R. Ludwig and G. Bogdanov
"RF Circuit Design: Theory and Applications"
2nd edition

Figures for Chapter 9

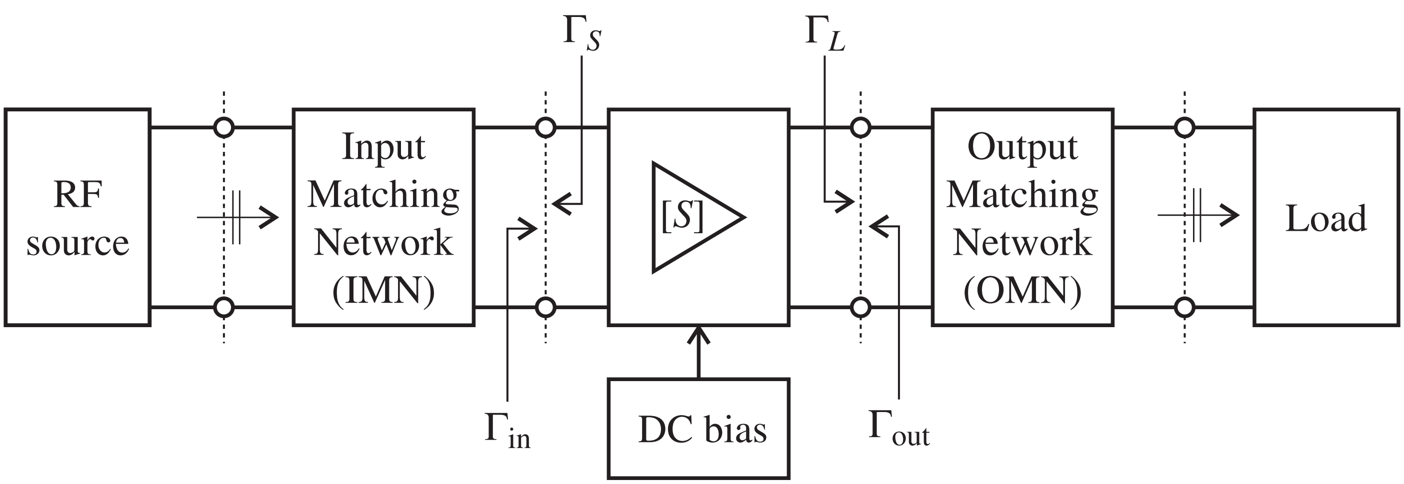
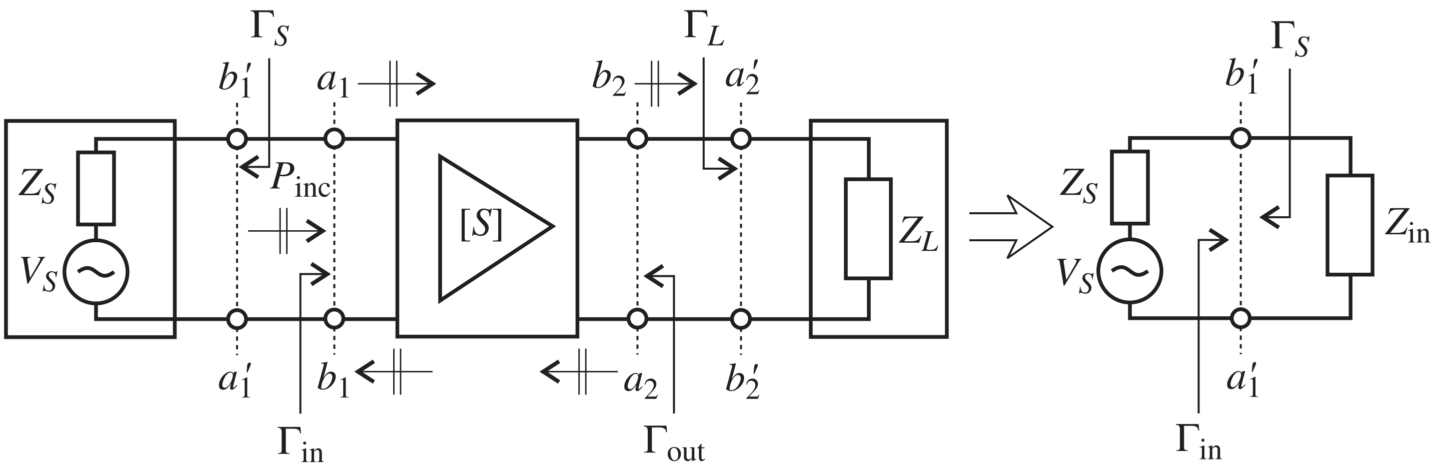
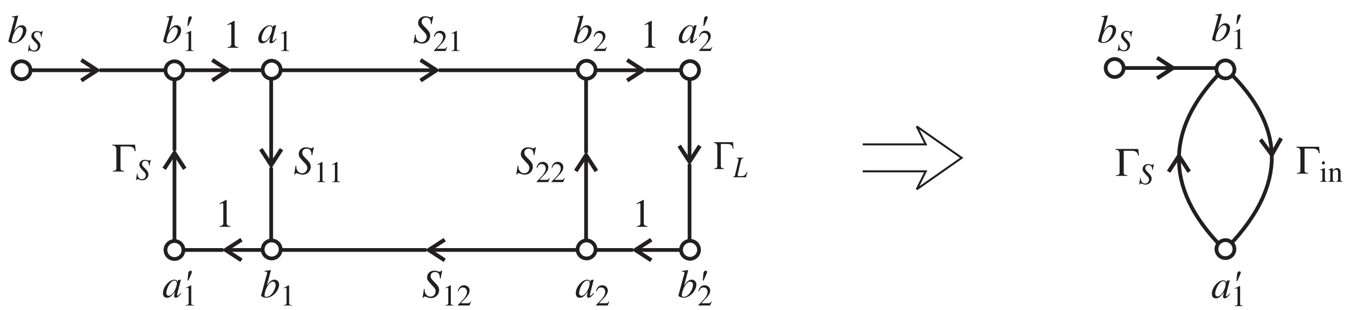


Figure 9-1 Generic amplifier system.



(a) Simplified schematics of a single-stage amplifier



(b) Signal flow graph

Figure 9-2 Source and load connected to a single-stage amplifier network.

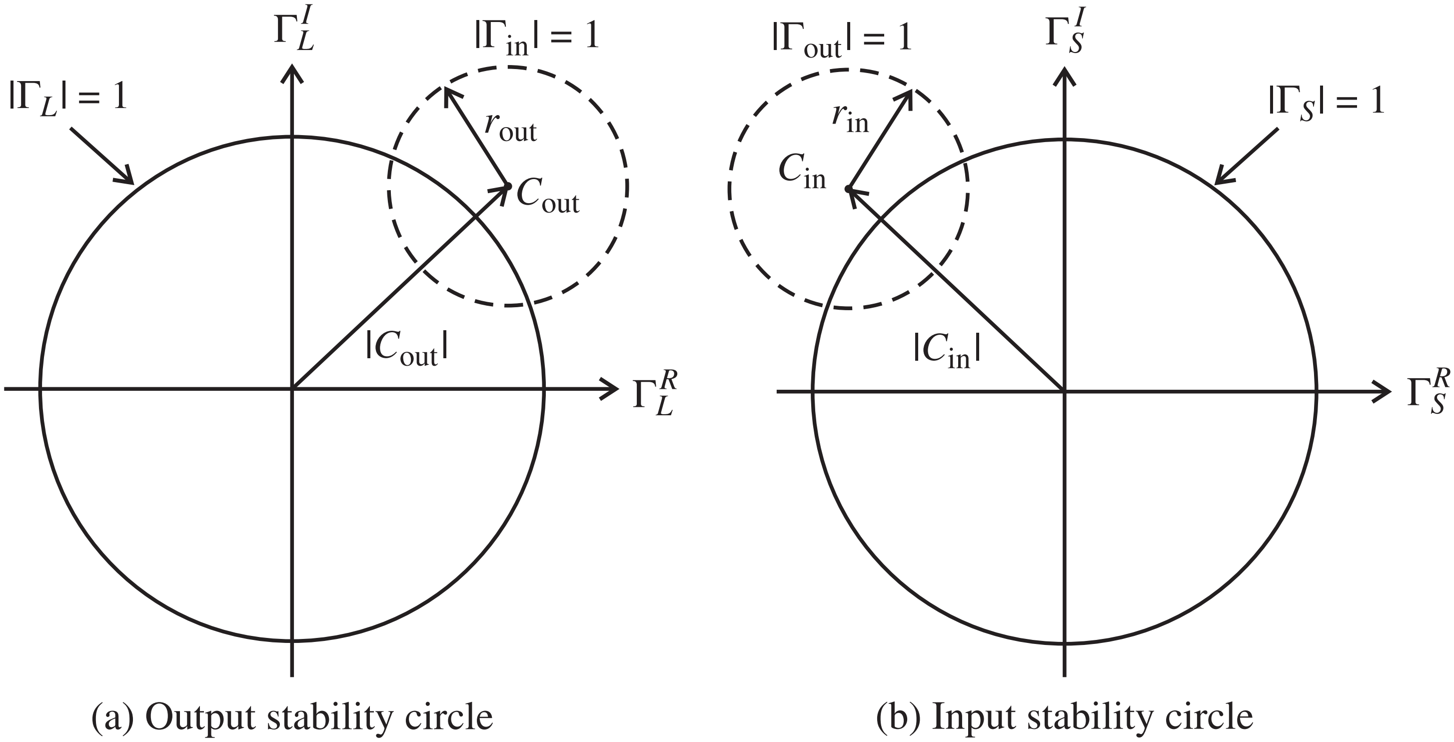


Figure 9-3 Stability circle $|\Gamma_{in}| = 1$ in the complex Γ_L-plane and stability circle $|\Gamma_{out}| = 1$ in the complex Γ_S-plane.

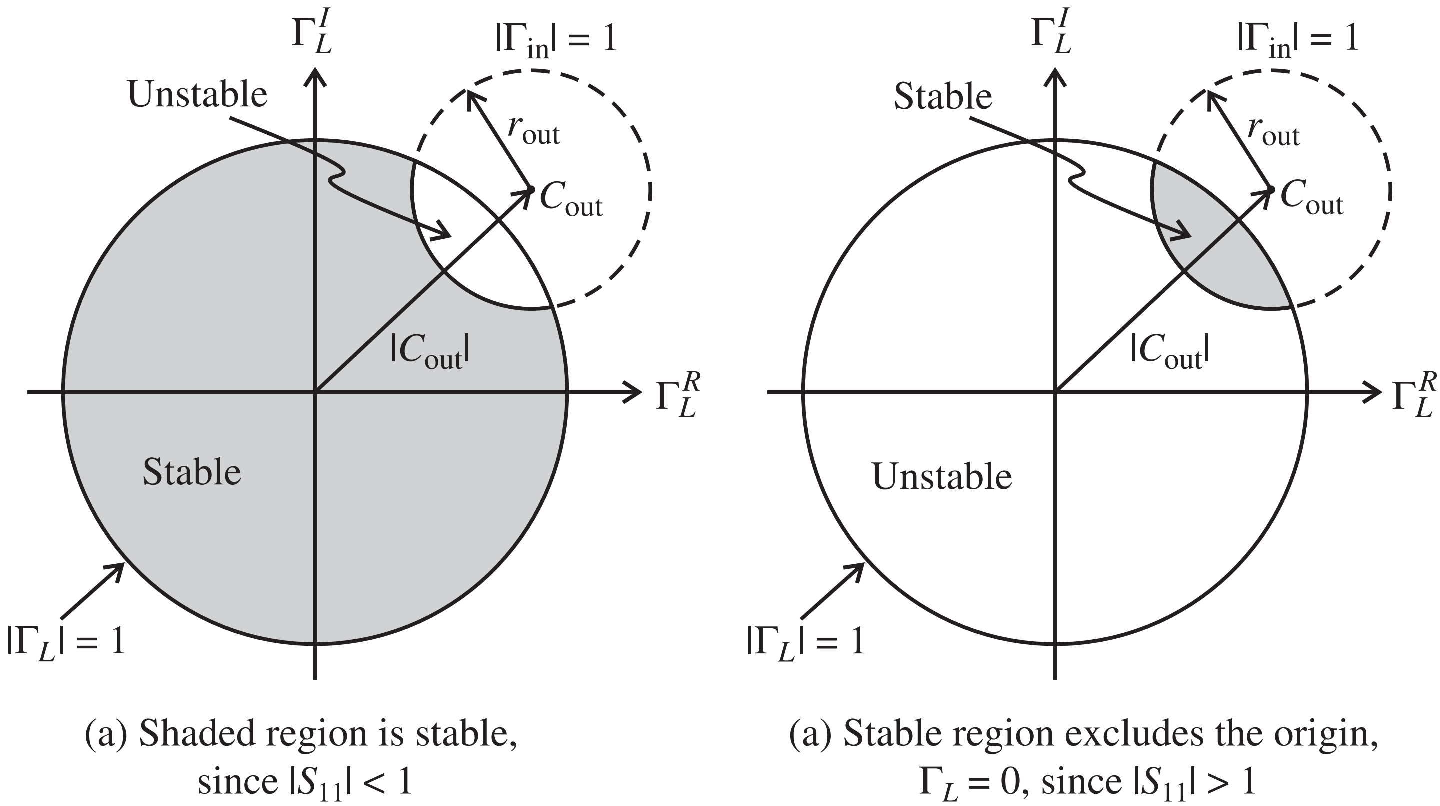


Figure 9-4 Output stability circles denoting stable and unstable regions.

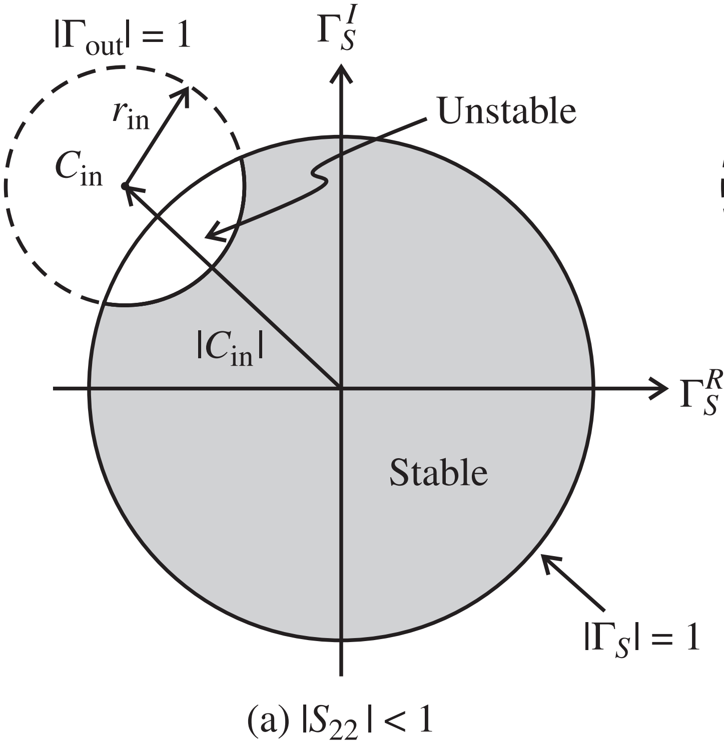


Figure 9-5 Input stability circles denoting stable and unstable regions.

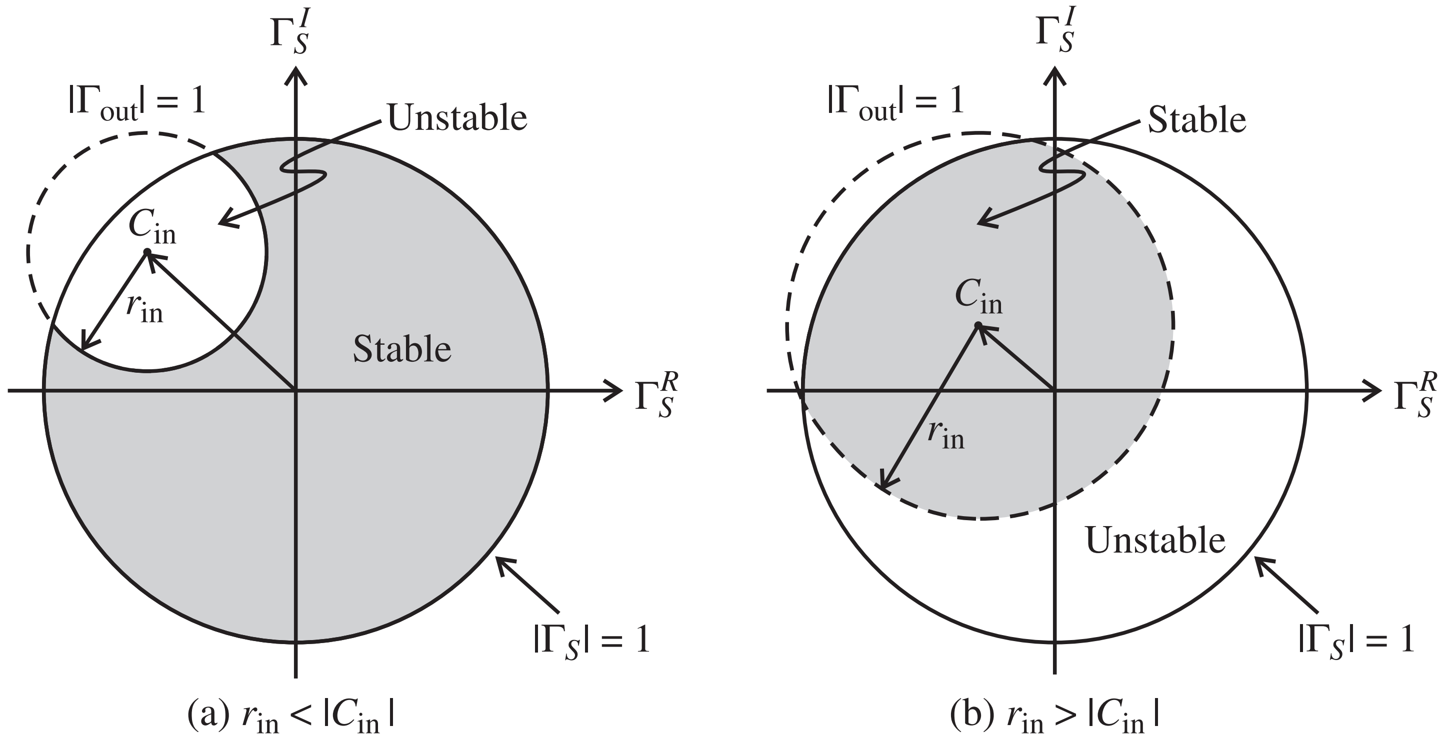
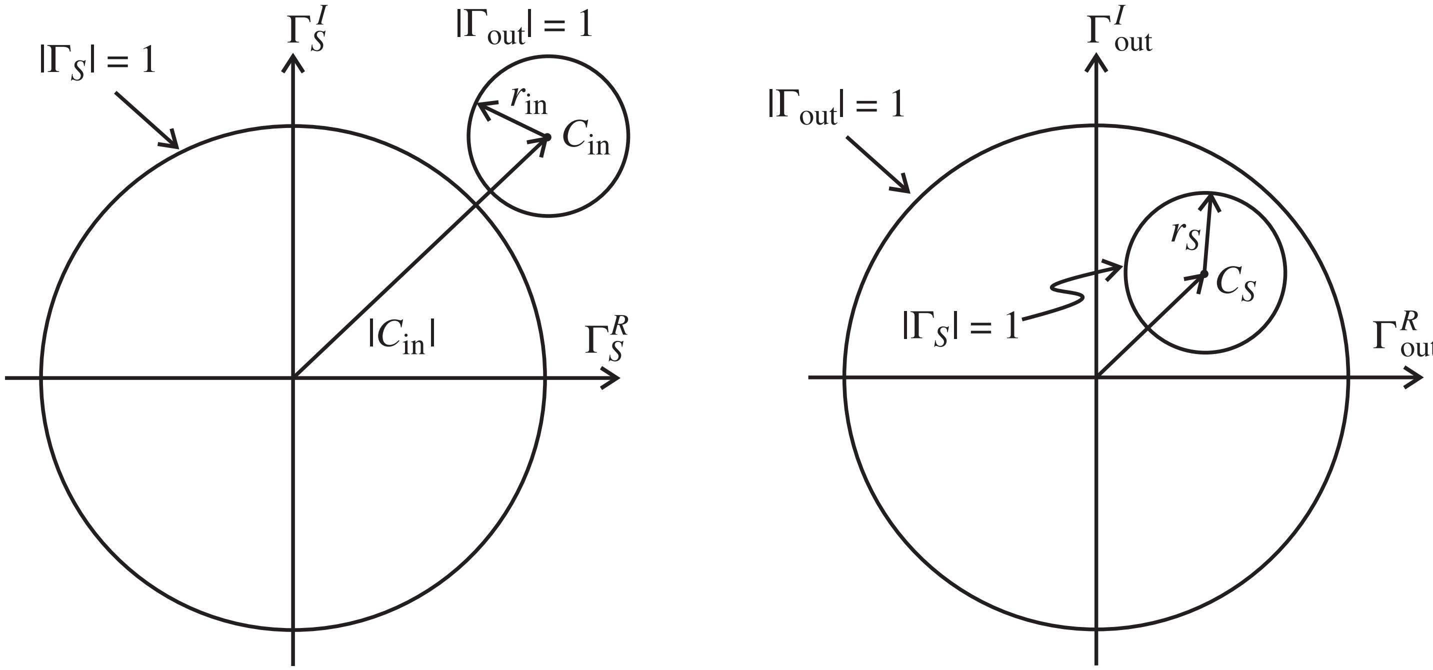


Figure 9-6 Different input stability regions for $|S_{22}| < 1$ depending on ratio between r_S and $|C_{in}|$.



(a) $|\Gamma_{out}| = 1$ circle must reside outside

(b) $|\Gamma_S| = 1$ circle must reside inside

Figure 9-7 Unconditional stability in the Γ_S and Γ_{out} planes for $|S_{11}| < 1$.

Table 9-1 BFG505W *S*-parameters as functions of frequency

Frequency	S_{11}	S_{12}	S_{21}	S_{22}
500 MHz	$0.70\angle{-57°}$	$0.04\angle{47°}$	$10.5\angle{136°}$	$0.79\angle{-33°}$
750 MHz	$0.56\angle{-78°}$	$0.05\angle{33°}$	$8.6\angle{122°}$	$0.66\angle{-42°}$
1000 MHz	$0.46\angle{-97°}$	$0.06\angle{22°}$	$7.1\angle{112°}$	$0.57\angle{-48°}$
1250 MHz	$0.38\angle{-115°}$	$0.06\angle{14°}$	$6.0\angle{104°}$	$0.50\angle{-52°}$

Table 9-2 Stability parameters for BFG505W

f, MHz	k	$\|\Delta\|$	C_{in}	r_{in}	C_{out}	r_{out}
500	0.41	0.69	$39.04\angle 108°$	38.62	$3.56\angle 70°$	3.03
750	0.60	0.56	$62.21\angle 119°$	61.60	$4.12\angle 70°$	3.44
1000	0.81	0.45	$206.23\angle 131°$	205.42	$4.39\angle 69°$	3.54
1250	1.02	0.37	$42.42\angle 143°$	41.40	$4.24\angle 68°$	3.22

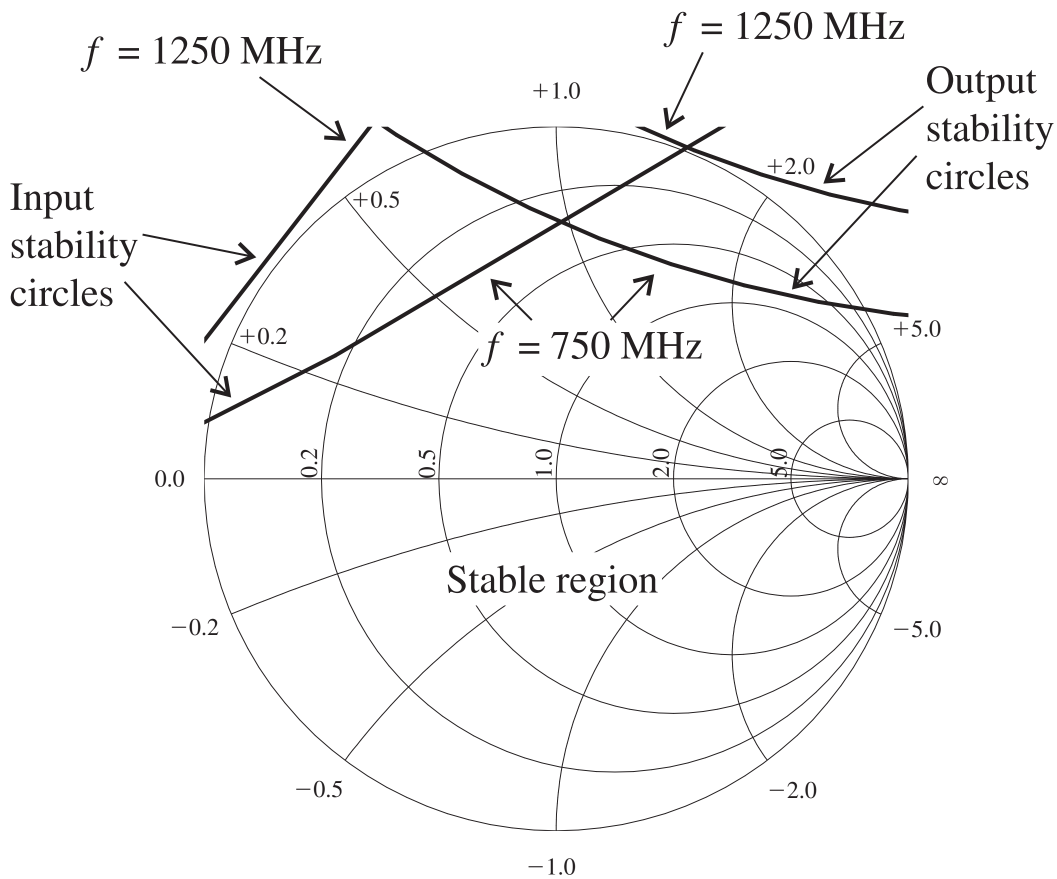


Figure 9-8 Input and output stability circles for BFG505W computed at f = 750 MHz and f = 1.25 GHz.

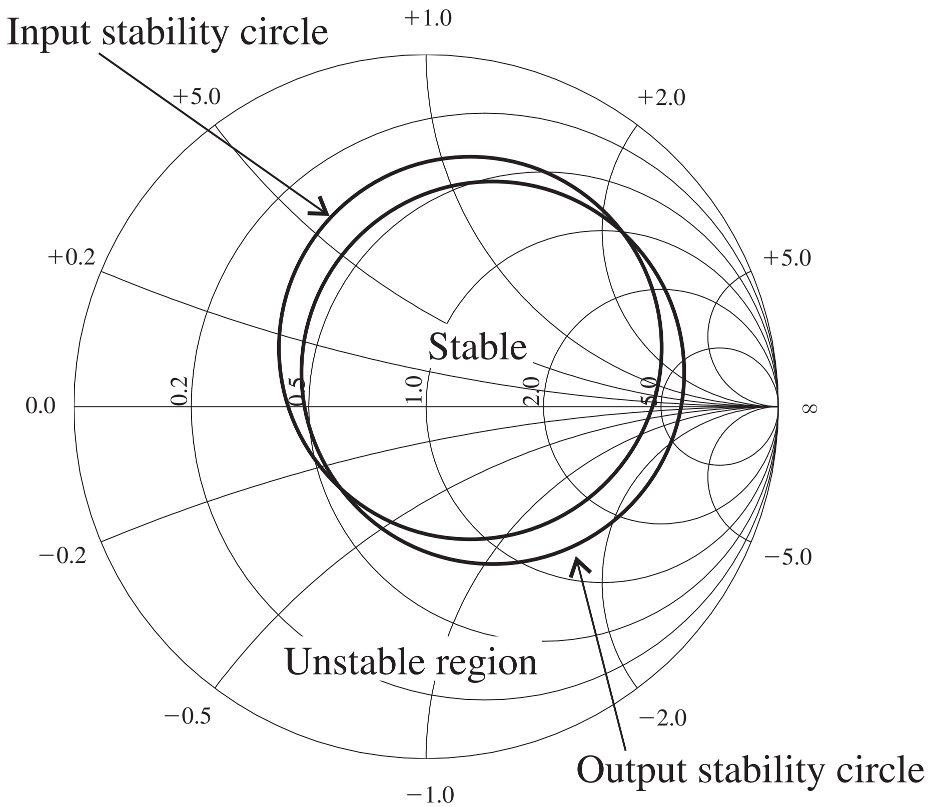


Figure 9-9 Stability circles for $k > 1$ and $|\Delta| > 1$.

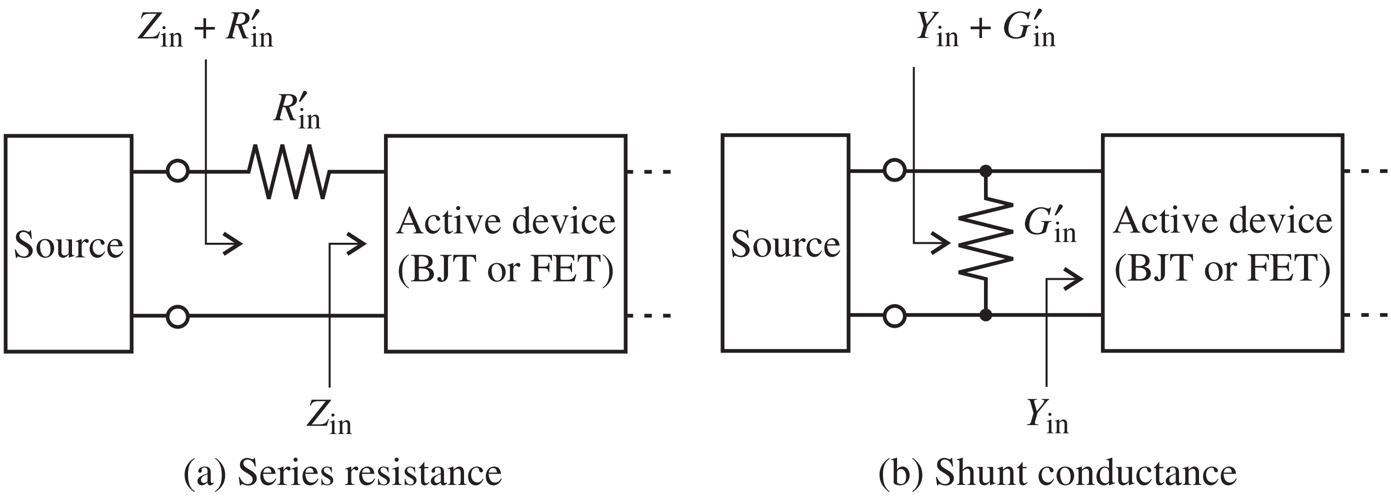
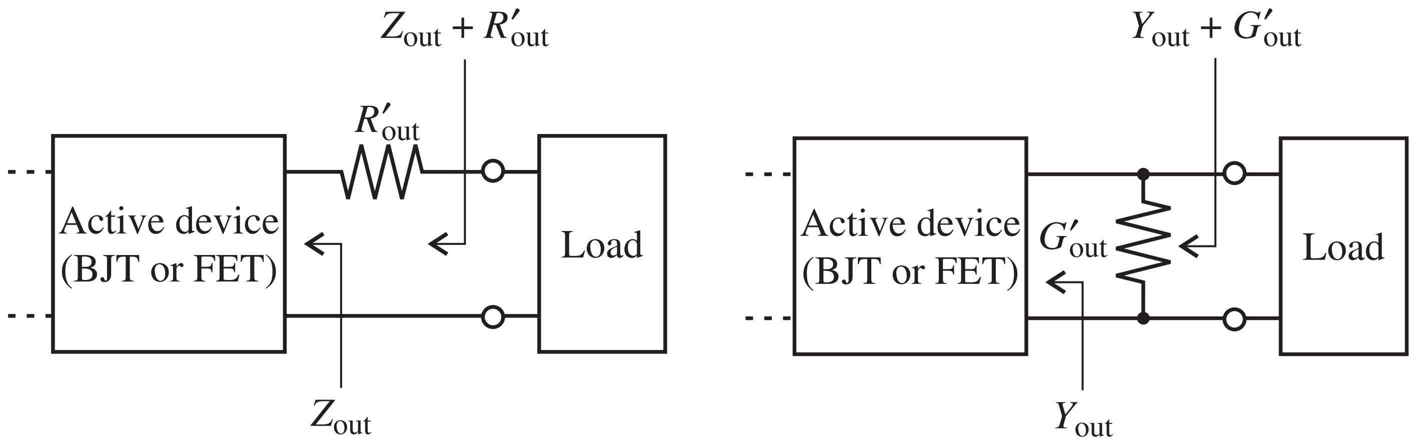


Figure 9-10 Stabilization of input port through series resistance or shunt conductance.



(a) Series resistance (b) Shunt conductance

Figure 9-11 Stabilization of output port through series resistance or shunt conductance.

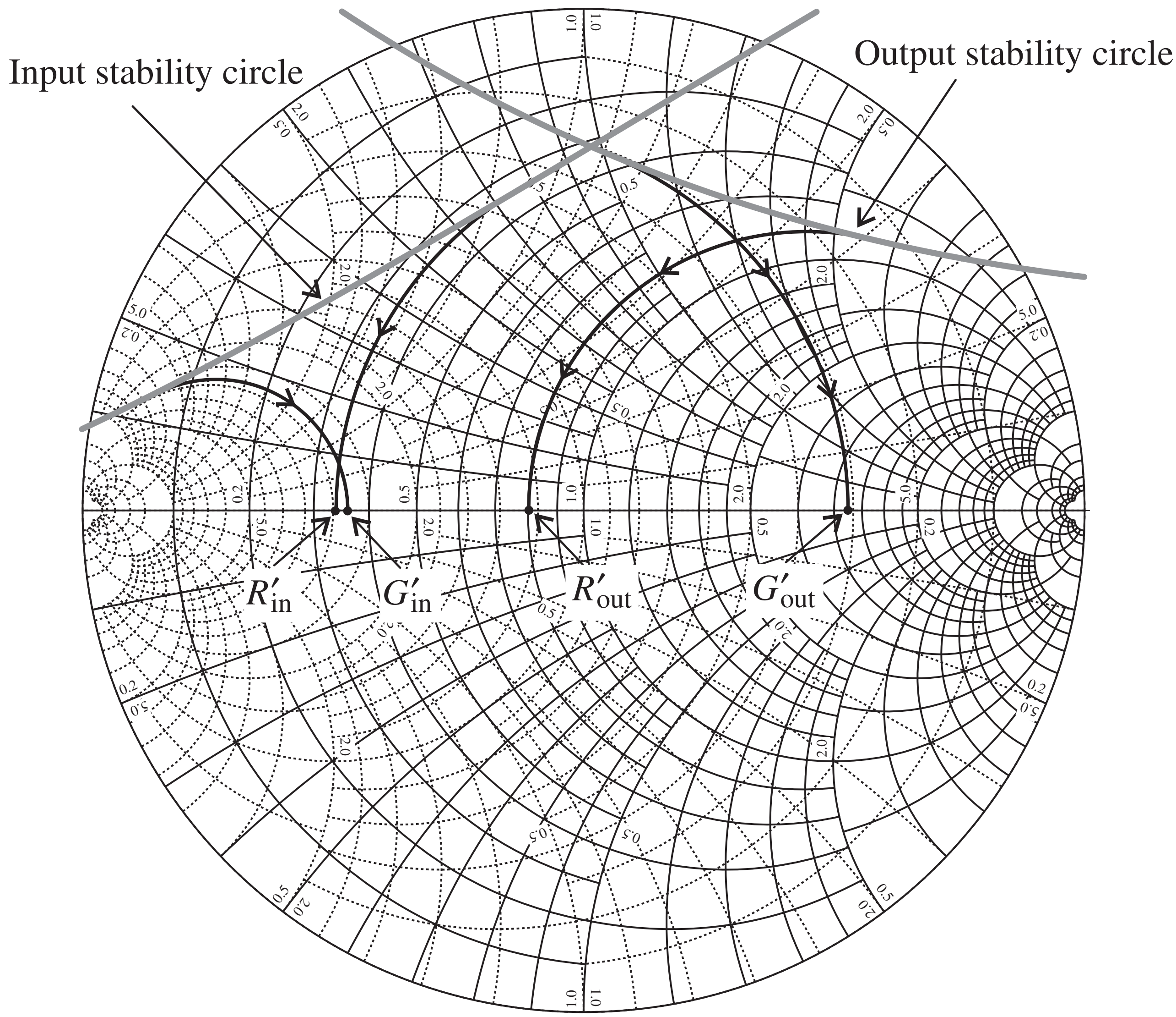


Figure 9-12 Input and output stability circles and circles for finding stabilizing series resistance and shunt conductances.

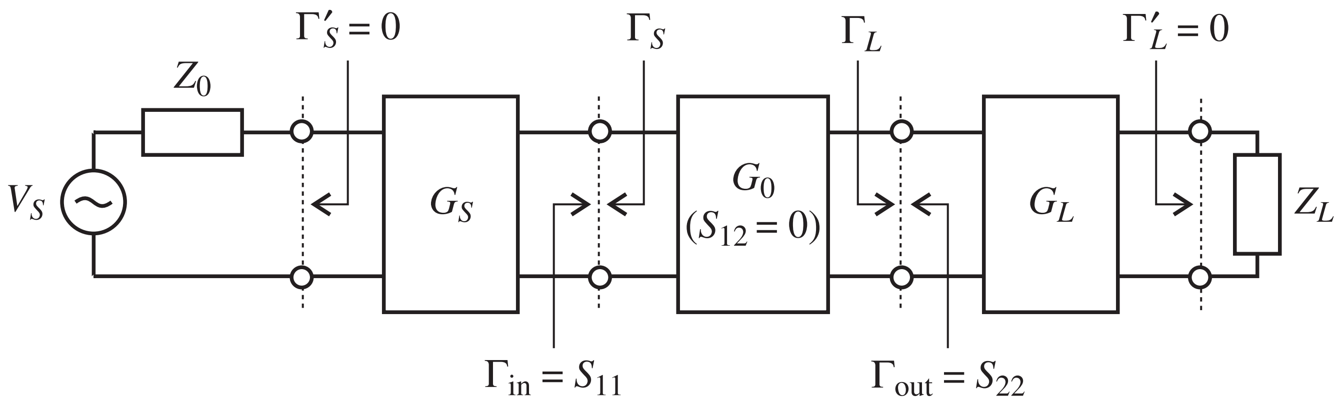


Figure 9-13 Unilateral power gain system arrangement.

Table 9-3 Parameters for constant source gain circles in Example 9-7

G_S	g_S	d_{g_S}	r_{g_S}
2.6 dB	0.93	$0.67\angle{-125°}$	0.14
2 dB	0.81	$0.62\angle{-125°}$	0.25
1 dB	0.64	$0.54\angle{-125°}$	0.37
0 dB	0.51	$0.47\angle{-125°}$	0.47
–1 dB	0.41	$0.40\angle{-125°}$	0.56

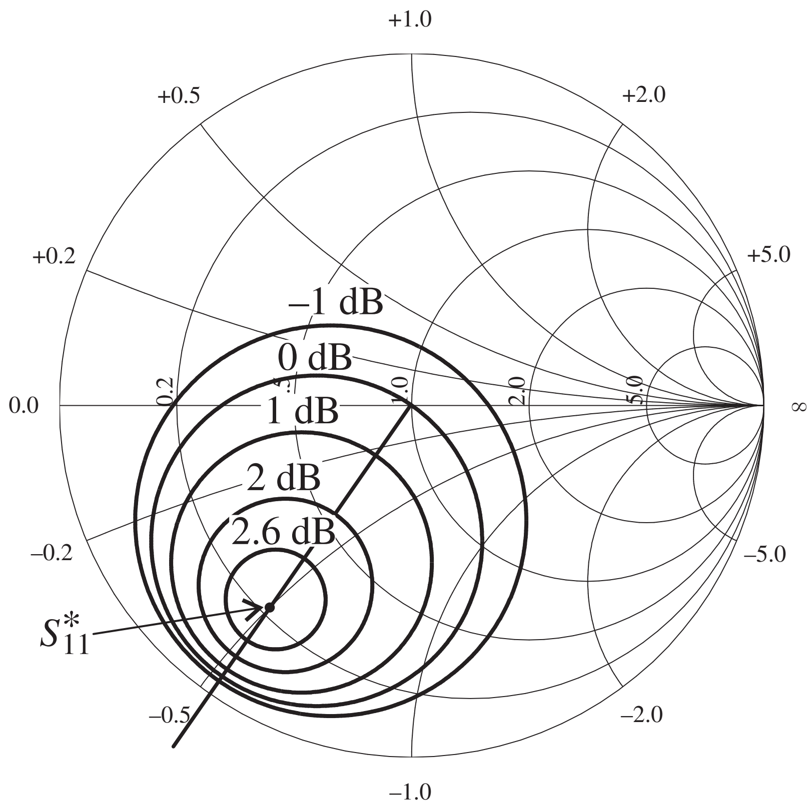


Figure 9-14 Constant source gain circles in the Smith Chart.

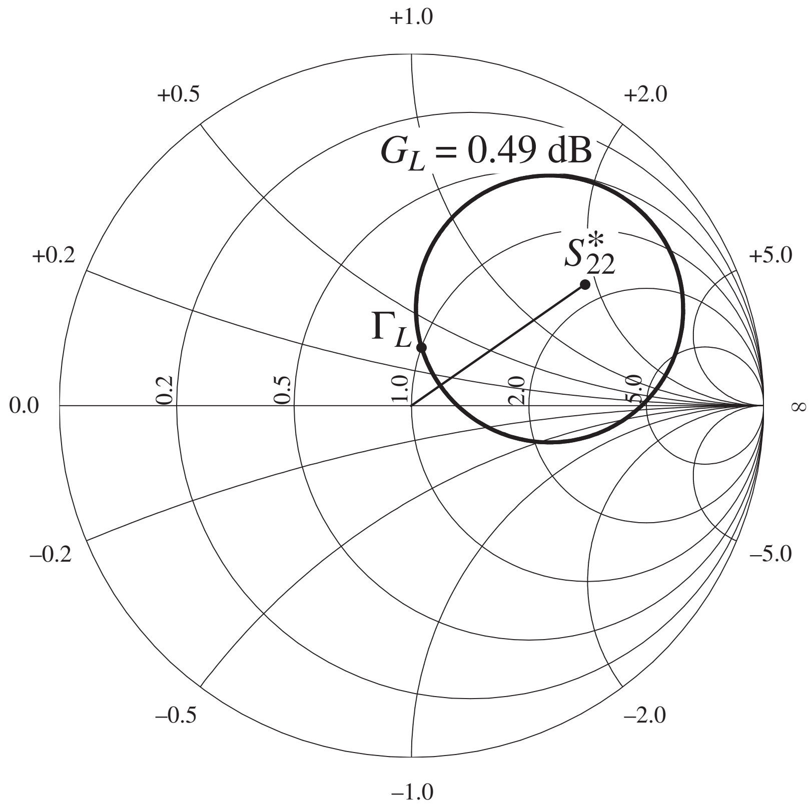


Figure 9-15 Constant load gain circle in the Smith Chart.

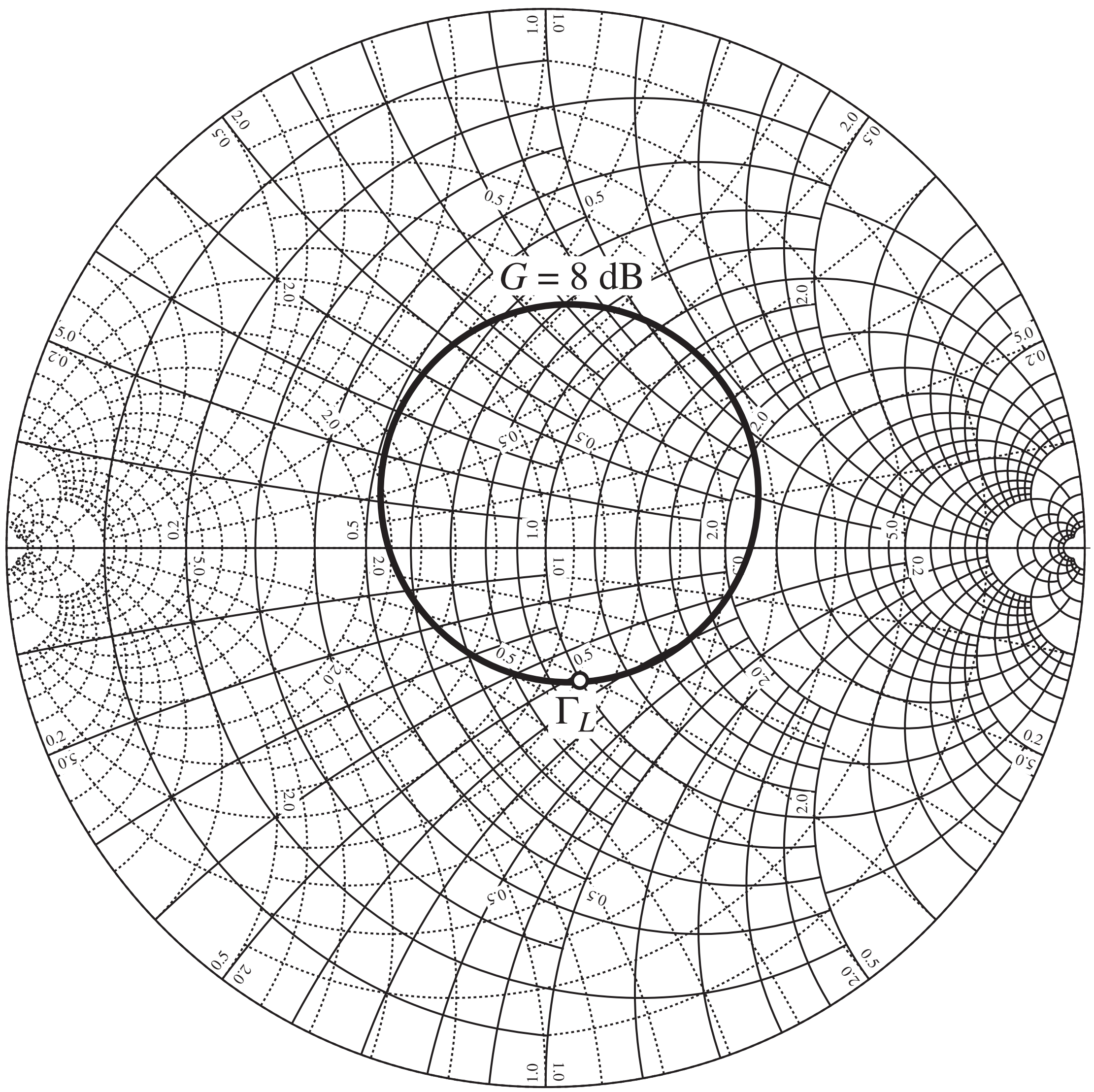


Figure 9-16 Constant operating power circle in the Γ_L -plane.

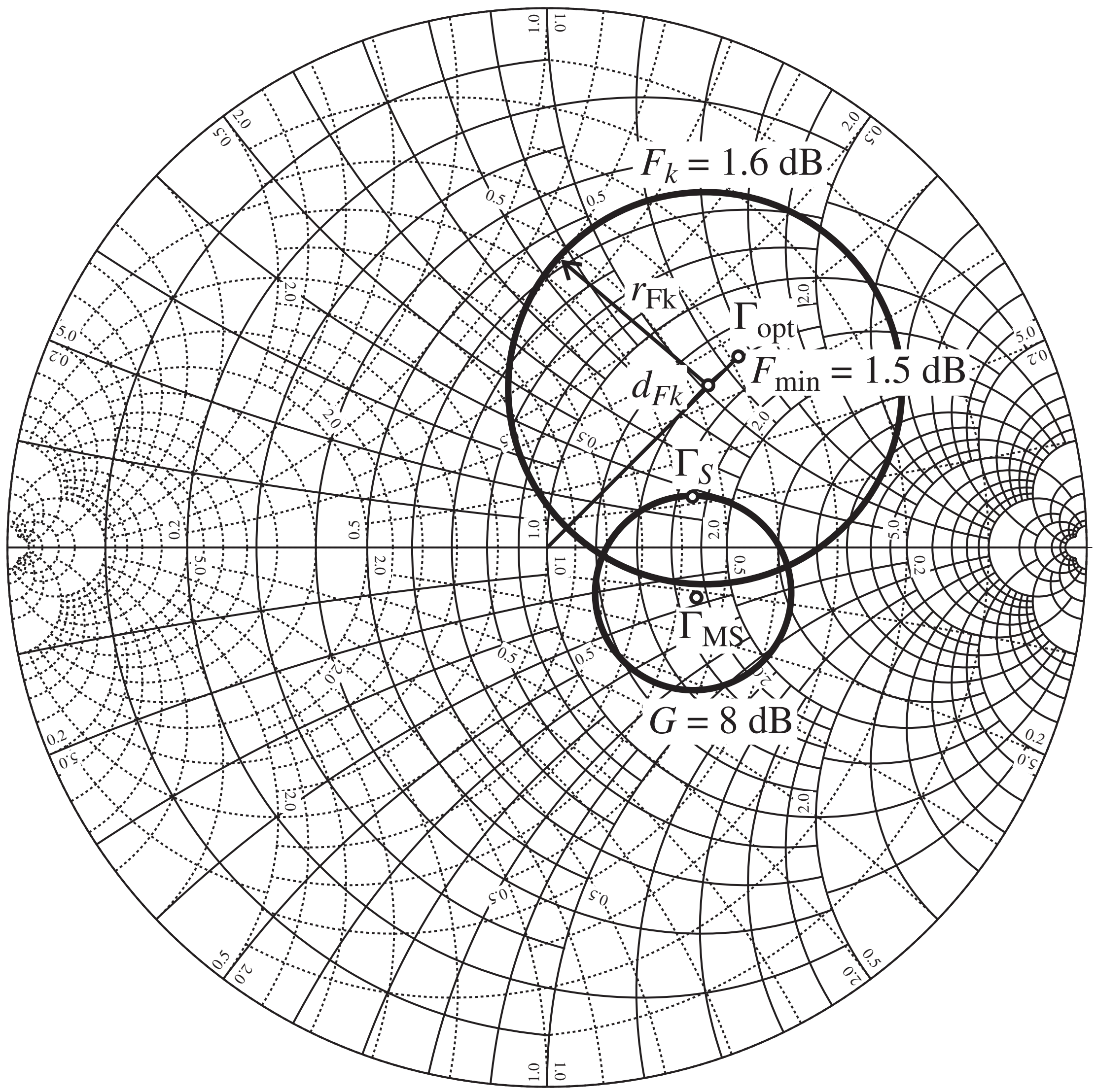


Figure 9-17 Constant noise figure circle and constant operating gain circle mapped into the Γ_S-plane.

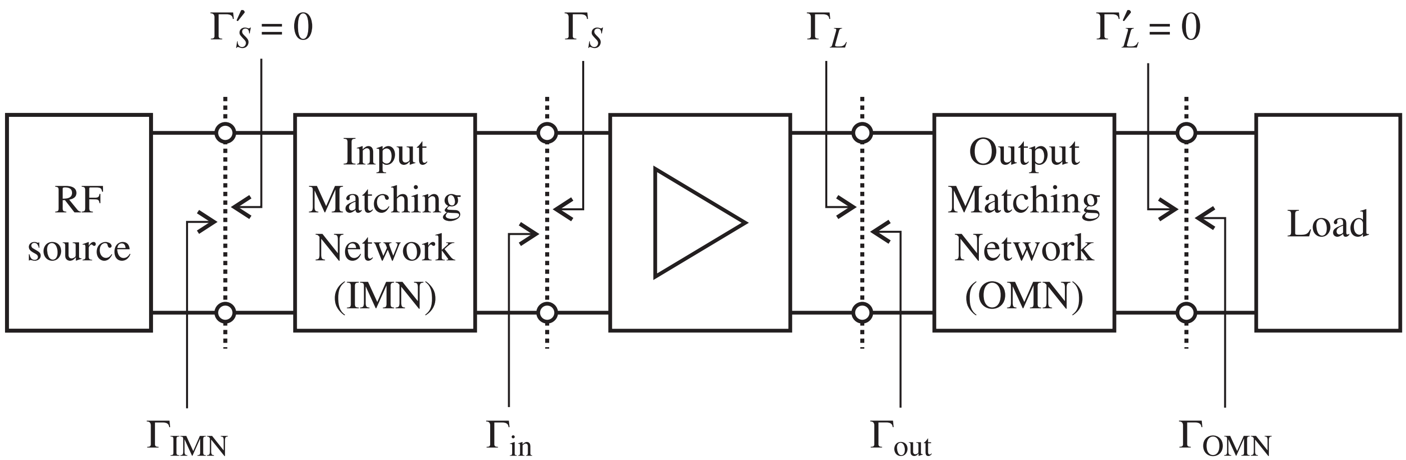


Figure 9-18 System configuration for input and output VSWR.

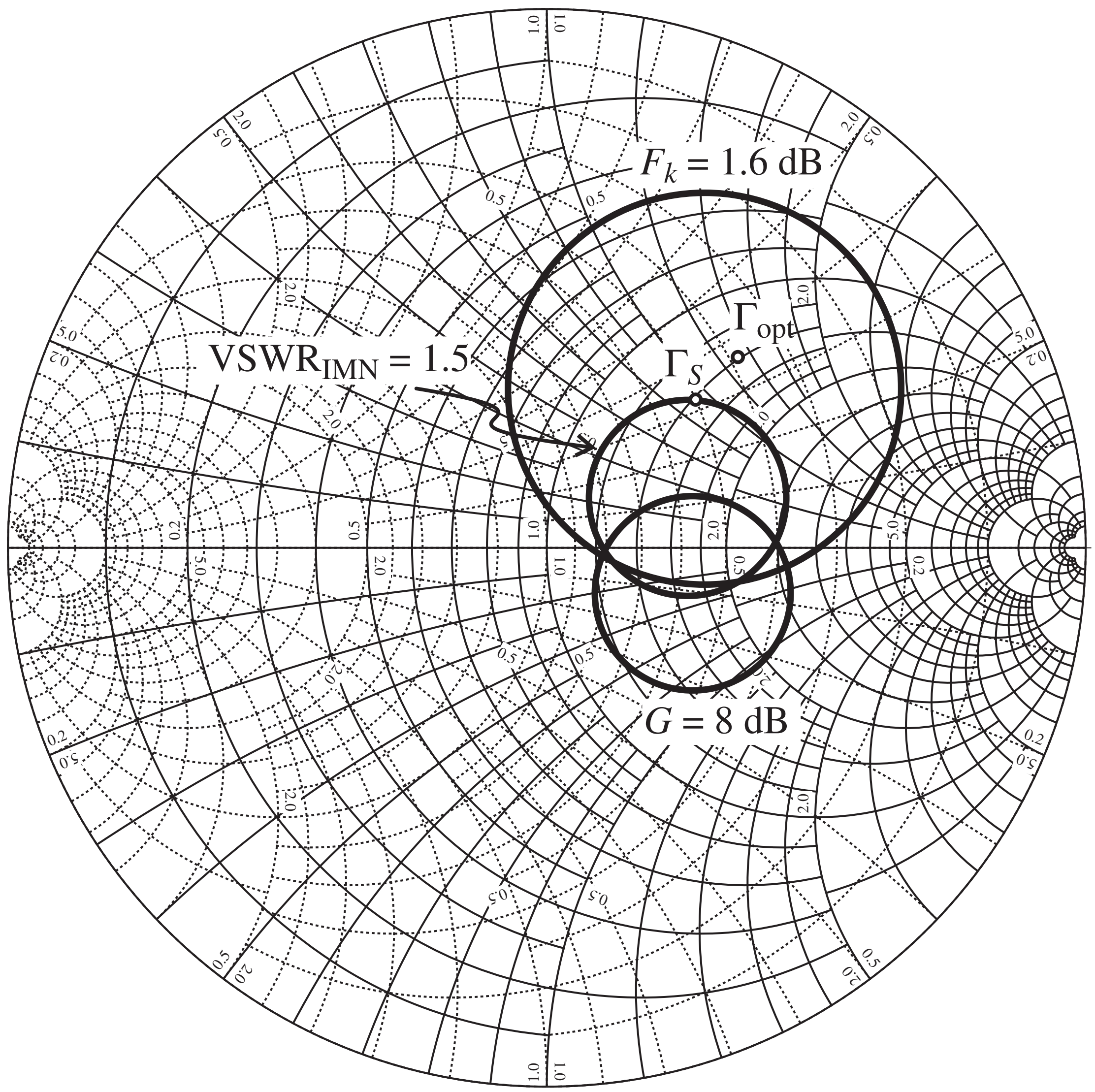


Figure 9-19 Constant operating power gain, noise figure, and input VSWR circle in Γ_S-plane.

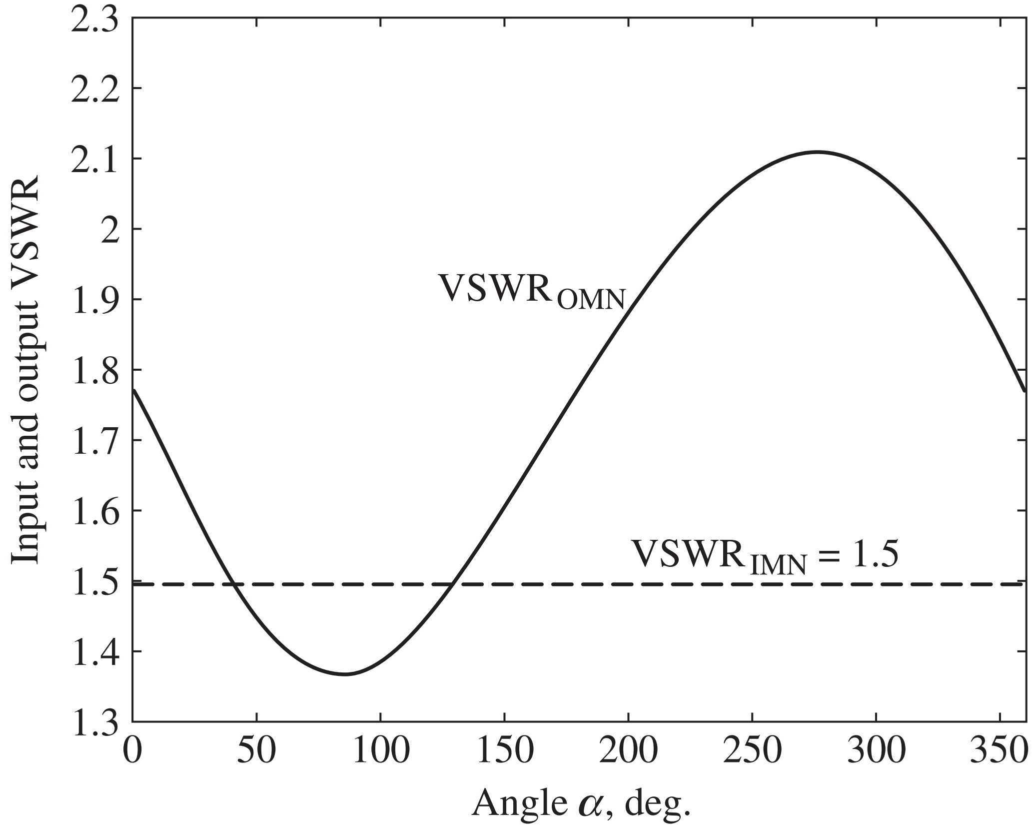


Figure 9-20 Input and output VSWR as a function of angle α.

Table 9-4 *S*-parameters of AT41410 BJT (I_C = 10 mA, V_{CE} = 8 V)

f, GHz	$\lvert S_{21} \rvert$	S_{11}	S_{22}
2	3.72	$0.61\angle 165°$	$0.45\angle -48°$
3	2.56	$0.62\angle 149°$	$0.44\angle -58°$
4	1.96	$0.62\angle 130°$	$0.48\angle -78°$

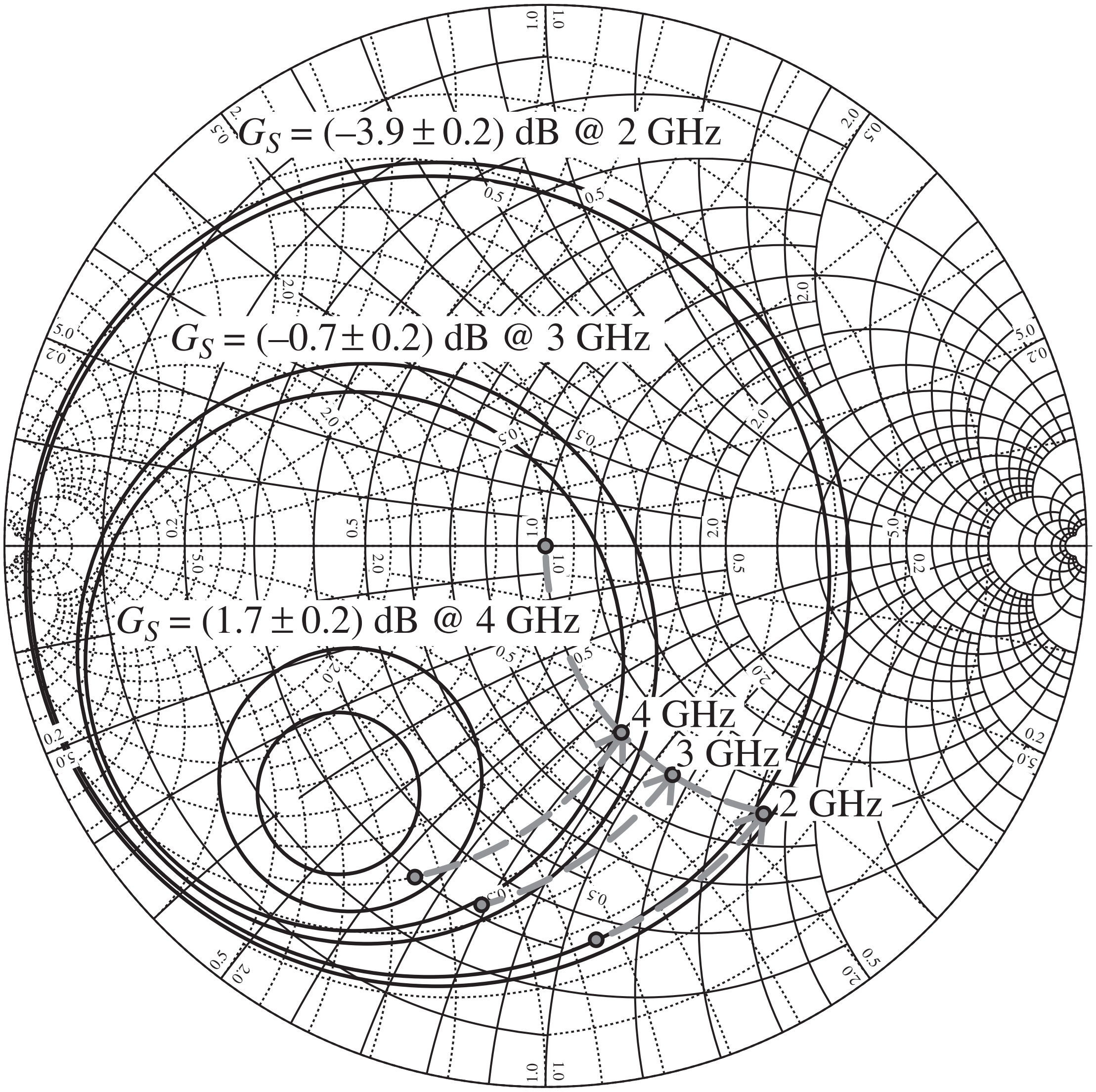


Figure 9-21 Smith Chart design of a broadband amplifier in Example 9-16.

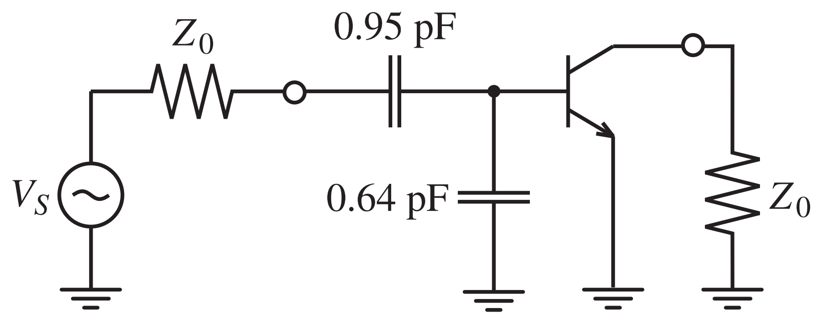


Figure 9-22 Broadband amplifier with 7.5 dB gain and ±0.2 dB gain flatness over a frequency range from 2 to 4 GHz.

Table 9-5 Parameters of a broadband amplifier

f, GHz	Γ_S	G_T, dB	VSWR_{IMN}	VSWR_{OMN}
2	$0.74\angle{-83°}$	7.65	13.1	2.6
3	$0.68\angle{-101°}$	7.57	5.3	2.6
4	$0.66\angle{-112°}$	7.43	2.0	2.8

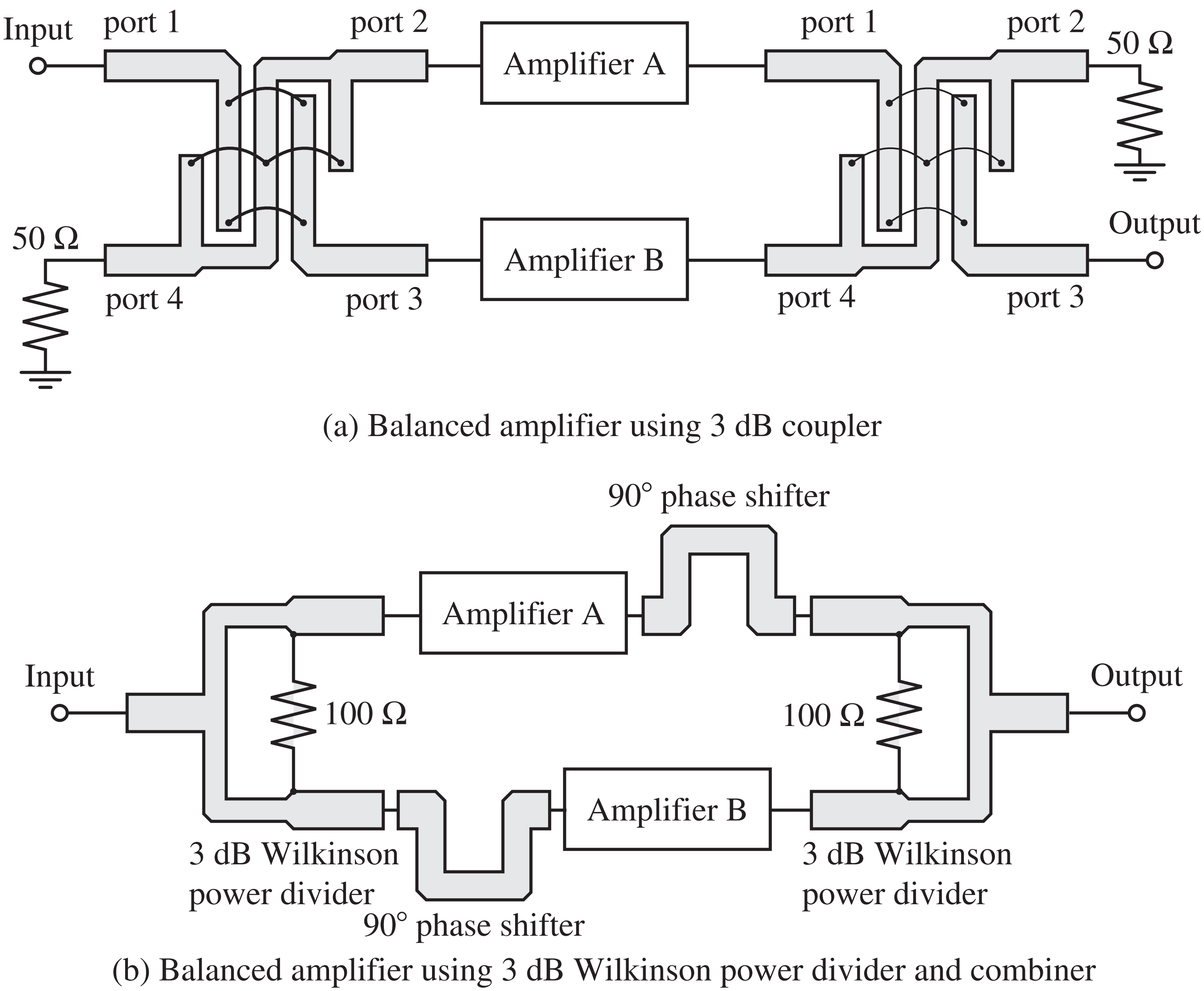
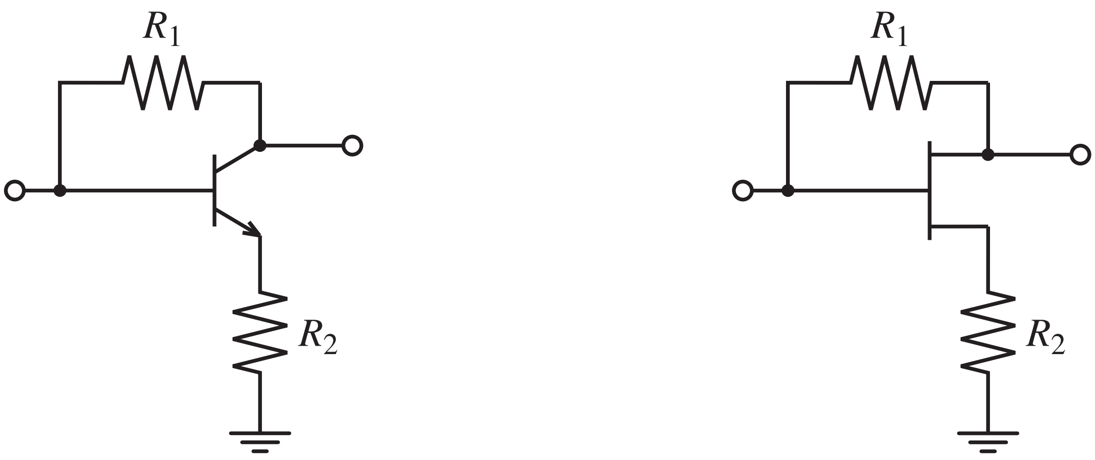


Figure 9-23 Block diagram of a balanced broadband amplifier.



(a) Feedback in BJTs

(b) Feedback in FETs

Figure 9-24 Negative resistive feedback circuits.

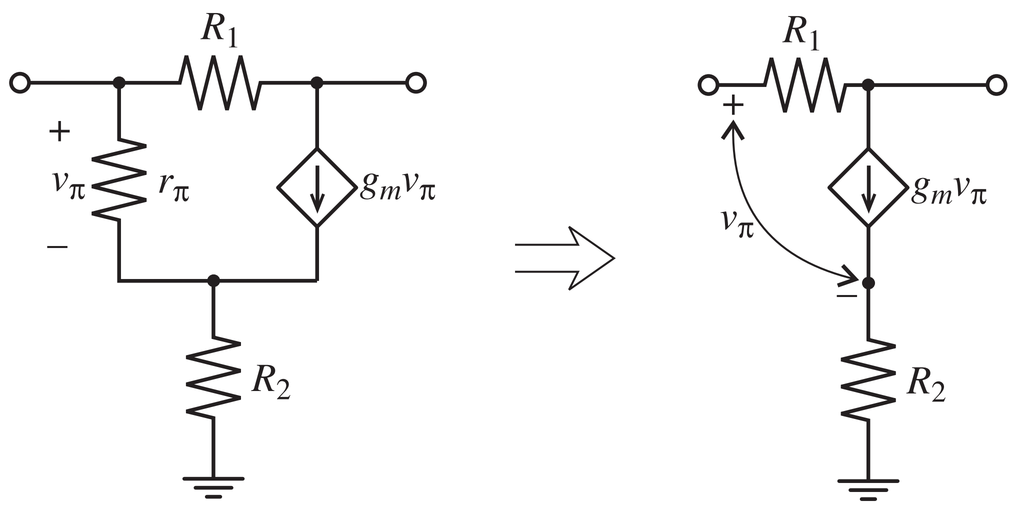


Figure 9-25 Low-frequency model of negative feedback circuit.

Table 9-6 *S*-parameters for the transistor in Example 9-17

f, MHz	$\lvert S_{11} \rvert$	$\angle S_{11}$	$\lvert S_{21} \rvert$	$\angle S_{21}$	$\lvert S_{12} \rvert$	$\angle S_{12}$	$\lvert S_{22} \rvert$	$\angle S_{22}$
10	0.877	–0.3°	7.035	179.6°	1×10^{-4}	66.8°	0.805	–0.1°
100	0.876	–2.4°	7.027	176.1°	7×10^{-4}	85.9°	0.805	–1.4°
250	0.870	–5.9°	6.983	170.2°	0.002	84.3°	0.803	–3.4°
500	0.850	–11.5°	6.834	160.6°	0.003	80.5°	0.797	–6.6°
750	0.820	–16.9°	6.607	151.4°	0.004	76.0°	0.789	–9.8°
1000	0.783	–21.7°	6.327	142.8°	0.005	68.2°	0.777	–12.7°
1500	0.700	–29.6°	5.711	127.2°	0.007	74.1°	0.755	–18.1°
2000	0.619	–35.7°	5.119	113.8°	0.007	74.1°	0.735	–23.0°

Table 9-7 Insertion gain of the feedback amplifier

f, MHz	$\lvert S_{21}\rvert^2$, dB		
	$R_1 = 208\ \Omega$, $R_2 = 4.1\ \Omega$	$R_1 = 276\ \Omega$, $R_2 = 1.4\ \Omega$	$R_1 = 276\ \Omega$, $R_2 = 1.4\ \Omega$, $L_1 = 4.5$ nH
10	7.50	10.01	10.01
100	7.50	10.01	10.01
250	7.50	10.00	10.01
500	7.50	9.97	10.00
750	7.50	9.93	10.00
1000	7.50	9.88	10.00
1500	7.51	9.75	9.99
2000	7.54	9.59	9.99

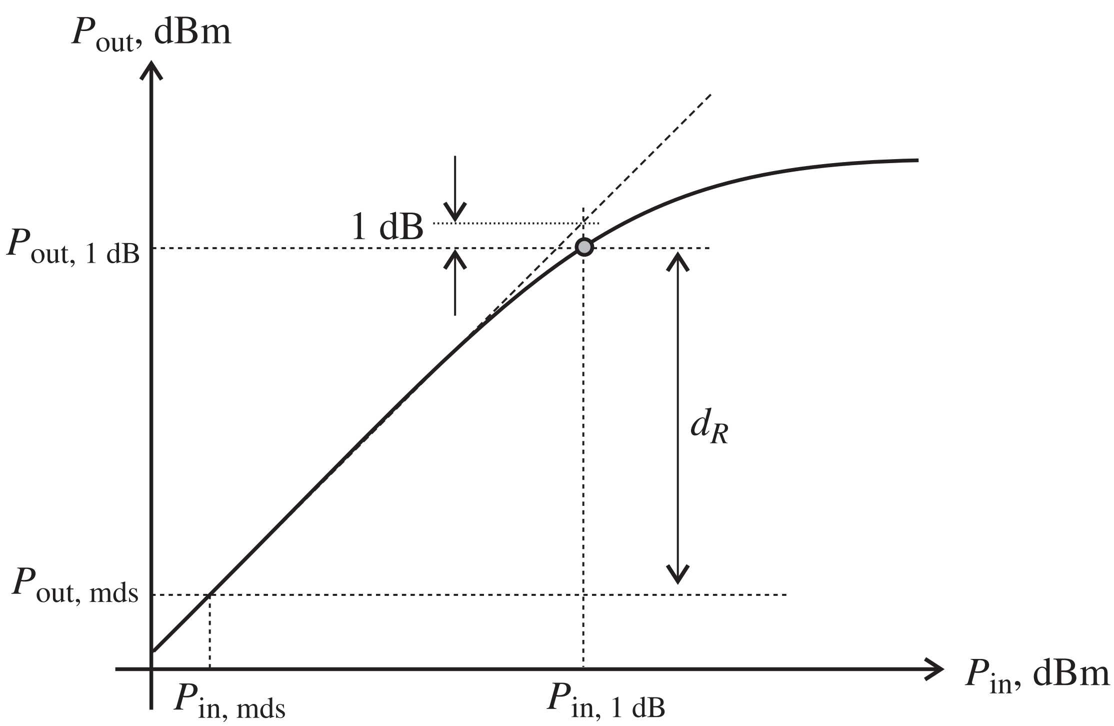


Figure 9-26   Output power of the amplifier as a function of input power.

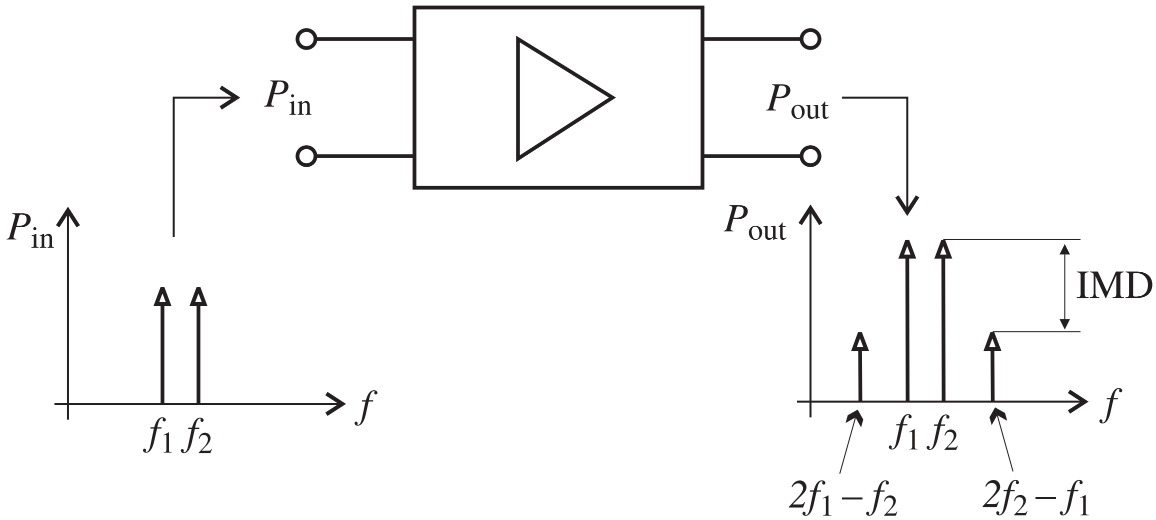


Figure 9-27 Observing the intermodulation distortion of an amplifier.

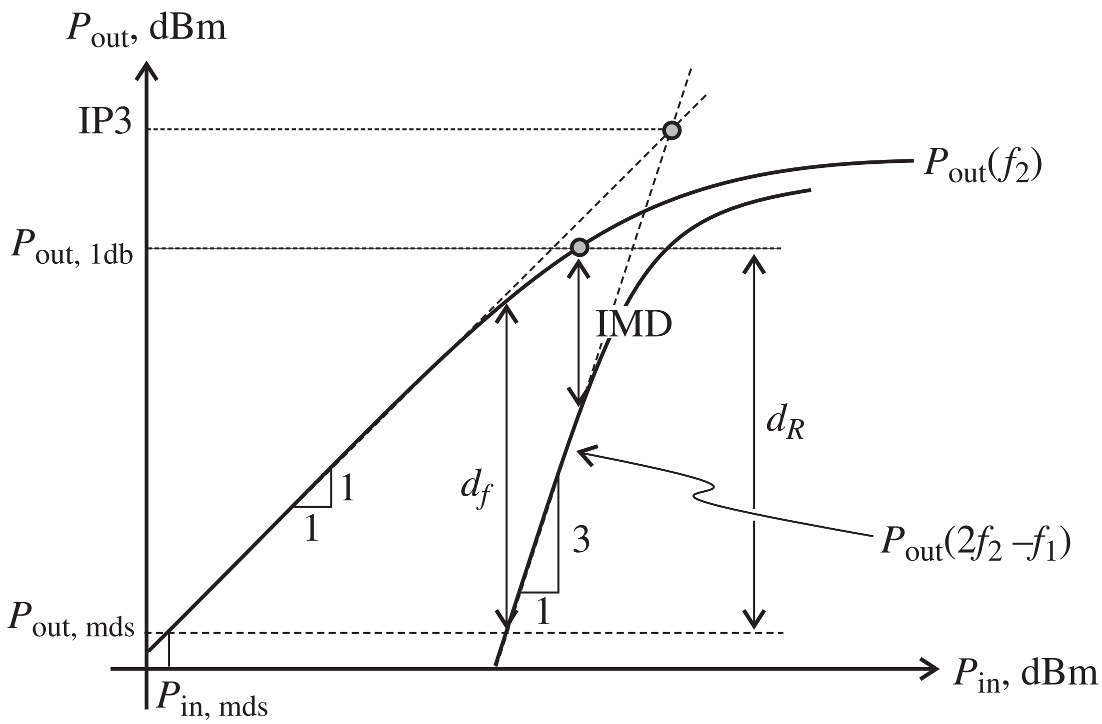


Figure 9-28 Recording of IMD based on input-output power relation.

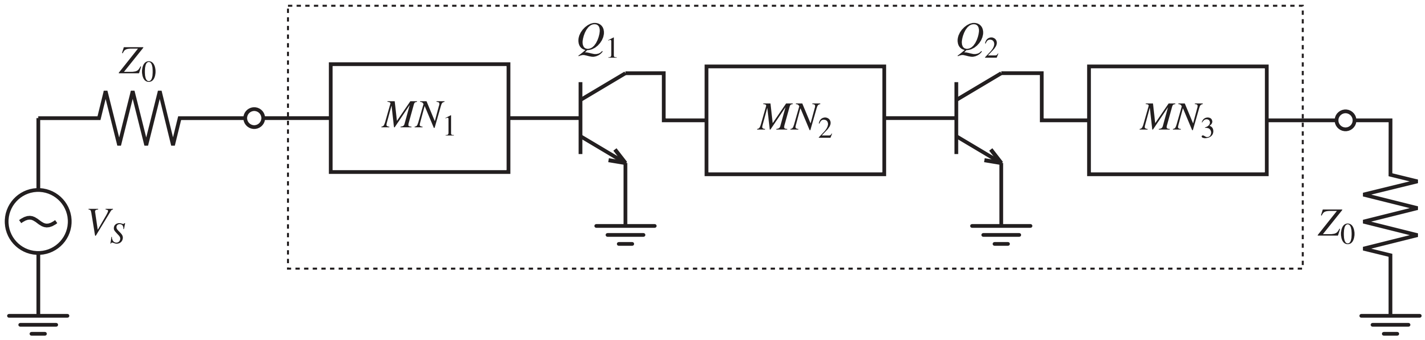


Figure 9-29 Dual-stage transistor amplifier.

Table 9-8 Transistor characteristics for Example 9-18

Transistor	F[dB]	G_{max}[dB]	$P_{out,\,1dB}$[dBm]	IP3[dBm]
BFG505	1.9	10	4	10
BFG520	1.9	9	17	26
BFG540	2	7	21	34

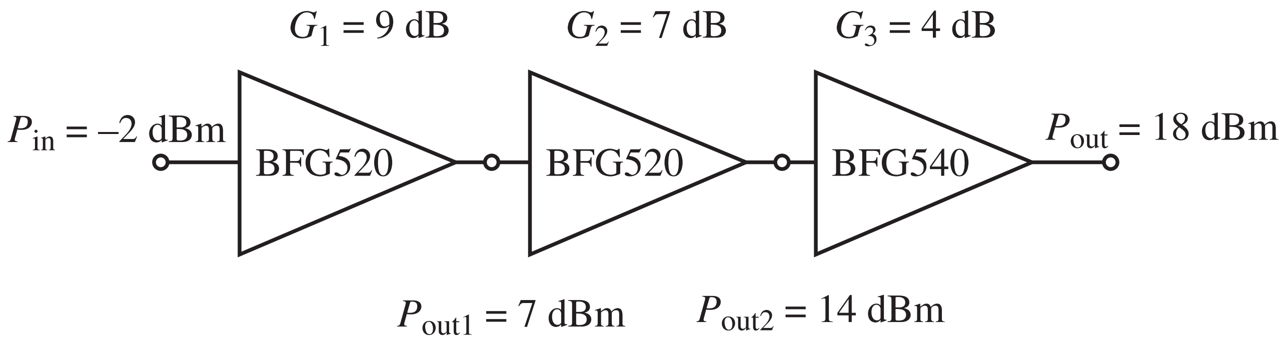
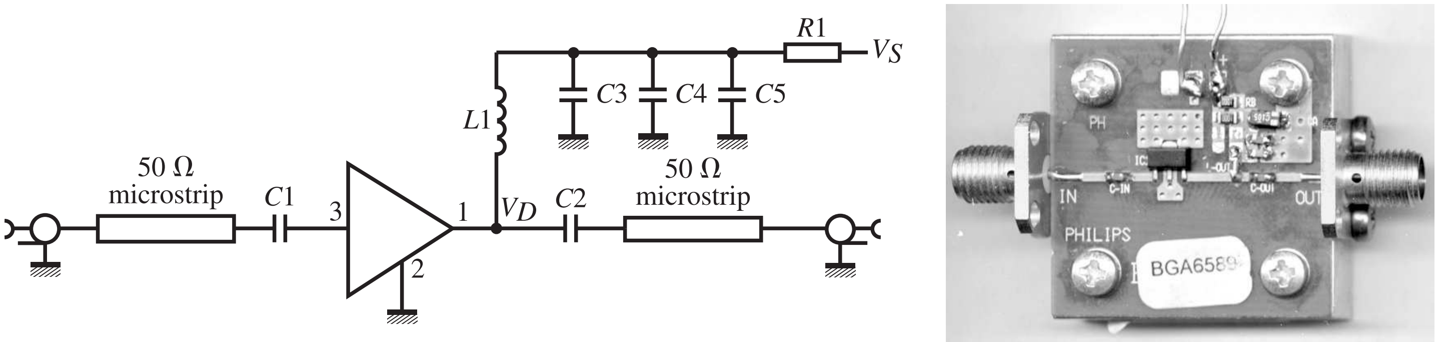


Figure 9-30 Block diagram of a three-stage amplifier.



(a) (b)

Figure 9-31 The MMIC amplifier schematic (courtesy of NXP) installed in a typical application circuit (a), and the corresponding layout (b).

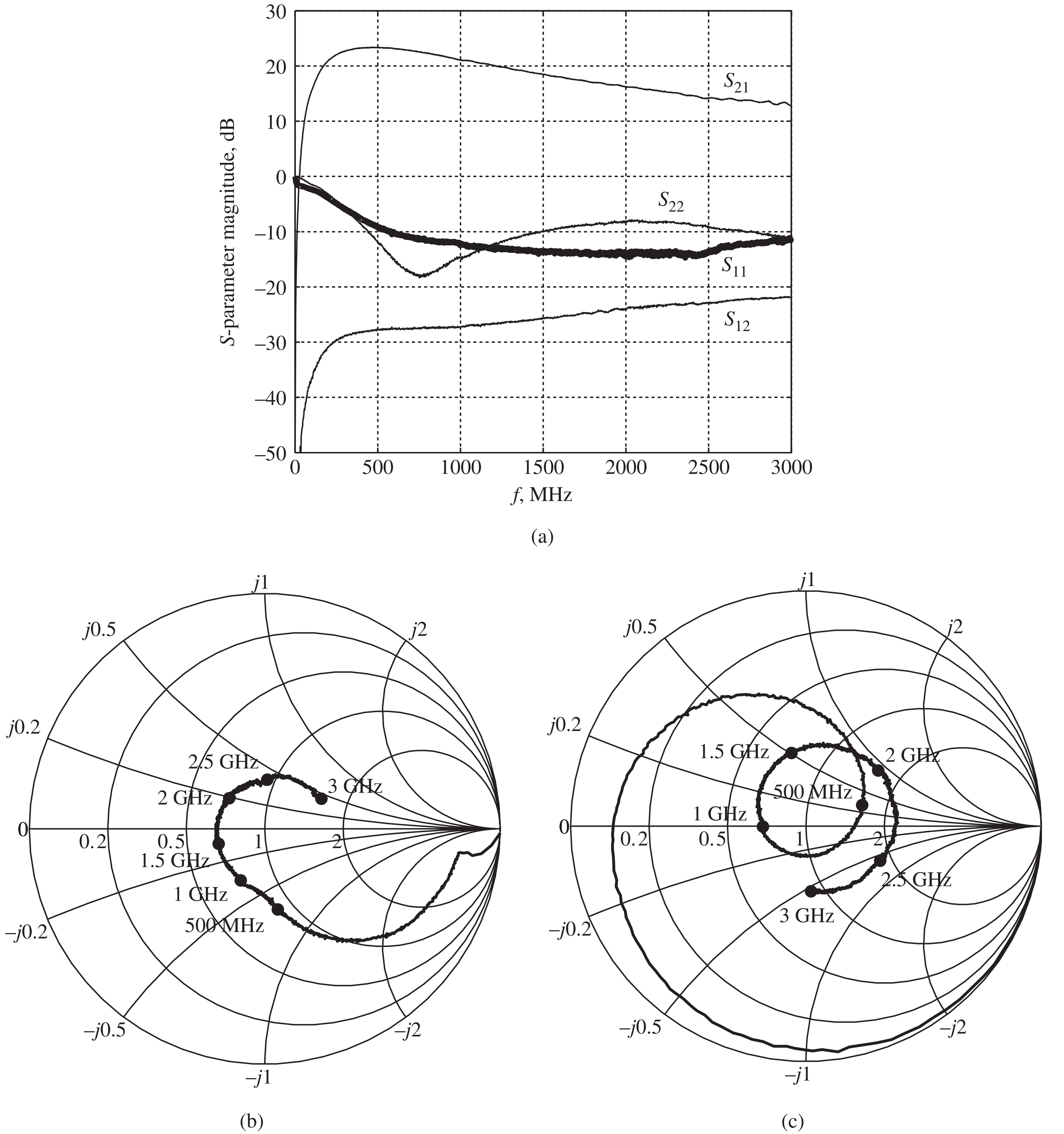


Figure 9-32 Measured MMIC amplifier *S*-parameters: (a) magnitude, (b) S_{11} values displayed in Smith Chart, and (c) S_{22} values displayed in Smith Chart.

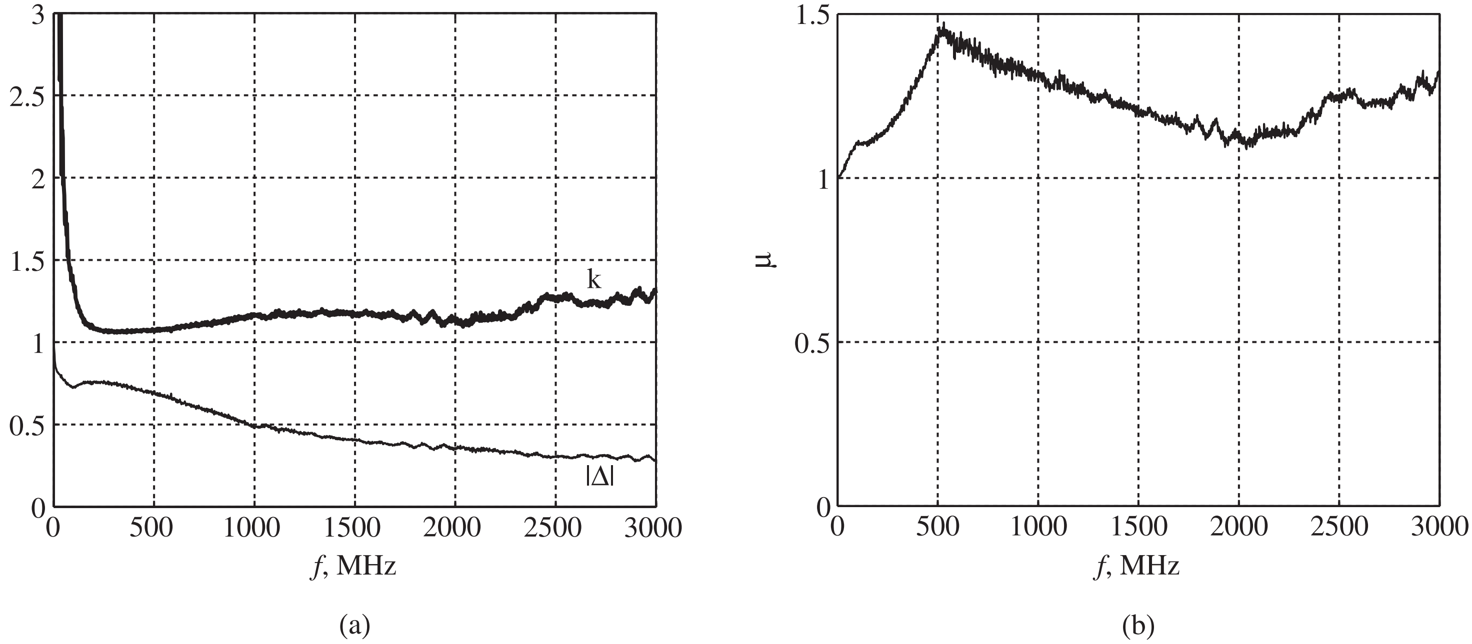


Figure 9-33 Stability factors determined from the *S*-parameter measurements: (a) Rollett stability factor, (b) μ-test.

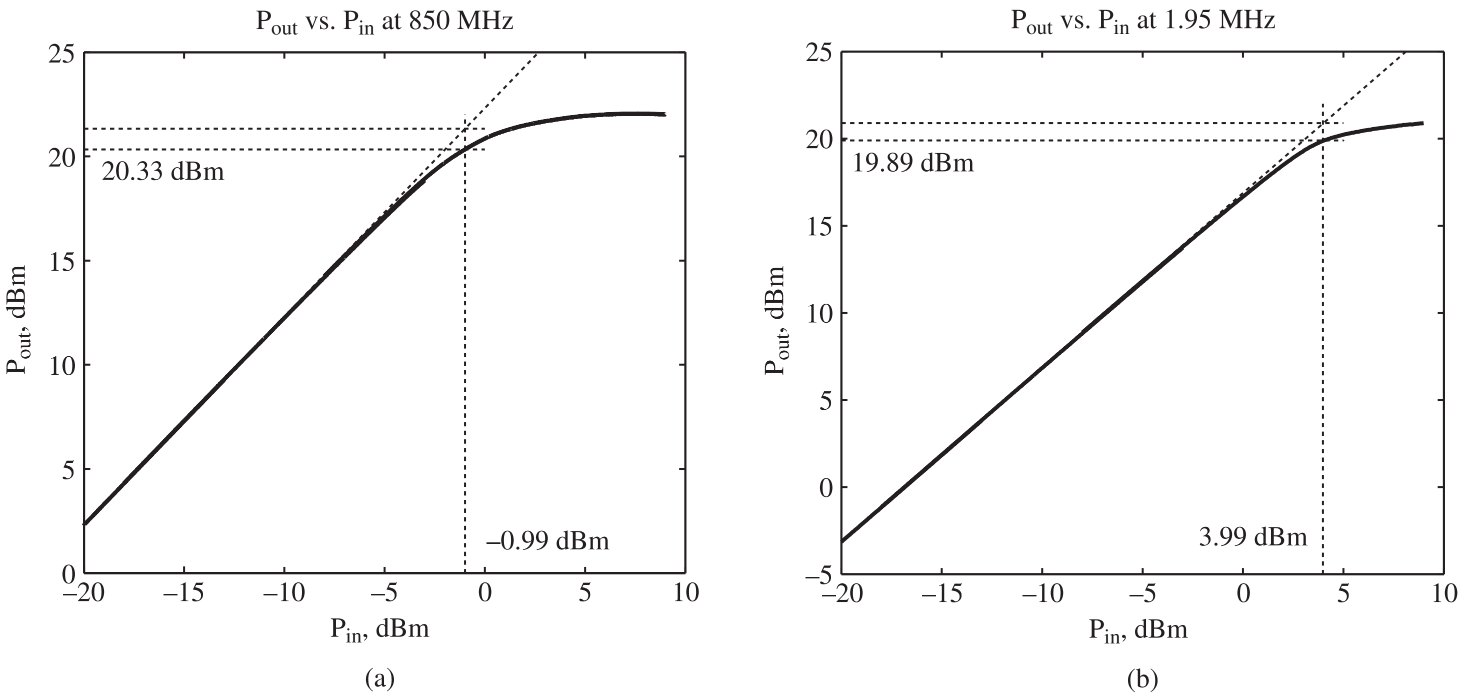


Figure 9-34 Gain compression observed in power sweeps at (a) 850 MHz and (b) 1.95 GHz.

Table 9-9 Comparison between the datasheet and network analyzer measurements

Parameter	850 MHz		1.95 GHz	
	Datasheet	**Measured**	**Datasheet**	**Measured**
Insertion power gain ($\|S_{21}\|^2$)	22 dB	22.1 dB	17 dB	16.6 dB
Input return loss	9 dB	11.7 dB	11 dB	13.8 dB
Output return loss	10 dB	17.2 dB	13 dB	8.4 dB
Stability factor k	1.1	1.13	1.1	1.15
Output power at 1 dB gain compression	21 dBm	20.3 dBm	20 dBm	19.9 dBm