

ECE 451

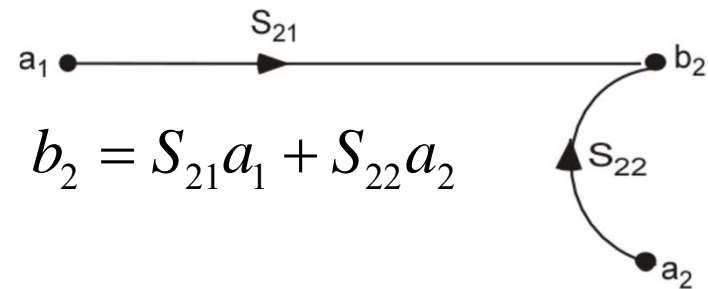
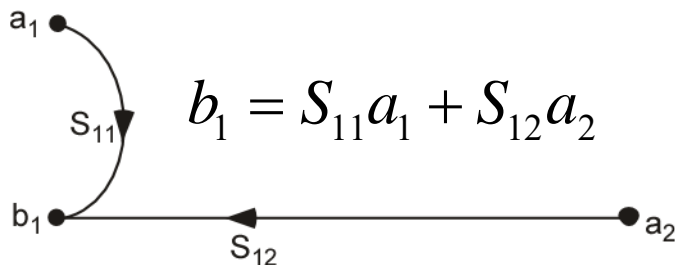
Advanced Microwave Measurements

Flow Graphs

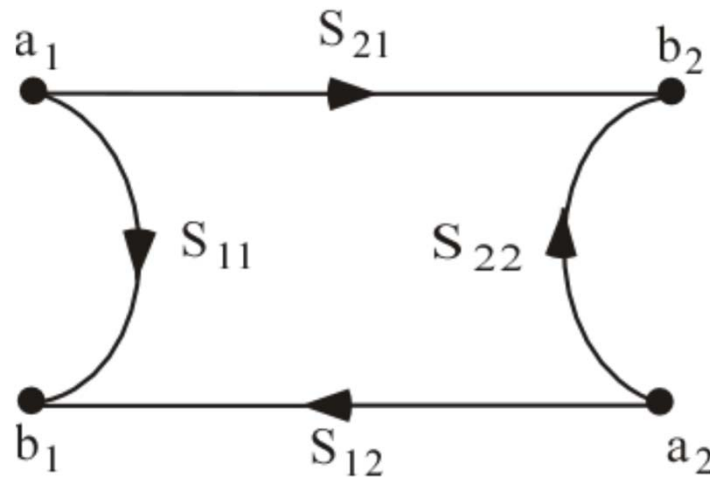
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Flow Graph Definitions

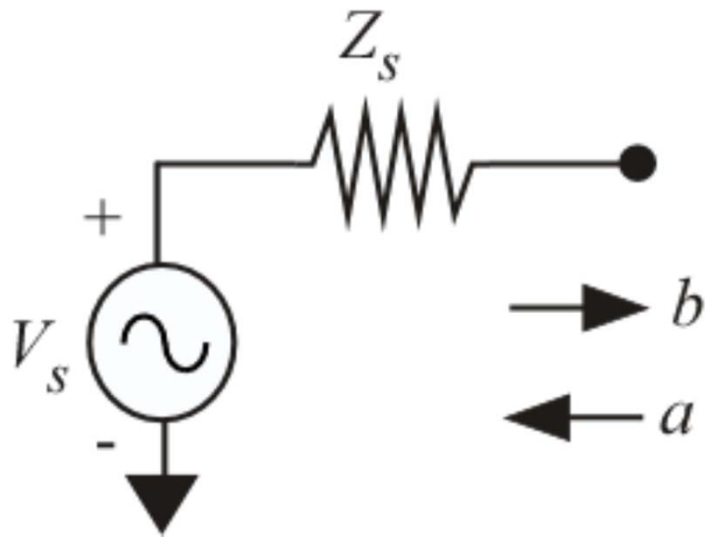
- Voltage waves designated as nodes.
- S parameters designated as branches
- Branches enter dependent nodes and emanate from independent nodes



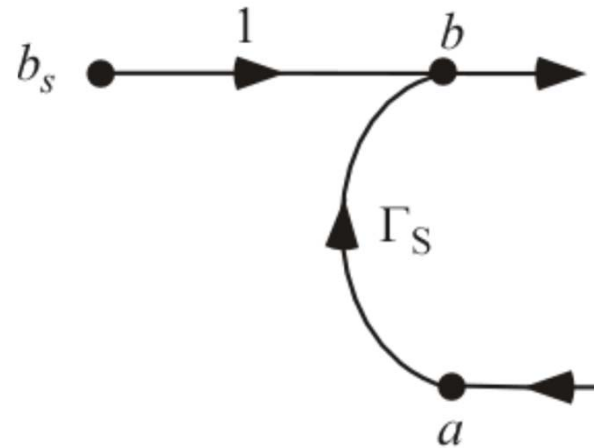
Two-Port Flow Graph



Flow Graph for Source



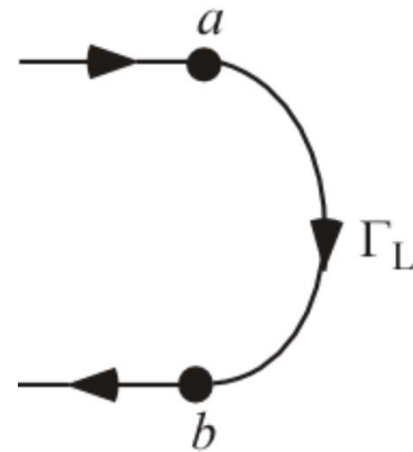
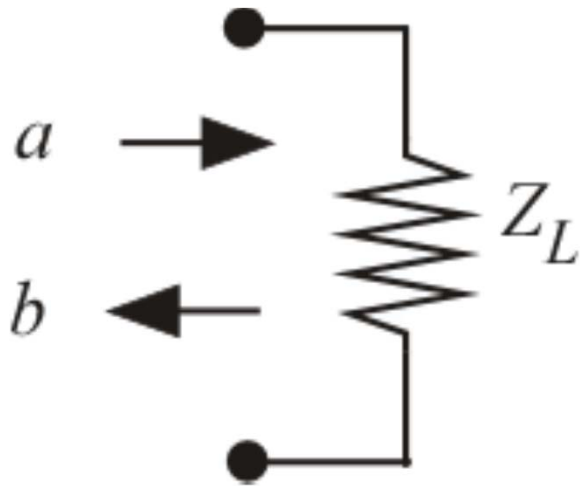
$$b_s = \frac{V_s \sqrt{Z_o}}{Z_s + Z_o}$$



$$\Gamma_s = \frac{Z_s - Z_o}{Z_s + Z_o}$$

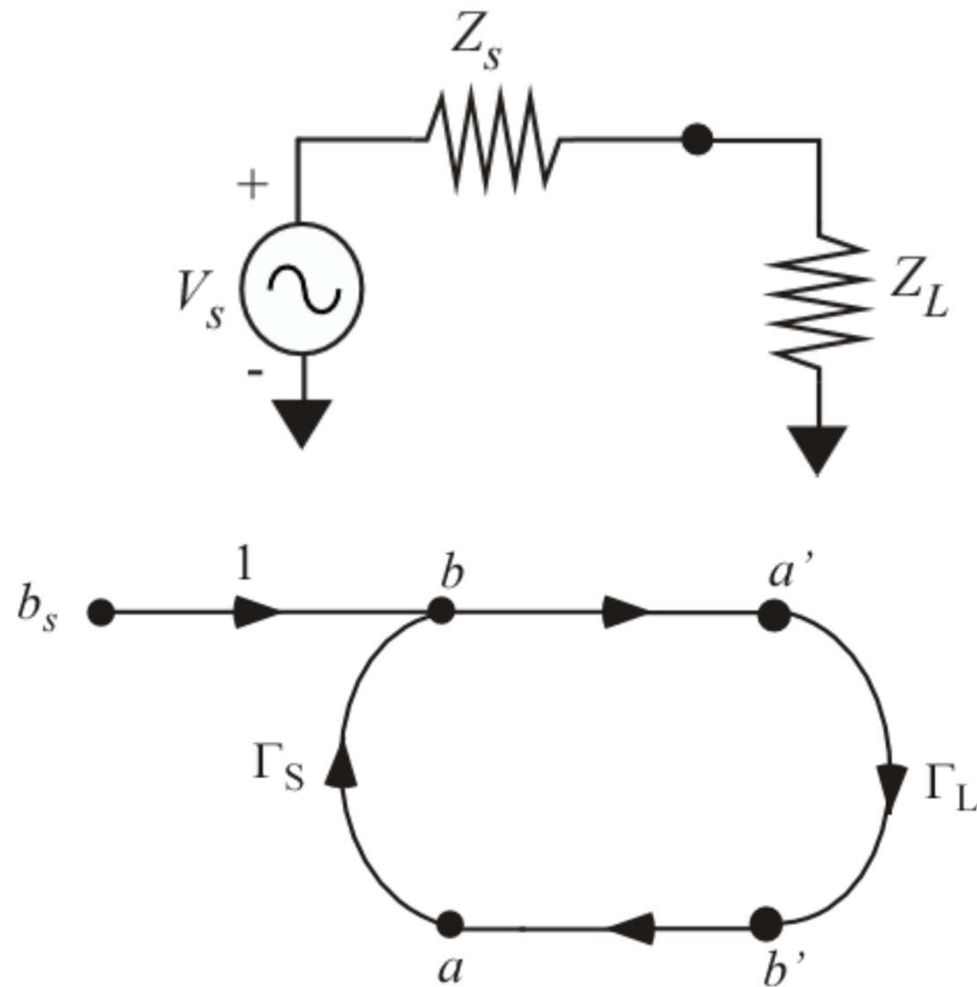
b_s is power wave associated with power dissipated in a load of value Z_o connected to the source.

Flow Graph for Load

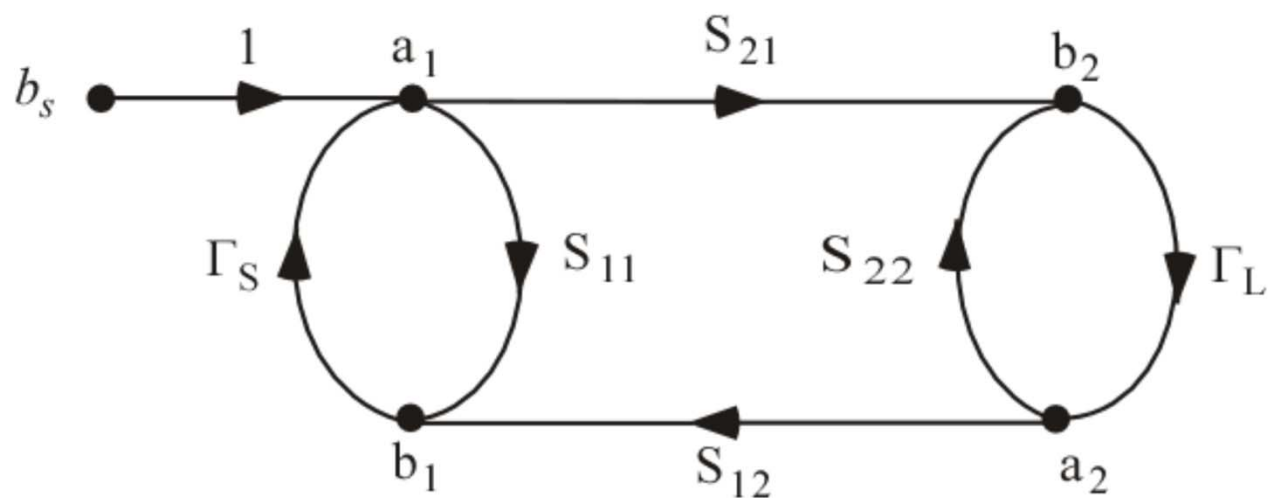
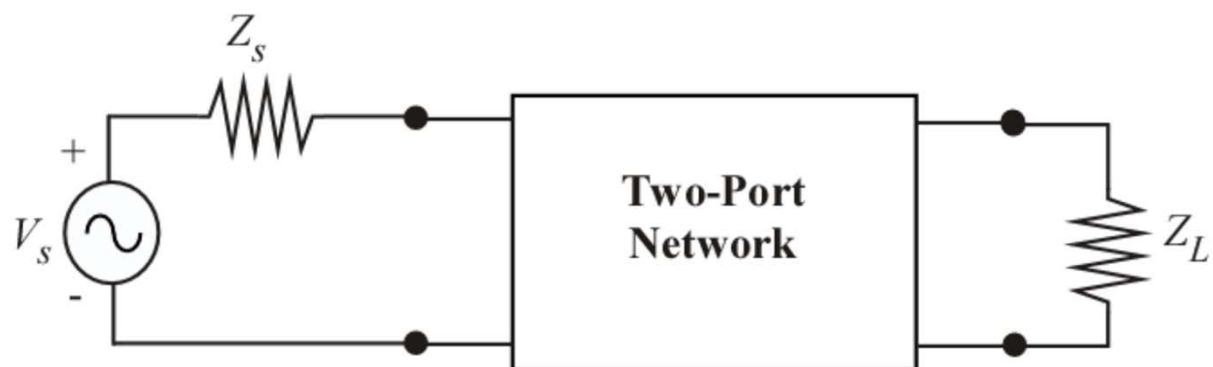


$$\Gamma_L = \frac{Z_L - Z_o}{Z_L + Z_o}$$

Flow Graph for Composite Circuit



Flow Graph of Complete Two-Port



Loop Definitions

- A first order loop is defined as the product of the branches encountered in a journey starting from anode and moving in the direction of the arrows back to that original node
- A second order loop is defined as the product of any two **non-touching** first order loops.
- A third order loop is defined as the product of any three **non-touching** first order loops.

Mason's Non-Touching Loop Rule

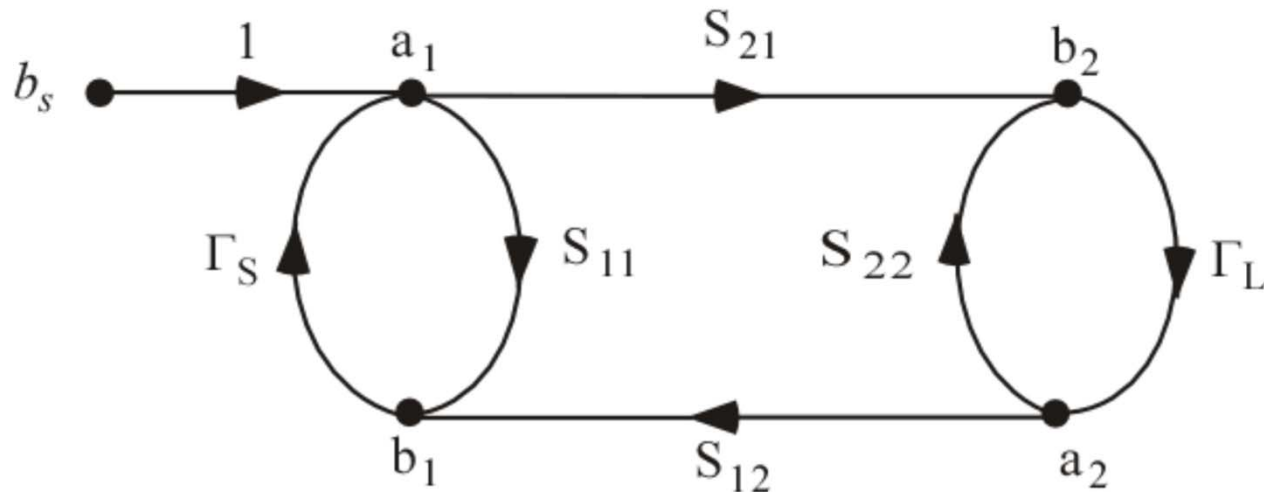
$$T = \frac{P_1 \left[1 - \sum L(1)^{(1)} + \sum L(2)^{(1)} - \dots \right] + P_2 \left[1 - \sum L(1)^{(2)} + \dots \right] + \dots}{1 - \sum L(1) + \sum L(2) - \sum L(3) + \dots}$$

T : ratio of dependent variable over independent variable

P_k 's: are the various paths connecting the two variables of interest

$L(j)^{(k)}$ is a loop of order j that does not touch path k

Example: Find b_2/b_s



First Order Loops: $S_{11}\Gamma_S$, $S_{22}\Gamma_L$, $S_{21}S_{12}\Gamma_L\Gamma_S$

Second Order Loops: $S_{11}\Gamma_S S_{22}\Gamma_L$

Paths: S_{21}

$$\frac{b_2}{b_s} = \frac{S_{21}}{1 - S_{11}\Gamma_S - S_{22}\Gamma_L - S_{21}S_{12}\Gamma_L\Gamma_S + S_{11}\Gamma_S S_{22}\Gamma_L}$$