DTG2D3

ELEKTRONIKA TELEKOMUNIKASI

Small-Signal RF Amplifier (RF Current Amplifier)

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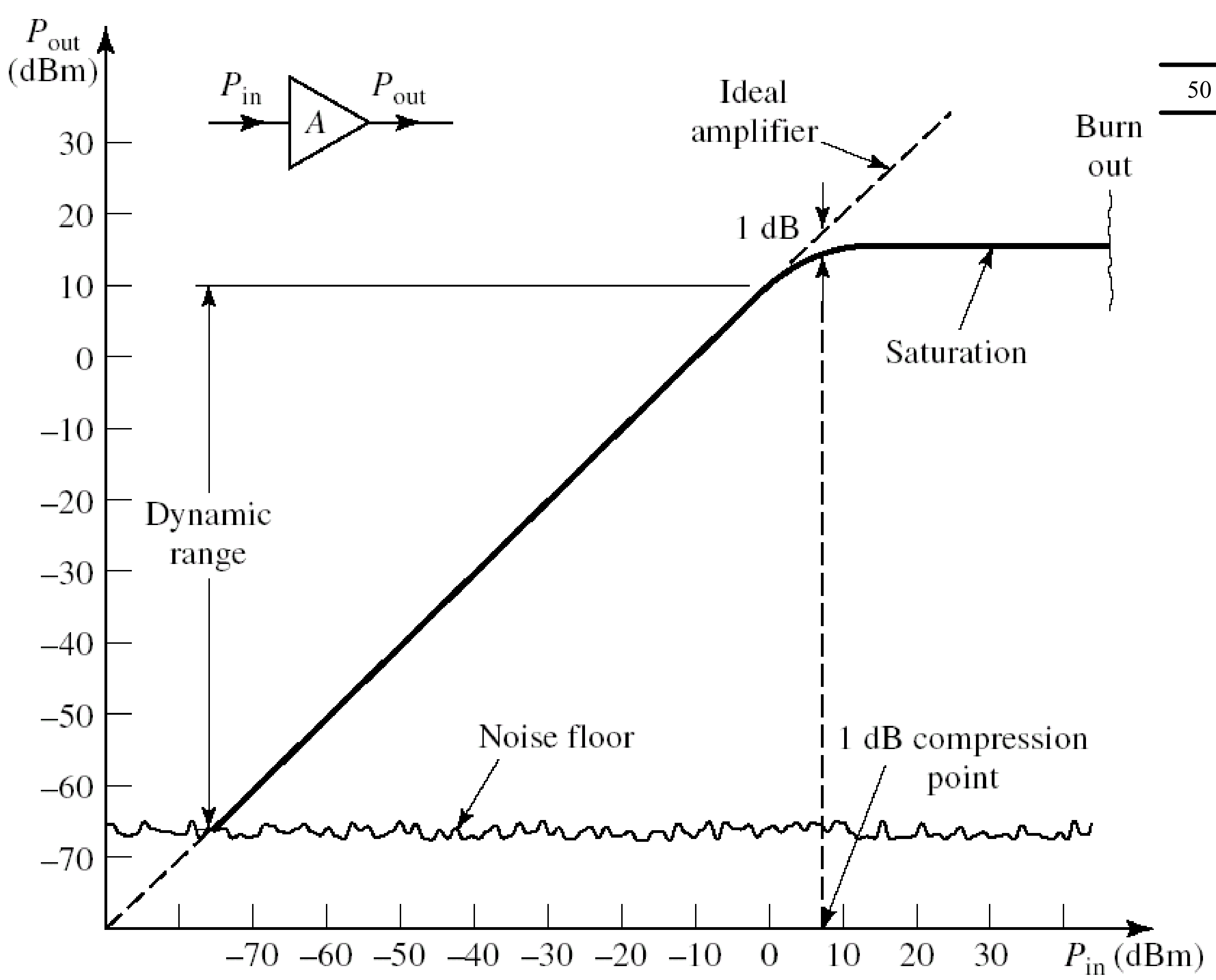
Small-Signal RF Amplifier

Agenda

- Model penguat
- Definisi parameter s dan konversi dari parameter y, z, h ke parameter s
- Definisi faktor-faktor penguatan
- Kemantapan penguat RF
- Lingkaran/daerah kemantapan penguat pada Smith Cart
- Perancangan Penguat dengan Gain Maksimum
- Perancangan Penguat dengan Operating Power Gain Ditentukan
- Perancangan Penguat dengan Available Power Gain Ditentukan
- Perancangan Penguat dengan VSWR Ditentukan
- Perancangan Penguat dengan Noise Figure Ditentukan

Small-Signal RF Amplifier

Model Sistem (Linear)



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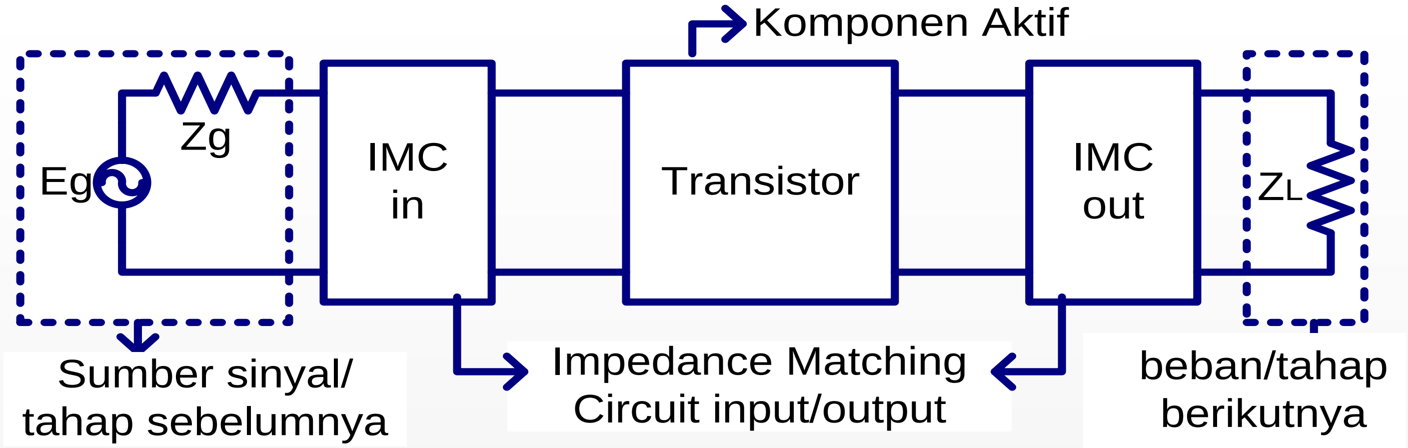
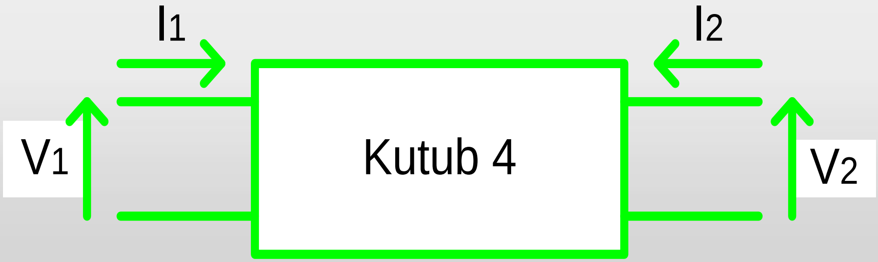
Penguat frekuensi tinggi SATU TAHAP dapat dimodelkan sebagai berikut :



Tampak bahwa sistem dapat dipandang sebagai hubungan kaskade dari kutub-4, sehingga pada umumnya metoda analisis yang dapat digunakan untuk mempelajari perilaku suatu penguat adalah dengan menggunakan parameter satu kutub empat.



Parameter Kutub 4 :

1. Parameter Z, Y, H, ABCD (frekuensi rendah)
2. Parameter S (frekuensi rendah sampai tinggi)

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Parameter Z, Parameter Y, Parameter H, dan Parameter ABCD

Parameter Z
$$\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} . \begin{bmatrix} i_1 \\ i_2 \end{bmatrix}$$

Parameter Y
$$\begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} Y_{11} & Y_{12} \\ Y_{21} & Y_{22} \end{bmatrix} . \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$

Parameter H
$$\begin{bmatrix} V_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} . \begin{bmatrix} i_1 \\ V_2 \end{bmatrix}$$

Parameter ABCD
$$\begin{bmatrix} V_1 \\ i_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} . \begin{bmatrix} V_2 \\ -i_2 \end{bmatrix}$$

Parameter-parameter tersebut diatas mudah diukur pada frekuensi rendah, karena pengukurannya membutuhkan BEBAN HUBUNG SINGKAT dan/atau BEBAN TERBUKA, yang mudah diperoleh pada frekuensi RENDAH.

Pada frekuensi tinggi, parameter Z(impedansi), H(hybrid), Y(admitansi) atau ABCD sangat sulit (tidak mungkin) DIUKUR, karena :

1. Penggunaan beban terbuka/tertutup (hubung singkat) dapat menyebabkan komponen aktif yang digunakan tidak stabil (OSILASI)
2. Pada frekuensi tinggi sulit memperoleh beban TERBUKA/TERTUTUP dengan range bidang frekuensi yang lebar (wilayah operasi frekuensi yang lebar)

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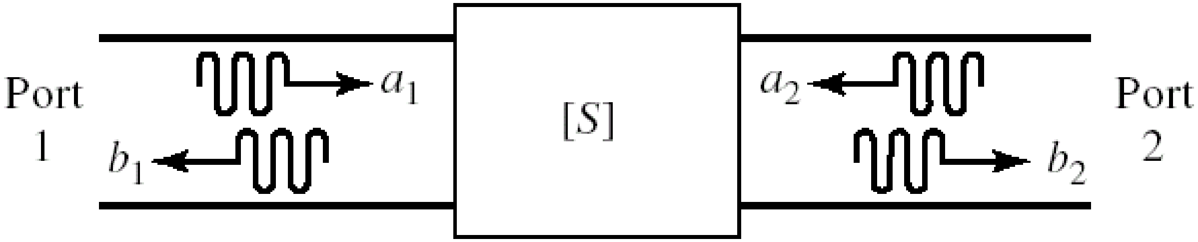
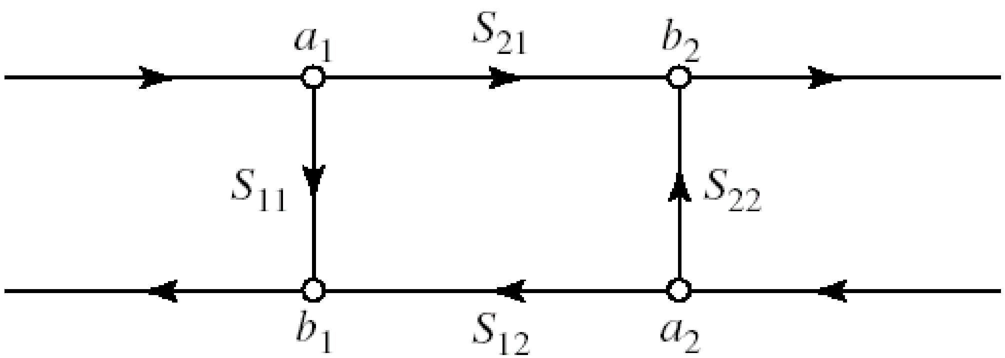
Parameter S

Maka digunakan Parameter S (Scattering Parameter):



Gambar a_i dan b_i



Signal flow graph

Dimana: i = 1(port 1) atau 2 (port 2)

$$a_i = \frac{V_i^+}{\sqrt{Z_{oi}}} = \text{gelombang datang}$$

$$b_i = \frac{V_i^-}{\sqrt{Z_{oi}}} = \text{gelombang pantul}$$

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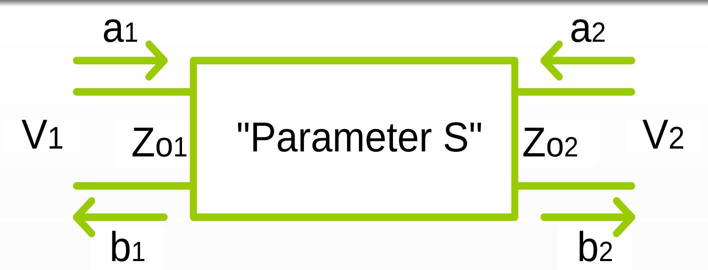
Parameter S



$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \cdot \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$

$$S_{11} = S_i = \left.\frac{b_1}{a_1}\right|_{a_2 = 0}$$

→ koefisien refleksi masukan dengan keluaran K-4 ditutup beban sesuai (match)

$$S_{21} = S_f = \left.\frac{b_2}{a_1}\right|_{a_2 = 0}$$

→ koefisien transmisi maju dengan keluaran K-4 ditutup beban sesuai

$$S_{22} = S_o = \left.\frac{b_2}{a_2}\right|_{a_1 = 0}$$

→ koefisien refleksi keluaran dengan masukan K-4 ditutup beban sesuai

$$S_{12} = S_r = \left.\frac{b_1}{a_2}\right|_{a_1 = 0}$$

→ koefisien transmisi balik dengan masukan K-4 ditutup beban sesuai

Small-Signal RF Amplifier

Hubungan parameter s dan parameter y

s-parameters in terms of y-parameters	y-parameters in terms of s-parameters
$s_{11} = \frac{(1-y_{11})(1+y_{22})+y_{12}y_{21}}{(1+y_{11})(1+y_{22})-y_{12}y_{21}}$	$y_{11} = \frac{(1+s_{22})(1-s_{11})+s_{12}s_{21}}{(1+s_{11})(1+s_{22})-s_{12}s_{21}}$
$s_{12} = \frac{-2y_{12}}{(1+y_{11})(1+y_{22})-y_{12}y_{21}}$	$y_{12} = \frac{-2s_{12}}{(1+s_{11})(1+s_{22})-s_{12}s_{21}}$
$s_{21} = \frac{-2y_{21}}{(1+y_{11})(1+y_{22})-y_{12}y_{21}}$	$y_{21} = \frac{-2s_{21}}{(1+s_{11})(1+s_{22})-s_{12}s_{21}}$
$s_{22} = \frac{(1+y_{11})(1-y_{22})+y_{12}y_{21}}{(1+y_{11})(1+y_{22})-y_{12}y_{21}}$	$y_{22} = \frac{(1+s_{11})(1-s_{22})+s_{12}s_{21}}{(1+s_{11})(1+s_{22})-s_{12}s_{21}}$

Small-Signal RF Amplifier

Hubungan parameter s dan parameter z

s-parameters in terms of z-parameters	z-parameters in terms of s-parameters
$s_{11} = \frac{(z_{11}-1)(z_{22}+1) - z_{12}z_{21}}{(z_{11}+1)(z_{22}+1) - z_{12}z_{21}}$	$z_{11} = \frac{(1+s_{11})(1-s_{22}) + s_{12}s_{21}}{(1-s_{11})(1-s_{22}) - s_{12}s_{21}}$
$s_{12} = \frac{2z_{12}}{(z_{11}+1)(z_{22}+1) - z_{12}z_{21}}$	$z_{12} = \frac{2s_{12}}{(1-s_{11})(1-s_{22}) - s_{12}s_{21}}$
$s_{21} = \frac{2z_{21}}{(z_{11}+1)(z_{22}+1) - z_{12}z_{21}}$	$z_{21} = \frac{2s_{21}}{(1-s_{11})(1-s_{22}) - s_{12}s_{21}}$
$s_{22} = \frac{(z_{11}+1)(z_{22}-1) - z_{12}z_{21}}{(z_{11}+1)(z_{22}+1) - z_{12}z_{21}}$	$z_{22} = \frac{(1+s_{22})(1-s_{11}) + s_{12}s_{21}}{(1-s_{11})(1-s_{22}) - s_{12}s_{21}}$

S

Z

Small-Signal RF Amplifier

Hubungan parameter s dan parameter h

s-parameters in terms of h-parameters	h-parameters in terms of s-parameters
$s_{11} = \frac{(h_{11}-1)(h_{22}+1) - h_{12}h_{21}}{(h_{11}+1)(h_{22}+1) - h_{12}h_{21}}$	$h_{11} = \frac{(1+s_{11})(1+s_{22}) - s_{12}s_{21}}{(1-s_{11})(1+s_{22}) + s_{12}s_{21}}$
$s_{12} = \frac{2h_{12}}{(h_{11}+1)(h_{22}+1) - h_{12}h_{21}}$	$h_{12} = \frac{2s_{12}}{(1-s_{11})(1+s_{22}) + s_{12}s_{21}}$
$s_{21} = \frac{-2h_{21}}{(h_{11}+1)(h_{22}+1) - h_{12}h_{21}}$	$h_{21} = \frac{-2s_{21}}{(1-s_{11})(1+s_{22}) + s_{12}s_{21}}$
$s_{22} = \frac{(1+h_{11})(1-h_{22}) + h_{12}h_{21}}{(h_{11}+1)(h_{22}+1) - h_{12}h_{21}}$	$h_{22} = \frac{(1-s_{22})(1-s_{11}) - s_{12}s_{21}}{(1-s_{11})(1+s_{22}) + s_{12}s_{21}}$

s h

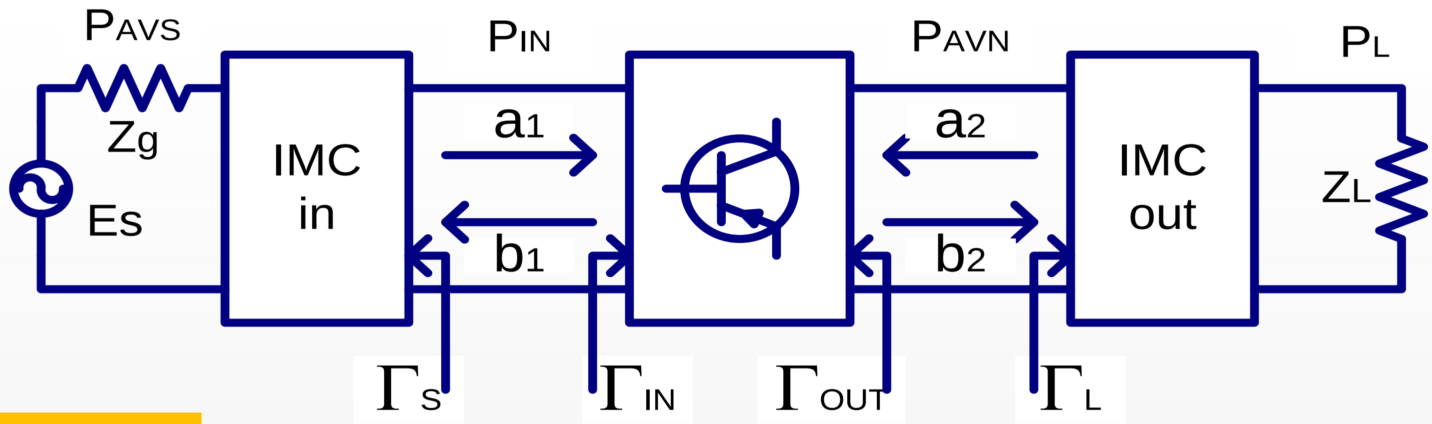
Small-Signal RF Amplifier

Denormalisasi parameter h, y dan z

The h–, y–, and z–parameters listed in previous tables are all normalized to Z_0. If h′, y′, z′ are the actual parameters, then:		
$z'_{11} = z_{11} Z_0$	$y'_{11} = y_{11} / Z_0$	$h'_{11} = h_{11} Z_0$
$z'_{12} = z_{12} Z_0$	$y'_{12} = y_{12} / Z_0$	$h'_{12} = h_{12}$
$z'_{21} = z_{21} Z_0$	$y'_{21} = y_{21} / Z_0$	$h'_{21} = h_{21}$
$z'_{22} = z_{22} Z_0$	$y'_{22} = y_{22} / Z_0$	$h'_{22} = h_{22} / Z_0$

Small-Signal RF Amplifier

FAKTOR PENGUATAN PENGUAT RF



Faktor Penguatan :

1. **Transducer Power Gain (GT)**

$$G_T = \frac{P_L}{P_{AVS}} = \frac{\text{Daya yang diberikan ke beban}}{\text{Daya yang tersedia pada sumber sinyal}}$$

2. **Operating Power Gain (GP)**

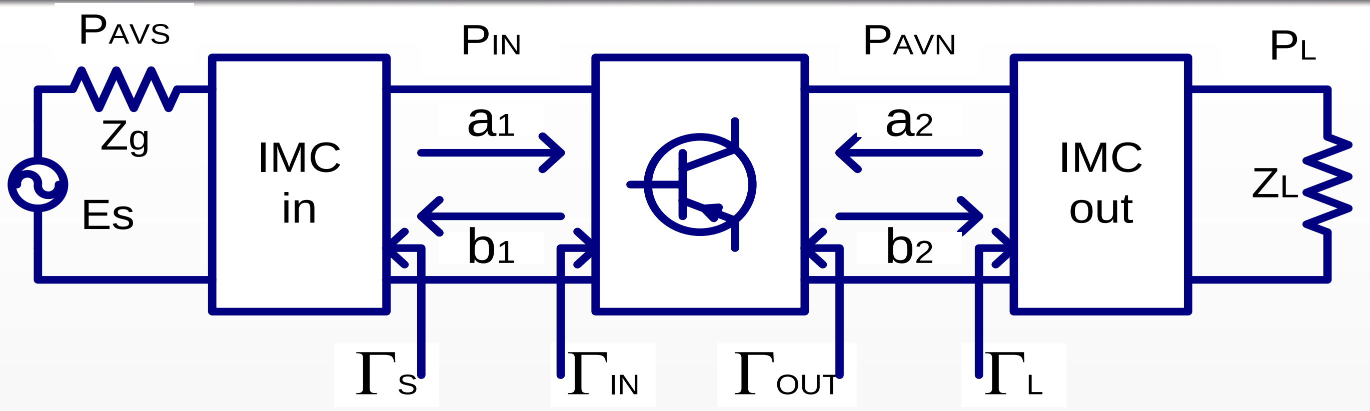
$$G_P = \frac{P_L}{P_{IN}} = \frac{\text{Daya yang diberikan ke beban}}{\text{Daya yang diberikan ke transistor}}$$

3. **Available Power Gain (GA)**

$$G_A = \frac{P_{AVN}}{P_{AVS}} = \frac{\text{Daya tersedia dari transistor}}{\text{Daya yang tersedia pada sumber sinyal}}$$

Small-Signal RF Amplifier

FAKTOR PENGUATAN PENGUAT RF



$$\left.\begin{aligned} b_1 &= S_{11}.a_1 + S_{12}.a_2 \\ b_2 &= S_{21}.a_1 + S_{22}.a_2 \\ \Gamma_L &= \frac{a_2}{b_2} \rightarrow a_2 = \Gamma_L.b_2 \end{aligned}\right\} \rightarrow b_1 = S_{11}.a_1 + S_{12}.\Gamma_L.b_2 = S_{11}.a_1 + \frac{S_{12}.S_{21}.\Gamma_L}{1 - S_{22}.\Gamma_L}.a_1$$

$$b_2 = S_{21}.a_1 + S_{22}.\Gamma_L.b_2 = \frac{S_{21}.a_1}{1 - S_{22}\Gamma_L}$$

$$\Gamma_{IN} = \frac{b_1}{a_1} \rightarrow \Gamma_{IN} = S_{11} + \frac{S_{12}.S_{21}.\Gamma_L}{1 - S_{22}.\Gamma_L}$$

$$\Gamma_{OUT} = \left.\frac{b_2}{a_2}\right|_{Es = 0}$$

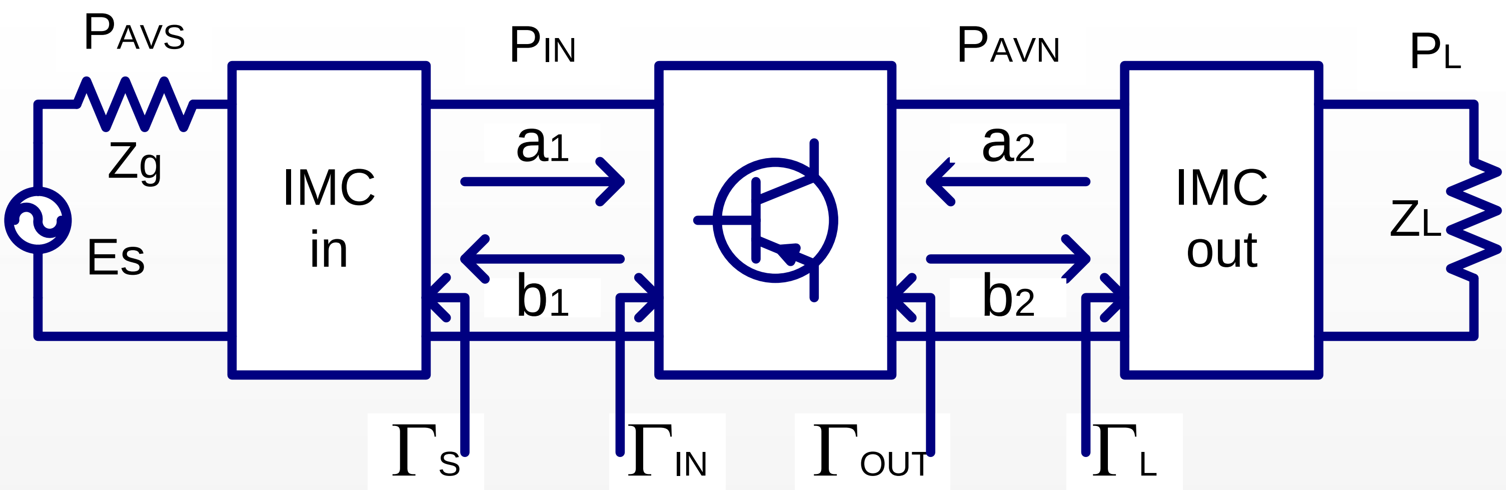
$E_S = 0 \rightarrow a_1 = \Gamma_S.b_1$

$b_1 = S_{11}.\Gamma_S.b_1 + S_{12}.a_2 \rightarrow$

$$b_1 = \frac{S_{12}.a_2}{1 - S_{11}.\Gamma_S}$$

Small-Signal RF Amplifier

FAKTOR PENGUATAN PENGUAT RF



$$b_2 = S_{21}.\Gamma_S.b_1 + S_{22}.a_2 = \frac{S_{12}.S_{21}.\Gamma_S}{1 - S_{11}.\Gamma_S} a_2 + S_{22}.a_2$$

$$\Gamma_{OUT} = \left.\frac{b_2}{a_2}\right|_{Es=0} = S_{22} + \frac{S_{12}.S_{21}.\Gamma_S}{1 - S_{11}.\Gamma_S}$$

$$P_{IN} = ½ \; |a_1|^2 - ½ \; |b_1|^2 = ½ \; |a_1|^2.(1 - |\Gamma_{IN}|^2)$$

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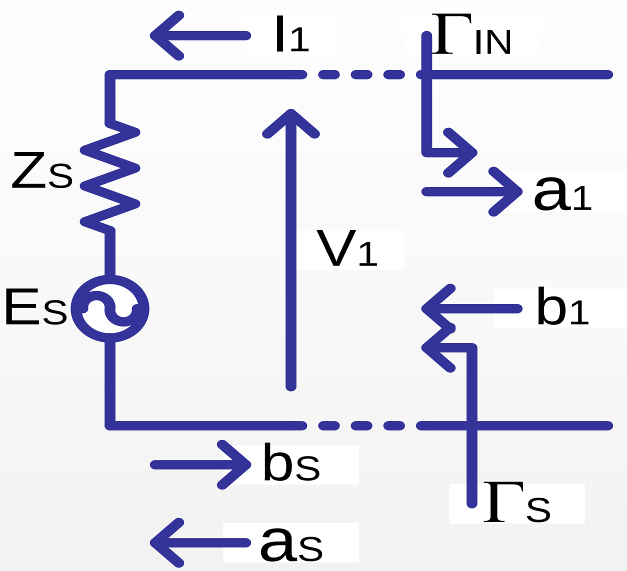
FAKTOR PENGUATAN PENGUAT RF

RANGKAIAN MASUKAN :



$V_1 = E_S + I_1.Z_S$

Bila : $a_1 = \frac{V_1^-}{\sqrt{Z_O}}$ $\quad b_1 = \frac{V_1^+}{\sqrt{Z_O}}$

$$\Gamma_S = \frac{Z_S - Z_O}{Z_S + Z_O}$$

$$b_S = \frac{E_S\sqrt{Z_O}}{Z_S + Z_O}$$

$$\left.\begin{aligned} a_1 &= b_s + \Gamma_s.b_1 \\ b_1 &= \Gamma_{IN}.a_1 \end{aligned}\right\} \rightarrow \quad a_1 = bs + \Gamma s.\Gamma_{IN}.a_1 \qquad a_1 = \frac{bs}{1 - \Gamma_S\Gamma_{IN}}$$

$$P_{IN} = \tfrac{1}{2}\left|b_S\right|^2 . \frac{1 - \left|\Gamma_{IN}\right|^2}{\left|1 - \Gamma_S.\Gamma_{IN}\right|^2}$$

Daya yang tersedia pada sumber sinyal (P_{AVS}) = Daya masukan transistor (P_{IN}), bila $\Gamma_{IN} = \Gamma_S*$, sehingga :

$$P_{AVS} = P_{IN}\Big|_{\Gamma_{IN} = \Gamma_S *} = \frac{\tfrac{1}{2}\left|b_S\right|^2}{1 - \left|\Gamma_S\right|^2}$$

$$P_{IN} = P_{AVS} . \frac{\left(1 - \left|\Gamma_S\right|^2\right).\left(1 - \left|\Gamma_{IN}\right|^2\right)}{\left|1 - \Gamma_S.\Gamma_{IN}\right|^2}$$

atau $P_{IN} = P_{AVS} . M_S$ dimana:

$$M_S = \frac{\left(1 - \left|\Gamma_S\right|^2\right).\left(1 - \left|\Gamma_{IN}\right|^2\right)}{\left|1 - \Gamma_S.\Gamma_{IN}\right|^2}$$

M_S = Source Mismatch Factor

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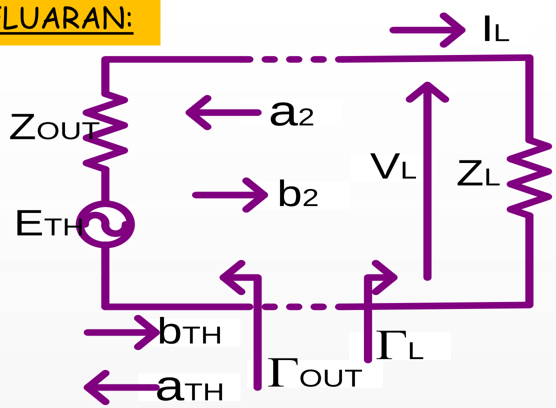
FAKTOR PENGUATAN PENGUAT RF

RANGKAIAN KELUARAN:



$V_L = E_{TH} - I_L \cdot Z_{OUT}$

Bila : $b_2 = \dfrac{V_L^-}{\sqrt{Z_O}}$ $\qquad a_2 = \dfrac{V_L^+}{\sqrt{Z_O}}$

$$b_{TH} = \frac{E_{TH}\sqrt{Z_O}}{Z_{OUT} + Z_O} \qquad \Gamma_{OUT} = \frac{Z_{OUT} - Z_O}{Z_{OUT} + Z_O}$$

$b_2 = b_{TH} + \Gamma_{OUT}.\Gamma_L.b_2$ dimana $\Gamma_L \cdot b_2 = a_2$ $\rightarrow$ $b_2 = \dfrac{b_{TH}}{1 - \Gamma_{OUT} \cdot \Gamma_L}$

Daya yang diberikan ke BEBAN :

$$P_L = \tfrac{1}{2}|b_2|^2 - \tfrac{1}{2}|a_2|^2 = \tfrac{1}{2}|b_2|^2 \cdot (1 - |\Gamma_L|^2)$$

$$P_L = \tfrac{1}{2}|b_{TH}|^2 \cdot \frac{1 - |\Gamma_L|^2}{|1 - \Gamma_{OUT}\Gamma_L|^2}$$

Daya tersedia dari Kutub-4:

$P_{AVN} = P_L$, bila $\Gamma_L = \Gamma_{OUT}^*$

$$P_{AVN} = P_L\Big|_{\Gamma_L = \Gamma_{OUT}^*} = \frac{\tfrac{1}{2}|b_{TH}|^2}{1 - |\Gamma_{OUT}|^2}$$

$$P_L = P_{AVN} \cdot \frac{(1 - |\Gamma_L|^2) \cdot (1 - |\Gamma_{OUT}|^2)}{|1 - \Gamma_{OUT}.\Gamma_L|^2}$$

atau $P_L = P_{AVN} \cdot M_L$ dimana

$$M_L = \frac{(1 - |\Gamma_L|^2) \cdot (1 - |\Gamma_{OUT}|^2)}{|1 - \Gamma_{OUT}.\Gamma_L|^2}$$

M_L = Load Mismatch Factor

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FAKTOR PENGUATAN PENGUAT RF

OPERATING POWER GAIN (GP):

$$G_P = \frac{P_L}{P_{IN}} = \frac{\frac{1}{2}|b_2|^2 .(1-|\Gamma_L|^2)}{\frac{1}{2}|a_1|^2 .(1-|\Gamma_{IN}|^2)}$$

$$b_2 = \frac{S_{21}.a_1}{1-S_{22}.r_L} \rightarrow \quad G_P = \frac{1}{1-|\Gamma_{IN}|^2}|S_{21}|^2 \frac{1-|\Gamma_L|^2}{|1-S_{22}.\Gamma_L|^2}$$

TRANDUCER POWER GAIN

$$G_T = \frac{P_L}{P_{AVS}} = \frac{P_L}{P_{IN}} . \frac{P_{IN}}{P_{AVS}} = G_P . \frac{P_{IN}}{P_{AVS}} = G_P.M_S = \frac{1-|\Gamma_S|^2}{|1-\Gamma_S.\Gamma_{IN}|^2}|S_{21}|^2 \frac{1-|\Gamma_L|^2}{|1-S_{22}.\Gamma_L|^2}$$

atau

$$G_T = \frac{1-|\Gamma_S|^2}{|1-S_{11}.\Gamma_S|^2}|S_{21}|^2 \frac{1-|\Gamma_L|^2}{|1-\Gamma_{OUT}.\Gamma_L|^2}$$

AVAILABLE POWER GAIN

$$G_A = \frac{P_{AVN}}{P_{AVS}} = \frac{P_L}{P_{AVS}} . \frac{P_{AVN}}{P_L} = \frac{G_T}{M_L}$$

$$G_A = \frac{1-|\Gamma_S|^2}{|1-S_{11}.\Gamma_S|^2}|S_{21}|^2 \frac{1}{|1-\Gamma_{OUT}|^2}$$

Small-Signal RF Amplifier

Contoh Soal

- Transistor microwave mempunyai parameter “S” pada 10 GHz, dengan impedansi referensi (Z_O) 50 Ω sbb.:

  S_{11}=0,45 <150^0

  S_{12}=0,01 <-10^0

  S_{21}=2,05 <10^0

  S_{22}=0,40 <-150^0

  Jika digunakan hambatan sumber Z_S=20 Ω dan Hambatan beban sebesar Z_L=30 Ω, hitunglah Operating power Gain, Available Power Gain, dan Transducer Power Gain!

  Solusi: Γ_S=-0.429, Γ_L=-0.250

  $$\Rightarrow \Gamma_{\mathrm{IN}} = 0.455\angle 150^0 \text{ dan } \Gamma_{\mathrm{OUT}} = 0.408\angle -151^0$$

  $$\Rightarrow G_P = 5.94$$

  $$\Rightarrow G_A = 5.85$$

  $$\Rightarrow G_T = 5.49$$

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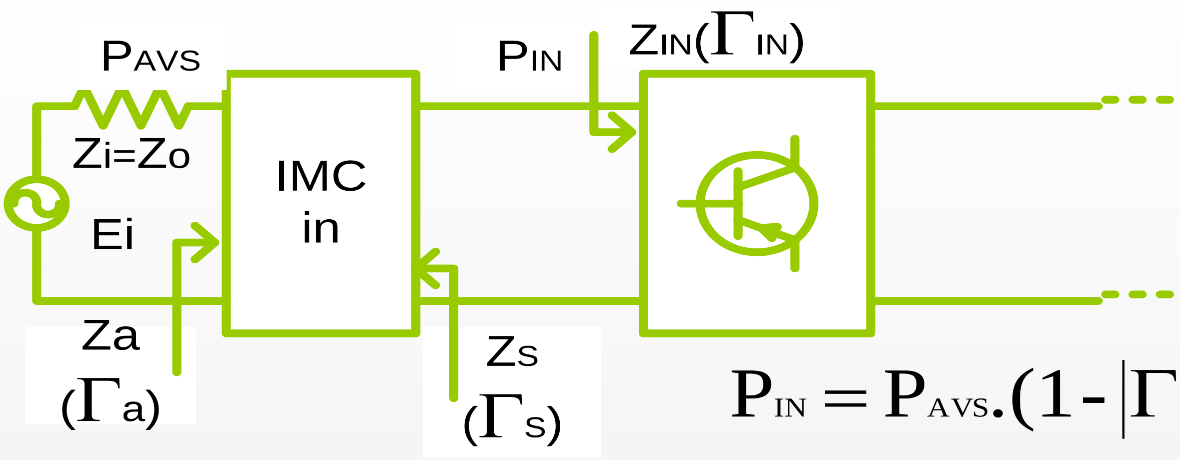
VSWR MASUKAN



$$VSWR_{IN} = \frac{1+|\Gamma a|}{1-|\Gamma a|}$$

$$\Gamma a = \frac{Za - Z_O}{Za + Z_O}$$

$$\left.\begin{aligned} P_{IN} &= P_{AVS}.(1-|\Gamma a|^2) \\ P_{IN} &= P_{AVS}.M_S \end{aligned}\right\}$$

$$M_S = (1-|\Gamma a|^2)$$

$$\left.\begin{aligned} |\Gamma a| &= \sqrt{1-M_S} \\ M_S &= \frac{(1-|\Gamma_S|^2).(1-|\Gamma_{IN}|^2)}{|1-\Gamma_S\Gamma_{IN}|^2} \end{aligned}\right\}$$

$$|\Gamma a| = \sqrt{1 - \frac{(1-|\Gamma_S|^2).(1-|\Gamma_{IN}|^2)}{|1-\Gamma_S\Gamma_{IN}|^2}}$$

$$|\Gamma a| = \left|\frac{\Gamma_{IN} - \Gamma_S{}^*}{1-\Gamma_{IN}\Gamma_S}\right|$$

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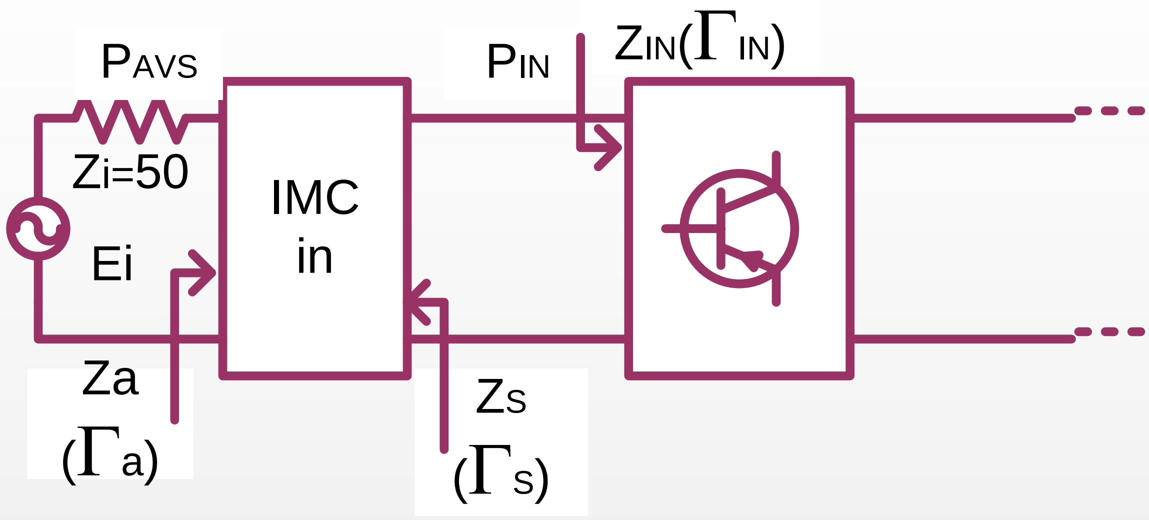
CONTOH SOAL

Γ_{IN} = 0,4 <-145°



Γ_{S} = 0,614 <160°

Hitunglah :

a. $|\Gamma_a|$ (0.326)

b. $VSWR_{IN}$ (1.985)

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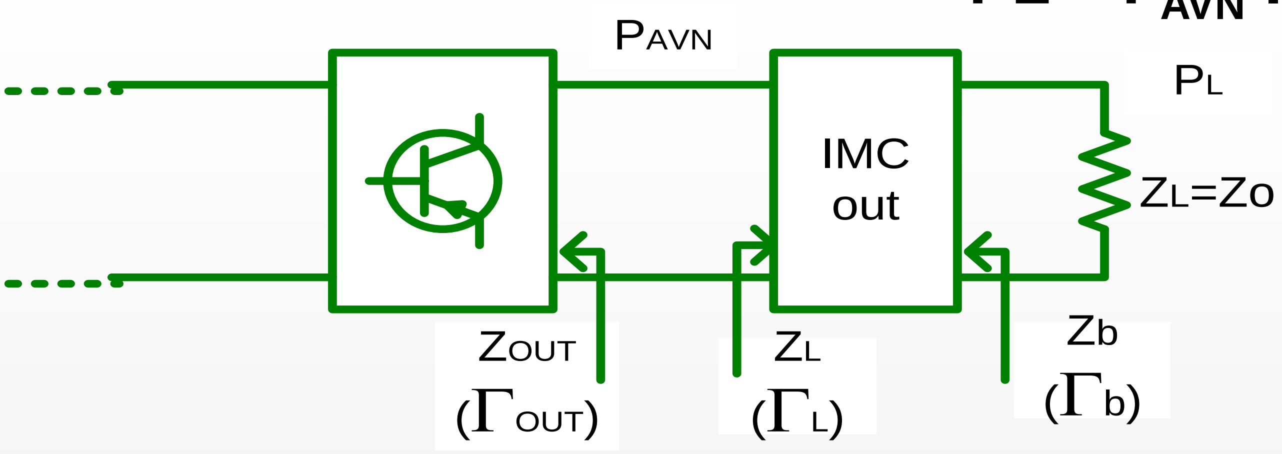
VSWR KELUARAN

$$P_L = P_{AVN} \cdot M_L$$



$$VSWR_{OUT} = \frac{1+|\Gamma_b|}{1-|\Gamma_b|} \qquad \Gamma_b = \frac{Z_b - Z_o}{Z_b + Z_o}$$

$$|\Gamma_b| = \sqrt{1 - M_L}$$

$$M_L = \frac{(1-|\Gamma_L|^2)\,.\,(1-|\Gamma_{OUT}|^2)}{|1-\Gamma_{OUT}\Gamma_L|^2}$$

$$|\Gamma_b| = \sqrt{1 - \frac{(1-|\Gamma_L|^2)\,.\,(1-|\Gamma_{OUT}|^2)}{|1-\Gamma_{OUT}\Gamma_L|^2}}$$

$$|\Gamma_b| = \left|\frac{\Gamma_{OUT} - \Gamma_L^*}{1-\Gamma_{OUT}\Gamma_L}\right|$$

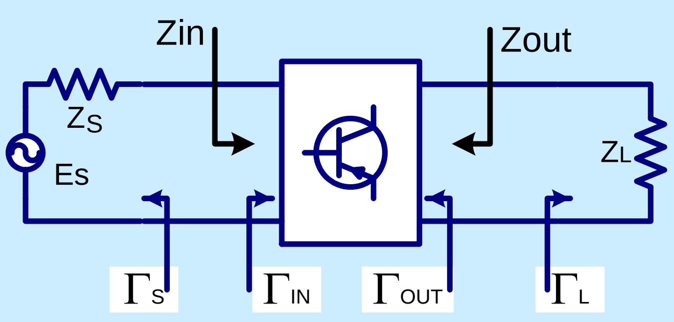
Small-Signal RF Amplifier

KEMANTAPAN PENGUAT RF

1. **Mantap tanpa syarat (Unconditionally Stable)**
   Suatu penguat dinyatakan MANTAP TANPA SYARAT, bila terpenuhi $|\Gamma_{IN}| < 1$ dan $|\Gamma_{OUT}| < 1$; untuk SEMUA harga impedansi sumber dan beban PASIF ($|\Gamma_S| < 1$ dan $|\Gamma_L| < 1$)
2. **Mantap bersyarat (Conditionally Stable, Potentially Unstable)**
   Suatu penguat dinyatakan MANTAP BERSYARAT, bila terpenuhi $|\Gamma_{IN}| < 1$ dan $|\Gamma_{OUT}| < 1$; untuk SEJUMLAH harga impedansi sumber dan beban PASIF

OSILASI terjadi pada penguat, jika pada terminal masukan atau keluarannya, terdapat RESISTANSI NEGATIF, yaitu bila $|\Gamma_{IN}| > 1$ atau $|\Gamma_{OUT}| > 1$. ($-R_{IN}$ = resistansi negatif)
Sebagai contoh, jika impedansi masukan : $Z_{IN} = -R_{IN} + jX_{IN}$

$$|\Gamma_{IN}| = \left| \frac{-R_{IN} + jX_{IN} - Z_O}{-R_{IN} + jX_{IN} + Z_O} \right| = \left| \frac{(R_{IN} + Z_O)^2 + X_{IN}^2}{(Z_O - R_{IN})^2 + X_{IN}^2} \right|^{1/2} > 1$$



$$I = \frac{E_S}{(R_S - R_{IN}) + j(X_{IN} + X_S)}$$

Small-Signal RF Amplifier

KEMANTAPAN PENGUAT RF

Pada satu frekuensi tertentu bisa terjadi : $\left.\begin{array}{l} R_S - R_{IN} = 0 \\ X_{IN} + X_S = 0 \end{array}\right\} \quad I = \infty$

Berdasarkan kepada koefisien refleksi, penguat yang MANTAP TANPA SYARAT akan terpenuhi bila :

1. $|\Gamma_S| < 1$
2. $|\Gamma_L| < 1$
3. $$|\Gamma_{OUT}| = \left| S_{22} + \frac{S_{12}.S_{21}.\Gamma_S}{1 - S_{11}.\Gamma_S} \right| < 1$$
4. $$|\Gamma_{IN}| = \left| S_{11} + \frac{S_{12}.S_{21}.\Gamma_L}{1 - S_{22}.\Gamma_L} \right| < 1$$

Pada penguat MANTAP BERSYARAT, harga $|\Gamma_S|$ dan $|\Gamma_L|$ yang memberikan kemantapan dapat ditentukan dengan menggunakan **PROSEDUR GRAFIS pada SMITH CHART**.

Tempat kedudukan Γ_S dan Γ_L yang menghasilkan $|\Gamma_{OUT}| = 1$ dan $|\Gamma_{IN}| = 1$ ditentukan dulu :

$$|\Gamma_{IN}| = \left| S_{11} + \frac{S_{12}.S_{21}.\Gamma_L}{1 - S_{22}.\Gamma_L} \right| = 1$$

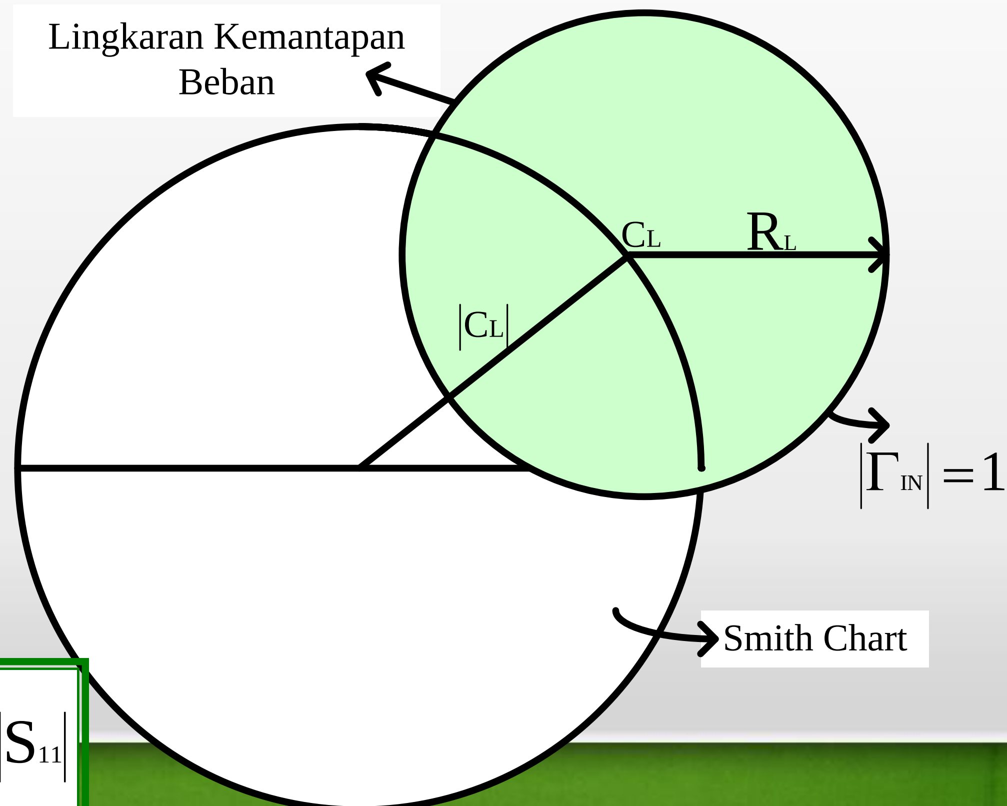
$$\left| \Gamma_L - \frac{(S_{22} - \Delta.S_{11}^*)^*}{|S_{22}|^2 - |\Delta|^2} \right| = \left| \frac{S_{12}.S_{21}}{|S_{22}|^2 - |\Delta|^2} \right| \qquad \text{dimana} \quad \Delta = S_{11}.S_{22} - S_{12}.S_{21}$$

Small-Signal RF Amplifier

Persamaan diatas merupakan persamaan lingkaran beban

(tempat kedudukan Γ_L untuk $|\Gamma_{IN}| = 1$):

$$\begin{cases} R_L = \left| \dfrac{S_{12}.S_{21}}{|S_{22}|^2 - |\Delta|^2} \right| & \rightarrow \text{ jari - jari} \\ C_L = \dfrac{(S_{22} - \Delta.S_{11}^*)^*}{|S_{22}|^2 - |\Delta|^2} & \rightarrow \text{ titik pusat lingkaran} \end{cases}$$



Bagaimana menentukan daerah Γ_L yang MANTAP ?

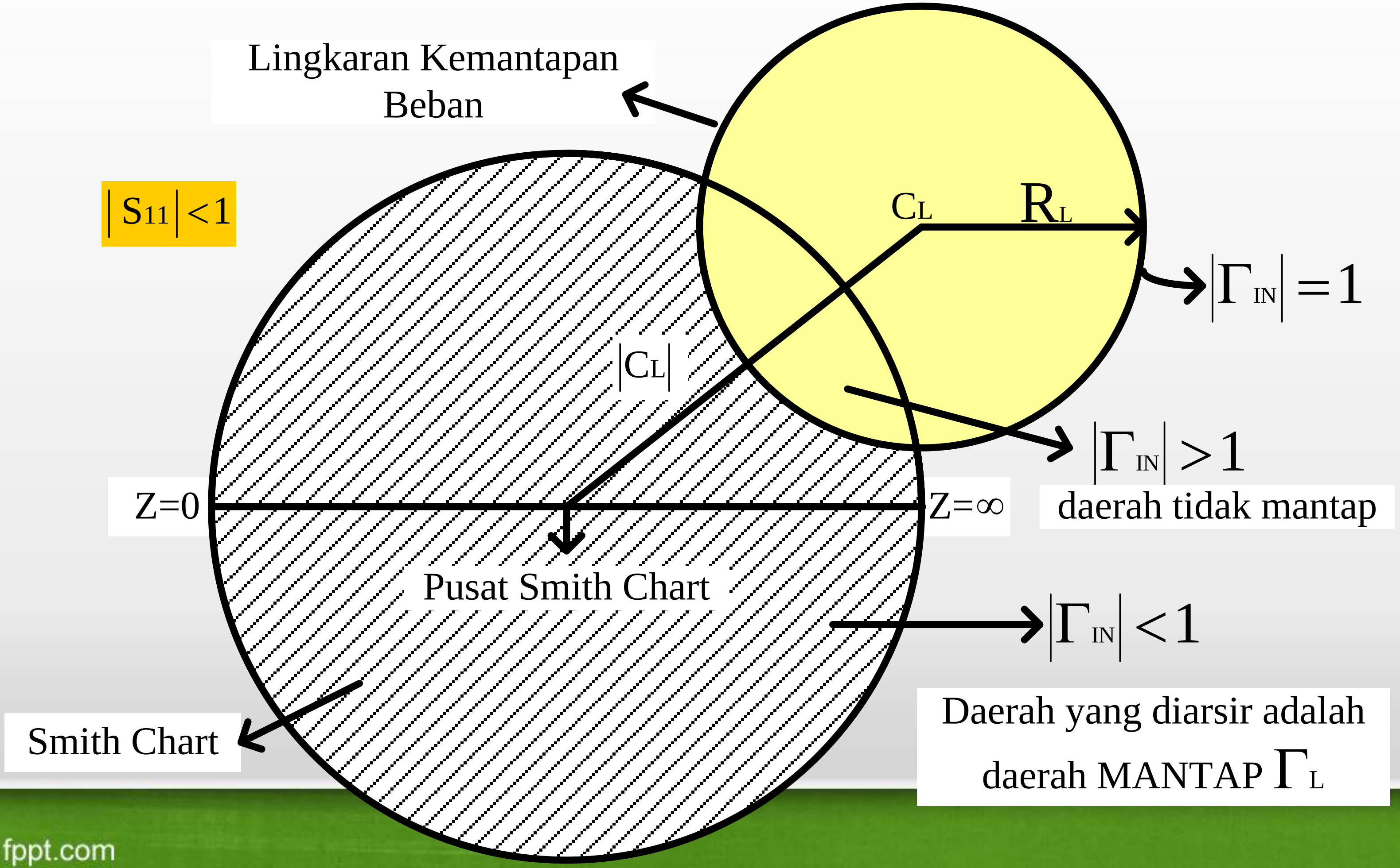
Jika

$$Z_L = Z_O \rightarrow \Gamma_L = \frac{Z_L - Z_O}{Z_L + Z_O} = 0 \quad \Rightarrow |\Gamma_{IN}| = |S_{11}|$$

Small-Signal RF Amplifier

➢ **Jadi bila $|S_{11}| < 1$, maka $|\Gamma_{IN}| < 1$, untuk $\Gamma_L = 0$ ($Z_L = Z_O$)**

→ **daerah yang mengandung titik pusat Smith Chart adalah daerah mantap**



Small-Signal RF Amplifier

➢ **Jadi jika $|S_{11}| > 1$, maka $|\Gamma_{IN}| > 1$ untuk $\Gamma_L = 0$ ($Z_L = Z_O$)**

→ daerah yang mengandung titik pusat Smith Chart adalah daerah tidak mantap

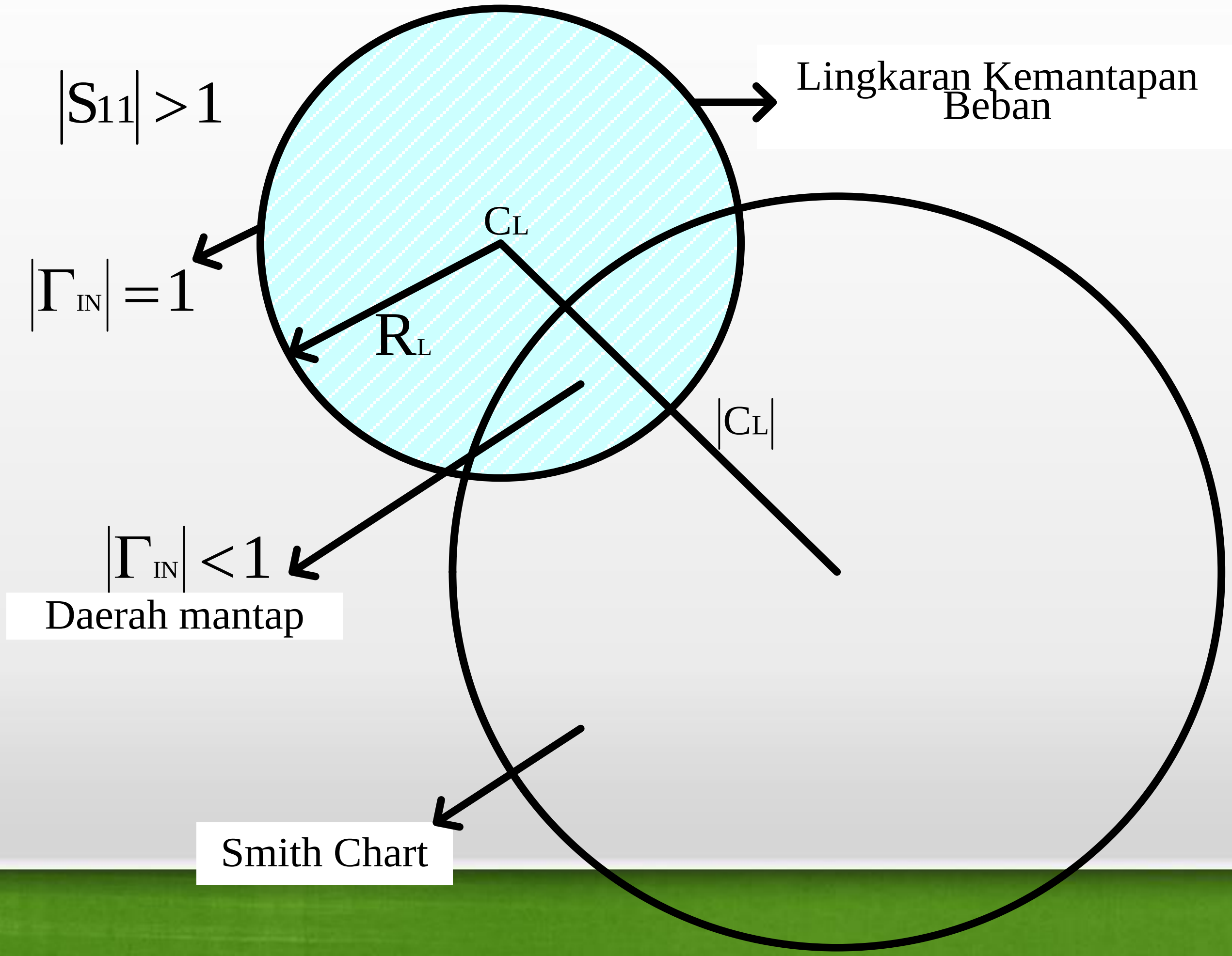
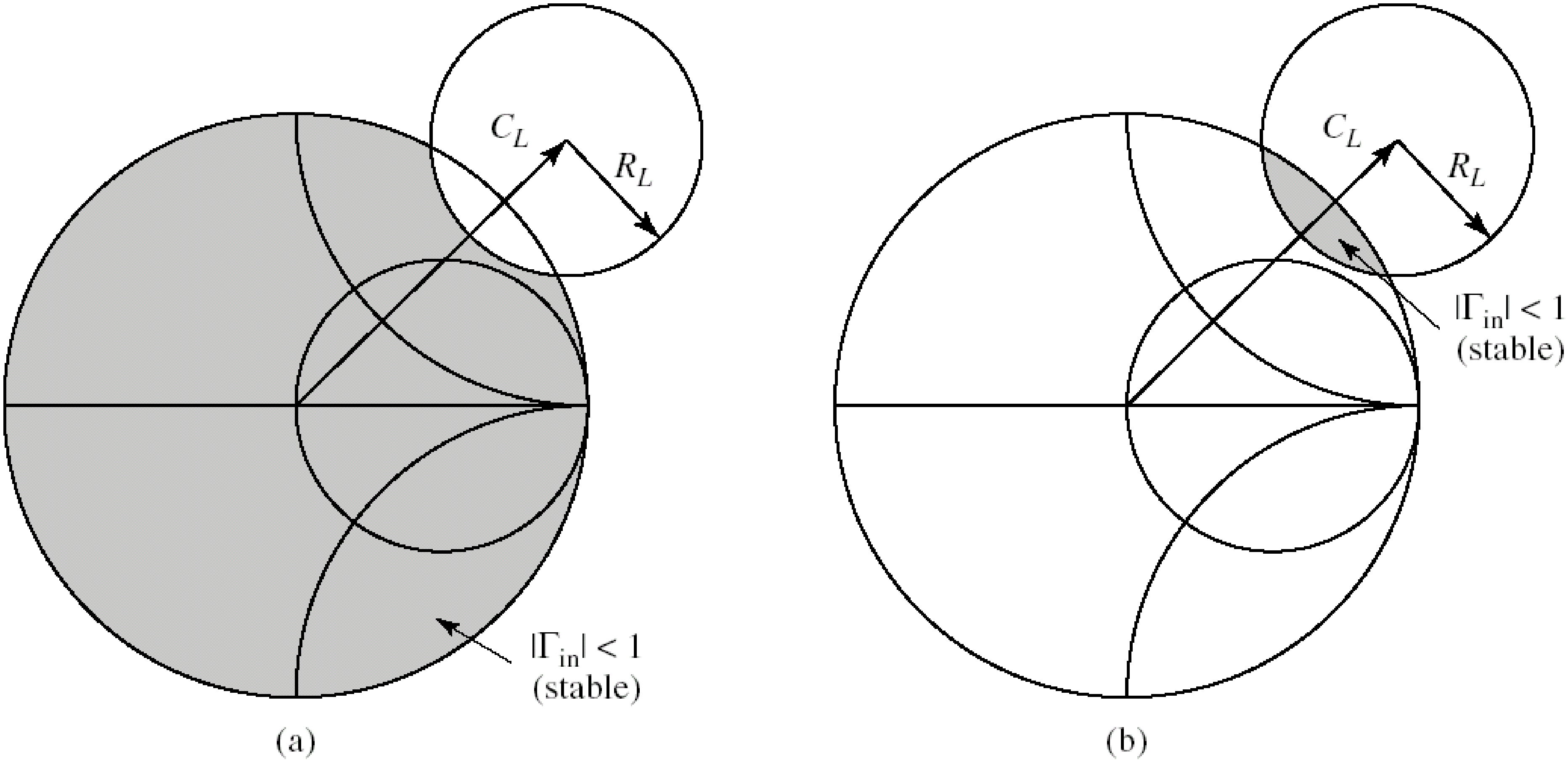


Figure 11-5 (p. 544)

Microwave Engineering, 3rd Edition, by David M Pozar

Load (Output) stability circles for a conditionally stable device.

(*a*) $|S_{11}| < 1$. (*b*) $|S_{11}| > 1$.



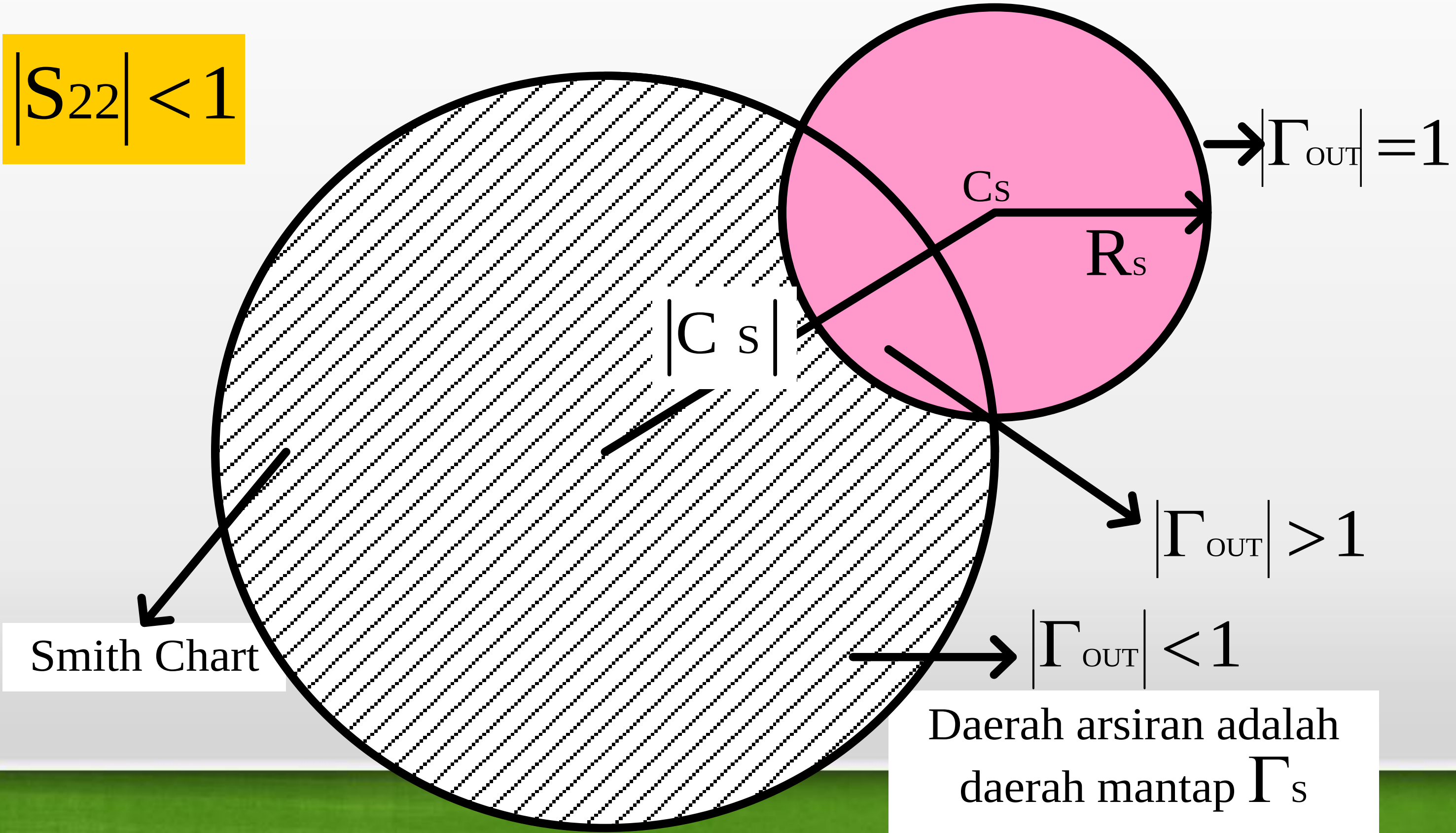
$$\left|\Gamma_{OUT}\right| = \left|S_{22} + \frac{S_{12}.S_{21}.\Gamma_S}{1 - S_{11}.\Gamma_S}\right| = 1$$

$$\left|\Gamma_S - \frac{(S_{11} - \Delta.S_{22}^*)^*}{\left|S_{11}\right|^2 - \left|\Delta\right|^2}\right| = \left|\frac{S_{12}.S_{21}}{\left|S_{11}\right|^2 - \left|\Delta\right|^2}\right| \quad \text{dimana} : \Delta = S_{11}.S_{22} - S_{12}.S_{21}$$

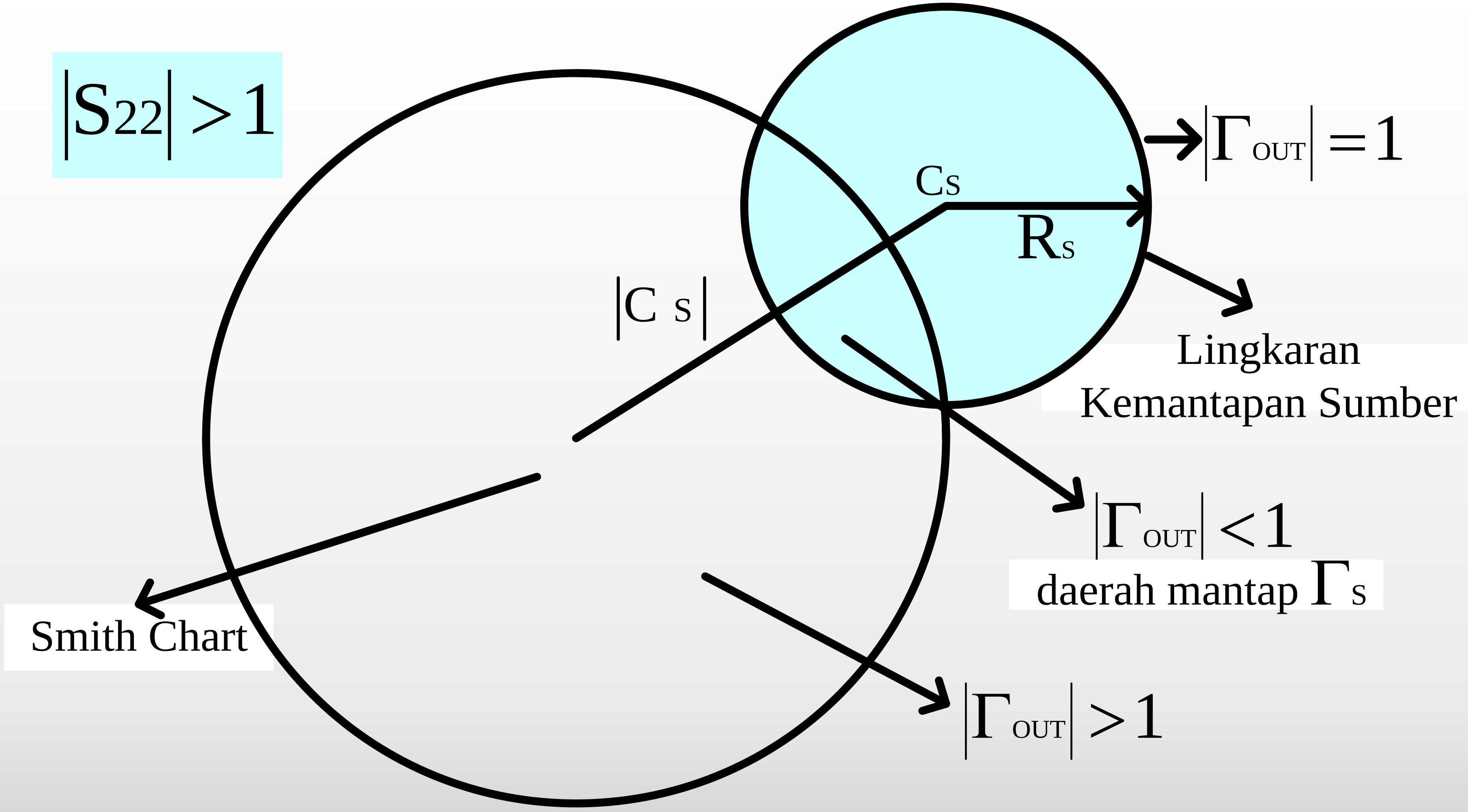
Persamaan diatas merupakan persamaan lingkaran sumber (tempat kedudukan Γ_S untuk $\left|\Gamma_{OUT}\right| = 1$):

$$\begin{cases} R_S = \left|\dfrac{S_{12}.S_{21}}{\left|S_{11}\right|^2 - \left|\Delta\right|^2}\right| & \rightarrow \text{jari - jari} \\ C_S = \dfrac{(S_{11} - \Delta.S_{22}^*)^*}{\left|S_{11}\right|^2 - \left|\Delta\right|^2} & \rightarrow \text{titik pusat lingkaran} \end{cases}$$

$\left|S_{22}\right| < 1$



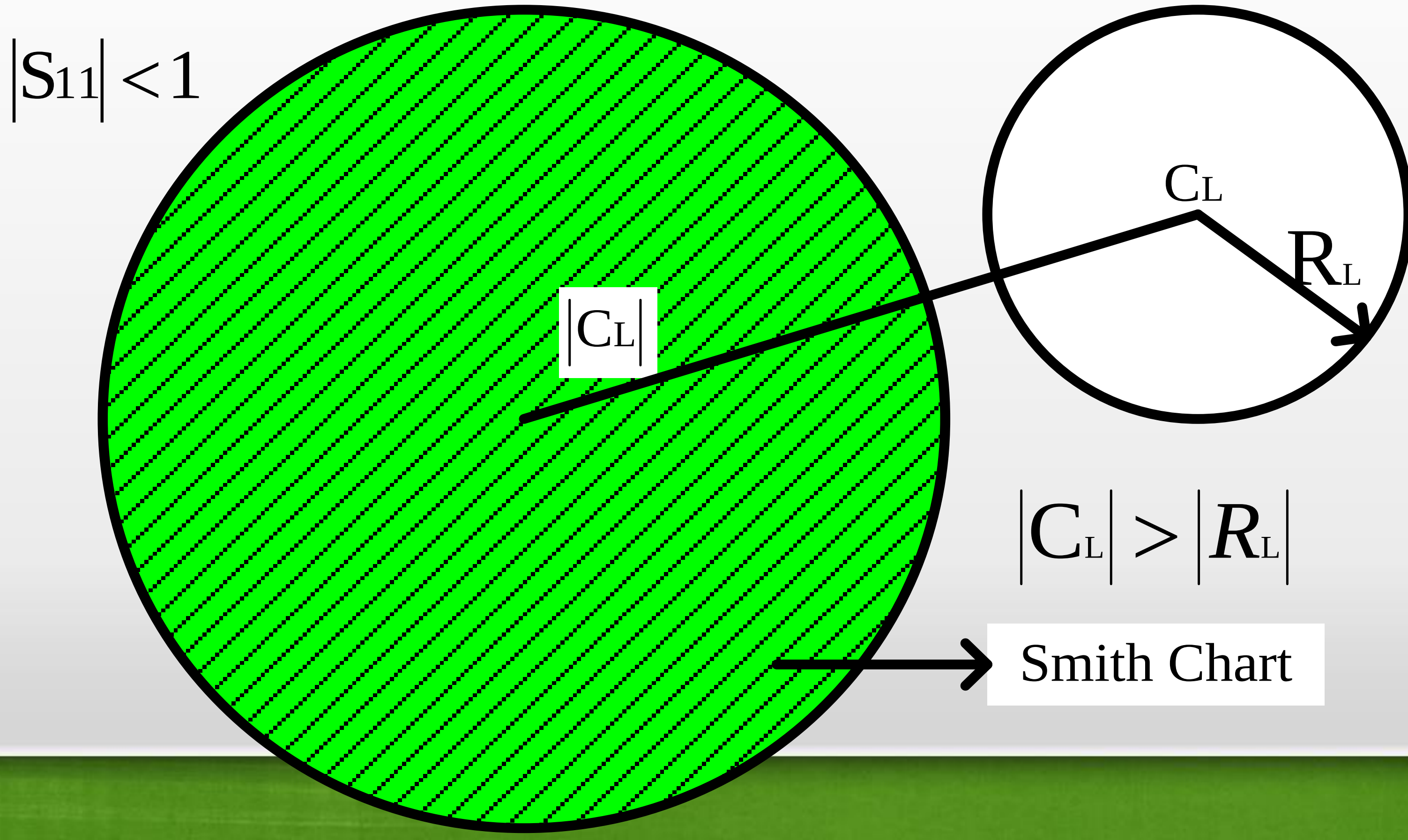
Small-Signal RF Amplifier



Small-Signal RF Amplifier

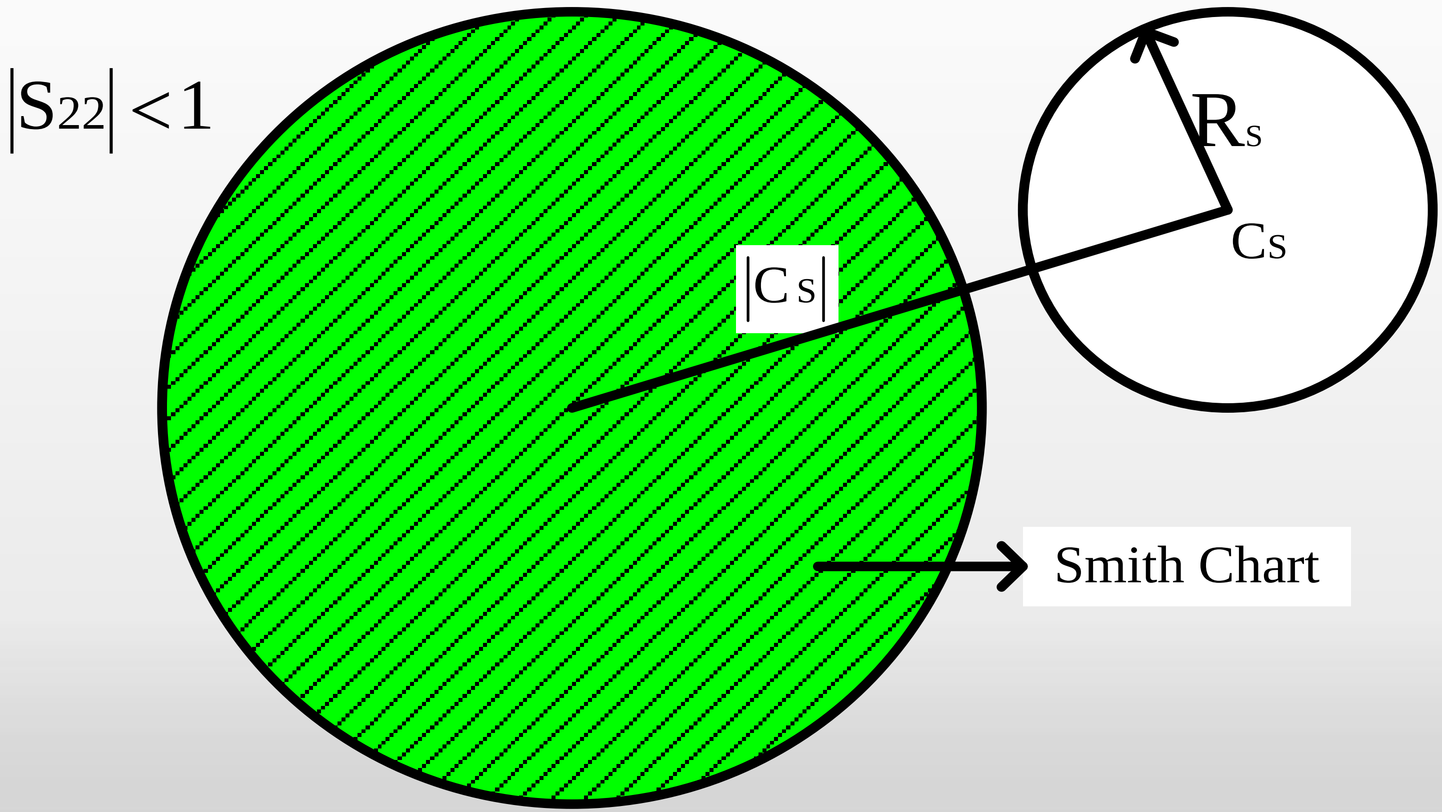
Kondisi mantap "TANPA SYARAT" untuk semua sumber atau beban dapat ditulis dengan :

$$\left|\,|C_L| - R_L\right| > 1 \quad \text{untuk} \quad |S_{11}| < 1$$



Small-Signal RF Amplifier

$$\left| \left| C_S \right| - R_S \right| > 1 \quad \text{untuk} \quad \left| S_{22} \right| < 1$$



Small-Signal RF Amplifier

FAKTOR KEMANTAPAN K

$$K = \frac{1 - |S_{11}|^2 - |S_{22}|^2 + |\Delta|^2}{2|S_{12}.S_{21}|} > 1 \qquad \text{dimana} \quad \Delta = S_{11}.S_{22} - S_{12}.S_{21}$$

$$1 - |S_{11}|^2 > |S_{12}.S_{21}| \qquad 1 - |S_{22}|^2 > |S_{12}.S_{21}|$$

kondisi cukup dan perlu untuk memperoleh KEMANTAPAN TANPA SYARAT :

$$K > 1 \qquad |S_{11}| < 1 \qquad 1 - |S_{11}|^2 > |S_{12}.S_{21}|$$

$$|S_{22}| < 1 \qquad 1 - |S_{22}|^2 > |S_{12}.S_{21}|$$

atau cukup dengan :

$$|\Delta| < 1$$

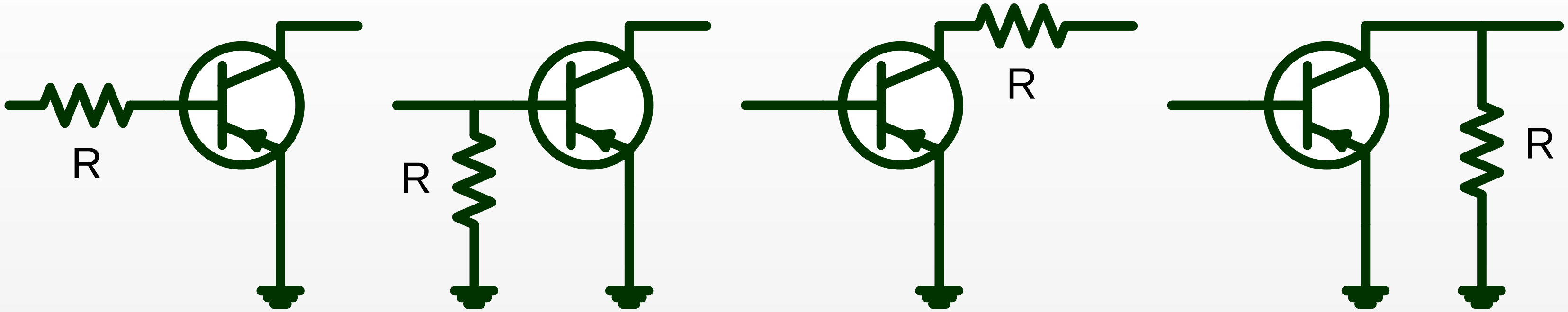
dan

$$K > 1$$

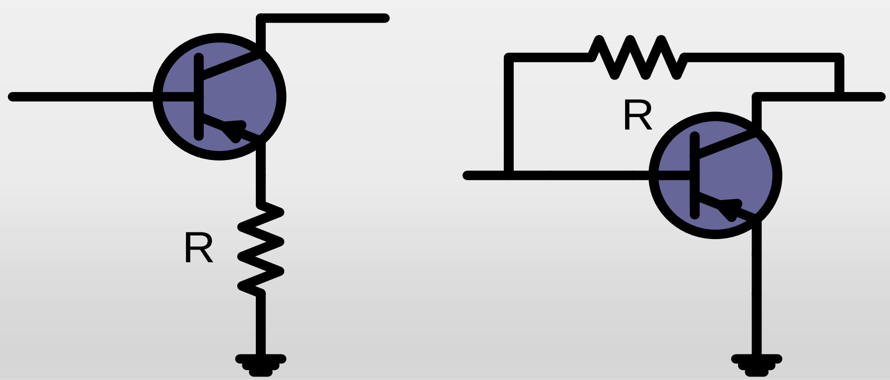
Small-Signal RF Amplifier

KONDISI TIDAK MANTAP → KONDISI MANTAP TANPA SYARAT :

1. **dengan pembebanan resistif**



2. **dengan umpan balik**



Small-Signal RF Amplifier

LATIHAN SOAL

1. Suatu transistor jenis GaAs MESFET dengan parameter s, diukur pada V_{ds} = 5 V dan I_{ds} = 40 mA, f = 9 GHz, referensi 50 ohm:

   $S_{11}=0,65 <-154^0$

   $S_{12}=0,02 <40^0$

   $S_{21}=2,04 <185^0$

   $S_{22}=0,55 <-30^0$

   $\Gamma_s = 0,38 <25^0$

   Tentukan:

   1. factor Delta Δ (0,332 < 171^0)
   2. Faktor stabilitas K (4,72)
   3. Koefisien refleksi keluaran Γ_{out} (0,56 < $-40,7^0$)
   4. GA (Available Power Gain) (6,94dB)

Ref: *Microwave Circuit Analysis & Amplifier Design*, by Samuel Y.Liao, Exp. 3-4-2.

Small-Signal RF Amplifier

LATIHAN SOAL (LANJUTAN)

2. Parameter S untuk HP HFET-102 GaAs FET pada frekuensi 2 GHz, dicatu dengan tegangan biasing $V_{gs} = 0$ dengan $Z_0 = 50\ \Omega$ sebagai berikut:

$S_{11} = 0.894 < -60.6^0$

$S_{12} = 0,020 < 62.4^0$

$S_{21} = 3.122 < 123.6^0$

$S_{22} = 0,781 < -27.6^0$

Tentukan kestabilan transistor tersebut dengan menghitung K dan Δ, kemudian plot-kan daerah kestabilannya !

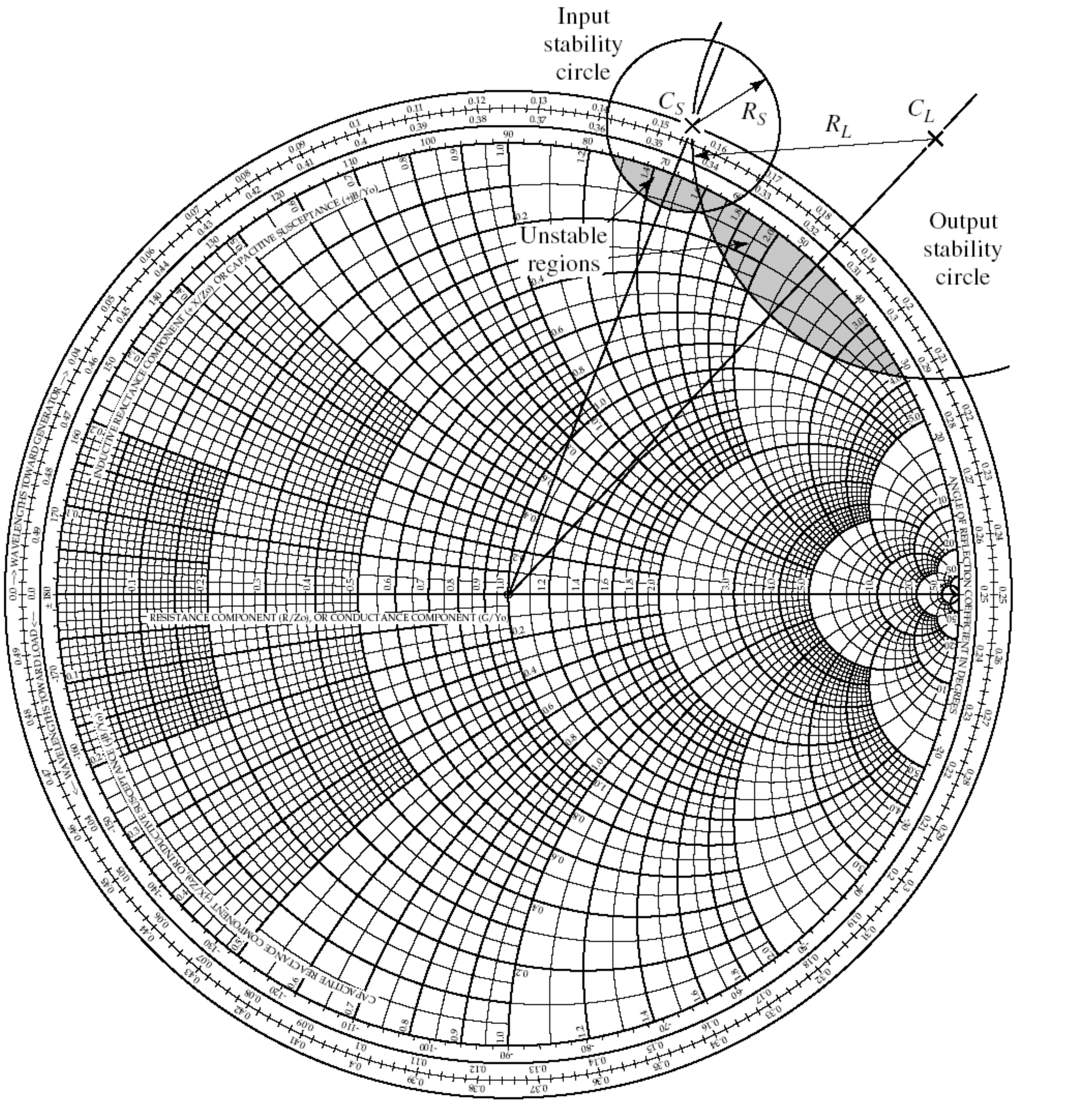
Solusi: $\Delta = 0.696 < -83^0$ — $K = 0,607 \Rightarrow$ potentially unstable

$C_L = 1.363 < 47^0$ — $R_L = 0.50$

$C_S = 1.132 < 68^0$ — $R_S = 0.199$

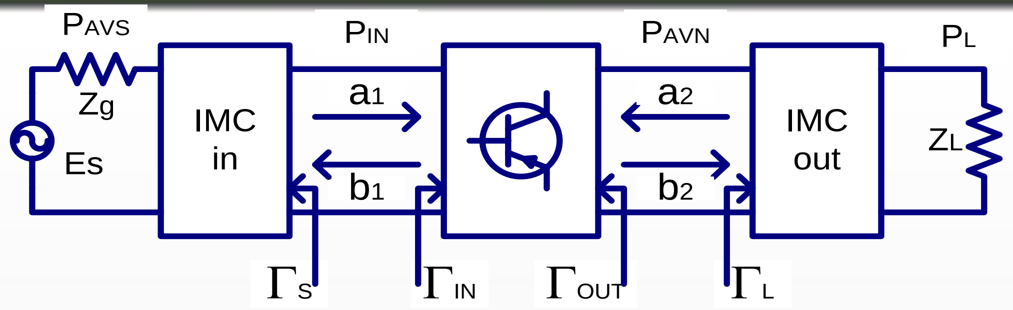
Ref: *Microwave Engineering*, *2nd Edition*, by David M Pozar, Exp 11.2

- Plot lingkaran kestabilan sumber dan beban



Small-Signal RF Amplifier

PERANCANGAN UNTUK GAIN MAKSIMUM (CONJUGATE MATCHING)



→ **syarat transistor mantap tanpa syarat**

Jika dipilih : $\left.\begin{matrix}\Gamma_{IN} = \Gamma_S^* \\ \Gamma_{OUT} = \Gamma_L^*\end{matrix}\right\}$ diperoleh penguatan daya transducer (G_T) maksimum

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

$$\Rightarrow \Gamma_{SM} = \frac{B_1 \pm \sqrt{B_1^2 - 4|C_1|^2}}{2C_1} \qquad \Rightarrow \Gamma_{LM} = \frac{B_2 \pm \sqrt{B_2^2 - 4|C_2|^2}}{2C_2}$$

dimana :

$$B_1 = 1 + |S_{11}|^2 - |S_{22}|^2 - |\Delta|^2 \qquad B_2 = 1 + |S_{22}|^2 - |S_{11}|^2 - |\Delta|^2$$

$$C_1 = S_{11} - \Delta.S_{22}^* \qquad C_2 = S_{22} - \Delta.S_{11}^*$$

$$G_{T,MAX} = \frac{1}{1 - |\Gamma_{SM}|^2} |S_{21}|^2 \frac{1 - |\Gamma_{LM}|^2}{|1 - S_{22}.\Gamma_{LM}|^2}$$

atau

$$G_{T,MAX} = \frac{|S_{21}|}{|S_{12}|}\left(K - \sqrt{K^2 - 1}\right)$$

Small-Signal RF Amplifier

LATIHAN SOAL

- Rancanglah suatu penguat dengan gain maximum pada frekuensi 4 GHz menggunakan single-stub matching! Transistor GaAs FET mempunyai parameter S dengan Z_0=50 Ω sebagai berikut:

  S_{11}=0.72 <-116^0

  S_{12}=0,03 <57^0

  S_{21}=2.60 <76^0

  S_{22}=0,73 <-54^0

Ref: *Microwave Engineering, 2nd Edition,* by David M Pozar, Exp 11.3

Solusi:

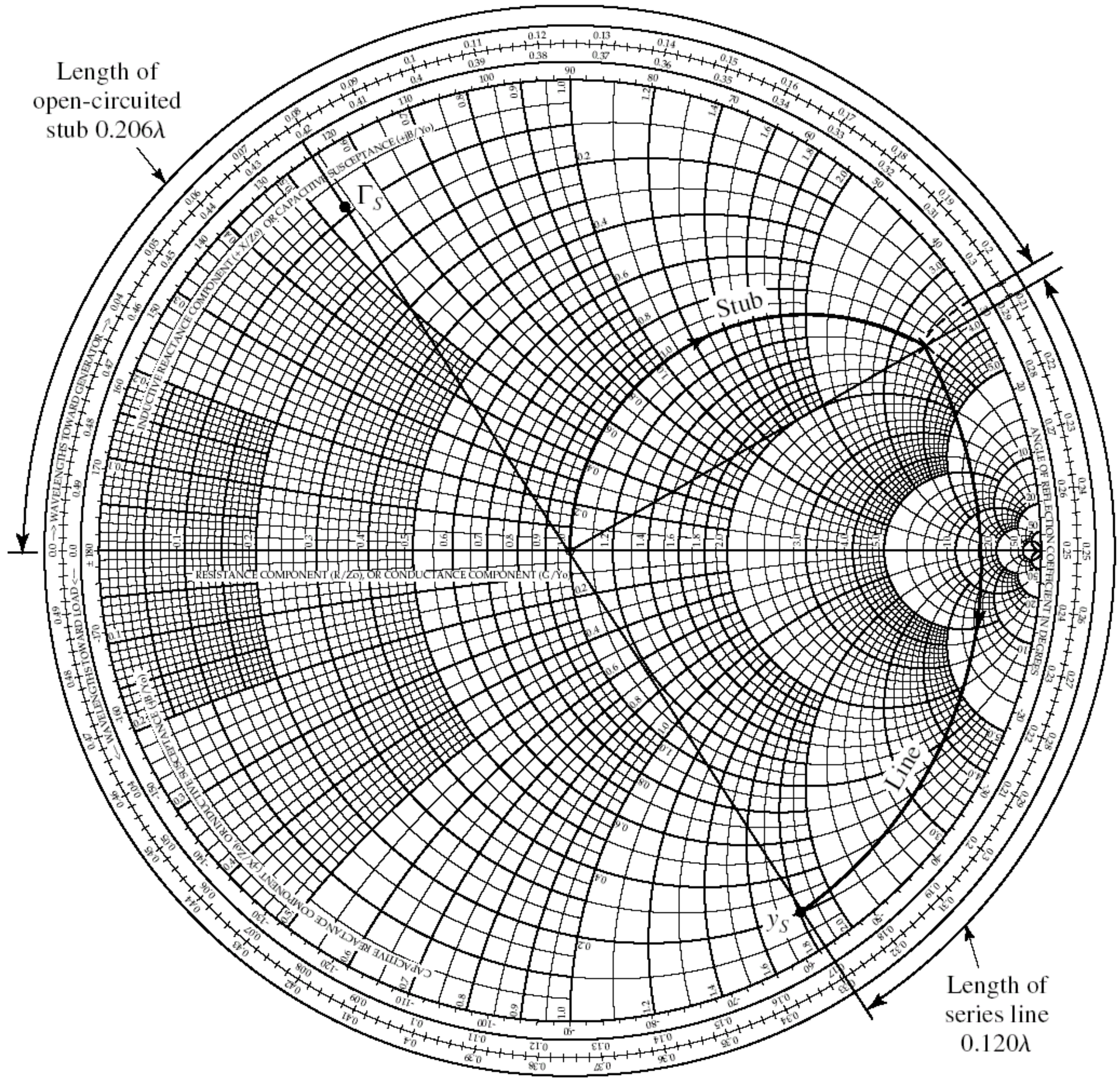
Δ = 0.488 < -162^0 K = 1,195 ⇒ unconditionally stable

Γ_{SM} = 0.872 < 123^0 Γ_{LM} = 0.876 < 61^0

$G_{T,max}$ = 16.7 dB

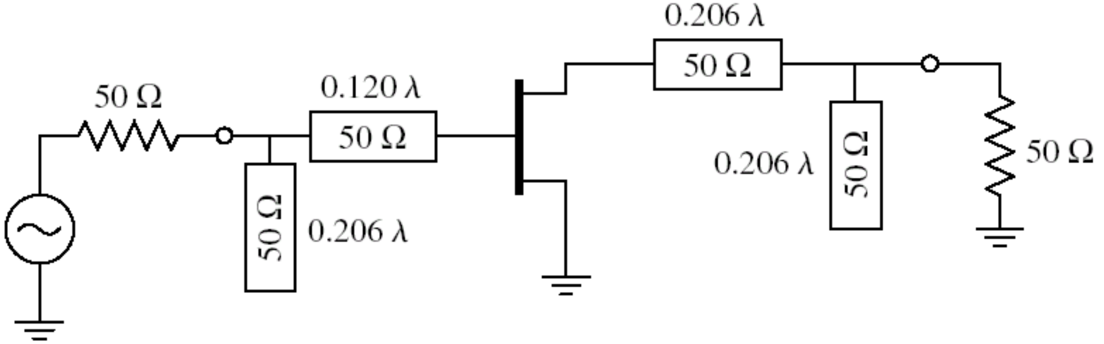
Perhatikan rangkaian penyesuai impedansi sbb:

Circuit design and frequency response for the transistor amplifier of Example 11.3. (*a*) Smith chart for the design of the input matching network.

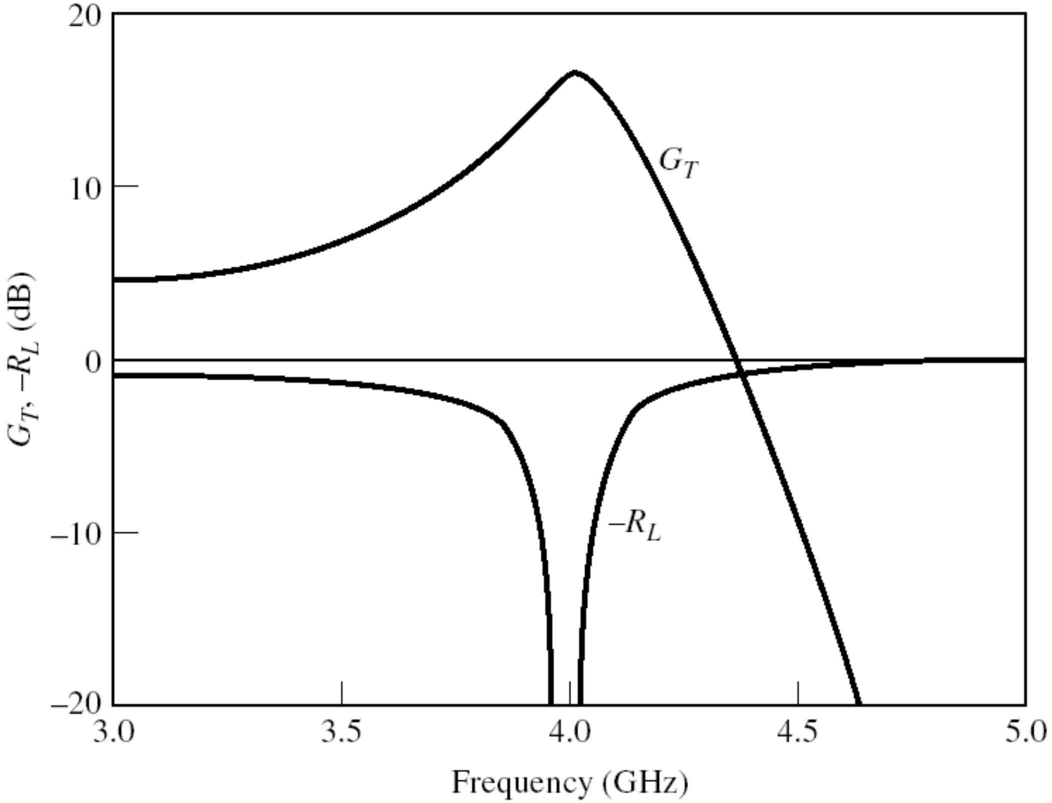


(a)

(*b*) RF circuit. (*c*) Frequency response.



(b)



(c)

Small-Signal RF Amplifier

PERANCANGAN PENGUAT DENGAN GP DITENTUKAN:

Lingkaran Gp (Operating Power Gain) Konstan

a. KASUS KEMANTAPAN TANPA SYARAT

$$G_P = \frac{1}{1-|\Gamma_{IN}|^2}|S_{21}|^2 \frac{1-|\Gamma_L|^2}{|1-S_{22}.\Gamma_L|^2} = |S_{21}|^2 . g_P$$

dimana:

$$g_P = \frac{1-|\Gamma_L|^2}{1-|S_{11}|^2+|\Gamma_L|^2.(|S_{22}|^2-|\Delta|^2)-2\,\mathrm{Re}[\Gamma_L.C_2]}$$

$$C_2 = S_{22} - \Delta.S_{11}^*$$

$$\Delta = S_{11}.S_{22} - S_{12}.S_{21}$$

$$|\Gamma_L|^2 - \{1+g_P.(|S_{22}|^2-|\Delta|^2)\} - 2.g_P.\mathrm{Re}[\Gamma_L.C_2] = 1-g_P(1-|S_{11}|^2)$$

$$\rightarrow \quad |\Gamma_L|^2 - \frac{g_P.C_2.\Gamma_L}{1+g_P(|S_{22}|^2-|\Delta|^2)} - \frac{g_P.C_2^*.\Gamma_L^*}{1+g_P(|S_{22}|^2-|\Delta|^2)} = \frac{1-g_P(1-|S_{11}|^2)}{1+g_P(|S_{22}|^2-|\Delta|^2)}$$

titik pusat lingkaran :

$$C_P = \frac{g_P.C_2^*}{1+g_P(|S_{22}|^2-|\Delta|^2)}$$

jari-jari lingkaran :

$$R_P = \frac{\{1-2K.|S_{12}.S_{21}|.g_P+|S_{12}.S_{21}|^2.g_P^2\}^{\frac{1}{2}}}{|1+g_P.(|S_{22}|^2-|\Delta|^2)|}$$

Small-Signal RF Amplifier

$\mathbf{G_P}$ maksimum terjadi pada $R_P = 0$; artinya :

$g_{P,MAX} \cdot |S_{12}.S_{21}|^2 - 2K.|S_{12}.S_{21}|.g_{P,MAX} + 1 = 0$

$$g_{P,\ MAX} = \frac{1}{|S_{12}.S_{21}|}\left(K - \sqrt{K^2 - 1}\right) = \frac{G_{P,MAX}}{|S_{21}|^2}$$

sehingga

$$G_{P,MAX} = \frac{|S_{21}|}{|S_{12}|}\left(K - \sqrt{K^2 - 1}\right)$$

Prosedur menggunakan lingkaran G_P konstan :

1) Untuk G_P yang ditentukan, hitung titik pusat dan jari-jari lingkaran G_P konstan
2) Pilih Γ_L yang diinginkan (di lingkaran tersebut)
3) Dengan Γ_L tersebut, daya keluaran maksimum diperoleh dengan melakukan conjugate match pada masukan, yaitu $\Gamma_S = \Gamma_{IN}^*$

   Γ_S ini akan memberikan $\mathbf{G_T = G_P}$

Contoh : Transistor		$S_{11} = 0{,}641\angle -171{,}3^o$	$S_{21} = 2{,}058\angle 28{,}5^o$
	$(f = 6GHz)$	$S_{12} = 0{,}057\angle 16{,}3^o$	$S_{22} = 0{,}572\angle -95{,}7^o$

Rancanglah sebuah penguat RF yang mempunyai G_P = 9 dB

Ref: Gonzalez, Guillermo; *Microwaves Transistor Amplifier: Analysis & Design*; Prentice Hall, 1984

Small-Signal RF Amplifier

Solusi

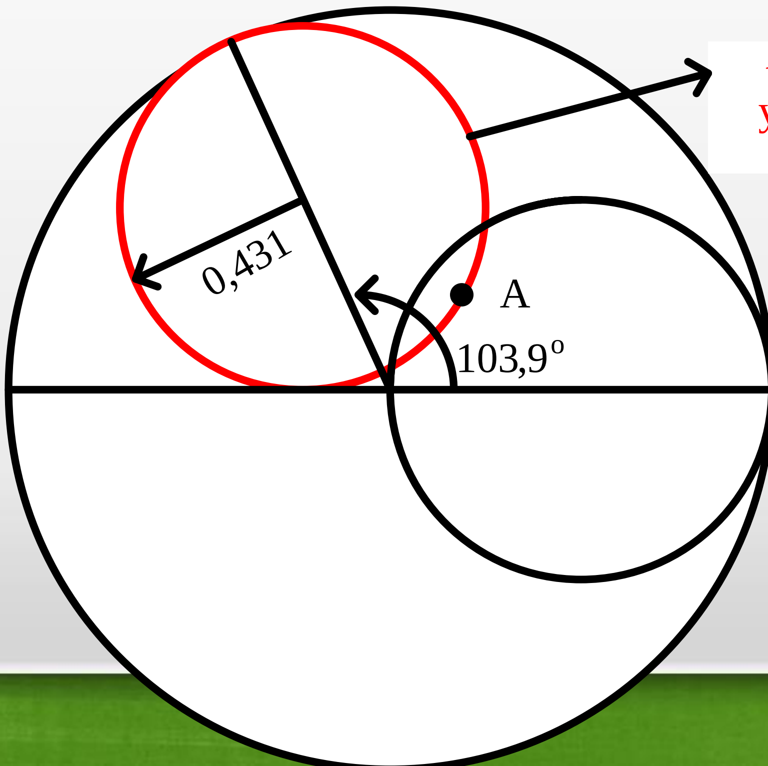
$|\Delta| = 0{,}3014$ K = 1,504 $\rightarrow$ mantap tanpa syarat

$$|S_{21}|^2 = (2{,}058)^2 = 4{,}235 \Rightarrow g_P = \frac{G_P}{|S_{21}|^2} = \frac{7{,}94}{4{,}235} = 1{,}875$$

$$C_2 = 0{,}3911 \angle -103{,}9^o$$

$$C_P = 0{,}508 \angle 103{,}9^o \quad R_P = 0{,}431$$

$\rightarrow$ gambar tempat kedudukan Γ_L yang memberikan **G_P = 9 dB**



Kita pilih $\Gamma_L = 0{,}36 \angle 47{,}5^o$ (titik A)

Γ_S yang memberikan daya keluar maksimum

$$\Gamma_S = \Gamma_{IN}{}^* = \left[S_{11} + \frac{S_{12}.S_{21}.\Gamma_L}{1 - S_{22}\Gamma_L} \right]^*$$

$$\Gamma_S = 0{,}629 \angle 175{,}51^o$$

Small-Signal RF Amplifier

LATIHAN SOAL

1. Suatu transistor jenis GaAs MESFET dengan parameter s, diukur pada V_{ds} = 5 V dan I_{ds} = 40 mA, f = 9 GHz, referensi 50 ohm:

   S_{11}=0,65 <-154^0

   S_{12}=0,02 <40^0

   S_{21}=2,04 <185^0

   S_{22}=0,55 <-30^0

   Tentukan:

   1. factor Delta Δ (0,332 < 171^0)
   2. Faktor stabilitas K (4,72)
   3. Carilah Γ_L dan Γ_S Yang manghasilkan Gp = 10 dB !
   4. Rancanglah IMC input dan IMC output-nya untuk Hambatan sumber dan beban 50 Ω!

Small-Signal RF Amplifier

PERANCANGAN PENGUAT DENGAN GP DITENTUKAN:

Lingkaran Gp (Operating Power Gain) Konstan

b. KASUS MANTAP BERSYARAT

Dengan transistor mantap bersyarat, prosedur perancangan untuk G_P tertentu adalah sebagai berikut:

1) Untuk **G_P** yang diinginkan, gambar lingkaran G_P konstan dan lingkaran kemantapan beban. Pilih Γ_L yang berada pada daerah mantap dan tidak terlalu dekat dengan lingkaran kemantapan beban.
2) Hitung Γ_{IN} dan tentukan apakah conjugate match pada masukan mungkin. Untuk itu gambar lingkaran kemantapan sumber dan periksa apakah $\Gamma_S = \Gamma_{IN}^*$ terletak pada daerah mantap.
3) Jika $\Gamma_S = \Gamma_{IN}^*$ tidak terletak pada daerah mantap atau terletak pada daerah mantap namun terlalu dekat dengan lingkaran kemantapan sumber, pilih Γ_L yang lain dan ulangi langkah 1) dan 2)

Catt: nilai Γ_S dan Γ_L sebaiknya tidak terlalu dekat dengan lingkaran kemantapan, karena ketidakmantapan (OSILASI) dapat terjadi oleh variasi nilai komponen yang digunakan sehingga Γ_L dan Γ_S masuk ke daerah tidak mantap.

Contoh : Transistor (f = 6 GHz)

$S_{11} = 0{,}5\angle -180^o$ $S_{21} = 2{,}5\angle 70^o$

$S_{12} = 0{,}08\angle 30^o$ $S_{22} = 0{,}8\angle -100^o$

Rancanglah sebuah penguat RF yang mempunyai G_P = 10 dB

Ref: Gonzalez, Guillermo; *Microwaves Transistor Amplifier: Analysis & Design*; Prentice Hall, 1984

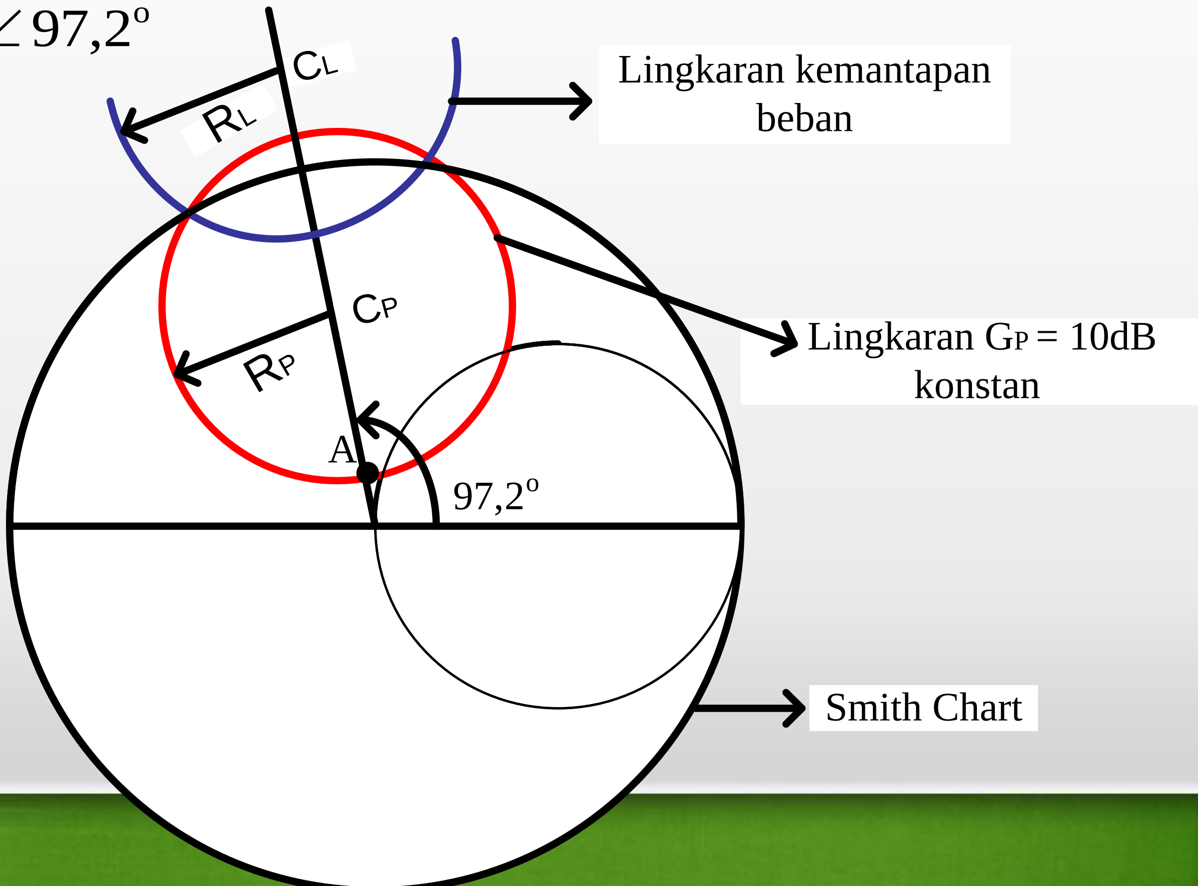
Small-Signal RF Amplifier

$\Delta = 0{,}223\angle 62{,}12^0$

K = 0,4 → transistor mantap bersyarat

$$G_P = 10\text{dB}\ \begin{cases} \begin{cases} C_P = 0{,}572\angle 97{,}2^o \\ R_P = 0{,}473 \end{cases} \\ \begin{cases} C_L = 1{,}18\angle 97{,}2^o \\ R_L = 0{,}34 \end{cases} \end{cases}$$

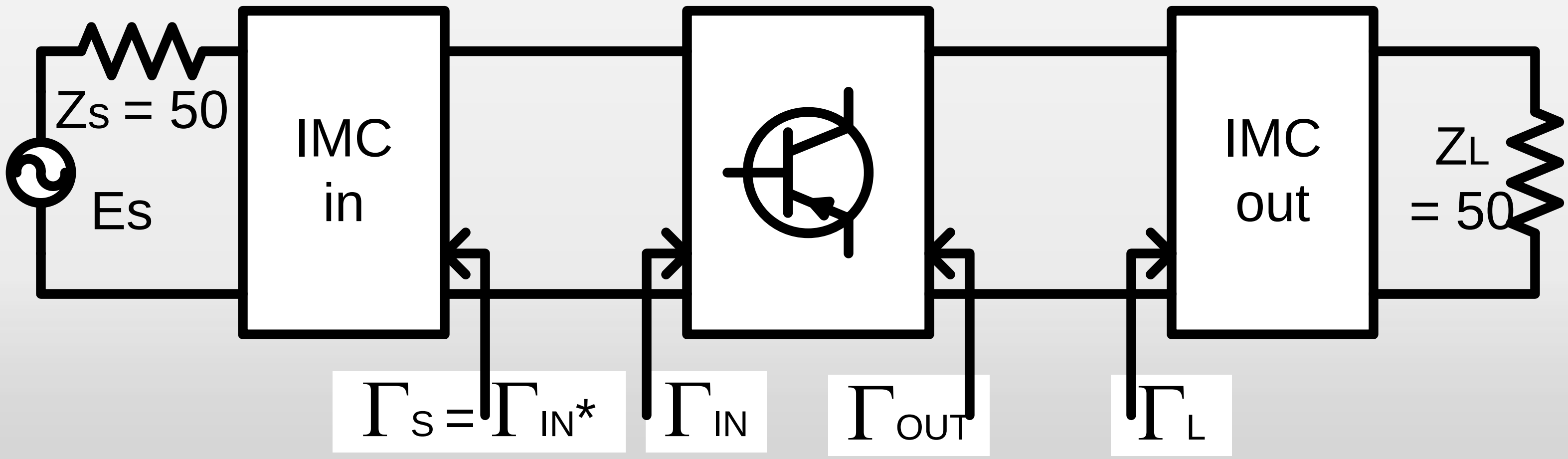
Solusi :



Small-Signal RF Amplifier

- Oleh karena $|S_{11}| < 1$, daerah MANTAP berada diluar lingkaran kemantapan BEBAN
- Pilih titk A → $\Gamma_L = 0{,}1 \angle 97{,}2^o$ → $\Gamma_S = \Gamma_{IN}^* = 0{,}52 \angle 179{,}32^o$
- Lingkaran kemantapan sumber : $C_S = 1{,}67 \angle 171^o$ **R_S = 1,0**

  Γ_S diatas harus diperiksa apakah berada di daerah MANTAP
- Daerah mantap berada di luar lingkaran kemantapan sumber → Γ_S berada di daerah mantap, maka Γ_S dapat digunakan



Small-Signal RF Amplifier

PERANCANGAN PENGUAT DENGAN GA DITENTUKAN:

*Lingkaran **Ga** (Available Power Gain) Konstan*

a) **KASUS MANTAP TANPA SYARAT**

$$G_A = \frac{1}{1-|\Gamma_{OUT}|^2}|S_{21}|^2\frac{1-|\Gamma_S|^2}{|1-S_{11}.\Gamma_S|^2} = |S_{21}|^2 . g_A$$

$$g_A = \frac{G_A}{|S_{21}|^2} = \frac{1-|\Gamma_S|^2}{1-|S_{22}|^2+|\Gamma_S|^2.(|S_{11}|^2-|\Delta|^2)-2\,\mathrm{Re}[\Gamma_S.C_1]}$$

$$C_1 = S_{11} - \Delta.S_{22}*$$

Dengan cara yang sama seperti lingkaran G_P konstan, diperoleh :

Lingkaran G_A konstan :

titik pusat lingkaran : $C_A = \frac{g_A.C_1*}{1+g_A(|S_{11}|^2-|\Delta|^2)}$

jari-jari lingkaran : $R_A = \frac{\left\{1-2K|S_{12}.S_{21}|g_A+|S_{12}.S_{21}|^2.g_A^{\;2}\right\}^{\frac{1}{2}}}{|1+g_A(|S_{11}|^2-|\Delta|^2)|}$

Semua Γ_S pada lingkaran, memberikan suatu G_A yang diinginkan. Untuk G_A tertentu, daya keluaran maksimum diperoleh dengan $\Gamma_L = \Gamma_{OUT}*$

→ Γ_L ini memberikan $G_T = G_A$

Small-Signal RF Amplifier

PERANCANGAN PENGUAT DENGAN GA DITENTUKAN:

Lingkaran ***Ga*** (Available Power Gain) Konstan

b) KASUS MANTAP BERSYARAT

1. Untuk GA yang diinginkan, gambar lingkaran G_A konstan dan lingkaran kemantapan sumber. Pilih Γ_S yang berada di daerah mantap dan tidak terlalu dekat dengan lingkaran kemantapan sumber.
2. Hitung Γ_{OUT} dan periksa apakah conjugate match mungkin, untuk itu gambar lingkaran kemantapan beban dan periksa apakah $\Gamma_L = \Gamma_{OUT}^*$ berada di daerah mantap.
3. Jika $\Gamma_L = \Gamma_{OUT}^*$ tidak berada pada daerah mantap atau terlalu dekat dengan lingkaran kemantapan beban, pilih Γ_S **(**atau $\mathbf{G_A}$**)** yang lain dan ulangi langkah 1) dan 2).

Catt: nilai Γ_S dan Γ_L sebaiknya tidak terlalu dekat dengan lingkaran kemantapan, karena ketidakmantapan (OSILASI) dapat terjadi oleh variasi nilai komponen yang digunakan sehingga Γ_L dan Γ_S masuk ke daerah tidak mantap.

Small-Signal RF Amplifier

LATIHAN SOAL

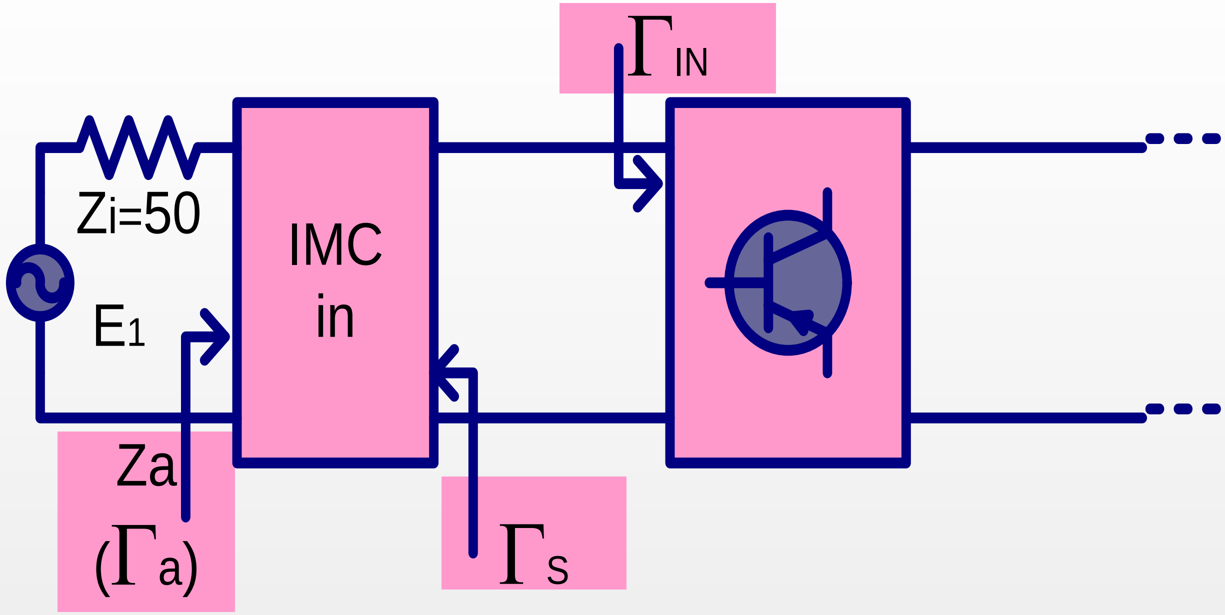
Contoh :	Transistor	$S_{11} = 0,5 \angle -180^o$	$S_{21} = 2,5 \angle 70^o$
	(f = 6 GHz)	$S_{12} = 0,08 \angle 30^o$	$S_{22} = 0,8 \angle -100^o$

Rancanglah sebuah penguat RF yang mempunyai G_A = 10 dB!
Rancang pula IMC-in dan IMC-out dengan menggunakan stub paralel-open circuit!

Small-Signal RF Amplifier

PERANCANGAN PENGUAT DENGAN VSWR DITENTUKAN:

- $VSWR_{IN}$ konstan



$$VSWR_{IN} = \frac{1+|\Gamma a|}{1-|\Gamma a|} \rightarrow |\Gamma a| = \left| \frac{\Gamma_{IN} - \Gamma_S^*}{1 - \Gamma_{IN}.\Gamma_S} \right|$$

$\rightarrow$ dapat diturunkan lingkaran $VSWR_{IN}$ konstan

Small-Signal RF Amplifier

PERANCANGAN PENGUAT DENGAN VSWR DITENTUKAN:

Lingkaran $VSWR_{IN}$ konstan :

titik pusat lingkaran :

$$Cvi = \frac{\Gamma_{IN}^{*}.(1-|\Gamma a|^{2})}{1-|\Gamma a.\Gamma_{IN}|^{2}}$$

jari-jari lingkaran :

$$Rvi = \frac{|\Gamma a|.(1-|\Gamma_{IN}|^{2})}{1-|\Gamma a.\Gamma_{IN}|^{2}}$$

Pada kasus mantap tanpa syarat dan beberapa kasus mantap bersyarat,

Γ_S dapat dipilih $=\Gamma_{IN}^*$; untuk memperoleh $VSWR_{IN} = 1$.

Bila $VSWR_{IN} = 1 \rightarrow |\Gamma a| = 0$ $\begin{cases} Cvi = \Gamma_{IN}^{*} \\ Rvi = 0 \end{cases}$

Jadi $\Gamma_S = \Gamma_{IN}^*$ memberikan $|\Gamma a| = 0 \rightarrow VSWR_{IN} = 1$

PERANCANGAN PENGUAT DENGAN VSWR DITENTUKAN:

- $VSWR_{out}$ konstan

DENGAN CARA YANG SAMA :

$$VSWR_{OUT} = \frac{1+|\Gamma b|}{1-|\Gamma b|} \rightarrow |\Gamma b| = \left|\frac{\Gamma_{OUT} - \Gamma_L^*}{1-\Gamma_{OUT}.\Gamma_L}\right|$$

Lingkaran $VSWR_{OUT}$ konstan :

titik pusat lingkaran :

$$Cvo = \frac{\Gamma_{OUT}^*.(1-|\Gamma b|^2)}{1-|\Gamma b.\Gamma_{OUT}|^2}$$

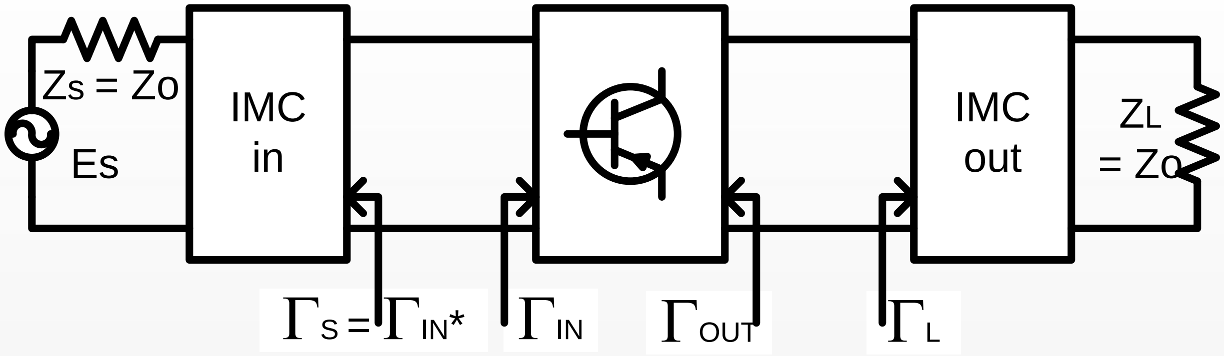
jari-jari lingkaran :

$$Rvo = \frac{|\Gamma_b|.(1-|\Gamma_{OUT}|^2)}{1-|\Gamma_b.\Gamma_{OUT}|^2}$$

Small-Signal RF Amplifier

PERANCANGAN PENGUAT DENGAN NOISE FIGURE DITENTUKAN:

Lingkaran Noise figure/Faktor Derau Konstan:



$$F = F_{MIN} + \frac{4 r_n \left|\Gamma_S - \Gamma_{opt}\right|^2}{\left(1 - \left|\Gamma_S\right|^2\right)\left|1 + \Gamma_{opt}\right|^2}$$

dimana: F_{MIN} = faktor derau minimum komponen aktif

r_n = equivalent normalized noise resistance (= R_N/Z_O)

Γ_{opt} = koefisien refleksi sumber yang dapat menghasilkan faktor derau minimum

Small-Signal RF Amplifier

Ambil satu harga F = Fi

$$\frac{\left|\Gamma_S - \Gamma_{opt}\right|^2}{1 - \left|\Gamma_S\right|^2} = \frac{F_i - F_{MIN}}{4\, r_n} . \left|1 + \Gamma_{opt}\right|^2$$

$$N_i = \frac{F_i - F_{MIN}}{4\, r_n} . \left|1 + \Gamma_{opt}\right|^2 = \text{konstan} \quad \Rightarrow \quad N_i = \frac{\left|\Gamma_S - \Gamma_{opt}\right|^2}{1 - \left|\Gamma_S\right|^2}$$

$(\Gamma_S - \Gamma_{opt}).(\Gamma_S^* - \Gamma_{opt}) = N_i – N_i\, |\Gamma_S|^2$

$|\Gamma_S|^2.(1 + N_i) – 2Re[\Gamma_S.\Gamma_{opt}^*] + |\Gamma_{opt}|^2 = N_i$

$$\left|\Gamma_S\right|^2 - \frac{2}{1+N_i} Re\left[\Gamma_S.\Gamma_{opt}^*\right] + \frac{\left|\Gamma_{opt}\right|^2}{1+N_i} = \frac{N_i}{1+N_i}$$

→ merupakan persamaan lingkaran di bidang Γ_S dan dapat ditulis menjadi :

$$\left|\Gamma_S - \frac{\Gamma_{opt}}{1+N_i}\right|^2 = \frac{N_i^2 + N_i\left(1 - \left|\Gamma_{opt}\right|^2\right)}{\left(1+N_i\right)^2}$$

untuk Ni tertentu, diperoleh lingkaran faktor derau Fi konstan.

Lingkaran faktor derau:

$$C_{Fi} = \frac{\Gamma_{opt}}{1+N_i}$$

$$R_{Fi} = \frac{1}{N_i + 1}\sqrt{N_i^2 + N_i\left(1 - \left|\Gamma_{opt}\right|^2\right)}$$

Small-Signal RF Amplifier

LATIHAN SOAL

Suatu transistor dengan parameter S sebagai berikut :

$S_{11} = 0,552 \angle 169^o$ $F_{MIN} = 2,5dB$

$S_{12} = 0,049 \angle 23^o$ $\Gamma opt = 0,475 \angle 166^o$

$S_{21} = 1,681 \angle 26^o$ $Rn = 3.5\,\Omega$

$S_{22} = 0,839 \angle -67^o$

Tentukan lingkaran faktor derau **Fi = 2,8dB** konstan

Solusi :

$$Ni = \frac{Fi - F_{MIN}}{4\,rn} . \left|1 + \Gamma opt\right|^2$$

$$rn = \frac{Rn}{Z_o} = \frac{3,5}{50} = 0,07$$

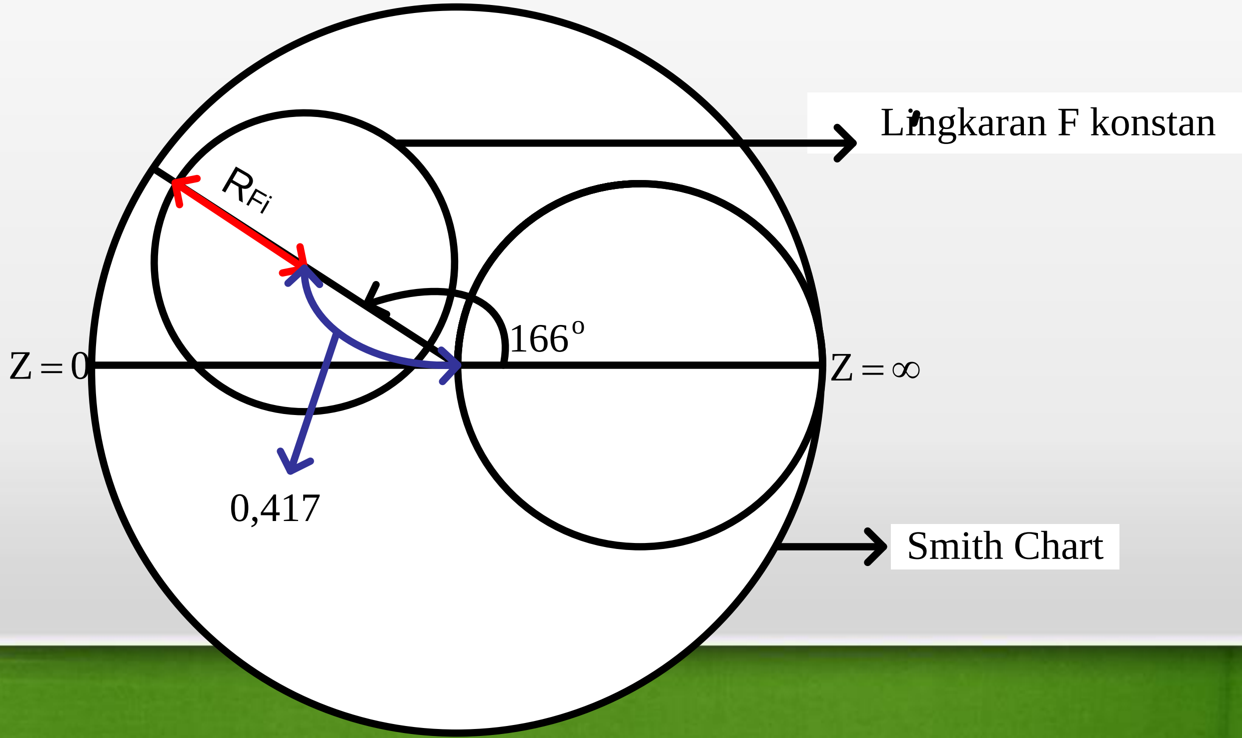
Fi = 2,8dB = 1,905

F_{MIN} = 2,5 dB = 1,778

→ Ni = 0,1378

$$C_{Fi} = \frac{\Gamma opt}{1 + Ni} = 0,417 \angle 166^o$$

R_{Fi} = 0,312




THANK
YOU