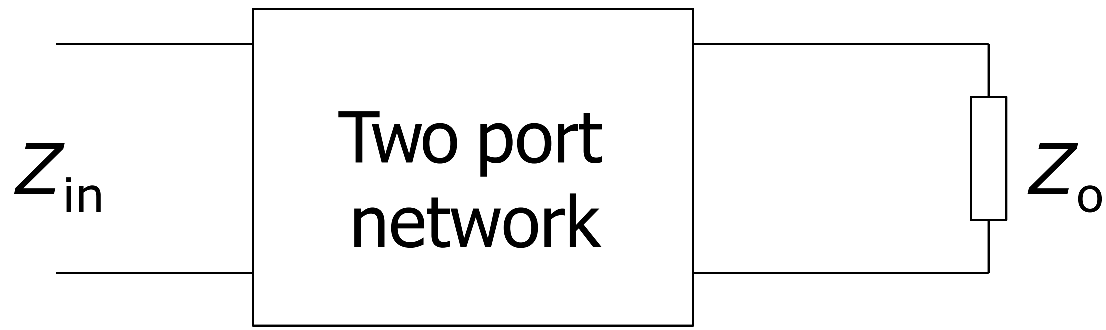
Transmission phase shift: $\phi = \angle S_{21}$

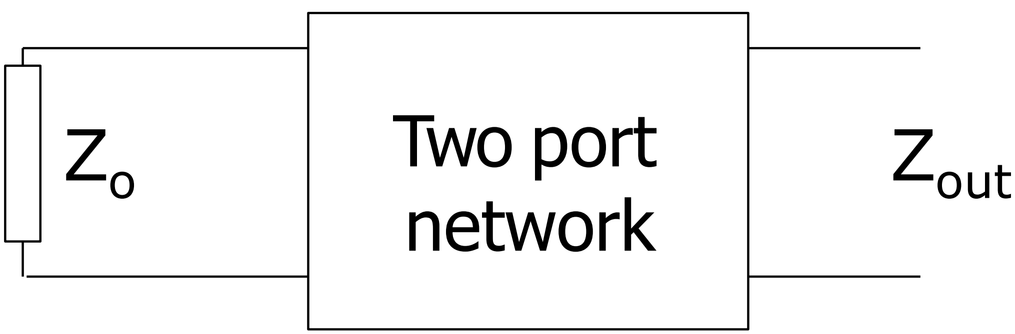
Input return loss (dB): $-20\times\log\left|S_{11}\right|$

Output return loss (dB): $-20\times\log\left|S_{22}\right|$

Evaluation of S_{11} and S_{22}

$$S_{11} = \Gamma_{in} = \frac{Z_{in} - Z_o}{Z_{in} + Z_o}$$

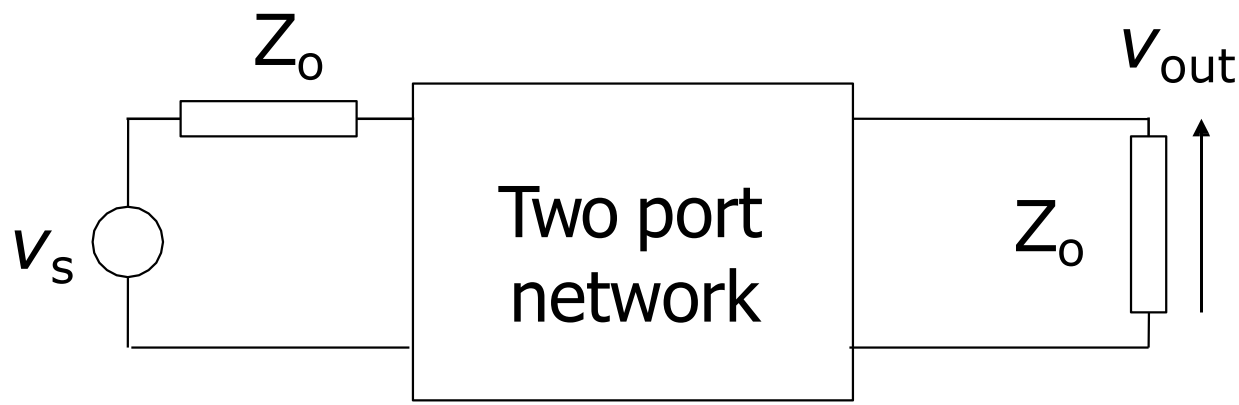


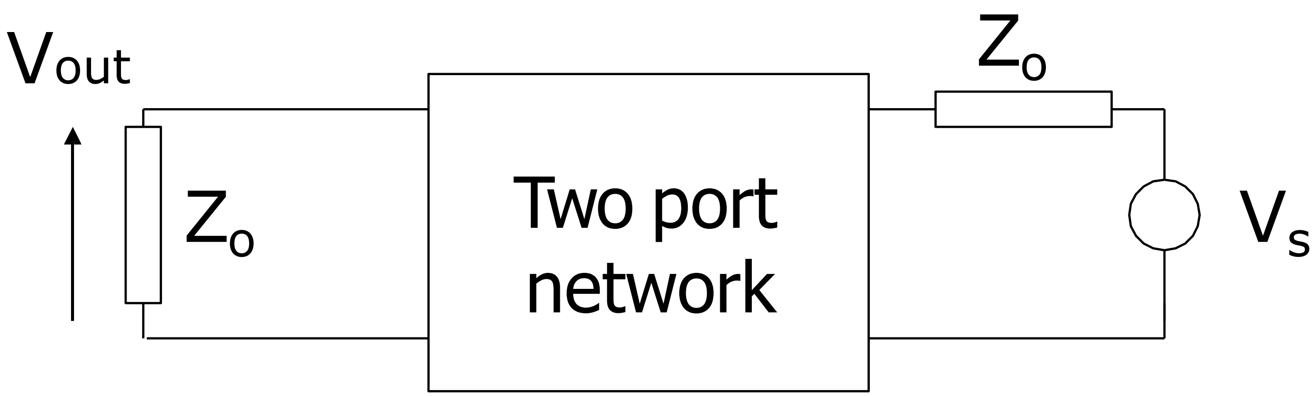


$$S_{22} = \Gamma_{out} = \frac{Z_{out} - Z_o}{Z_{out} + Z_o}$$

Evaluation of S_{21} and S_{12}

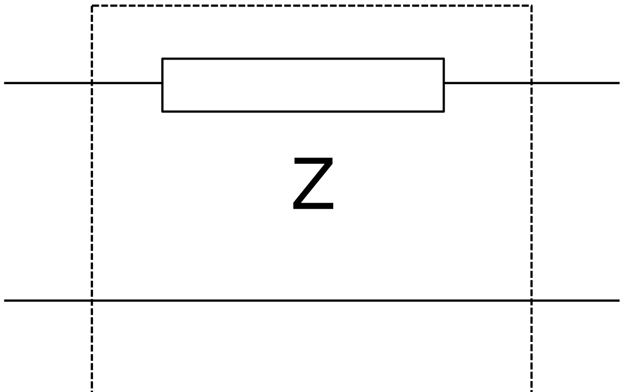
$$S_{21} = 2\frac{v_{out}}{v_s}$$





$$S_{12} = 2\frac{v_{out}}{v_s}$$

Example (Attenuation)



$$S_{21} = \frac{2Z_o}{Z + Z_o}$$

$$\alpha = 20 \cdot \log |S_{21}| = 20 \cdot \log \left| \frac{2Z_0}{R + jX + Z_0} \right|$$

$$= 20 \cdot \log \frac{2Z_0}{\sqrt{(R + Z_0)^2 + X^2}}$$

Example (Phase Shift)

$$\phi = \angle S_{21}$$

$$= \angle \frac{2Z_o}{R + 2Z_o + jX}$$

$$= \angle(2Z_o) - \angle(R + 2Z_o + jX)$$

$$= -\tan^{-1}\left(\frac{X}{R + 2Z_o}\right)$$

S-ABCD conversion

$$\begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} = \begin{bmatrix} \dfrac{A + BY_o - CZ_o - D}{\Delta} & \dfrac{2(AD - BC)}{\Delta} \\ \dfrac{2}{\Delta} & \dfrac{-A + BY_o - CZ_o + D}{\Delta} \end{bmatrix}$$

$$\Delta = A + BY_o + CZ_o + D$$

THANK YOU