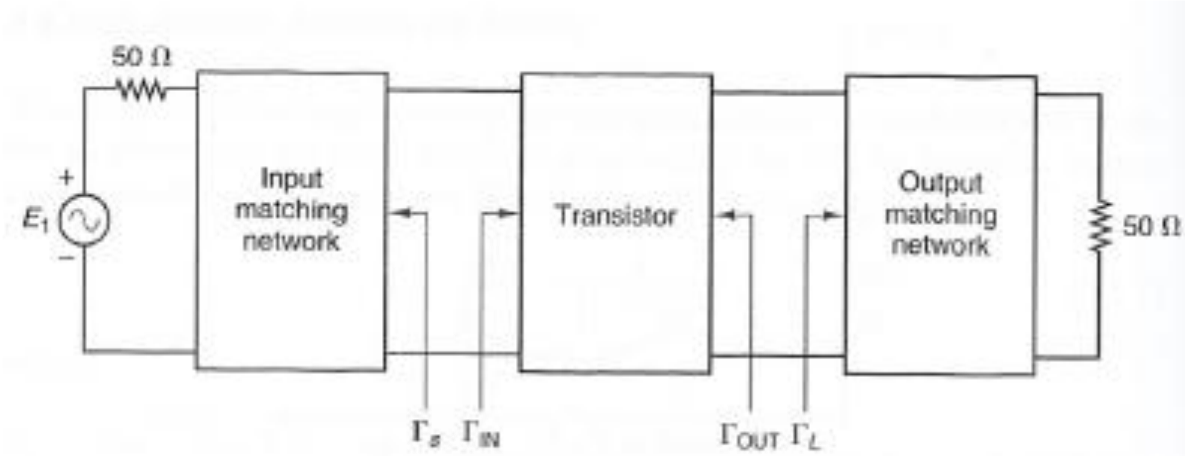
Bilateral design

$S_{12} \neq 0$



A conjugate match using transducer gain would require simultaneous adjustment of both input and output matching networks because changing one changes the other.

$$\Gamma_s^* = S_{11} + \frac{S_{12}S_{21}\Gamma_L}{1 - S_{22}\Gamma_L}$$

$$\Gamma_L^* = S_{22} + \frac{S_{12}S_{21}\Gamma_s}{1 - S_{11}\Gamma_s}$$

Design using power gain

- Using power gain allows us to decouple the input and output matching network designs

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

- We can write the input reflection coefficient in terms of the load reflection coefficient

$$|\Gamma_{\text{in}}| = \left|S_{11} + \frac{S_{12}S_{21}\Gamma_L}{1-S_{22}\Gamma_L}\right| = \left|\frac{S_{11} - S_{11}S_{22}\Gamma_L + S_{12}S_{21}\Gamma_L}{1-S_{22}\Gamma_L}\right| = \left|\frac{S_{11}-\Delta\Gamma_L}{1-S_{22}\Gamma_L}\right|$$

- Then we can write the power gain in solely in terms of the load reflection coefficient

$$G_P = \frac{1}{1-\left|\frac{S_{11}-\Delta\Gamma_L}{1-S_{22}\Gamma_L}\right|^2}|S_{21}|^2\frac{1-|\Gamma_L|^2}{|1-S_{22}\Gamma_L|^2}$$

Normalized power gain

-As before we will draw circles based on normalized gain

$$g_P = \frac{G_P}{|S_{21}|^2}$$

-We define a circle in terms of the location of its center and its radius in the Γ_L-plane.

$$C_P = \frac{g_P(S_{22}^* - \Delta^* S_{11})}{1 + g_P(|S_{22}|^2 - |\Delta|^2)}$$

$$r_P = \frac{[1 - 2k|S_{12}S_{21}|g_P + |S_{12}S_{21}|^2 g_P^2]^{1/2}}{|1 + g_P(|S_{22}|^2 - |\Delta|^2)|}$$

$$k = \frac{1 - |S_{11}|^2 - |S_{22}|^2 + |\Delta|^2}{2|S_{12}S_{21}|}$$

Range of power gain

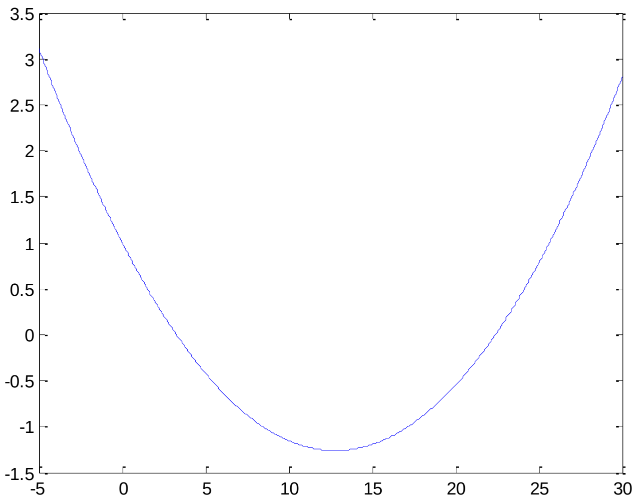
$$r_P = \frac{[1 - 2k|S_{12}S_{21}|g_P + |S_{12}S_{21}|^2 g_P^2]^{1/2}}{|1 + g_P(|S_{22}|^2 - |\Delta|^2)|}$$

$$S_{11} = 0.641\angle -171.3^\circ$$

$$S_{12} = 0.057\angle 16.3^\circ$$

$$S_{21} = 2.058\angle 28.5^\circ$$

$$S_{22} = 0.572\angle -95.7^\circ$$

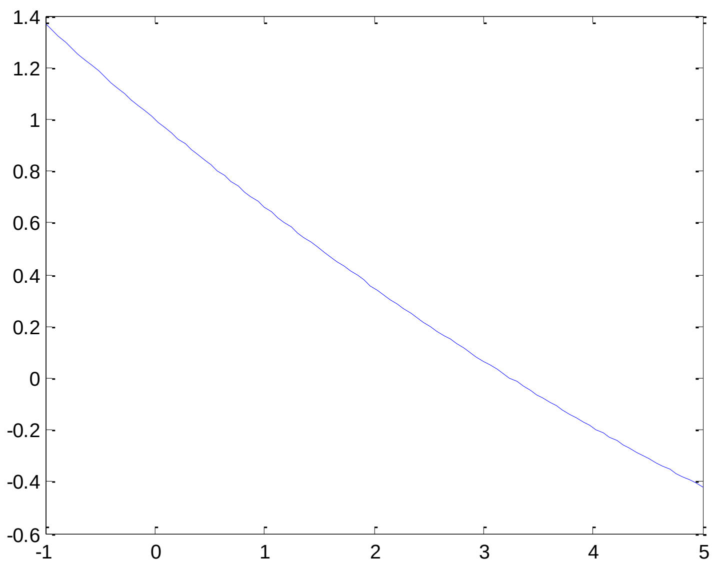


--Let’s plot the numerator of the equation of the radius equation for actual values

--It is parabolic and has two zero crossings

--It is obvious that our radius can’t be zero

Zoomed in range of normalized gain



$$g_{P,\max} = \frac{1}{|S_{12}S_{21}|}[k - \sqrt{k^2 - 1}]$$

$$G_{P,\max} = \left|\frac{S_{21}}{S_{12}}\right| [k - \sqrt{k^2 - 1}]$$

Radius must be positive so the maximum value of g_p is about 3.24.

Also if g_p=0 then the radius goes to 1 according to the equation

This means we can only choose g_p from 0 to 3.24 for this problem.

Example problem

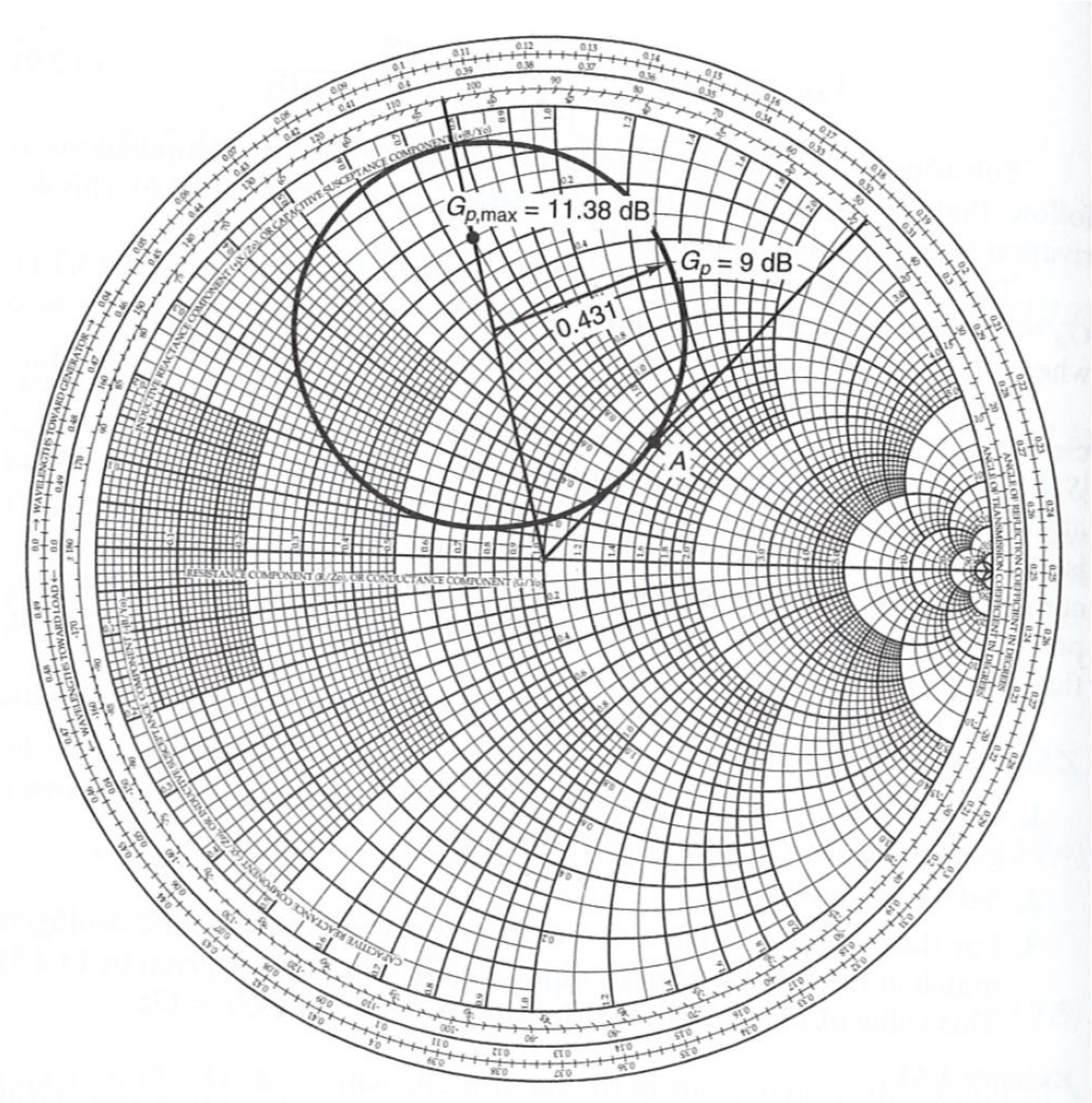
- Using S-parameters shown design an amplifier with a gain of 9 dB (7.94).
- Then we calculate where the center and radius
- Plot these on Smith Chart

$$S_{11} = 0.641\angle -171.3^\circ$$
$$S_{12} = 0.057\angle 16.3^\circ$$
$$S_{21} = 2.058\angle 28.5^\circ$$
$$S_{22} = 0.572\angle -95.7^\circ$$

$$g_p = \frac{G_p}{|S_{21}|^2} = \frac{7.94}{4.235} = 1.875$$

$$r_p = 0.431 \text{ and } C_p = 0.508\angle 103.9^\circ$$

Smith Chart solution



Get maximum output power

- Choose a Γ_L that lies on the circle, point A

$$\Gamma_L = 0.36\angle 47.5^\circ$$

$$\Gamma_s^* = S_{11} + \frac{S_{12}S_{21}\Gamma_L}{1 - S_{22}\Gamma_L}$$
$$= 0.629\angle 175.51^\circ$$

- Find corresponding Γ_s
- Because it is matched the source side VSWR unity
- The output VSWR is found as follows

$$|\Gamma_b| = \left|\frac{\Gamma_{OUT} - \Gamma_L^*}{1 - \Gamma_{OUT}\Gamma_L}\right| = \left|\frac{0.67\angle -102.66^\circ - 0.36\angle -47.5^\circ}{1 - 0.67\angle -102.66^\circ(0.36\angle 47.5^\circ)}\right| = 0.622$$

$$(\text{VSWR})_{out} = \frac{1 + 0.622}{1 - 0.622} = 4.3$$