



# **SNS COLLEGE OF TECHNOLOGY**

**Coimbatore-35**  
**An Autonomous Institution**



Accredited by NBA – AICTE and Accredited by NAAC – UGC with 'A+' Grade  
Approved by AICTE, New Delhi & Affiliated to Anna University, Chennai

## **DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING**

### **MICROWAVE ENGINEERING**

IV YEAR/ VII SEMESTER

#### **UNIT 2 – MICROWAVE PASSIVE DEVICES**

#### **TOPIC 1 – S PARAMETERS**

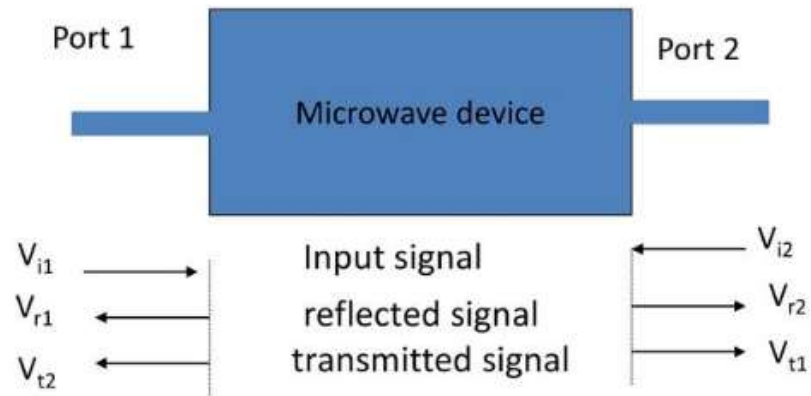


**Guess the Topic????**





## S PARAMETERS



Transmission and reflection coefficients

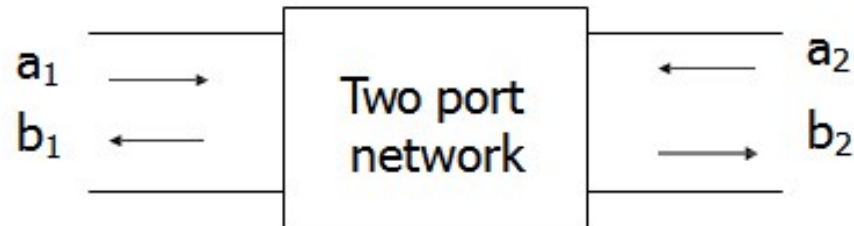
$$\tau = \frac{V_t}{V_i} \quad \rho = \frac{V_r}{V_i}$$



## S PARAMETERS

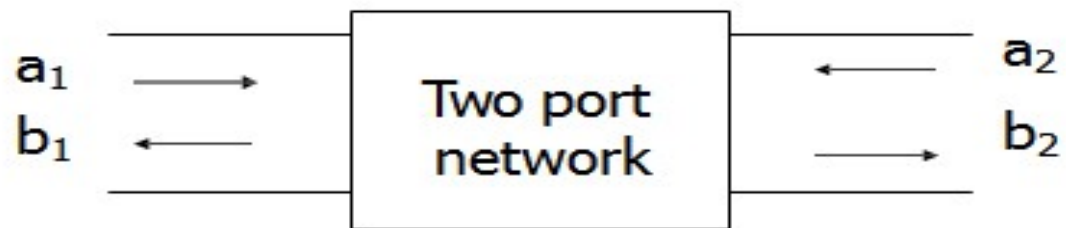


- Incident and reflected waves are being monitored instead.
- Resistive termination is employed.
- Active devices are normally quite stable under resistive termination.





## Scattering Parameters



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

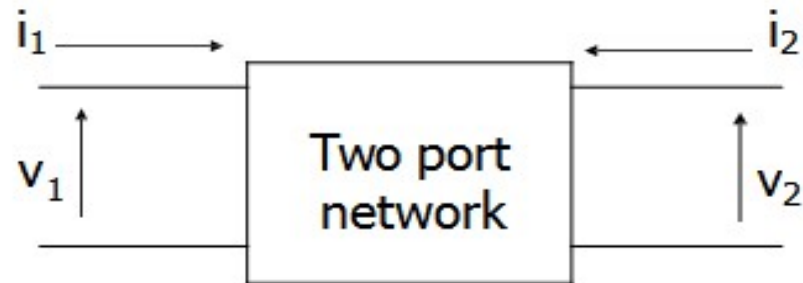
$$a_2 = \frac{v_{i,2}}{\sqrt{Z_o}}$$

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

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



## Waves and Total voltage/current



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

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

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

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



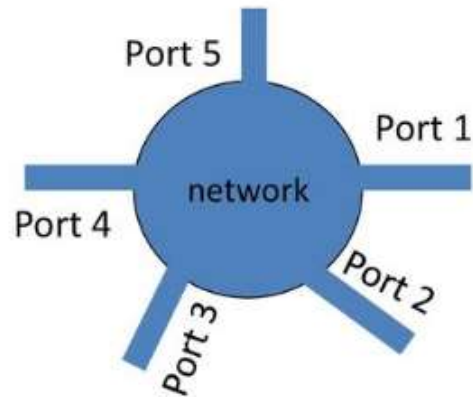
## Scattering parameters



$$\begin{aligned} b_1 &= S_{11}a_1 + S_{12}a_2 \\ b_2 &= S_{21}a_1 + S_{22}a_2 \end{aligned} \quad \longrightarrow \quad \begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$



## Multiport Network



$$\begin{bmatrix} b_1 \\ b_2 \\ b_3 \\ b_4 \\ b_5 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} & S_{13} & S_{14} & S_{15} \\ S_{21} & S_{22} & S_{23} & S_{24} & S_{25} \\ S_{31} & S_{32} & S_{33} & S_{34} & S_{35} \\ S_{41} & S_{42} & S_{43} & S_{44} & S_{45} \\ S_{51} & S_{52} & S_{53} & S_{54} & S_{55} \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \\ a_5 \end{bmatrix}$$

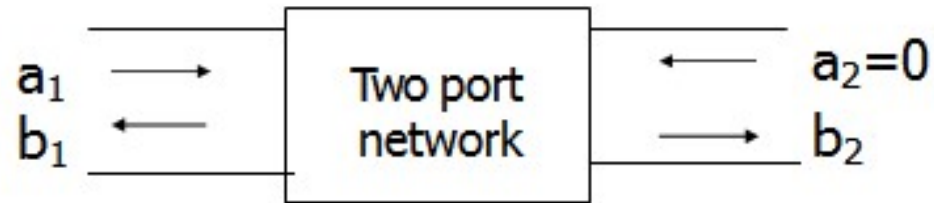




## Scattering parameters



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

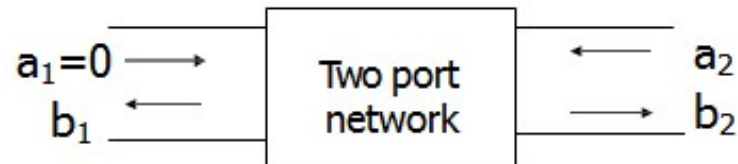


$$S_{21} = \left. \frac{b_2}{a_1} \right|_{a_2=0} = \text{forward transmission coefficient from port 1 to 2 with } a_2=0$$



## 2-port network (new terms)

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



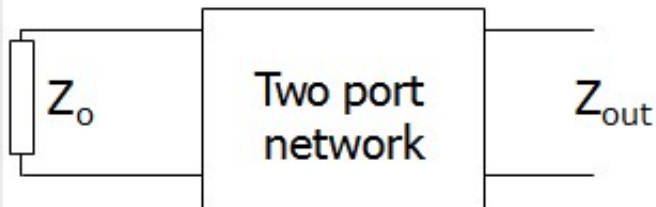
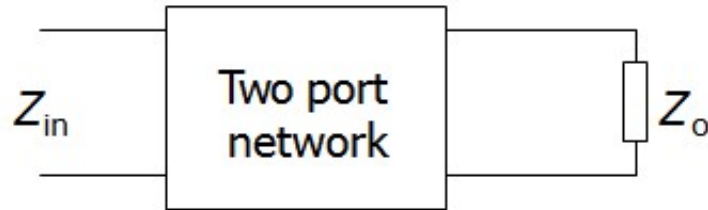
$$S_{22} = \left. \frac{b_2}{a_2} \right|_{a_1=0} = \text{reflection coefficient at port 2 with } a_1=0$$



## Evaluation of S11 and S22



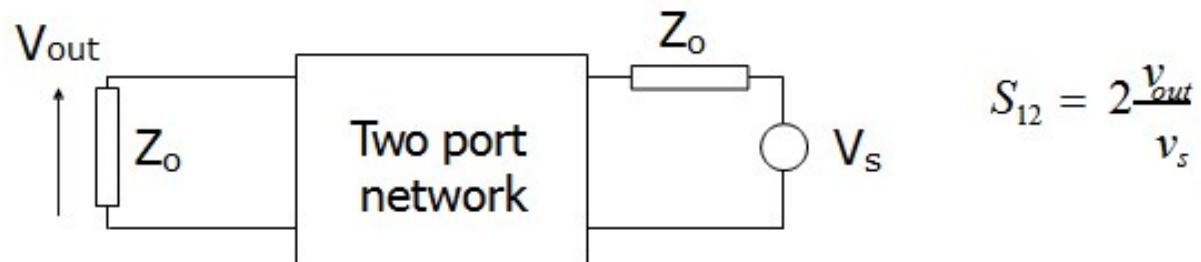
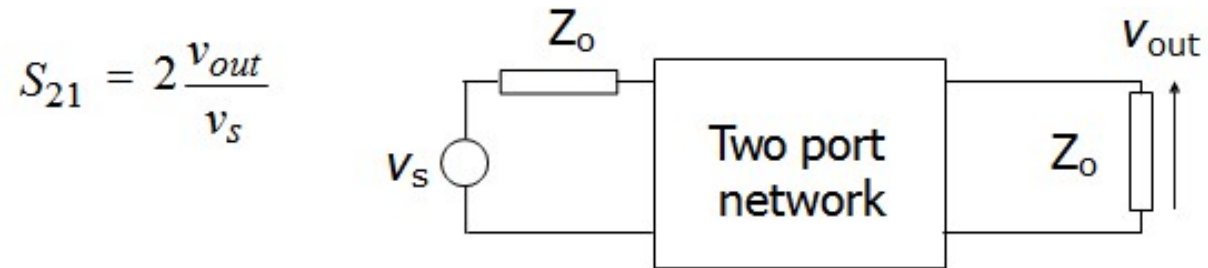
$$S_{11} = \Gamma_{in} = \frac{Z_{in} - Z_o}{Z_{in} + Z_o}$$



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

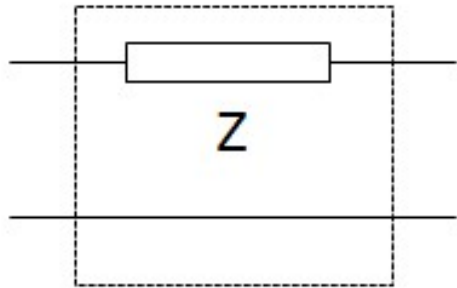


## Evaluation of S11 and S22





## Example (Attenuation)



$$S_{21} = \frac{2Z_0}{Z + Z_0}$$

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



## Example (Phase Shift)

$$\begin{aligned}\phi &= \angle S_{21} \\ &= \angle \frac{2Z_o}{R + 2Z_o + jX} \\ &= \angle(2Z_o) - \angle(R + 2Z_o + jX) \\ &= -\tan^{-1}\left(\frac{X}{R + 2Z_o}\right)\end{aligned}$$



## ABCD PARAMETERS



Voltages and currents in a general circuit

$$I_2 \propto V_2 - V_1 \quad V_2 \propto I_1 - I_2$$

This can be written as

$$V_1 \propto V_2 - I_2 \quad I_1 \propto V_2 + I_2$$

Or

$$V_1 = AV_2 - BI_2 \quad I_1 = CV_2 - DI_2$$

A -ve sign is included in the definition of D

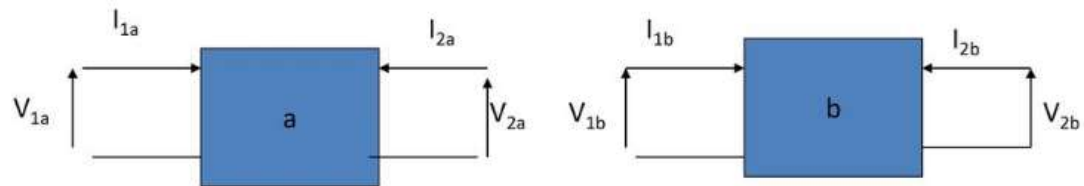
In matrix form

$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_2 \\ -I_2 \end{bmatrix}$$

Given  $V_1$  and  $I_1$ ,  $V_2$  and  $I_2$  can be determined if ABCD matrix is known.



## Cascaded Network



$$\begin{bmatrix} V_{1a} \\ I_{1a} \end{bmatrix} = \begin{bmatrix} A_a & B_a \\ C_a & D_a \end{bmatrix} \begin{bmatrix} V_{2a} \\ -I_{2a} \end{bmatrix}$$

$$\begin{bmatrix} V_{1b} \\ I_{1b} \end{bmatrix} = \begin{bmatrix} A_b & B_b \\ C_b & D_b \end{bmatrix} \begin{bmatrix} V_{2b} \\ -I_{2b} \end{bmatrix}$$

However  $V_{2a} = V_{1b}$  and  $-I_{2a} = I_{1b}$  then

$$\begin{bmatrix} V_{1a} \\ I_{1a} \end{bmatrix} = \begin{bmatrix} A_a & B_a \\ C_a & D_a \end{bmatrix} \begin{bmatrix} A_b & B_b \\ C_b & D_b \end{bmatrix} \begin{bmatrix} V_{2b} \\ -I_{2b} \end{bmatrix}$$

The main use of ABCD matrices are for chaining circuit elements together

Or just convert to one matrix

$$\begin{bmatrix} V_{1a} \\ I_{1a} \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_{2b} \\ -I_{2b} \end{bmatrix}$$

Where

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} A_a & B_a \\ C_a & D_a \end{bmatrix} \begin{bmatrix} A_b & B_b \\ C_b & D_b \end{bmatrix}$$





## S-ABCD Conversion



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

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



**THANK YOU**