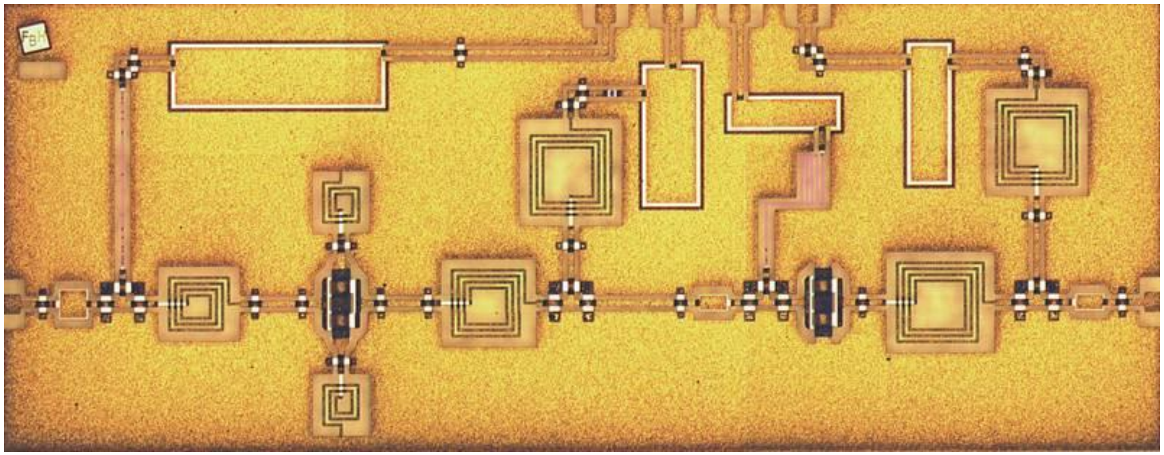
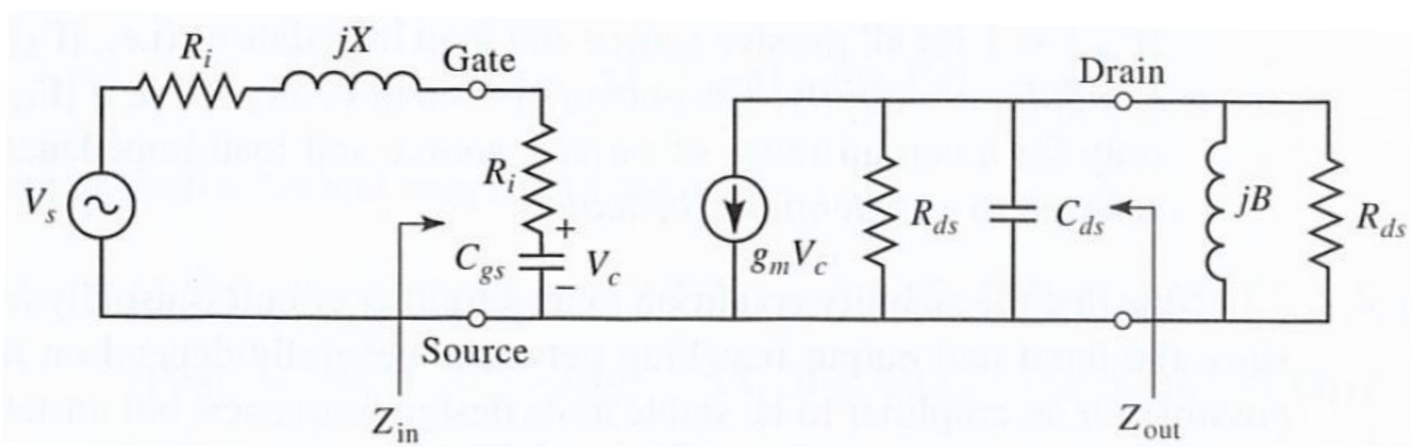
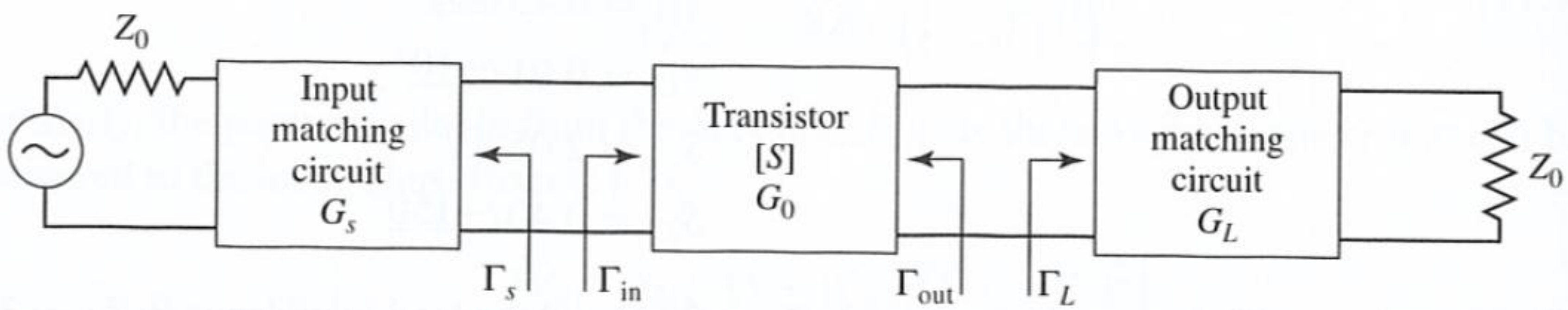
Unilateral Amplifier Design





Two-port representation



$G_T = G_S G_0 G_L$ the unilateral transducer gain reduces to $G_{TU} = G_S G_0 G_L$

$$\Gamma_{in} = S_{11}, \Gamma_{out} = S_{22}$$

$$G_S = \frac{1 - |\Gamma_S|^2}{|1 - \Gamma_{in}\Gamma_S|^2},$$

$$G_0 = |S_{21}|^2,$$

$$G_L = \frac{1 - |\Gamma_L|^2}{|1 - S_{22}\Gamma_L|^2}.$$

$$G_S = \frac{1 - |\Gamma_S|^2}{|1 - S_{11}\Gamma_S|^2},$$

$$G_0 = |S_{21}|^2,$$

$$G_L = \frac{1 - |\Gamma_L|^2}{|1 - S_{22}\Gamma_L|^2}.$$

Maximum Gain

The maximum gain occurs when both the input and output matching networks are designed to have a conjugate match

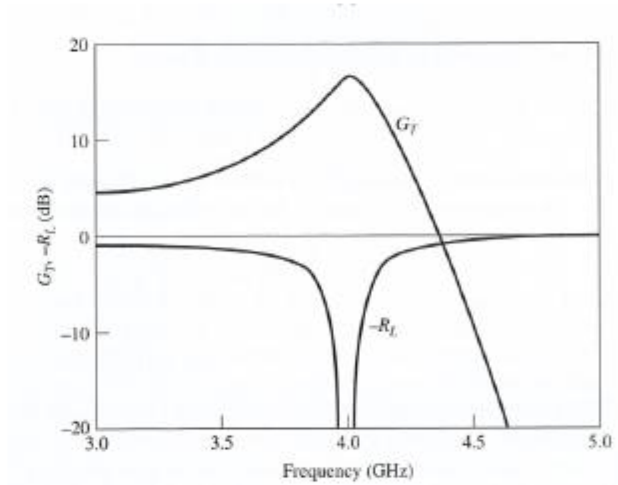
$$\Gamma_{in} = \Gamma_S^*$$

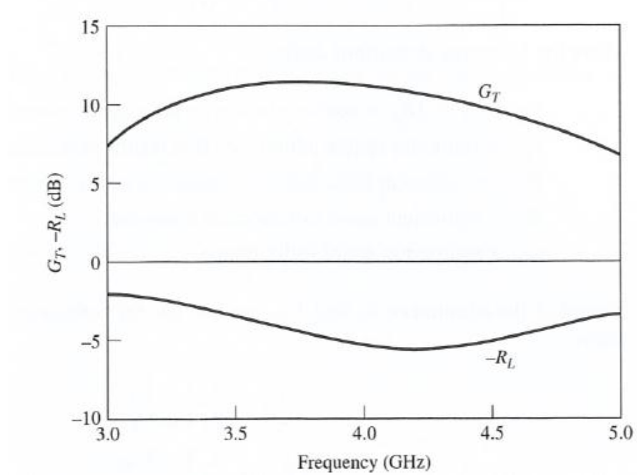
$$\Gamma_{out} = \Gamma_L^*$$

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

Design for specified gain

- Maximum gain is not always needed and backing of on gain can improve bandwidth response





Normalized gain

- Gain relative to max gain for the input and output matching networks gives us the normalized gain for input and output

$$G_S = \frac{1 - |\Gamma_S|^2}{|1 - S_{11}\Gamma_S|^2},$$

$$G_L = \frac{1 - |\Gamma_L|^2}{|1 - S_{22}\Gamma_L|^2}.$$

$$G_{S_{\max}} = \frac{1}{1 - |S_{11}|^2},$$

$$G_{L_{\max}} = \frac{1}{1 - |S_{22}|^2}.$$

$$g_S = \frac{G_S}{G_{S_{\max}}} = \frac{1 - |\Gamma_S|^2}{|1 - S_{11}\Gamma_S|^2}(1 - |S_{11}|^2)$$

$$g_L = \frac{G_L}{G_{L_{\max}}} = \frac{1 - |\Gamma_L|^2}{|1 - S_{22}\Gamma_L|^2}(1 - |S_{22}|^2)$$

Gain circles

- For a given gain and max gain we can plot circles of constant gain on the Smith chart for both source and load networks
- The accompanying equations predict the location of the centers and radii of the gain circles

$$C_S = \frac{g_S S_{11}^*}{1-(1-g_S)|S_{11}|^2},$$

$$R_S = \frac{\sqrt{1-g_S}\left(1-|S_{11}|^2\right)}{1-(1-g_S)|S_{11}|^2}.$$

$$C_L = \frac{g_L S_{22}^*}{1-(1-g_L)|S_{22}|^2},$$

$$R_L = \frac{\sqrt{1-g_L}\left(1-|S_{22}|^2\right)}{1-(1-g_L)|S_{22}|^2}.$$

Specified gain example

EXAMPLE 11.4 AMPLIFIER DESIGN FOR SPECIFIED GAIN

Design an amplifier to have a gain of 11 dB at 4.0 GHz. Plot constant gain circles for $G_S = 2$ dB and 3 dB, and $G_L = 0$ dB and 1 dB. Calculate and plot the input return loss and overall amplifier gain from 3 to 5 GHz. The FET has the following S parameters ($Z_0 = 50\ \Omega$):

f (GHz)	S_{11}	S_{21}	S_{12}	S_{22}
3	$0.80\angle{-90^\circ}$	$2.8\angle{100^\circ}$	0	$0.66\angle{-50^\circ}$
4	$0.75\angle{-120^\circ}$	$2.5\angle{80^\circ}$	0	$0.60\angle{-70^\circ}$
5	$0.71\angle{-140^\circ}$	$2.3\angle{60^\circ}$	0	$0.58\angle{-85^\circ}$

Solution

Since $S_{12} = 0$ and $|S_{11}| < 1$ and $|S_{22}| < 1$, the transistor is unilateral and unconditionally stable. From (11.47) we calculate the maximum matching section gains as

$$G_{S_{\max}} = \frac{1}{1 - |S_{11}|^2} = 2.29 = 3.6 \text{ dB},$$

$$G_{L_{\max}} = \frac{1}{1 - |S_{22}|^2} = 1.56 = 1.9 \text{ dB}.$$

The gain of the mismatched transistor is

$$G_o = |S_{21}|^2 = 6.25 = 8.0 \text{ dB},$$

so the maximum unilateral transducer gain is

$$G_{TU_{\max}} = 3.6 + 1.9 + 8.0 = 13.5 \text{ dB}.$$

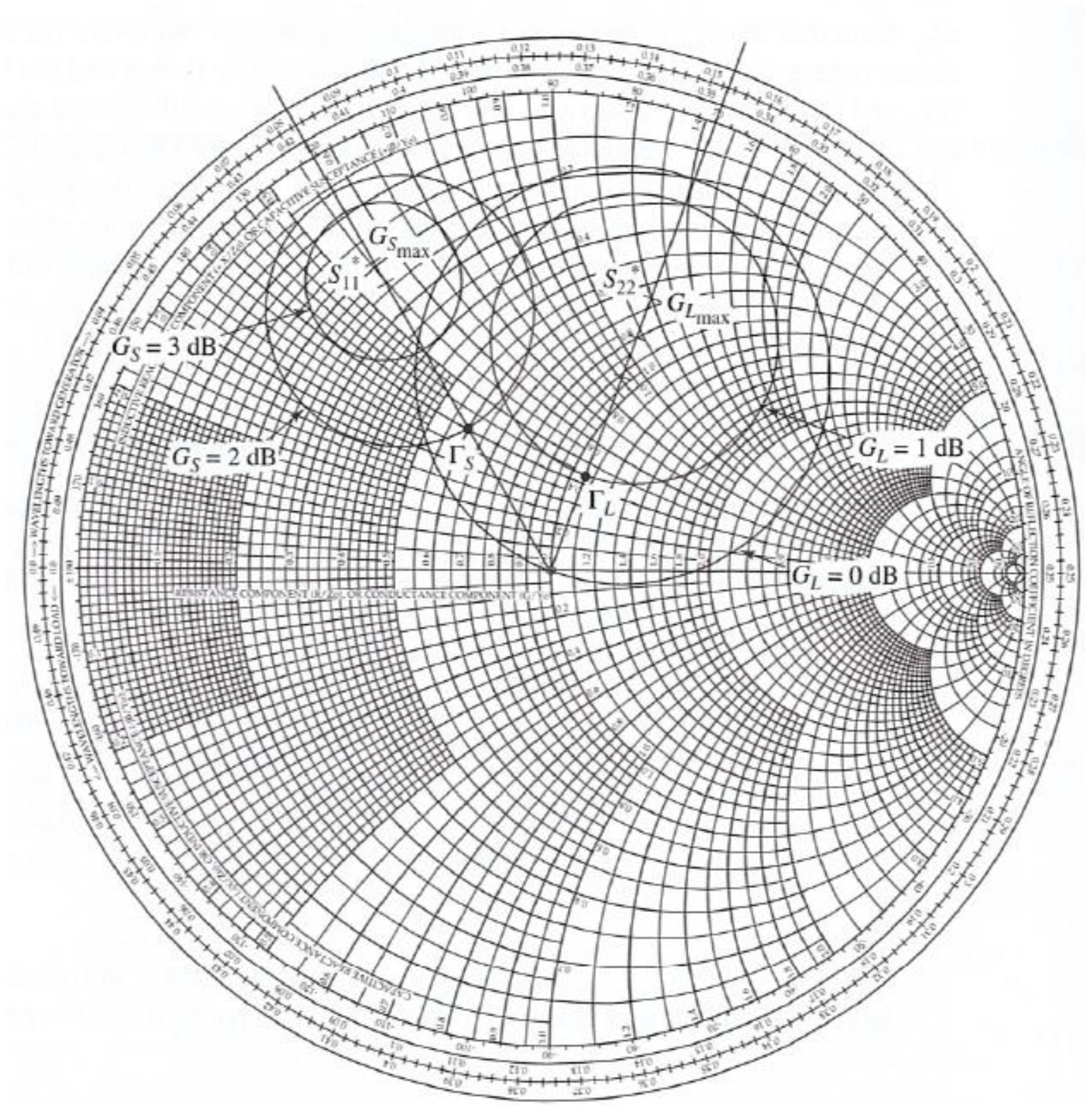
Thus we have 2.5 dB more available gain than is required by the specifications.

We use (11.48), (11.51), and (11.52) to calculate the following data for the constant gain circles:

$$\begin{array}{llll}
G_S = 3 \text{ dB} & g_S = 0.875 & C_S = 0.706\angle{120^\circ} & R_S = 0.166 \\
G_S = 2 \text{ dB} & g_S = 0.691 & C_S = 0.627\angle{120^\circ} & R_S = 0.294 \\
G_L = 1 \text{ dB} & g_L = 0.806 & C_L = 0.520\angle{70^\circ} & R_L = 0.303 \\
G_L = 0 \text{ dB} & g_L = 0.640 & C_L = 0.440\angle{70^\circ} & R_L = 0.440
\end{array}$$

The constant gain circles are shown in Figure 11.8a. We choose $G_S = 2$ dB and $G_L = 1$ dB, for an overall amplifier gain of 11 dB. Then we select Γ_S and Γ_L along these circles as shown, to minimize the distance from the center of the chart (this places Γ_S and Γ_L along the radial lines at 120° and 70°, respectively). Thus, $\Gamma_S = 0.33\angle{120^\circ}$ and $\Gamma_L = 0.22\angle{70^\circ}$, and the matching networks can be designed using shunt stubs as in Example 11.3.

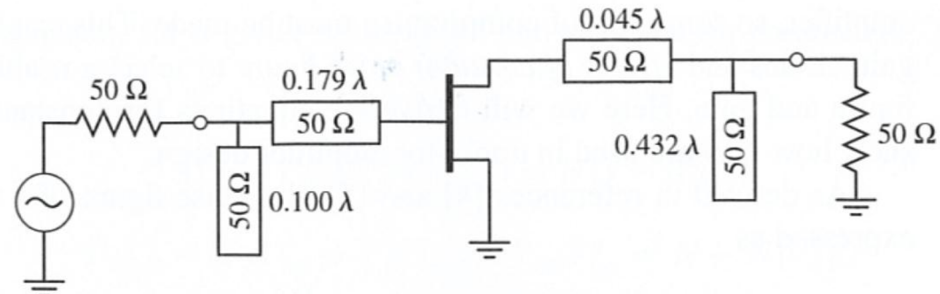
Example 11.4 Smith Chart

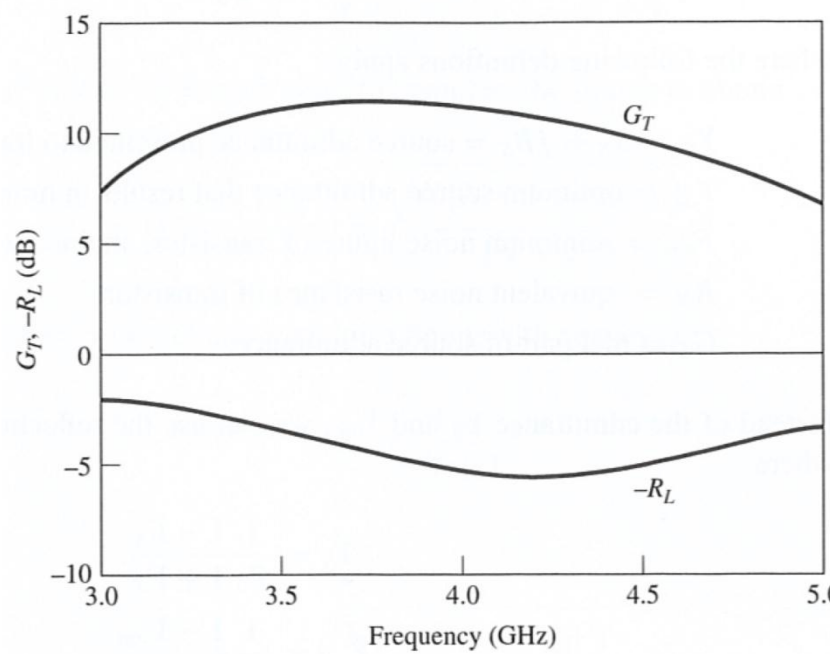


Matching network and frequency response

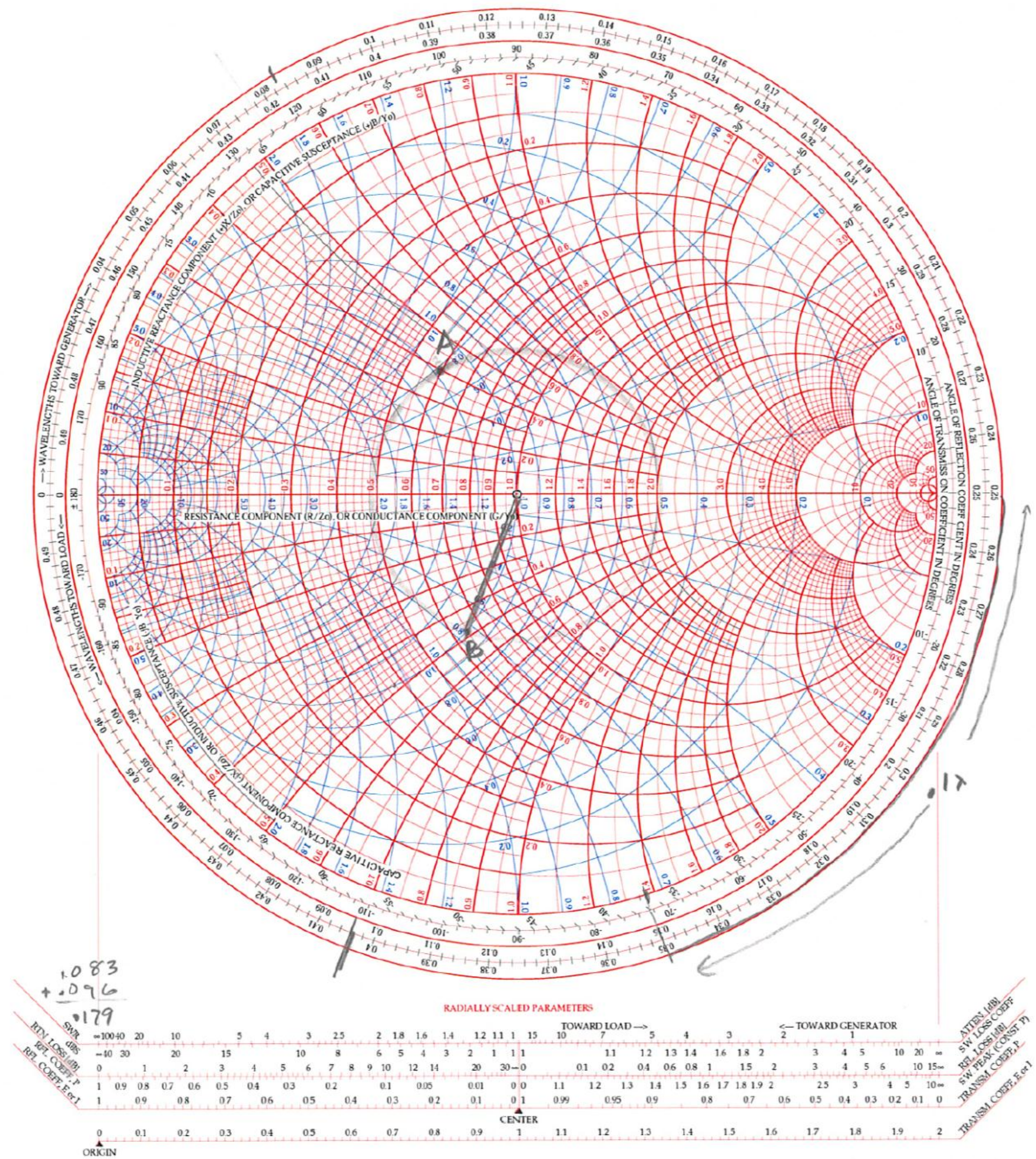
- Use Smith chart to verify

See next page





NORMALIZED IMPEDANCE AND ADMITTANCE COORDINATES



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