ECE 453
Wireless Communication Systems

Power Definitions

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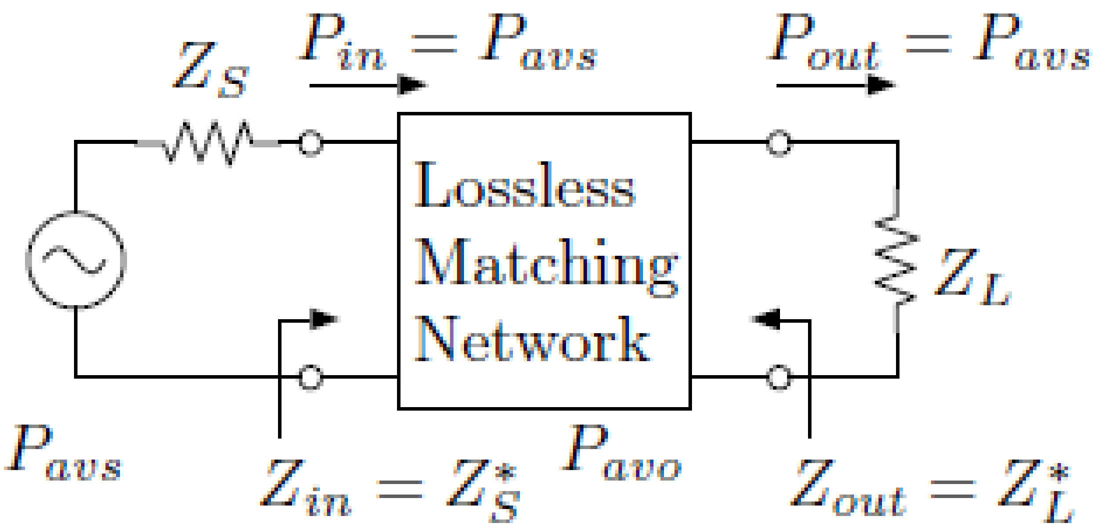
Power Definitions



P_{in}: Power delivered to input of 2-port

P_{out}: Power delivered to the load

P_{avs}: Power available from the source

Power Gain Definitions

Operating Power Gain

$$G = \frac{\text{Power delivered to load}}{\text{Power delivered to input of 2-port}} = \frac{P_{out}}{P_{in}}$$

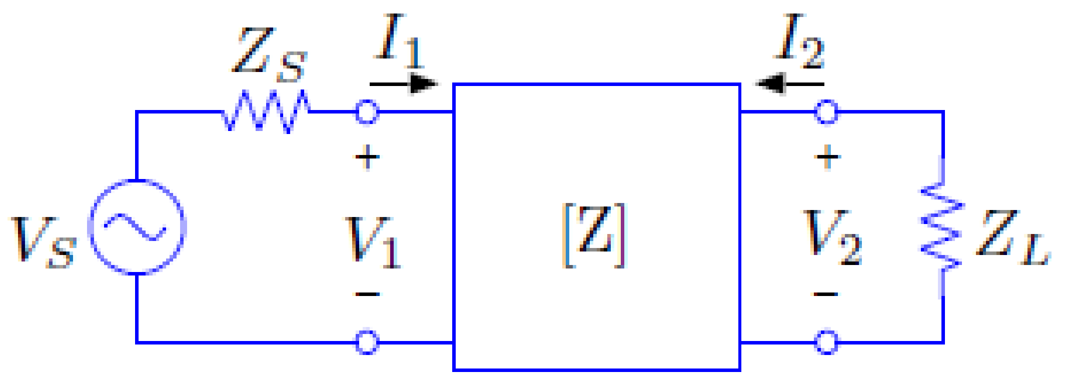
Transducer Power Gain

$$G_T = \frac{\text{Power delivered to load}}{\text{Power available from source}} = \frac{P_{out}}{P_{avs}}$$

Available Power Gain

$$G_A = \frac{\text{Power available from output}}{\text{Power available from source}} = \frac{P_{avo}}{P_{avs}}$$

Power Available from a Source

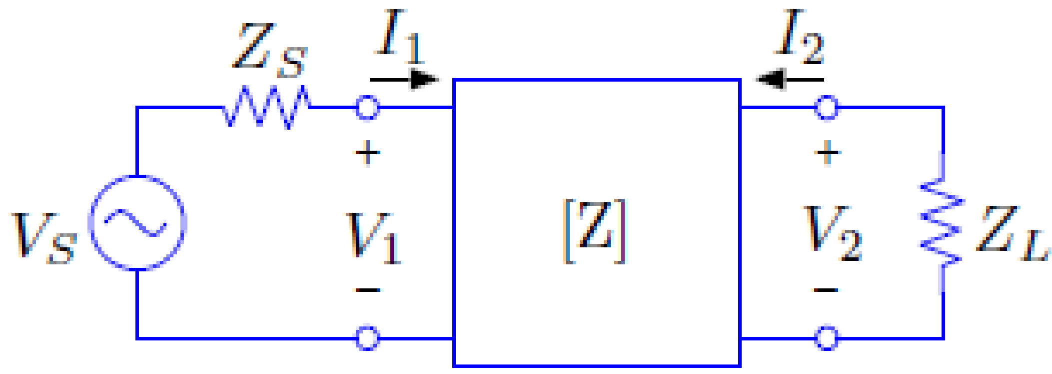


$$Z_S = R_S + jX_S$$

$$Z_L = R_L + jX_L$$

$$P_{avs} = \frac{\left|V_S\right|^2}{8R_S}$$

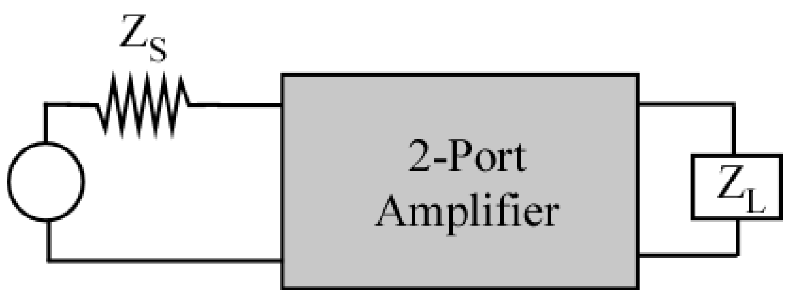
Transducer Gain with Z-Parameters



$$G_T = 4\frac{\left|Z_{21}\right|^2 R_L R_S}{\left|\left(Z_{11}+Z_S\right)\left(Z_{22}+Z_L\right)-Z_{12}Z_{21}\right|^2}$$

Linear Amplifiers

The transducer power gain is defined as the power delivered to the load divided by the power available from the source.



$$\Gamma_S = \frac{Z_S - Z_o}{Z_S + Z_o} \qquad \Gamma_L = \frac{Z_L - Z_o}{Z_L + Z_o}$$

Z_o is reference impedance for S parameters

Transducer Gain

Definition of transducer gain

$$G_T = \frac{P_{del}}{P_{avs}}$$

In terms of two-port scattering parameters

$$G_T = \frac{|S_{21}|^2\left(1-|\Gamma_S|^2\right)\left(1-|\Gamma_L|^2\right)}{\left|\left(1-S_{11}\Gamma_S\right)\left(1-S_{22}\Gamma_L\right)-S_{21}S_{12}\Gamma_S\Gamma_L\right|^2}$$

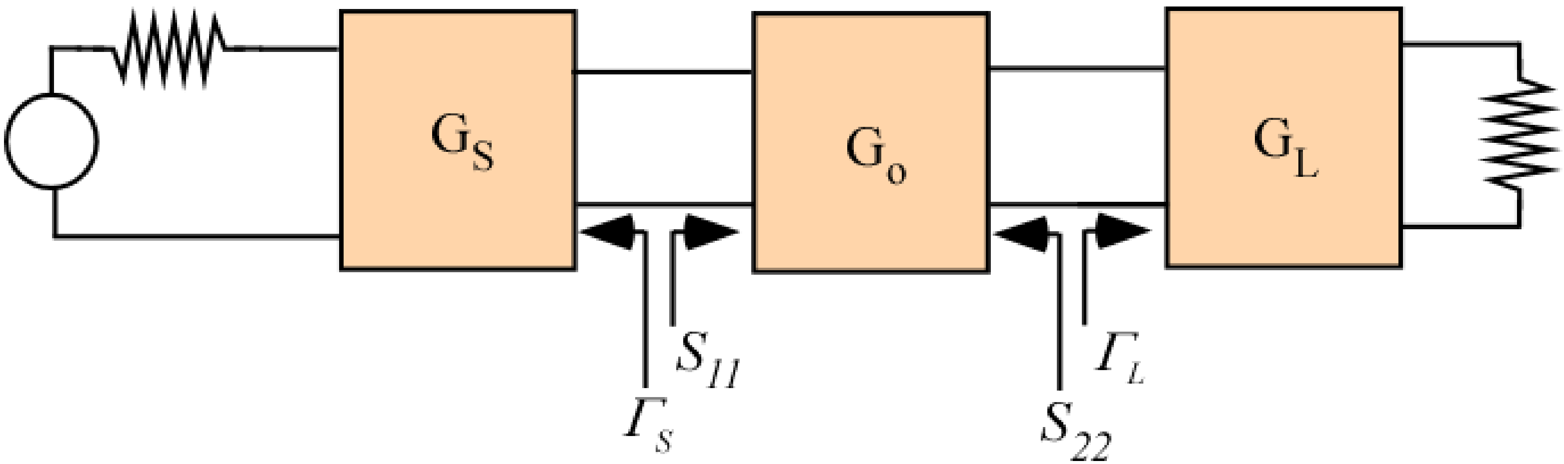
Linear Amplifiers

If we assume that the network is unilateral, then we can neglect S_{12} and get the unilateral transducer gain for $S_{12}=0$.

$$G_{TU} = \left|S_{21}\right|^2 \frac{\left(1-\left|\Gamma_S\right|^2\right)}{\left|1-S_{11}\Gamma_S\right|^2} \frac{\left(1-\left|\Gamma_L\right|^2\right)}{\left|1-S_{22}\Gamma_L\right|^2}$$

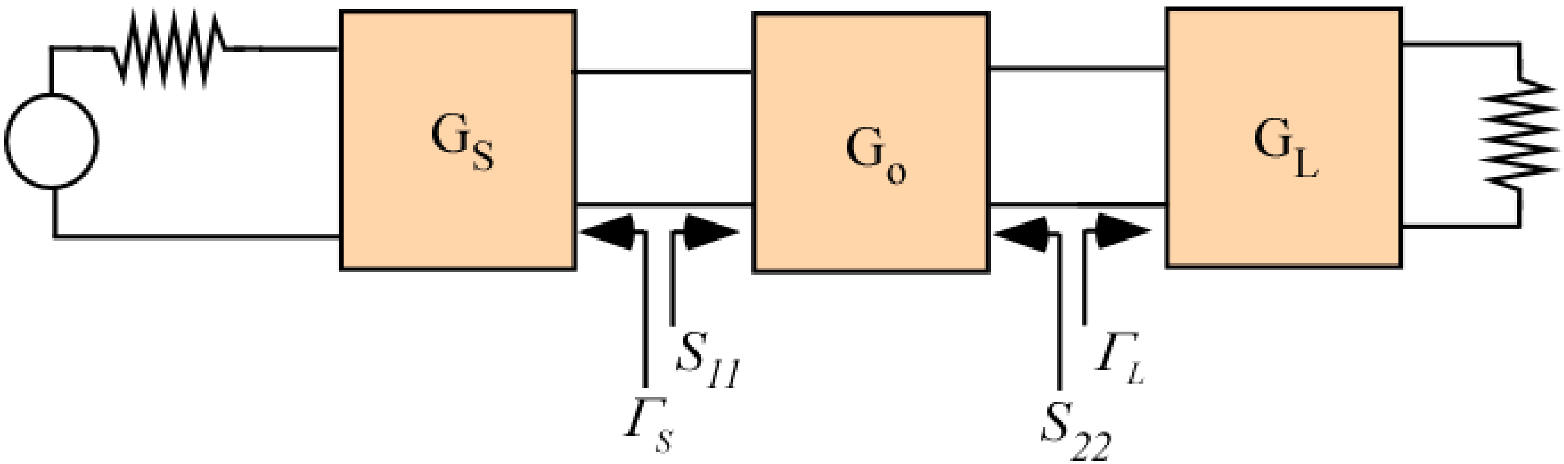
The first term ($|S_{21}|^2$) depends on the transistor. The other 2 terms depend on the source and the load.

Linear Amplifiers



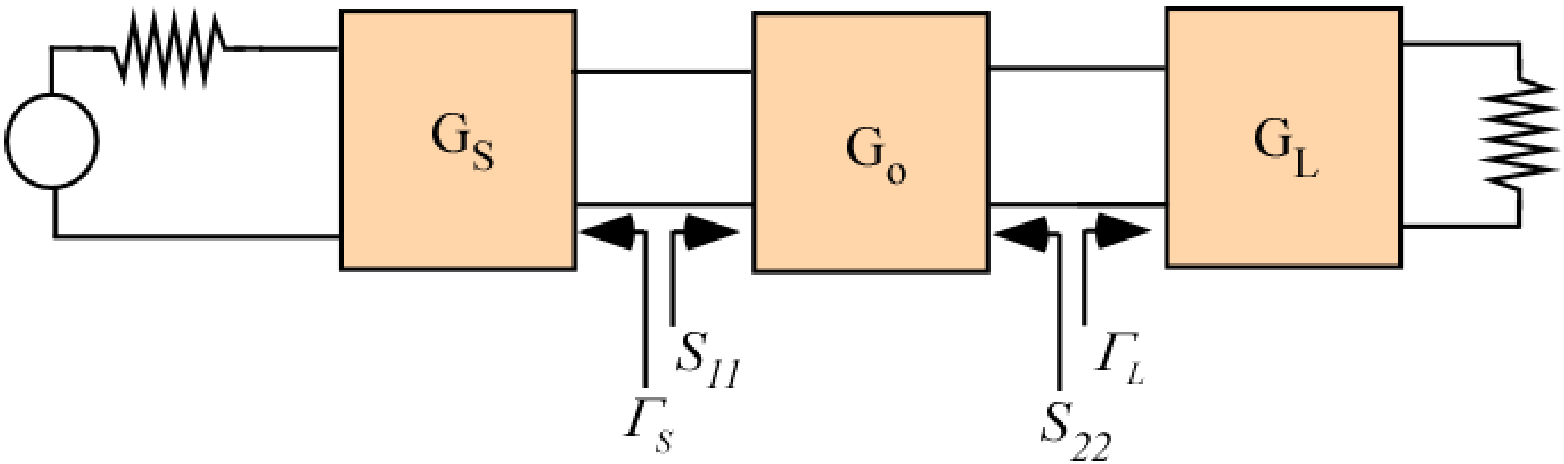
G_s affects the degree of mismatch between the source and the input reflection coefficient of the two-port.

Linear Amplifiers



G_L affects the degree of mismatch between the load and the output reflection coefficient of the 2-port.

Linear Amplifiers



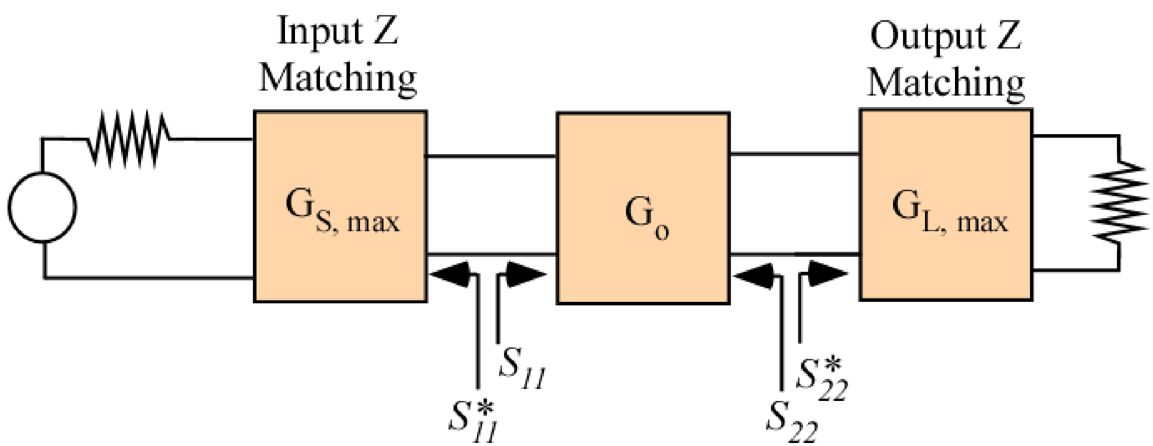
G_o depends on the device and bias conditions

Linear Amplifiers

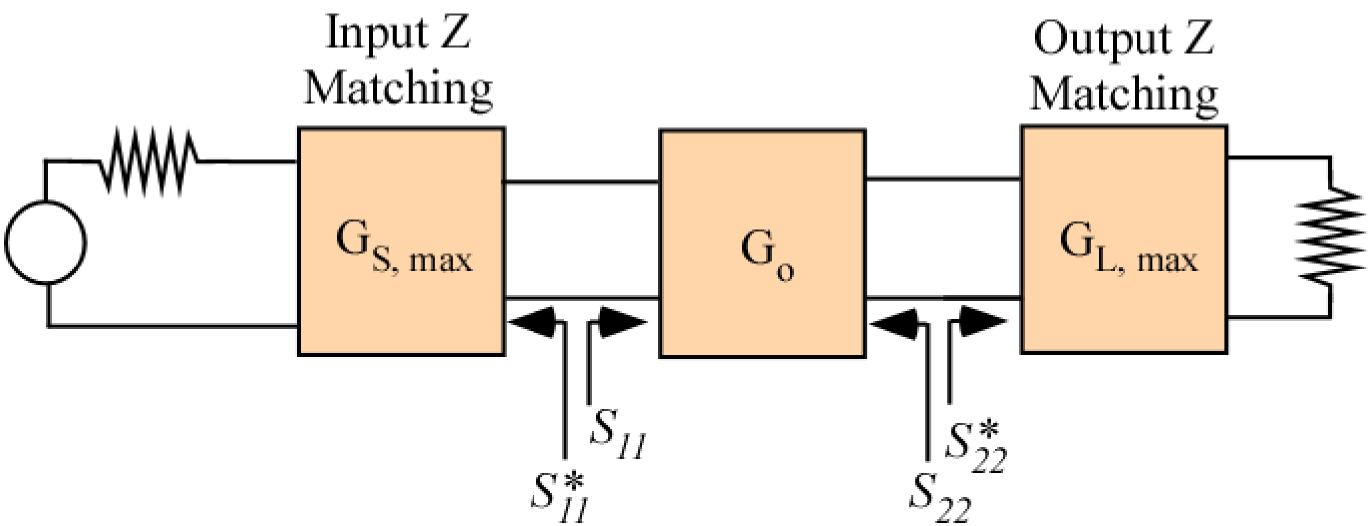
Maximum unilateral transducer gain can be accomplished by choosing impedance matching networks such that.

$$\Gamma_S = S_{11}^* \qquad \Gamma_L = S_{22}^*$$

$$G_{UMAX} = \frac{1}{1-|S_{11}|^2} \cdot |S_{21}|^2 \cdot \frac{1}{1-|S_{22}|^2}$$



Linear Amplifiers



$$G_{UMAX}(dB) = G_{S\max}(dB) + G_o(dB) + G_{L\max}(dB)$$

For $\Gamma_S = S_{11}^*$, **G_S is a maximum**

For $|\Gamma_S| = 1$, **G_S is 0**

Dissipated Power

$$P_d = \frac{1}{2}\mathbf{a}^{\mathrm{T}}\left(\mathbf{U}-\mathbf{S}^{\mathrm{T}}\mathbf{S}^{*}\right)\mathbf{a}^{*}$$

The dissipation matrix D is given by:

$$\mathbf{D} = \mathbf{U}-\mathbf{S}^{\mathrm{T}}\mathbf{S}^{*}$$

Passivity insures that the system will always be stable provided that it is connected to another passive network

For passivity

- (1) the determinant of D must be ≥ 0
- (2) the determinant of the principal minors must be ≥ 0

Dissipated Power

When the dissipation matrix is 0, we have a lossless network➔

$$\mathbf{S}^{\mathrm{T}}\mathbf{S}^{*} = \mathbf{U}$$

The S matrix is unitary.

For a lossless two-port:

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

$$|S_{22}|^2 + |S_{12}|^2 = 1$$

If in addition the network is reciprocal, then

$$S_{12} = S_{21} \text{ and } |S_{11}| = |S_{22}| = \sqrt{1 - |S_{12}|^2}$$