Electromagnetics:

Microwave Engineering

Network Performance Metrics

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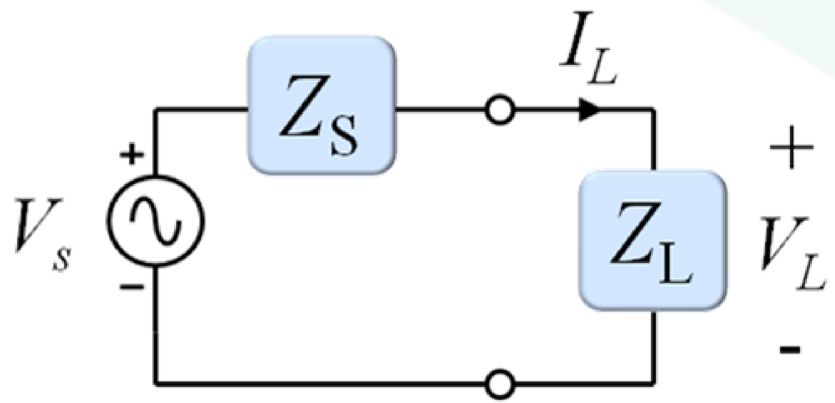
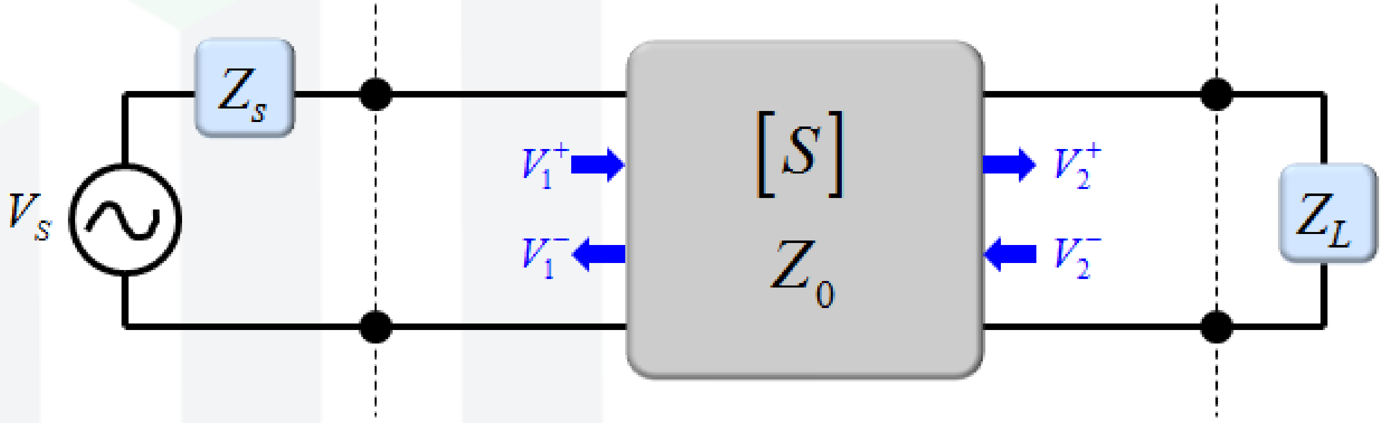


Performance without network



Performance with network

Insertion Loss

Quantifies how much less power is delivered to the load due to inserting the network between the source and load.

$$L_I = 10\log_{10}\left(\frac{P_L \text{ w/o network}}{P_L \text{ w/ network}}\right) = 10\log_{10}\left|\frac{AZ_L + B + CZ_sZ_L + DZ_s}{Z_s + Z_L}\right|^2$$

We can invert this to calculate insertion gain

$$L_I = 10\log_{10}\left(\frac{P_L \text{ w/ network}}{P_L \text{ w/o network}}\right) = 10\log_{10}\left|\frac{Z_s + Z_L}{AZ_L + B + CZ_sZ_L + DZ_s}\right|^2$$

(~relative to reality)

Insertion Phase

Quantifies how much the phase changes at the load when the network is inserted between the source and the load

$$\theta_I = \theta_{after} - \theta_{before} = \tan^{-1}\left(\frac{\mathrm{Im}[AZ_L + B + CZ_sZ_L + DZ_s]}{\mathrm{Re}[AZ_L + B + CZ_sZ_L + DZ_s]}\right)$$

(~relative to reality)

EMPossible

Transducer Loss

The network (or transducer) can perform impedance matching and actually increase the power delivered to the load. Despite this, the transducer probably also dissipates energy and therefore is responsible for some loss.

$$L_T = 10\log_{10}\left(\frac{P_A}{P_L}\right) = 10\log_{10}\left(\frac{|AZ_L + B + CZ_sZ_L + DZ_s|^2}{4R_sR_L}\right)$$

(~relative to ideal)

We can invert this to calculate transducer gain.

$$G_T = 10\log_{10}\left(\frac{P_L}{P_A}\right) = 10\log_{10}\left(\frac{4R_sR_L}{|AZ_L + B + CZ_sZ_L + DZ_s|^2}\right)$$

$$G_T = \frac{P_L}{P_{s,max}} = \frac{|S_{21}|^2(1-|\Gamma_s|^2)(1-|\Gamma_L|^2)}{|1-S_{22}\Gamma_L^2||1-\Gamma_s\Gamma_{in}|^2}$$

Transducer Loss

Note that $L_I = L_T$ when $Z_s = Z_L$.

The actual power gain through the network is

$$G = \frac{P_L}{P_{in}} = \frac{|S_{21}|^2(1 - |\Gamma_s|^2)(1 - |\Gamma_L|^2)}{|1 - S_{22}\Gamma_L|^2 |1 - \Gamma_s \Gamma_{\text{in}}|^2}$$

$G \leq 1$ for passive networks

The maximum gain available from the network is then

$$G_A = \frac{P_{L,max}}{P_{s,max}} = \frac{|S_{21}|^2(1 - |\Gamma_s|^2)}{|1 - S_{11}\Gamma_s|^2 (1 - |\Gamma_{\text{out}}|)^2}$$

EMPossible

Mismatch Loss

Mismatch loss is how much less power is delivered to the load due to reflection.

$$L_M = 10\log_{10}\left(\frac{1}{1-|\Gamma_{in}|^2}\right)$$

Dissipative Loss

The overall loss from source to load is the transducer loss. The power loss either reflects back to the source (L_M) or is dissipated as heat inside the network or transducer (L_σ)

$$L_T = L_M + L_\sigma$$

EMPossible

Special Case: Conjugate Matched System

When both the input and output ports are matched, we have

$$\Gamma_s = \Gamma_L = 0 \qquad \text{(local reflection)}$$

$$\Gamma_{in} = S_{11} \qquad \text{(global reflection)}$$

$$\Gamma_{out} = S_{22} \qquad \text{(global reflection)}$$

$$P_A = \frac{|V_s|^2}{8Z_0}$$

$$P_{in} = \frac{|V_s|^2}{8Z_0}(1 - |S_{11}|^2)$$

$$P_L = \frac{|V_s|^2}{8Z_0}|S_{21}|^2$$

$$G = \frac{|S_{21}|^2}{1 - |S_{11}|^2}$$

$$P_{L,\max} = \frac{|V_s|^2}{8Z_0}\frac{|S_{21}|^2}{1 - |S_{11}|^2}$$

$$G_T = |S_{21}|^2$$