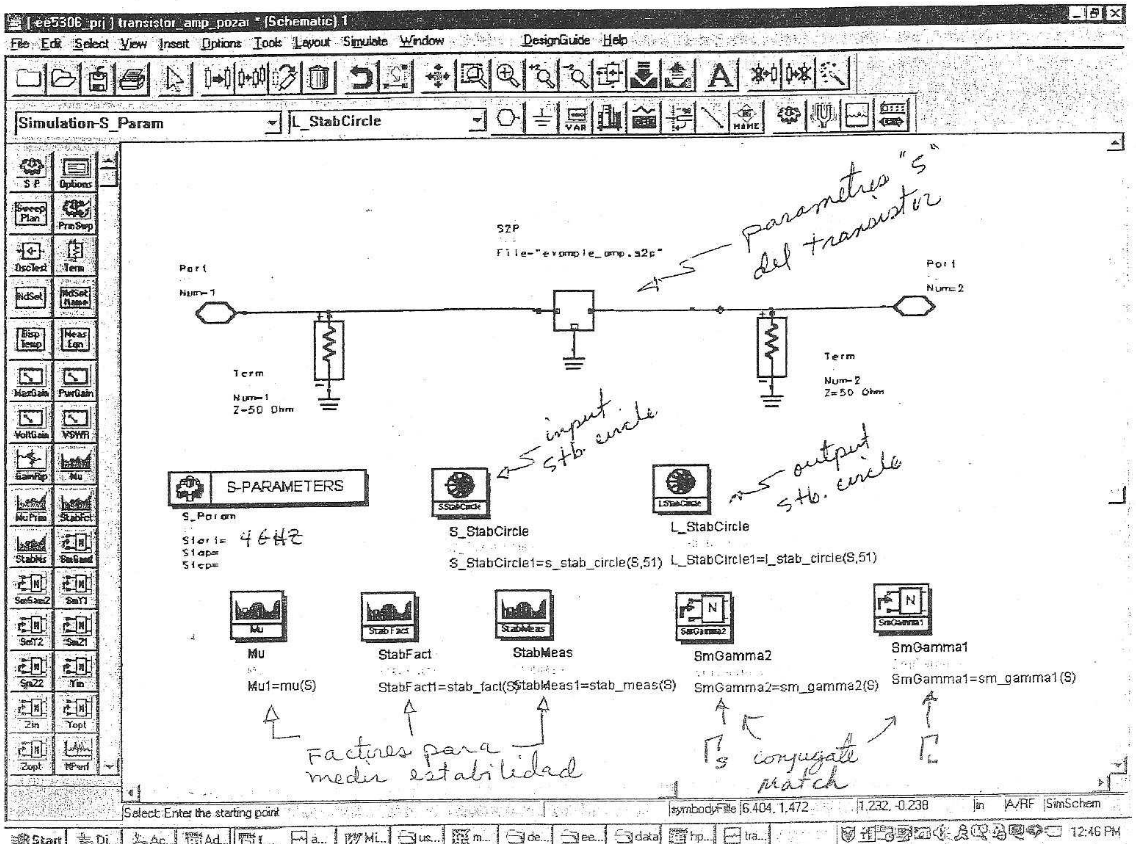
Microondas


```
r
!
# GHz S MA R 50
!f GHz   S11        S21        S12        S22
!        MAG   ANG  MAG   ANG  MAG  ANG   MAG  ANG
3 0      0.8   89   2.86  99.  .03  56    .76  -41
4 0      .72   -116 2.86  76   .03  57    .73  -54
5 0      .66   -142 2.86  54   .03  62    .72  -68
```

File: example_amp.S2P debe colocarlo en directorio DATA C:\AMP_prj\DATA\



stab_Meas ⇒ $b = 1 + |S_{11}|^2 - |S_{22}|^2 - |S_{11}S_{22} - S_{12}S_{21}|^2$

stab_Fact ⇒ K (a) Si $K > 1$ y $b > 0$

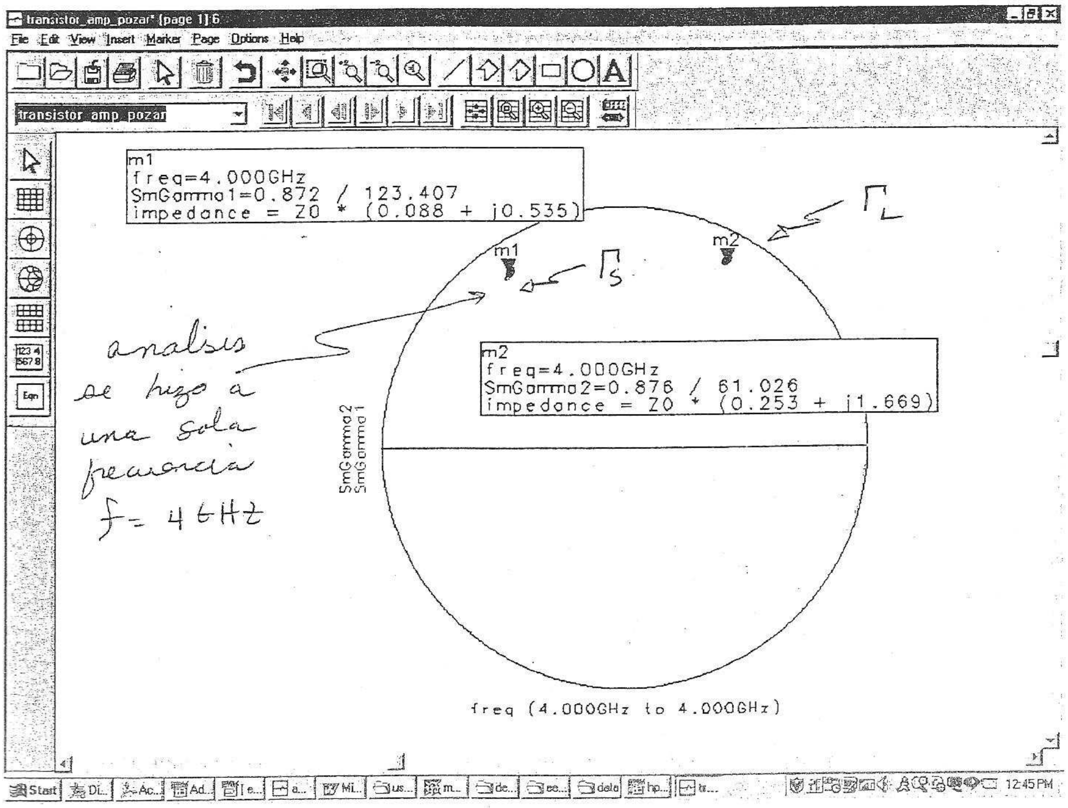
∴ estabilidad sin condición

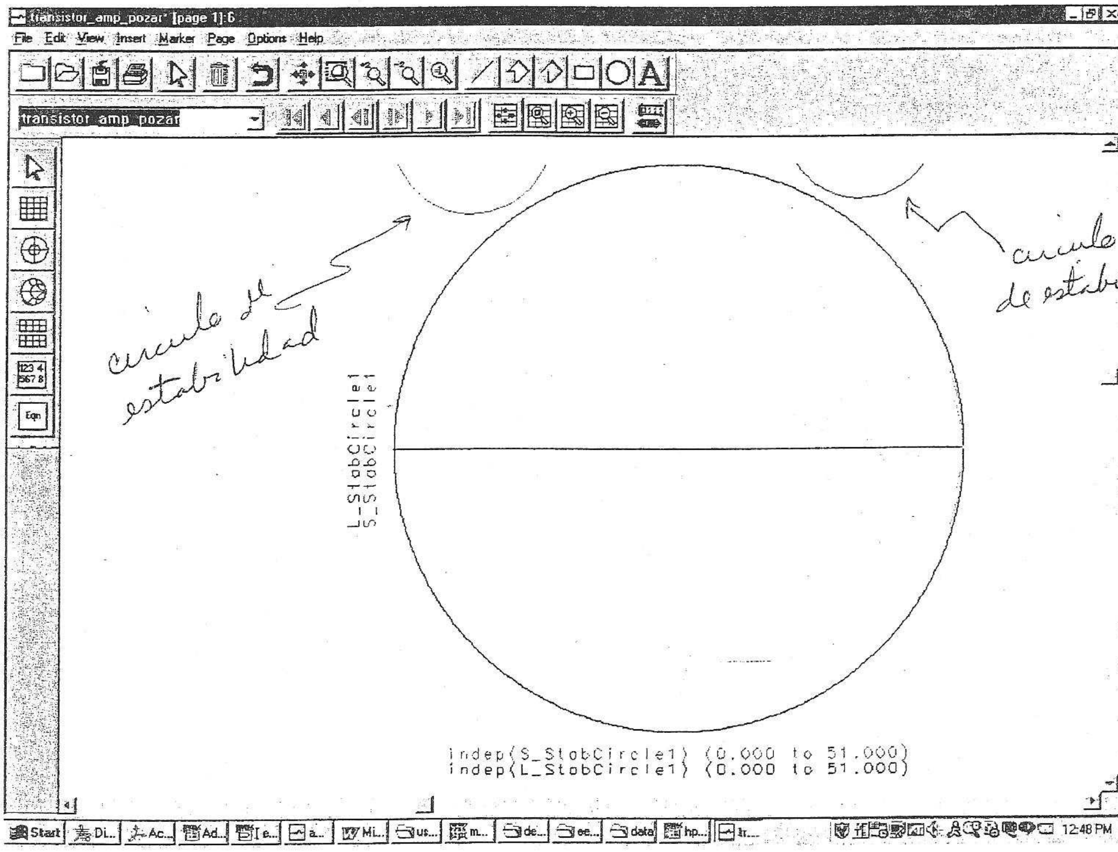
(b) mu ⇒ $\mu > 1$

∴ estabilidad sin condición

for conjugate match

freq	Mu1	StabFact1	StabMeas1	SmGamma1	SmGamma2
4.000GHz	1.040	1.195	0.748	0.872 / 123.407	0.876 / 61.026
$\mu > 1$		$K > 1$	$b > 0$	Γ_S	Γ_L





notar q. ambos circulos estan fuera del Smith Chart. ∴ estabilidad sin condicion para $S_{11} < 1$ y $S_{22} < 1$

The Complete Smith Chart

Black Magic Design

— diseñar "Matching Network"

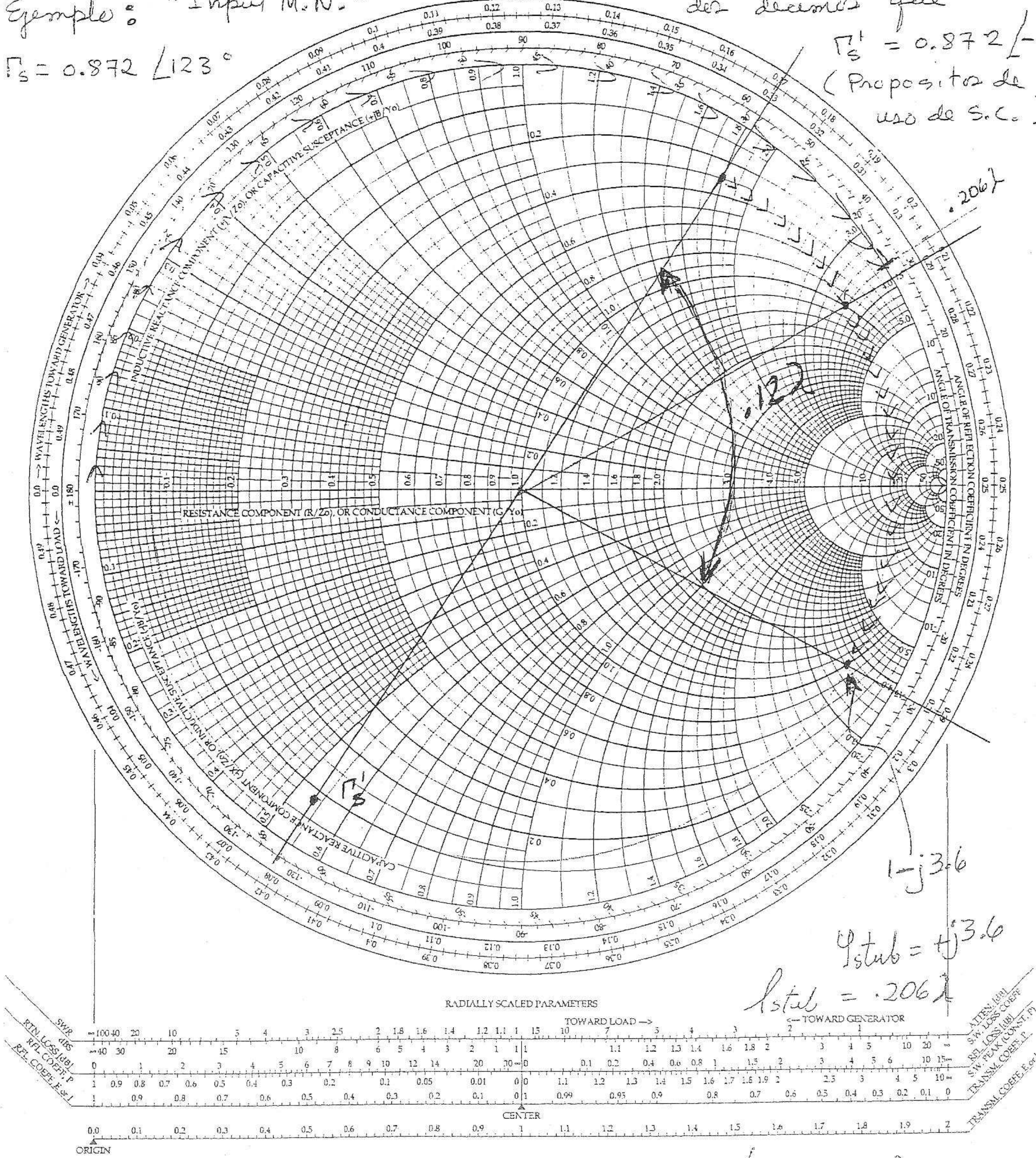
Ejemplo: "Input M.N."

$\Gamma_S = 0.872 \angle 123°$

Truco: Para usar S.C. como estamos acostumbrados decimos que

$\Gamma_S' = 0.872 \angle -12$

(Propositos de uso de S.C.)



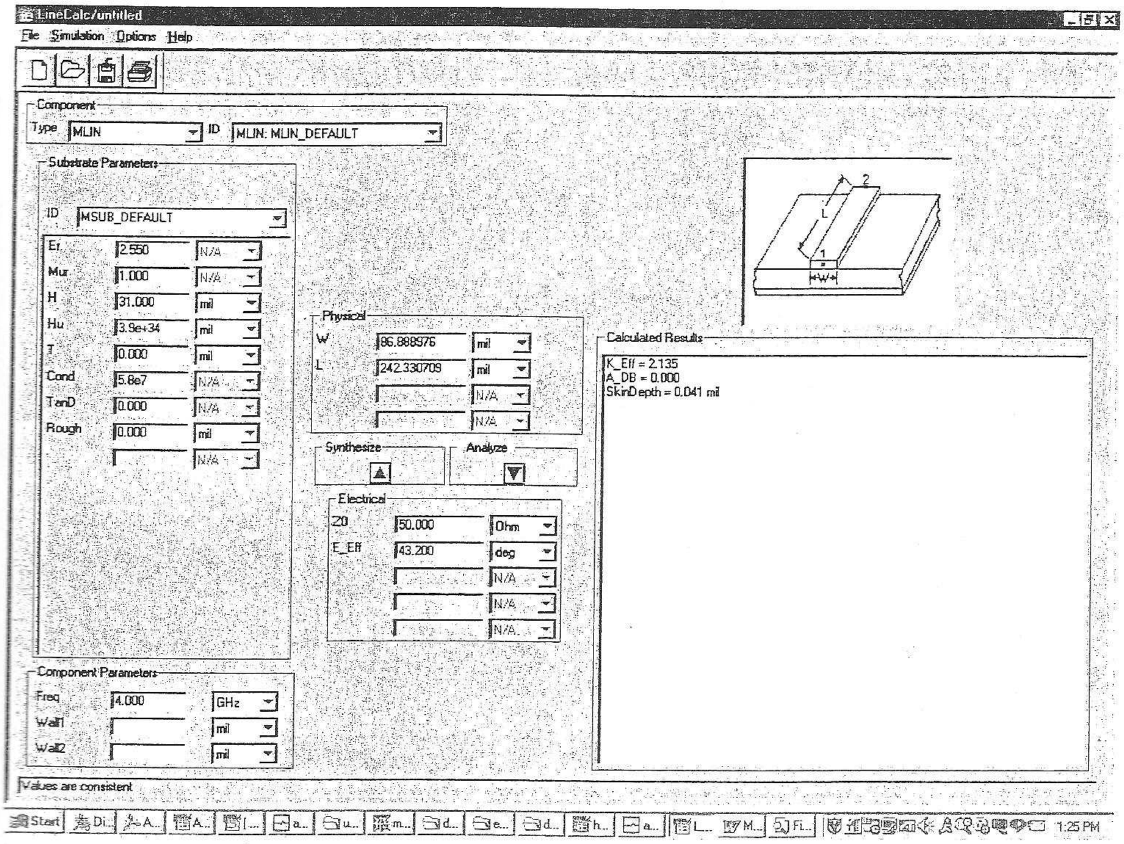
1−j3.6

$y_{stub} = +j3.6$

$l_{stub} = .206\lambda$

$d_{línea} = .12\lambda$

Uso Linecalc para determinar dimensiones de líneas de microcinta.

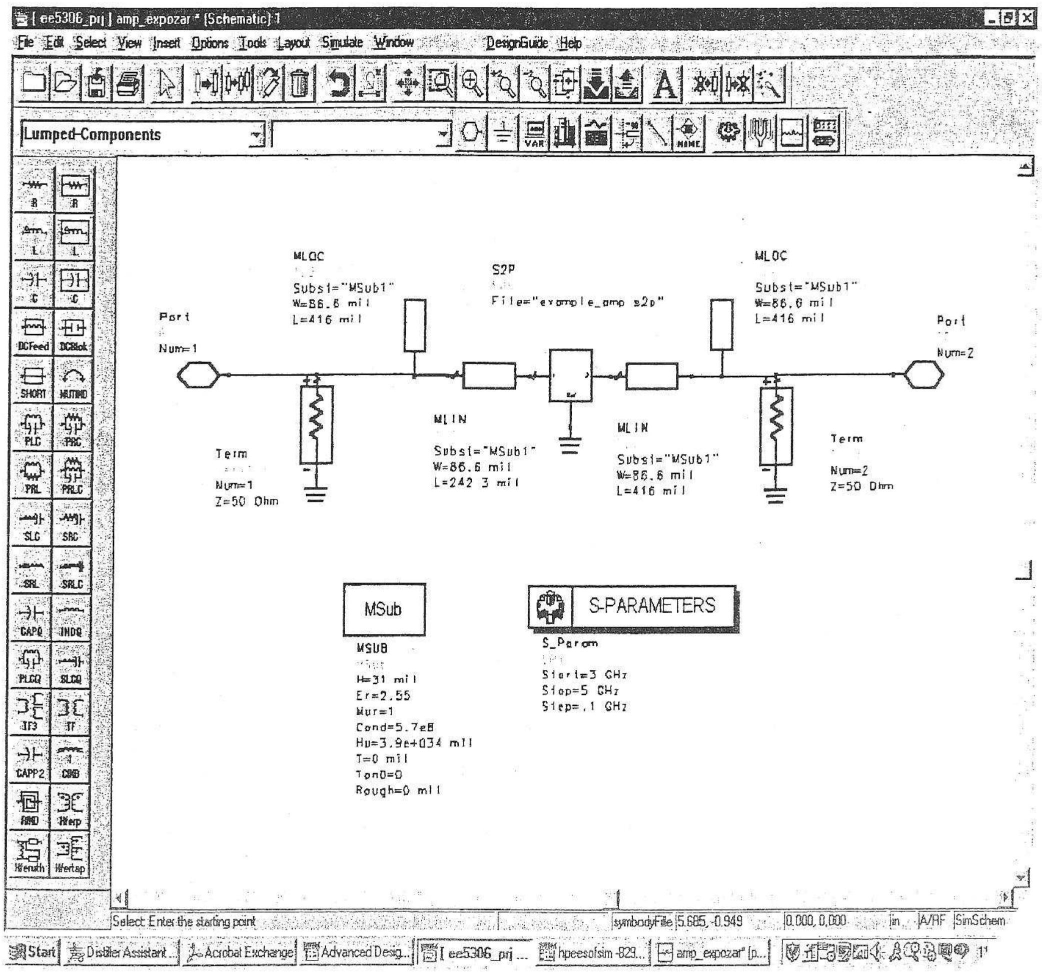


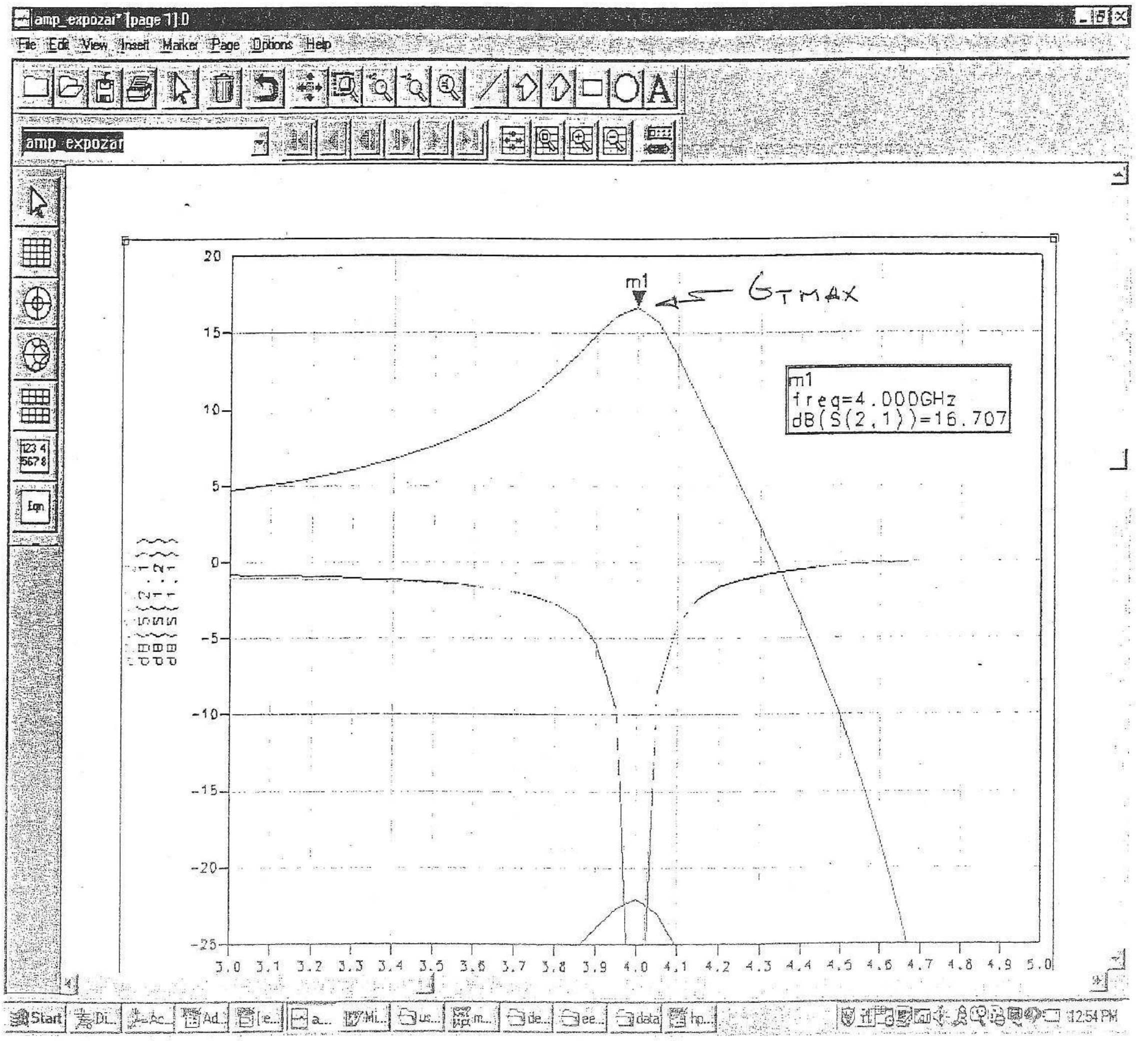
Por ejemplo: $0.120\lambda = \theta = 0.120(360) = 43.2^\circ$

para líneas de 50Ω y $\theta = 43.2$

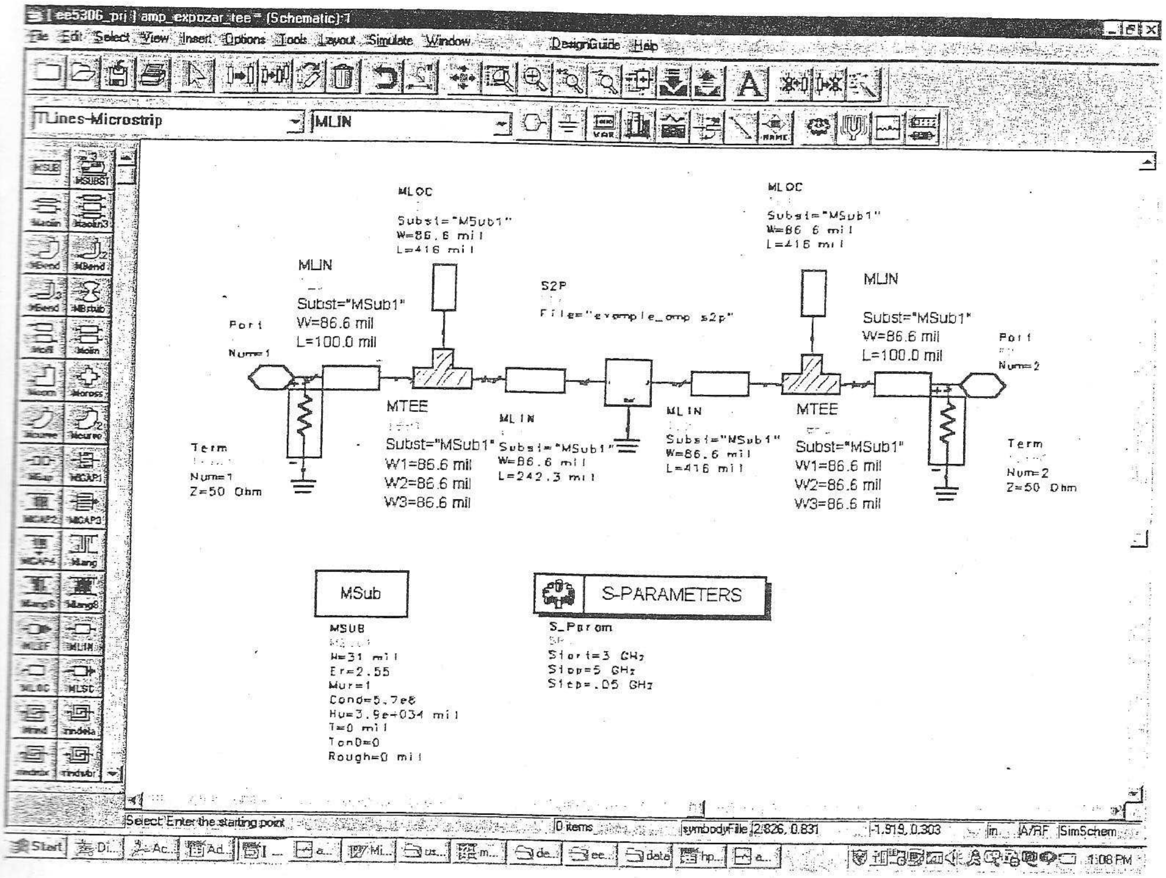
$w = 86.9$ mils $\quad l = 242.3$ mils

Asumir $\epsilon_r = 2.55$ $\quad h = 31$ mils $\quad F = 4$ GHz

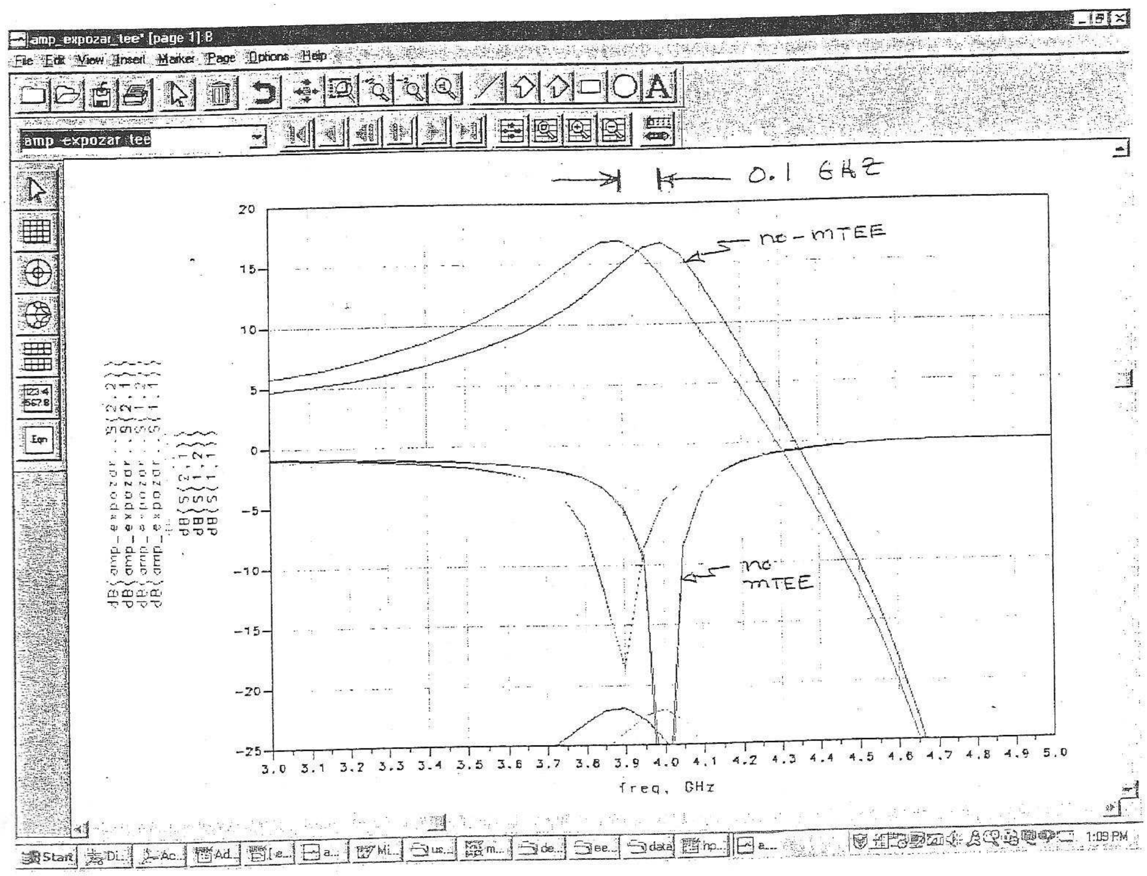

[ee5306_prj] amp_expozar * (Schematic):1
File Edit Select View Insert Options Tools Layout Simulate Window DesignGuide Help
Lumped-Components
MLOC
Subst="MSub1"
W=86.6 mil
L=416 mil
S2P
File="example_amp s2p"
MLOC
Subst="MSub1"
W=86.6 mil
L=416 mil
Port
Num=1
Port
Num=2
MLIN
Subst="MSub1"
W=86.6 mil
L=242 3 mil
MLIN
Subst="MSub1"
W=86.6 mil
L=416 mil
Term
Num=1
Z=50 Ohm
Term
Num=2
Z=50 Ohm
MSub
MSUB
H=31 mil
Er=2.55
Mur=1
Cond=5.7e8
Hu=3.9e+034 mil
T=0 mil
TanD=0
Rough=0 mil
S-PARAMETERS
S_Param
Start=3 GHz
Stop=5 GHz
Step=.1 GHz
Select: Enter the starting point
symbodyFile 5.685, -0.949
0.000, 0.000
in
A/RF
SimSchem
Start
Distiller Assistant
Acrobat Exchange
Advanced Desig...
[ee5306_prj ...
hpeesofsim -829...
amp_expozar* [p...



amp_expozar* [page 1]:D
File Edit View Insert Marker Page Options Help
amp_expozar
m1
GTMAX
m1
freq=4.000GHz
dB(S(2,1))=16.707
dB(S(2,1))
dB(S(1,1))
dB(S(2,2))
20
15
10
5
0
-5
-10
-15
-20
-25
3.0 3.1 3.2 3.3 3.4 3.5 3.6 3.7 3.8 3.9 4.0 4.1 4.2 4.3 4.4 4.5 4.6 4.7 4.8 4.9 5.0
Start
12:54 PM


ee5306_prj amp_expozar_tee* (Schematic):1
File Edit Select View Insert Options Tools Layout Simulate Window DesignGuide Help
TLines-Microstrip
MLIN
MLOC
Subst="MSub1"
W=86.6 mil
L=416 mil
MLIN
Subst="MSub1"
W=86.6 mil
L=100.0 mil
S2P
File="example_amp.s2p"
Port
Num=1
Port
Num=2
MTEE
Subst="MSub1"
W1=86.6 mil
W2=86.6 mil
W3=86.6 mil
MLIN
Subst="MSub1"
W=86.6 mil
L=242.3 mil
MLIN
Subst="MSub1"
W=86.6 mil
L=416 mil
Term
Num=1
Z=50 Ohm
Term
Num=2
Z=50 Ohm
MSub
MSUB
H=31 mil
Er=2.55
Mur=1
Cond=5.7e8
Hu=3.9e+034 mil
T=0 mil
TanD=0
Rough=0 mil
S-PARAMETERS
S_Param
Start=3 GHz
Stop=5 GHz
Step=.05 GHz
Select: Enter the starting point
0 items
1:08 PM

Resultados de amplificador con MTEE
Desplazamiento en frecuencia de 0.1 GHz



En general

$$G_T = \frac{1-|\Gamma_S|^2}{|1-\Gamma_S\Gamma_{in}|^2}\,|S_{21}|^2\,\frac{1-|\Gamma_L|^2}{|1-S_{22}\Gamma_L|^2}$$

$$\Gamma_{in} = S_{11} + \frac{S_{12}S_{21}\Gamma_L}{1-S_{22}\Gamma_L} \qquad \Gamma_{out} = S_{22} + \frac{S_{12}S_{21}\Gamma_S}{1-S_{11}\Gamma_S}$$

Diseño para Ganancia Especifica:

$$G_T = G_S \quad G_0 \quad G_L$$

$G_S \rightarrow \dfrac{1-|\Gamma_S|^2}{|1-\Gamma_{in}\Gamma_S|^2}$ ← controlo con "Matching Networks" → $\dfrac{1-|\Gamma_L|^2}{|1-S_{22}\Gamma_L|^2} \leftarrow G_L$

caso unilateral: $(S_{12}=0)$ $\quad \Gamma_{in} = S_{11} \qquad \Gamma_{out} = S_{22}$

(Notar que si S_{11} y S_{22} son <1, esta condicion es suficiente para estabilidad sin condicion en caso unilateral).

Ganancia maxima: $\Gamma_S = \Gamma_{in}^* = S_{11}^*$

$\Gamma_L = S_{22}^*$

<u>caso unilateral</u> $(S_{12} = 0)$

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

$$G_{SU} = \frac{1 - |\Gamma_S|^2}{|1 - S_{11}\Gamma_S|^2} \qquad G_{LU} = \frac{1 - |\Gamma_L|^2}{|1 - S_{22}\Gamma_L|^2}$$

Si $S_{12} \neq 0$ todavía puedo asumir caso unilateral despreciando S_{12}. Necesito medida del error.

$$\frac{1}{(1+U)^2} < \frac{G_T}{G_{TU}} < \frac{1}{(1-U)^2}$$

donde $U = \dfrac{|S_{12}|\,|S_{21}|\,|S_{11}|\,|S_{22}|}{(1-|S_{11}|)^2 \, (1-|S_{22}|^2)}$ ⟹ Figura de mérito

<u>Ejemplo</u>:

$S_{11} = 0.6\angle{-60^\circ}$ $\quad S_{21} = 1.9\angle 81^\circ$

$S_{12} = 0.05\angle 26^\circ$ $\quad S_{22} = 0.5\angle{-60^\circ}$

$$0.891 < \frac{G_T}{G_{TU}} < 1.130$$

$$-0.5 < G_T - G_{TU} < 0.53 \text{ dB}$$

Puedo asumir caso unilateral si el error es una fracción de 1 dB.

[S]ustituyo en G_{TU} ; $\Gamma_S = S_{11}^*$ y $\Gamma_L = S_{22}^*$

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

$$G_{SU\,max} = \frac{1}{1-|S_{11}|^2} \qquad G_{LU\,max} = \frac{1}{1-|S_{22}|^2}$$

Definimos:

$$g_s = \frac{G_{SU}}{G_{SU\,max}} \qquad g_l = \frac{G_{LU}}{G_{LU\,max}}$$

Resultan familias de circulos en plano de Γ_S y Γ_L. Usar Smith Chart.

$$C_S = \frac{g_s S_{11}^*}{1-(1-g_s)|S_{11}|^2} \qquad R_S = \frac{\sqrt{1-g_s}\,(1-|S_{11}|^2)}{1-(1-g_s)|S_{11}|^2}$$

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

[E]j Libro:

Para $f = 4$ GHz.

$S_{11} = 0.75 \angle -120°$ $\quad S_{21} = 2.8 \angle 100°$

$S_{12} = 0$ $\quad S_{22} = 0.6 \angle -70°$

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

$$G_{L\,max} = \frac{1}{1-|S_{22}|^2} = 1.56 = 1.9\ dB$$

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

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

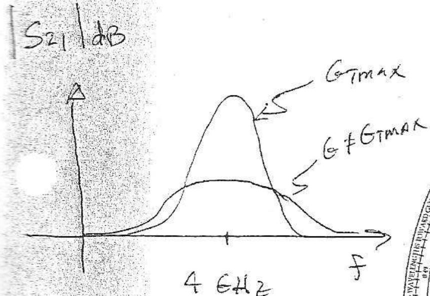
Thus we have 2.5 dB more available gain than is required by the specifications.

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

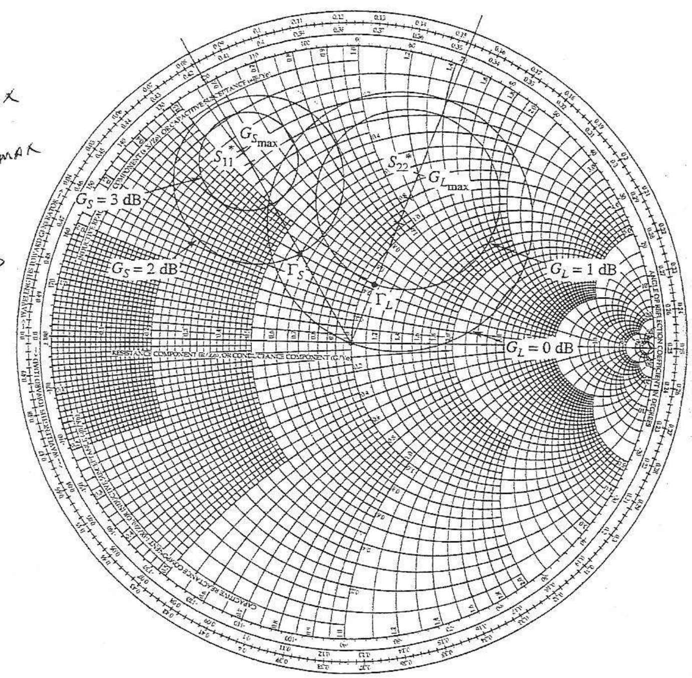
$G_S = 3$ dB	$g_S = 0.875$	$C_S = 0.706\angle 120°$	$R_S = 0.166$
$G_S = 2$ dB	$g_S = 0.691$	$C_S = 0.627\angle 120°$	$R_S = 0.294$
$G_L = 1$ dB	$g_L = 0.806$	$C_L = 0.520\angle 70°$	$R_L = 0.303$
$G_L = 0$ dB	$g_L = 0.640$	$C_L = 0.440\angle 70°$	$R_L = 0.440$

$g_s = \frac{G_{su}}{G_{sumax}} = \frac{2}{2.29} = .875$

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



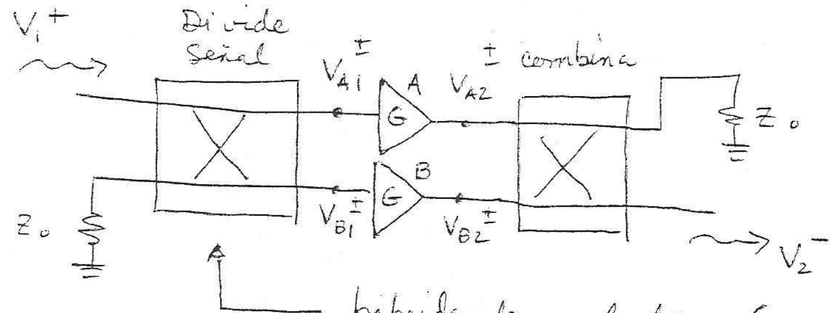
- Aumento ancho de banda
- Se degrada S11 y S22



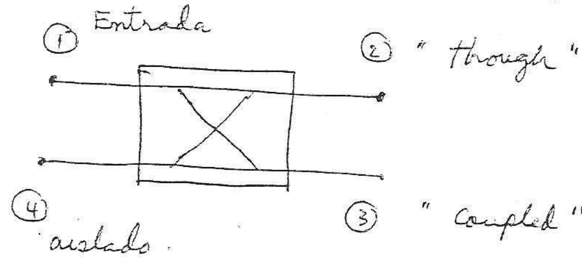
(a)

FIGURE 11.8 Circuit design and frequency response for the transistor amplifier of Example 11.– (a) Constant gain circles.

Amplificador balanceado – puedo lograr buen ancho de banda sin sacrificar S_{11} ó S_{22}.



híbrido de cuadratura (3 dB y 90°)



$$[S] = \frac{1}{\sqrt{2}} \begin{bmatrix} 0 & 1 & -j & 0 \\ 1 & 0 & 0 & -j \\ -j & 0 & 0 & 1 \\ 0 & -j & 1 & 0 \end{bmatrix}$$

– "branch line coupler"
– "coupled " " "
– "Lange coupler"
– "Wilkinson Divider"

$$V_{A1}^+ = \frac{1}{\sqrt{2}} V_1^+ \qquad V_{B1}^+ = \frac{-j}{\sqrt{2}} V_1^+$$

$$V_2^- = \frac{-j}{\sqrt{2}} V_{A2}^+ + \frac{1}{\sqrt{2}} V_{B2}^+$$

pero $V_{A2}^+ = G_A V_{A1}^+$ $\qquad V_{B2}^+ = G_B V_{B1}^+$

$$V_2^- = \frac{-j}{\sqrt{2}} \left(G_A \frac{1}{\sqrt{2}} V_1^+ \right) + \frac{1}{\sqrt{2}} G_B \left(\frac{-j}{\sqrt{2}} V_1^+ \right)$$

$$V_2^- = \frac{-j}{2} V_1^+ \left(G_A + G_B \right)$$

$$S_{21} = \frac{V_2^-}{V_1^+} = \frac{-j}{2}\left(G_A + G_B\right)$$

$$V_1^- = \frac{1}{\sqrt{2}} V_{A1}^- + \frac{-j}{\sqrt{2}} V_{B1}^- \qquad \frac{V_{A1}^-}{V_{A1}^+} = \Gamma_A$$

$$V_1^- = \frac{1}{\sqrt{2}}\left(\Gamma_A V_{A1}^+\right) + \frac{-j}{\sqrt{2}}\left(\Gamma_B V_{B1}^+\right) \qquad \frac{V_{B1}^-}{V_{B1}^+} = \Gamma_B$$

$$= \frac{1}{\sqrt{2}}\Gamma_A\left(\frac{1}{\sqrt{2}}V_1^+\right) + \frac{-j}{\sqrt{2}}\Gamma_B\left(\frac{-j}{\sqrt{2}}V_1^+\right) = \frac{1}{2}V_1^+\left(\Gamma_A - \Gamma_B\right)$$

$$S_{11} = \frac{V_1^-}{V_1^+} = \frac{1}{2}\left(\Gamma_A - \Gamma_B\right) \qquad \left(S_{11} = 0 \text{ si son identicos}\right)$$

- Ancho de banda limitado por "coupler"
- Si falla un amplificador, todavia hay ganancia.
- desventajas: tamaño, consume mas potencia, dos transistores.