TEMA 4: CIRCUITOS DE CONTROL Y CONMUTACIÓN

1.- INTRODUCCIÓN

Sistemas típicos:

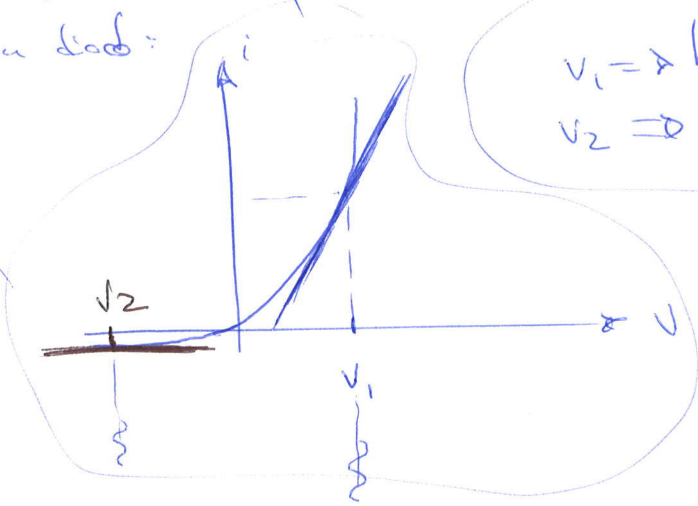
- Conmutadores: desvían la RF de un sitio a otro
- Atenuadores variables
- Desfasadores variables

Dispositivo usado desde siempre → diodo pin

✓ Velocidad de respuesta alta

✓ Baja capacidad parásita

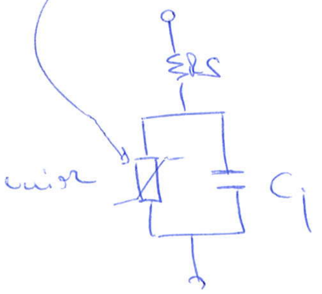
Curva típica de un diodo:



$V_1 \Rightarrow$ baja impedancia

$V_2 \Rightarrow$ alta impedancia

(bombeo discreto)



• baja impedancia →

(muy pequeño)

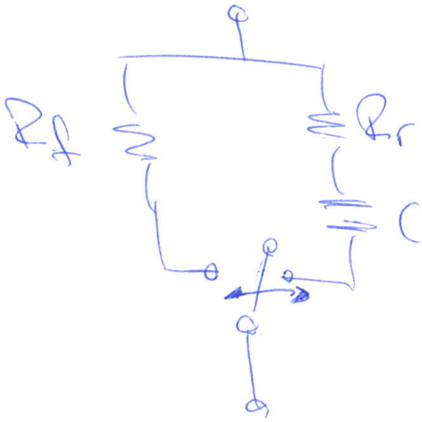
• alta impedancia →

C_j ⇒ sigue siendo alta impedancia

- Modelo que vamos a usar:

Rr: resistencia en inversa

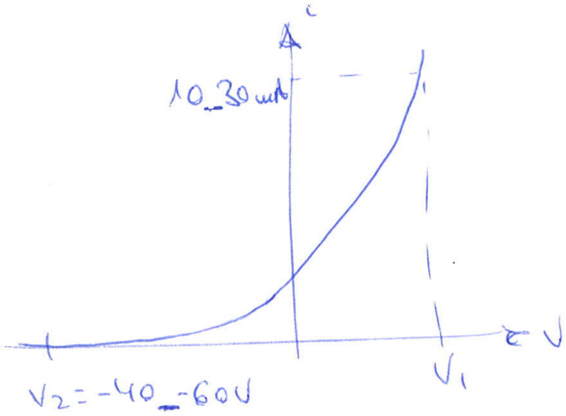
Rf: resistencia en directa



Polarización inversa → 40_60 V

Polarización directa → I_{pol} = 10_30 mA

Rf cambia mucho en la zona directa (→ atenuadores variables)



CONMUTADOR

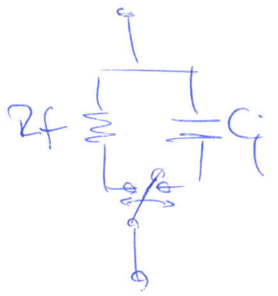
Valores típicos:

$R_r = 5\ \Omega$ ← muchas veces la despreciamos respecto a C_i

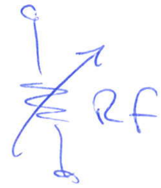
$C_i = 0{,}1\ pF$

$R_f = 1\ \Omega$

CONMUTADOR:

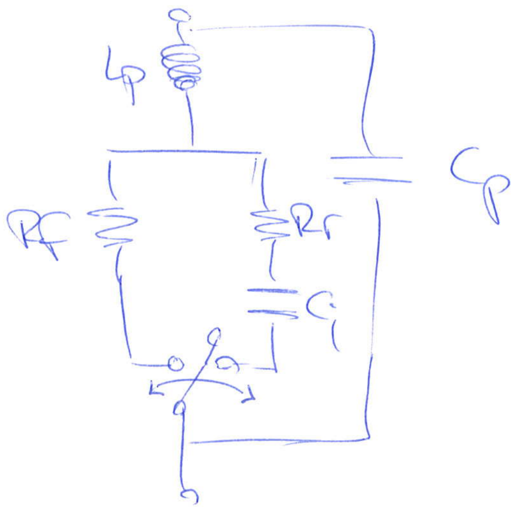


RESISTENCIA VARIABLE:



$$R_f \simeq \frac{K}{I_{pol}}$$

Diodo encapsulado:



Frecuencia de corte:

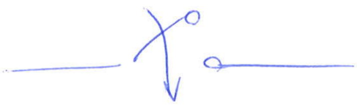
$$\boxed{f_{c_s} = \frac{1}{2\pi C_i \sqrt{R_f R_r}}}$$

(sin encapsular)

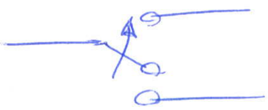
2.- CONMUTADORES

2.1.- CLASIFICACIÓN

- SPST



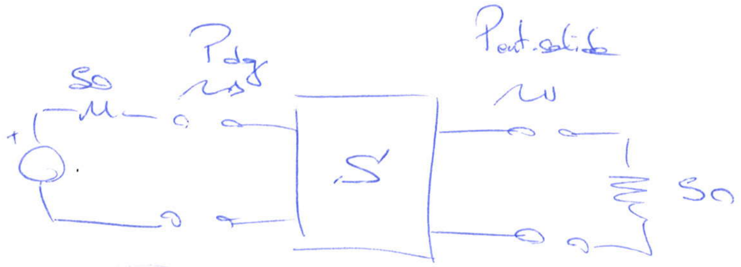
- SPDT



Parámetros:
- Aislamiento (OFF)
- Pérdidas de inserción (ON)

$$A = \left.\frac{P_{dg}}{P_{ent.\,salida}}\right|_{OFF}$$

$$L_I = \left.\frac{P_{dg}}{P_{ent.\,salida}}\right|_{ON}$$



S_{ON}
S_{OFF}

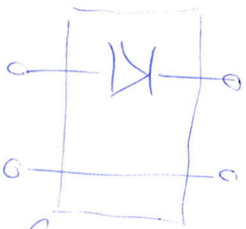
$$|S_{21}^{ON}|^2 = L_I^{-1} \qquad |S_{21}^{OFF}|^2 = A^{-1}$$

Nos pueden especificar también ROE_{IN} o ROE_{OUT}, que serían diferentes en ON y OFF

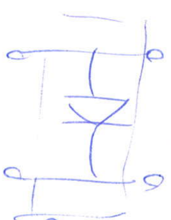
→ $S_{11}|_{ON}$, $S_{11}|_{OFF}$

→ $S_{22}|_{ON}$, $S_{22}|_{OFF}$

2.2 - SPST con un diodo



Configuración serie

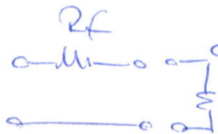


Configuración paralelo

'reverse' ↑ diodo ↓ 'forward'

'reverse' → 

estado OFF

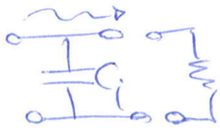
'forward' → 

estado ON

'forward' ↑ diodo ↓ 'reverse'

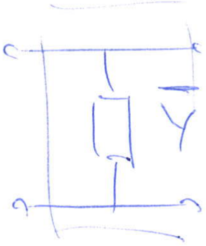
'forward' → 

(no adaptado) estado OFF

'reverse' → 

estado ON

PARALELO:



$$S' = \frac{1}{2+\bar{Y}} \begin{bmatrix} -\bar{Y} & 2 \\ 2 & -\bar{Y} \end{bmatrix}$$

$$\bar{Y} = \frac{Y}{Y_0}$$

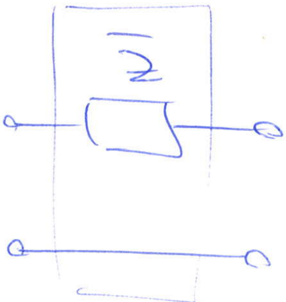
$$\boxed{S_{21} = \frac{2}{2+\bar{Y}}} = \frac{1}{1+\bar{Y}/2}$$

$$\boxed{A = \left(1+\frac{Z_0}{2R_f}\right)^2} \qquad \boxed{L_I = 1+\left(\frac{\omega C_j Z_0}{2}\right)^2}$$

Constante con la frecuencia

Se degrada con la frecuencia

SERIE:



$$S' = \frac{1}{2+\bar{Z}} \begin{bmatrix} \bar{Z} & 2 \\ 2 & \bar{Z} \end{bmatrix}$$

$$\boxed{S_{21} = \frac{2}{2+\bar{Z}}} = \frac{1}{1+\bar{Z}/2}$$

$$\boxed{A = 1+\left(\frac{1}{2\omega C_j Z_0}\right)^2} \qquad \boxed{L_I = \left(1+\frac{R_f}{2Z_0}\right)^2}$$

En muchos casos es más importante el aislamiento que las pérdidas de inserción

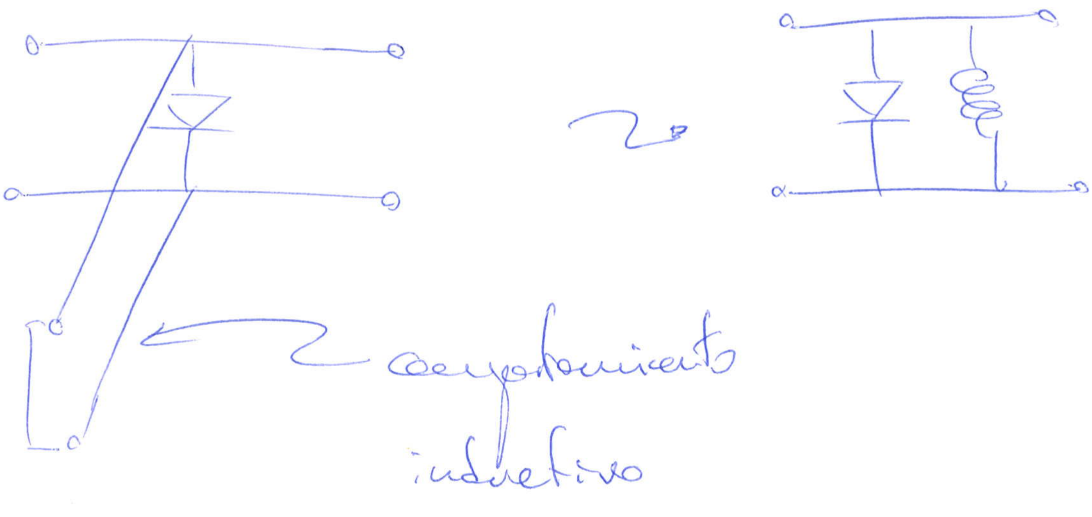
=> mejor configuración paralelo

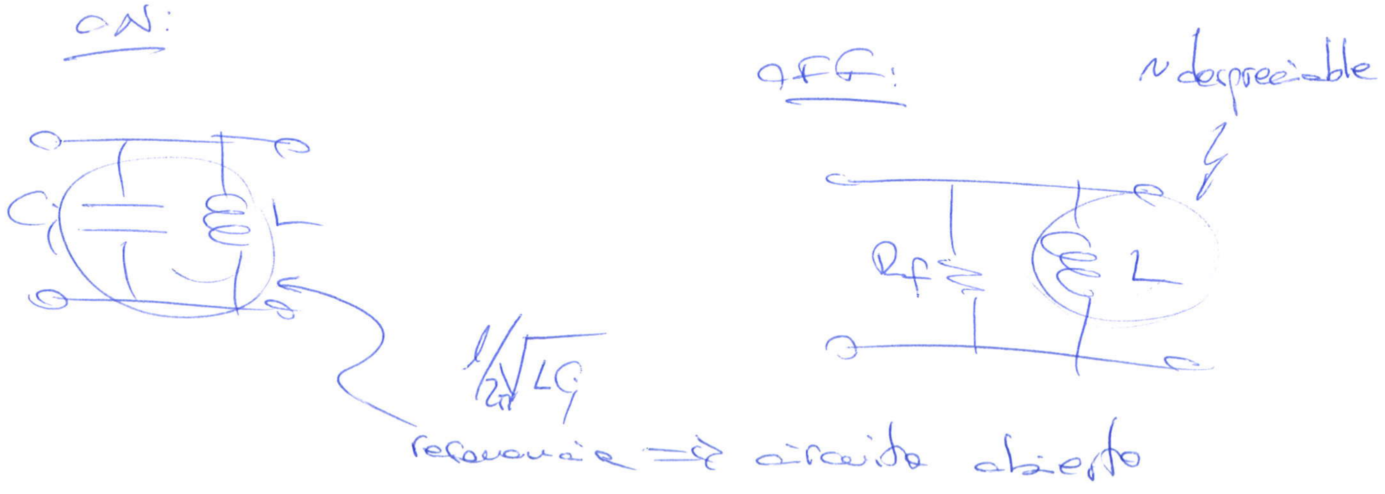
Problema: montaje físico y parásito asociado peor que el serie

- Disminuir las pérdidas de inserción (paralelo):

-> Sintonizar => banda estrecha

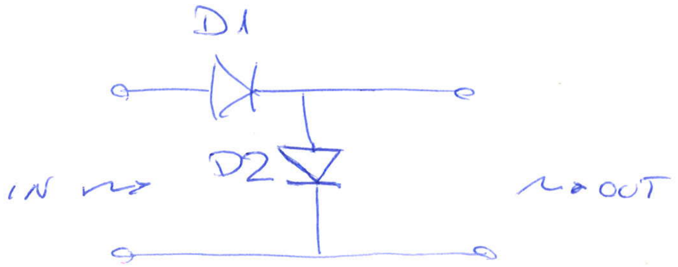
(Compensación de C_j)





2.3.- CONMUTADOR SPST CON 2 DIODOS

✓ Aumenta el aislamiento



D1 directa
D2 inversa } ON

D1 inversa
D2 directa } OFF

Números orientativos: MA-47899 → $f = 6{,}37$ GHz

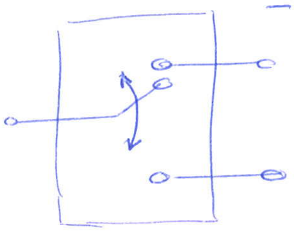
Configuración	LI	A
2 diodos serie/paralelo	0,11 dB	20,17 dB
serie	0,15 dB	8,29 dB
paralelo	0,06 dB	7,52 dB

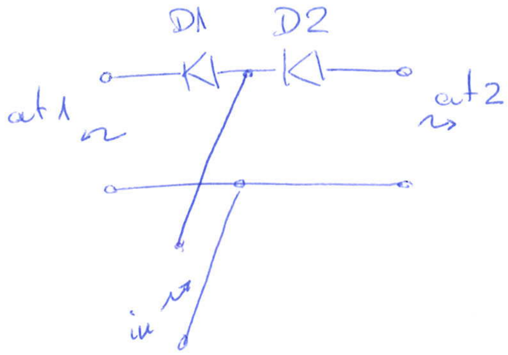
diodos en chip (sin encapsular)

A ↑ ⇒ concatenar etapas serie/paralelo
(~70-80 dB)

2.4.- CONMUTADOR SPDT (*4.5*)

- Serie:





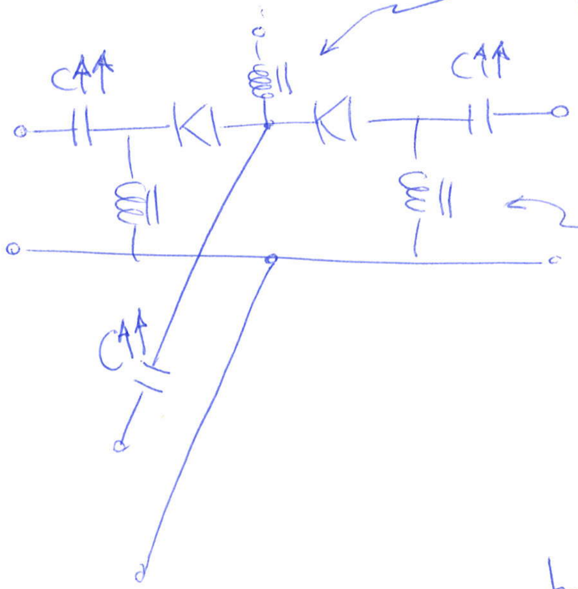
D1 Directa
D2 inversa } → out 1

D1 Inversa
D2 Directa } → out 2

Posible circuito de polarización:

- Serie:

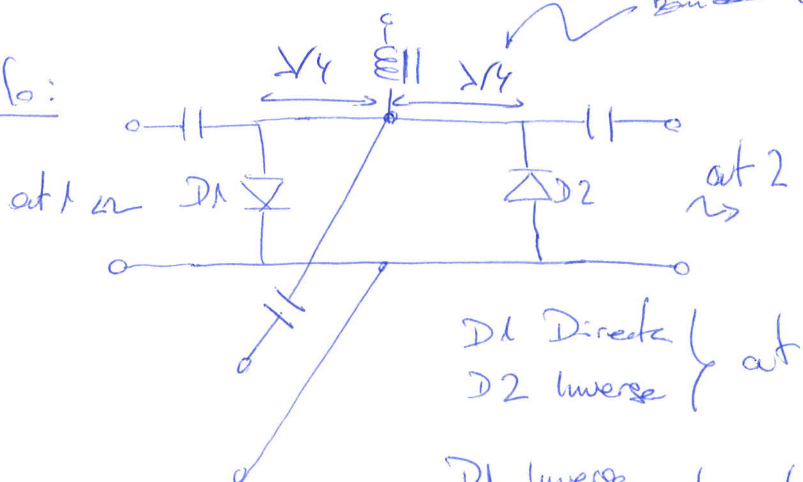
choque de radiofrecuencia



retorno de continua

banda estrecha

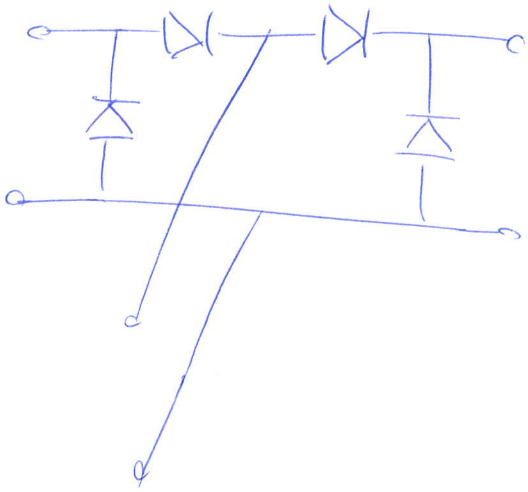
- Paralelo:



D1 Directa
D2 Inversa } out 2

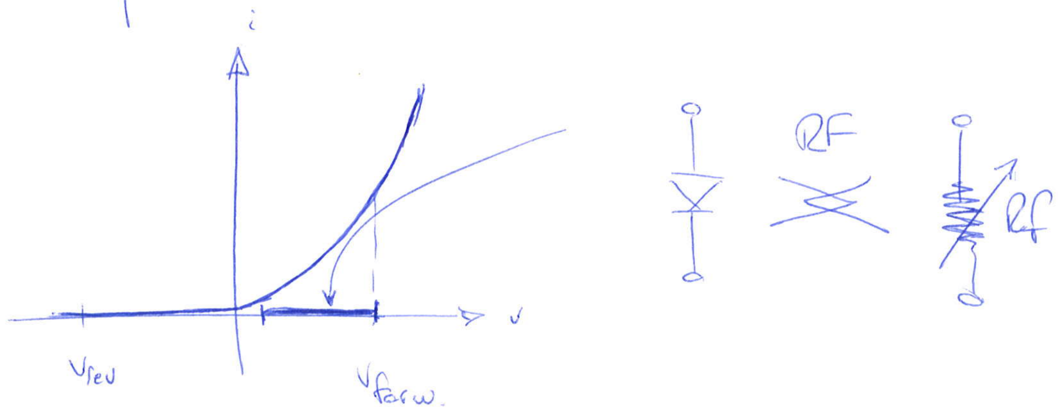
D1 Inversa
D2 Directa } out 1

Mejor comportamiento: serie-paralelo



3.- ATENUADORES VARIABLES

Diodo siempre en directa => resistencia variable



$$I = I_S\left(e^{\alpha V} - 1\right) \simeq I_S e^{\alpha V}$$

$$\frac{dI}{dV} = I_S e^{\alpha V} \alpha = \alpha I \Rightarrow \boxed{R_f = \frac{1/\alpha}{I}}$$

$\xrightarrow{\text{idealmente}}$ $S = \begin{bmatrix} 0 & S_{12}(V_c) \\ S_{21}(V_c) & 0 \end{bmatrix}$

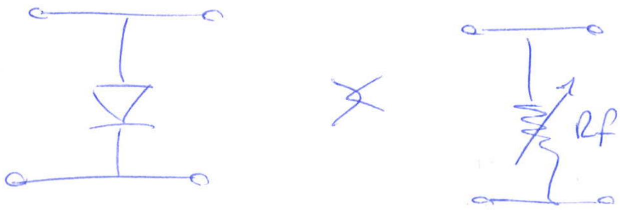
V_c = tensión de control

$S_{11} = S_{22} = 0 \Longrightarrow$ tiene que estar adaptado

$$A_t = \frac{P_{dg}}{P_L} = \frac{1}{|S_{21}(V_c)|^2}$$

$Z_g = Z_L = 50\,\Omega$

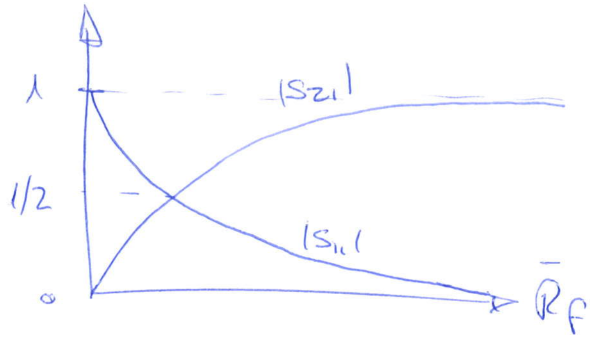
Normalmente $S_{12}(V_c) = S_{21}(V_c)$



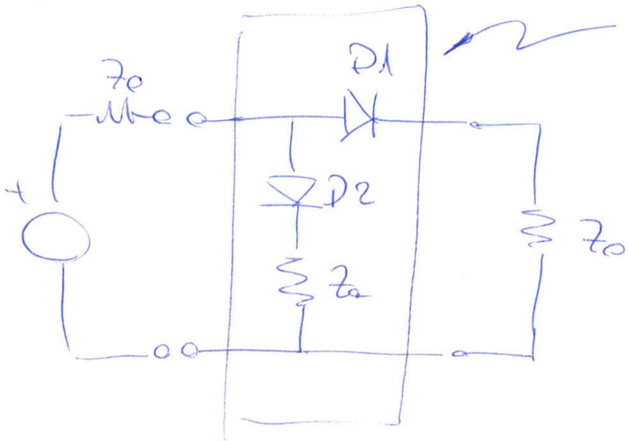
$$S_{11} = \frac{-\bar{Y}}{2+\bar{Y}} = \frac{-1}{1+2\bar{R}_f}$$!!

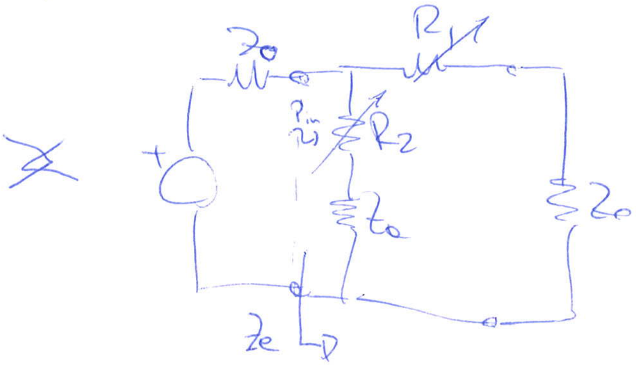
$$S_{21} = \frac{2}{2+\bar{Y}} = \frac{2\bar{R}_f}{1+2\bar{R}_f}$$ $|S_{11}| + |S_{21}| = 1$

Cuanto más atenuamos, más desadaptamos



Se puede adaptar la puerta de entrada





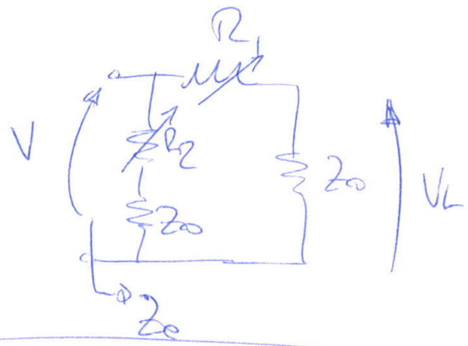
$$S_{11} = 0 \Rightarrow Z_e = Z_0 \Rightarrow Y_e = Y_0 = \frac{1}{Z_0 + R_2} + \frac{1}{Z_0 + R_1}$$

$$\boxed{R_1 R_2 = Z_0^2}$$

$$\left.\begin{aligned} R_1 &= \frac{1/\alpha}{I_1} \\ R_2 &= \frac{1/\alpha}{I_2} \end{aligned}\right\} I_1 I_2 = \frac{(1/\alpha)^2}{Z_0^2}$$

$$\left.\begin{aligned} I_1 &= I_s e^{\alpha V_1} \\ I_2 &= I_s e^{\alpha V_2} \end{aligned}\right\} \Rightarrow V_1 + V_2 = -\frac{2}{\alpha} \ln \alpha I_s Z_0$$

$$A_t = \frac{P_{dg}}{P_L} = \underbrace{\frac{P_{dg}}{P_{in}}}_{\eta_g = 1} \frac{P_{in}}{P_L} = \frac{P_{in}}{P_L}$$



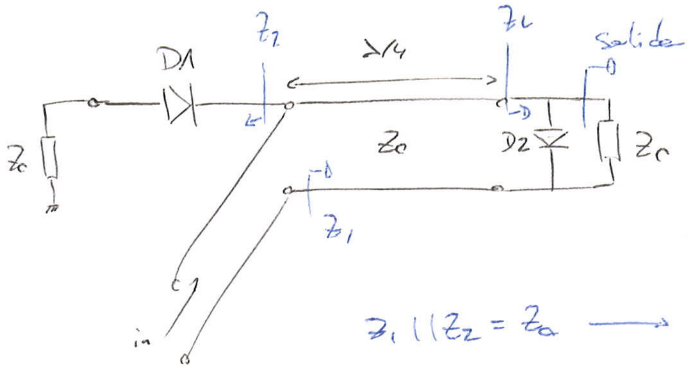
$$P_{in} = \frac{1}{2} \frac{V^2}{Z_0}$$

$$P_L = \frac{1}{2} \frac{V_L^2}{Z_0}$$

$$\boxed{A_t = \left| \frac{V}{V_L} \right|^2 = \left| \frac{Z_0 + R_1}{Z_0} \right|^2}$$

$$= \left| 1 + \bar{R}_1 \right|^2$$

Ejercicio pág 157 (atenuadores variables)



$$Z_1 \| Z_2 = Z_o \longrightarrow Y_1 + Y_2 = Y_o$$

$G_1 = 1/R_1$

$G_2 = 1/R_2$

$$Z_1 = \frac{Z_o^2}{Z_L} \; ; \; Y_1 = \frac{Y_o^2}{Y_L} = \frac{Y_o^2}{G_2 + Y_o}$$

$$Y_2 = \frac{1}{Z_o + R_1} = \frac{G_1 Y_o}{G_1 + Y_o}$$

$$Y_1 + Y_2 = Y_o = \frac{Y_o^2}{G_2 + Y_o} + \frac{G_1 Y_o}{G_1 + Y_o} \longrightarrow (G_1 + Y_o)(G_2 + Y_o) = Y_o(G_1 + Y_o) + G_1(G_2 + Y_o)$$

$$\cancel{Y_o^2} + \cancel{Y_o}(G_1 + G_2) + \cancel{G_1 G_2} = \cancel{Y_o^2} + \cancel{Y_o}(G_1 + G_1) + \cancel{G_1 G_2}$$

$$\cancel{G_1} + G_2 = G_1 + \cancel{G_1} \Rightarrow \boxed{G_1 = G_2 \Rightarrow R_1 = R_2}$$

$$P_{Y_1} = P_{in} \frac{Re(Y_1)}{Re(Y_1 + Y_2)} = P_{in} \frac{Y_o^2 / (Y_o + G_2)}{Y_o} = P_{in} \frac{Y_o}{Y_o + G_2}$$

$$P_{Y_{salida}} = P_{Y_1} \frac{Re(Y_o)}{Re(G_2 + Y_o)} = P_{in} \left(\frac{Y_o}{Y_o + G_2}\right)^2$$

$$\boxed{A_{tt} = \left(\frac{Y_o + G_2}{Y_o}\right)^2}$$

• Estructura física de los Diodos PIN

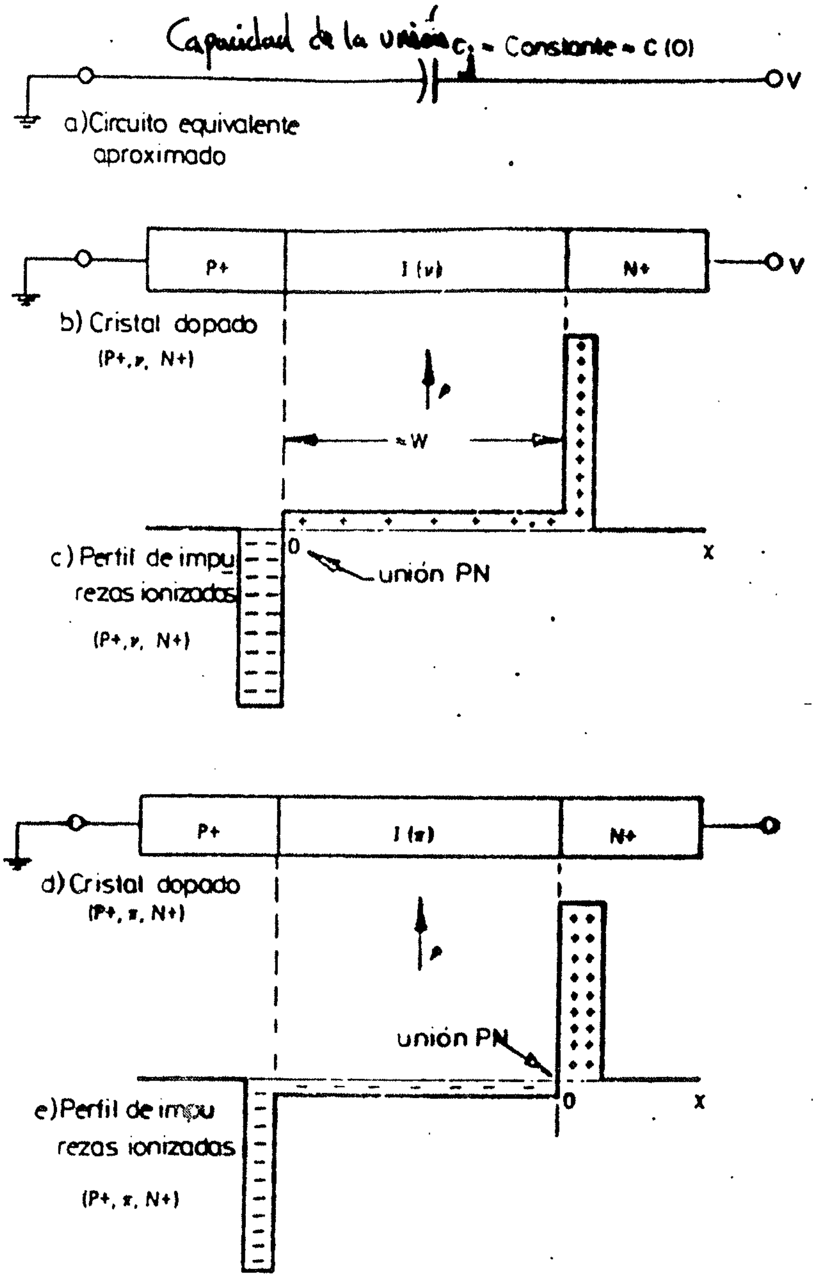


Fig. 1. Perfiles "ideales" de impurezas en los dos tipos de diodos PIN.

Perfiles ideales ⇒ * Perfiles de impurezas ionizadas con variación abrupta.

* Zona intrínseca completamente ionizada

• Diodo PIN real ⇒ { * perfil de impurezas variación mas suave
* región I no tiene todas las impurezas ionizadas cuando la polarización es nula

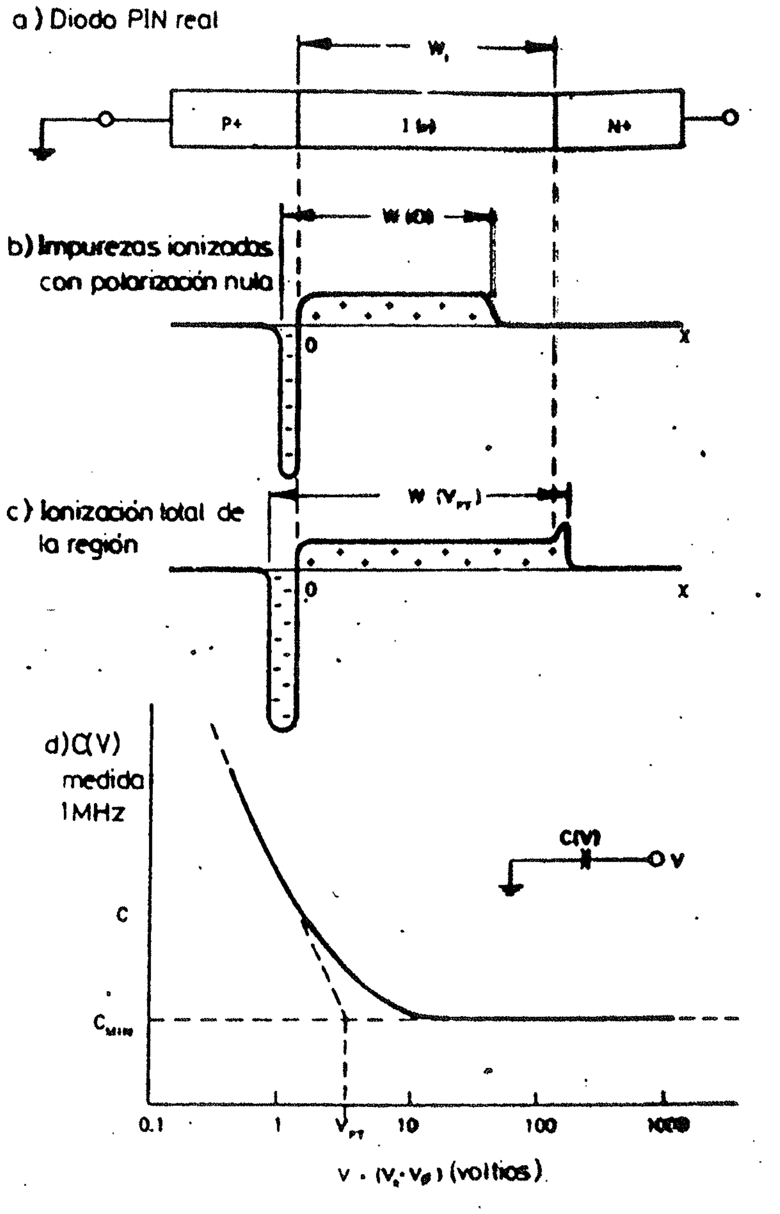


Fig. 2. Diodo PIN real y variación de su capacidad con la tensión.

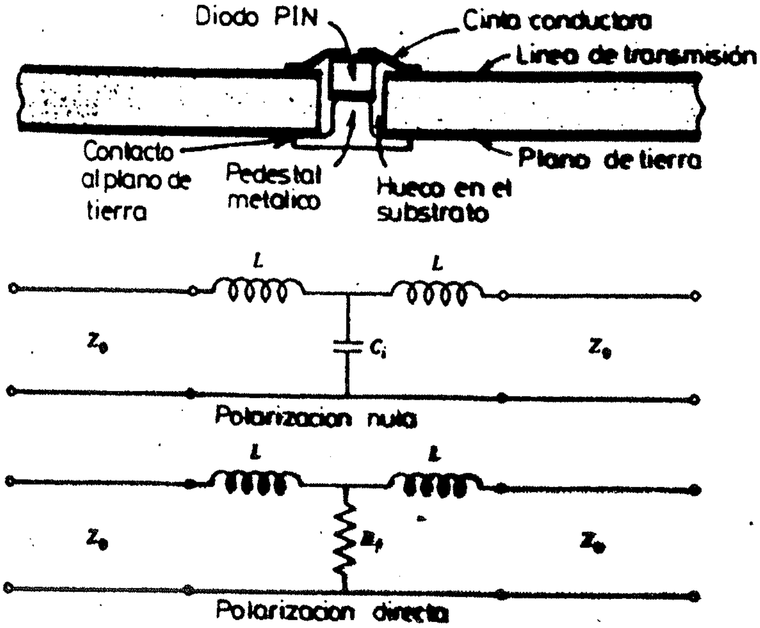


Fig. 5. Diodc sin encapsular montado **en paralelo** sobre una línea microstrip.

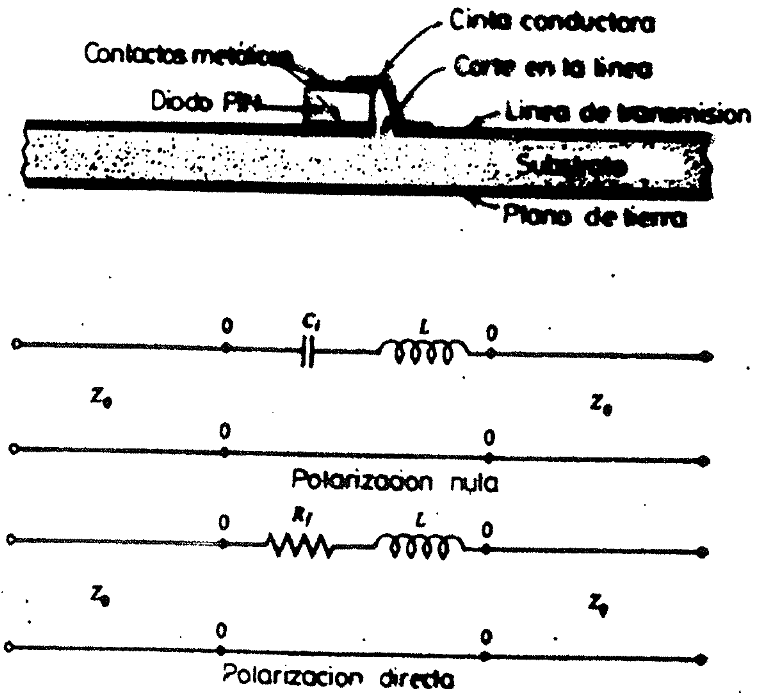


Fig. 6. Liodo sin encapsular montado **en serie** sobre una línea microstrip.

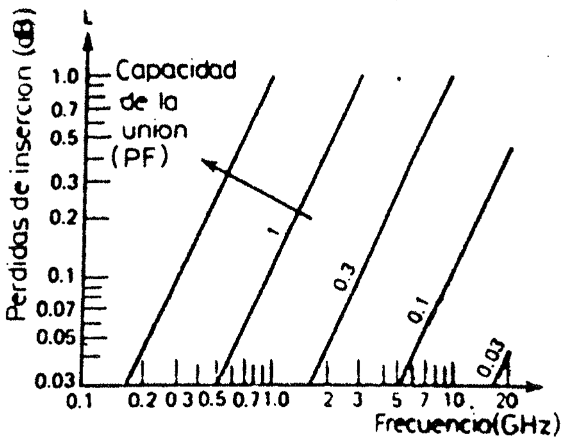


Fig. 7. Pérdidas de inserción de un diodo en paralelo.

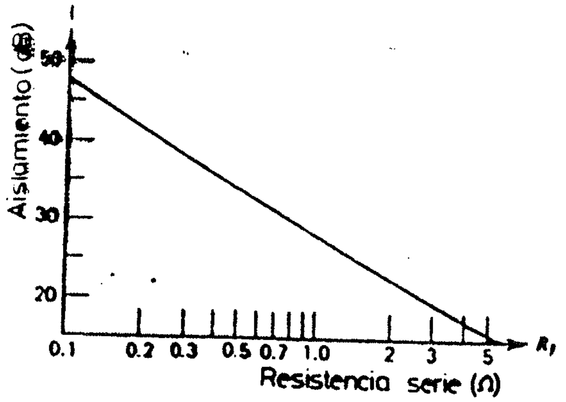


Fig. 8. Aislamiento de un diodo en paralelo.

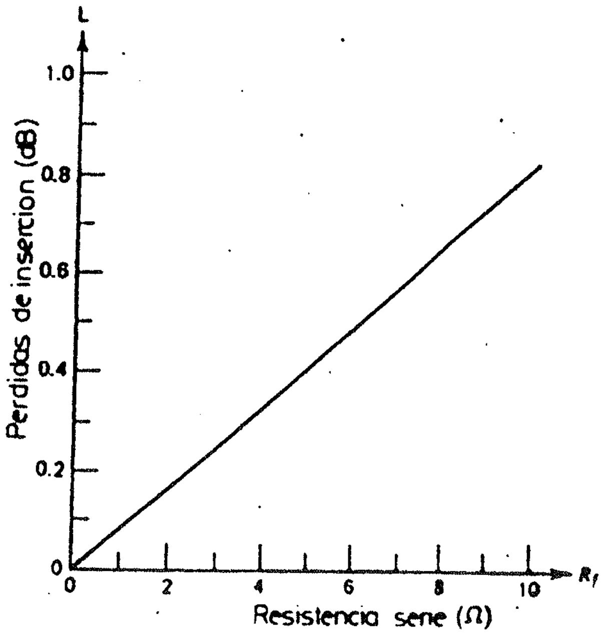


Fig. 9. Pérdidas de inserción de un diodo en serie.

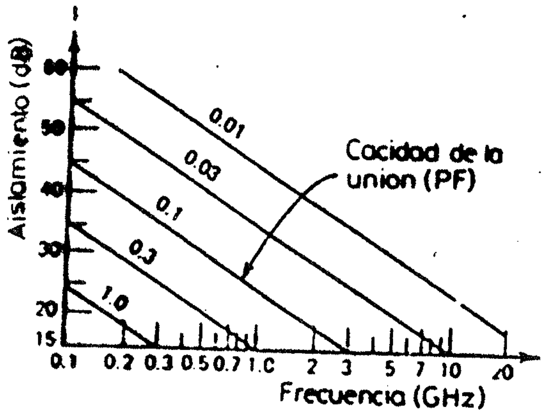


Fig. 10. Aislamiento de un diodo en serie.

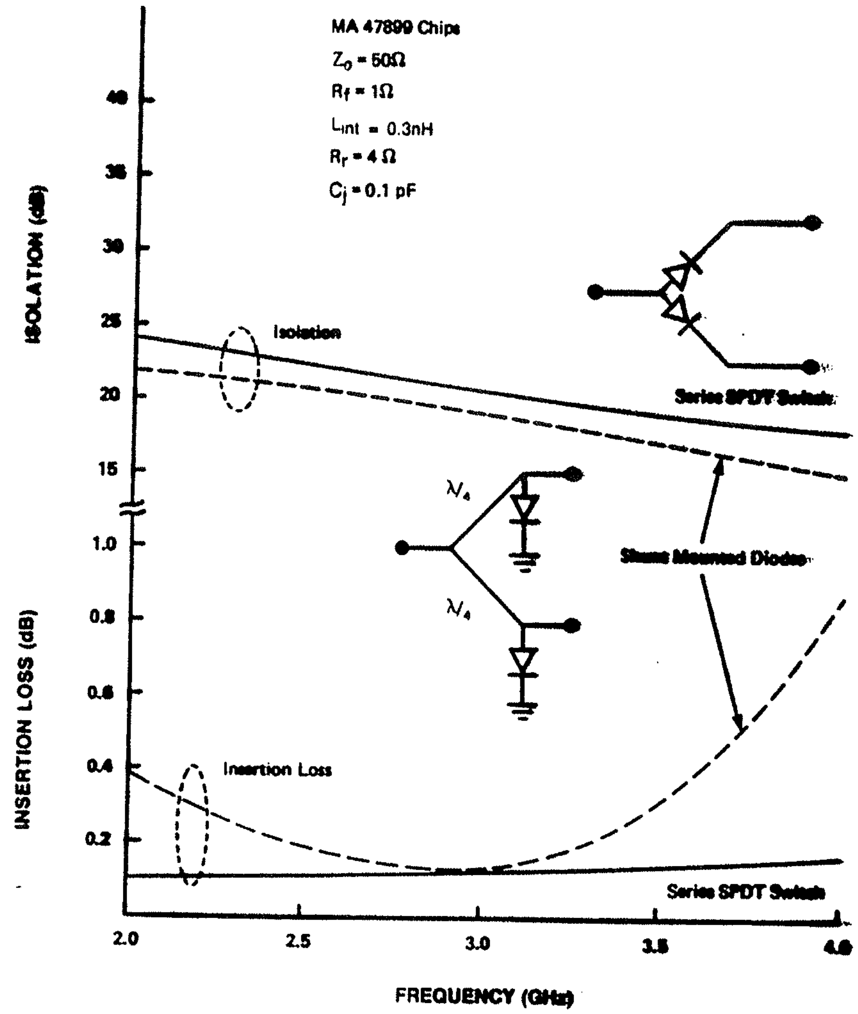


Figure 12.8 Typical insertion loss and isolation performance of SPDT switches using two *pin* diodes.

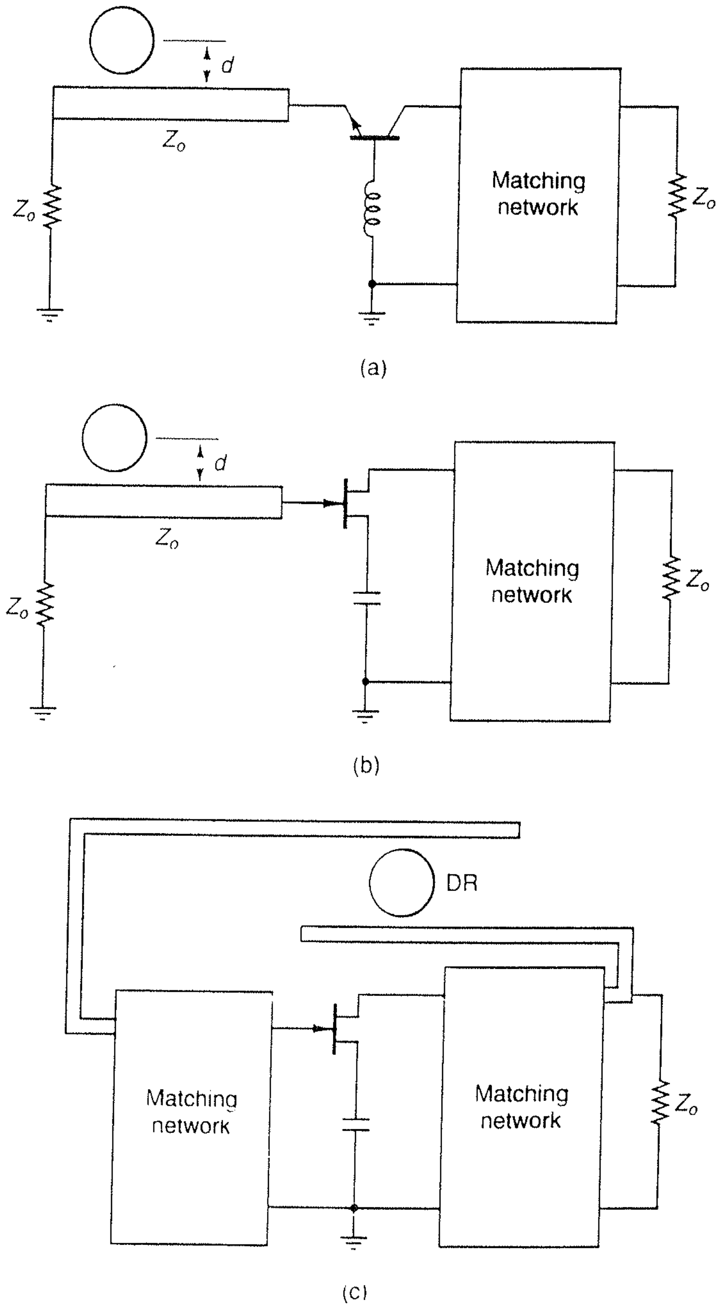
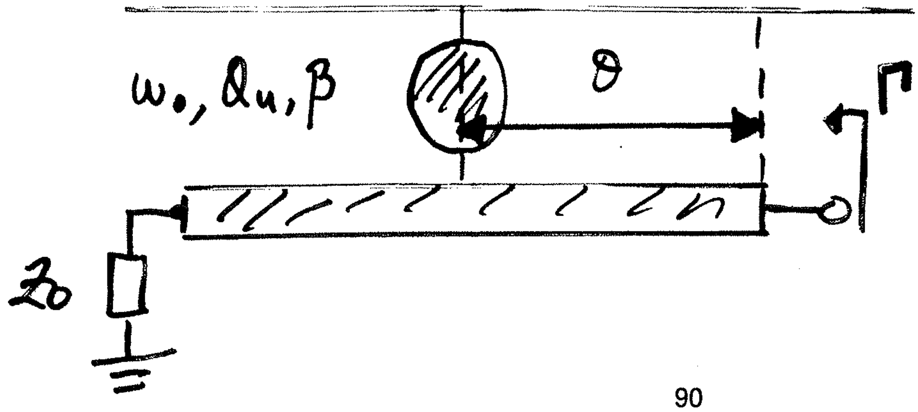
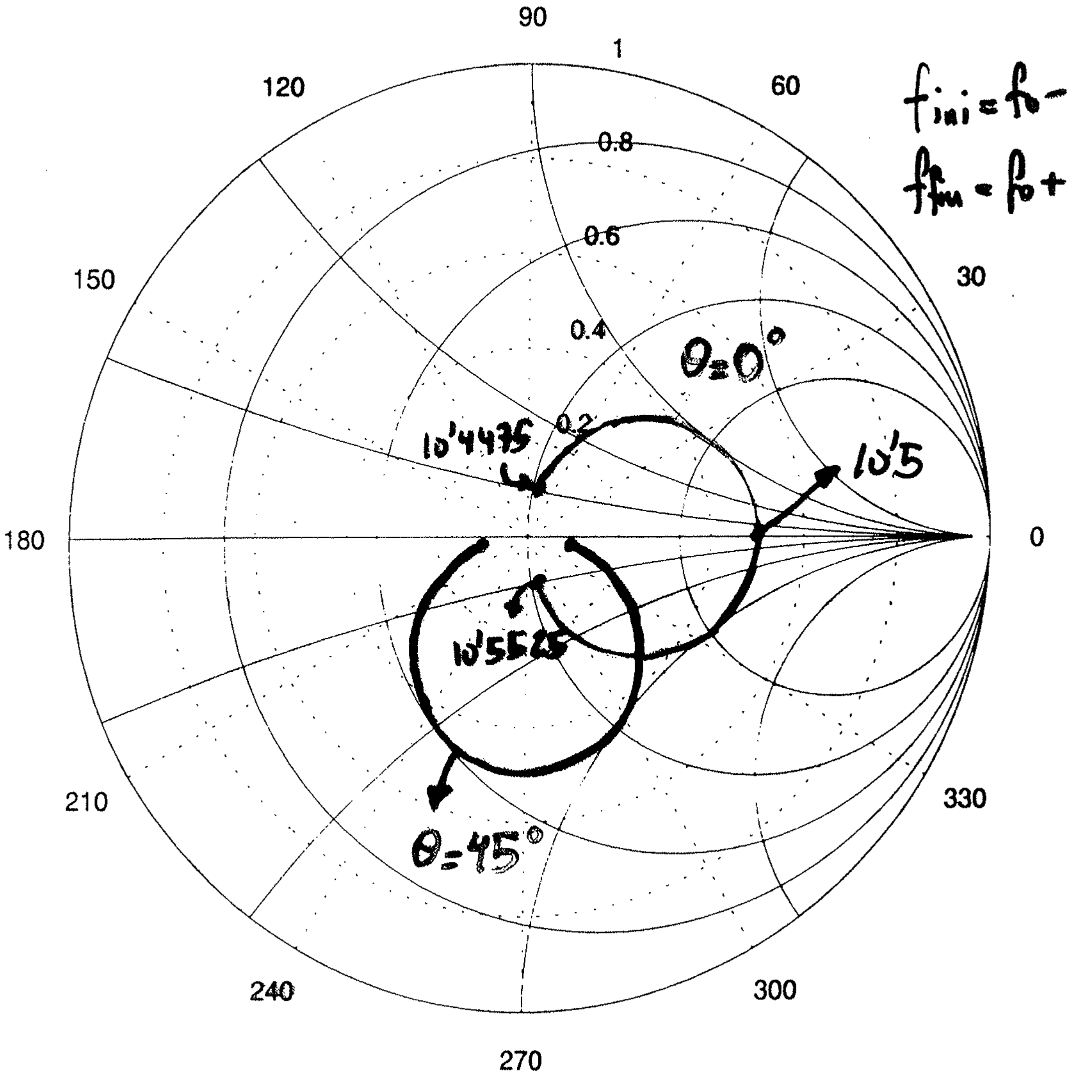


Figure 5.5.9 (a) A series feedback DRO using a BJT; (b) a series feedback DRO using a GaAs FET; (c) a parallel feedback DRO.

* Caracterización del DR



Datos:
$Q_u = 1000$;
$\beta = 1$; $f_0 = 10'5$ GH



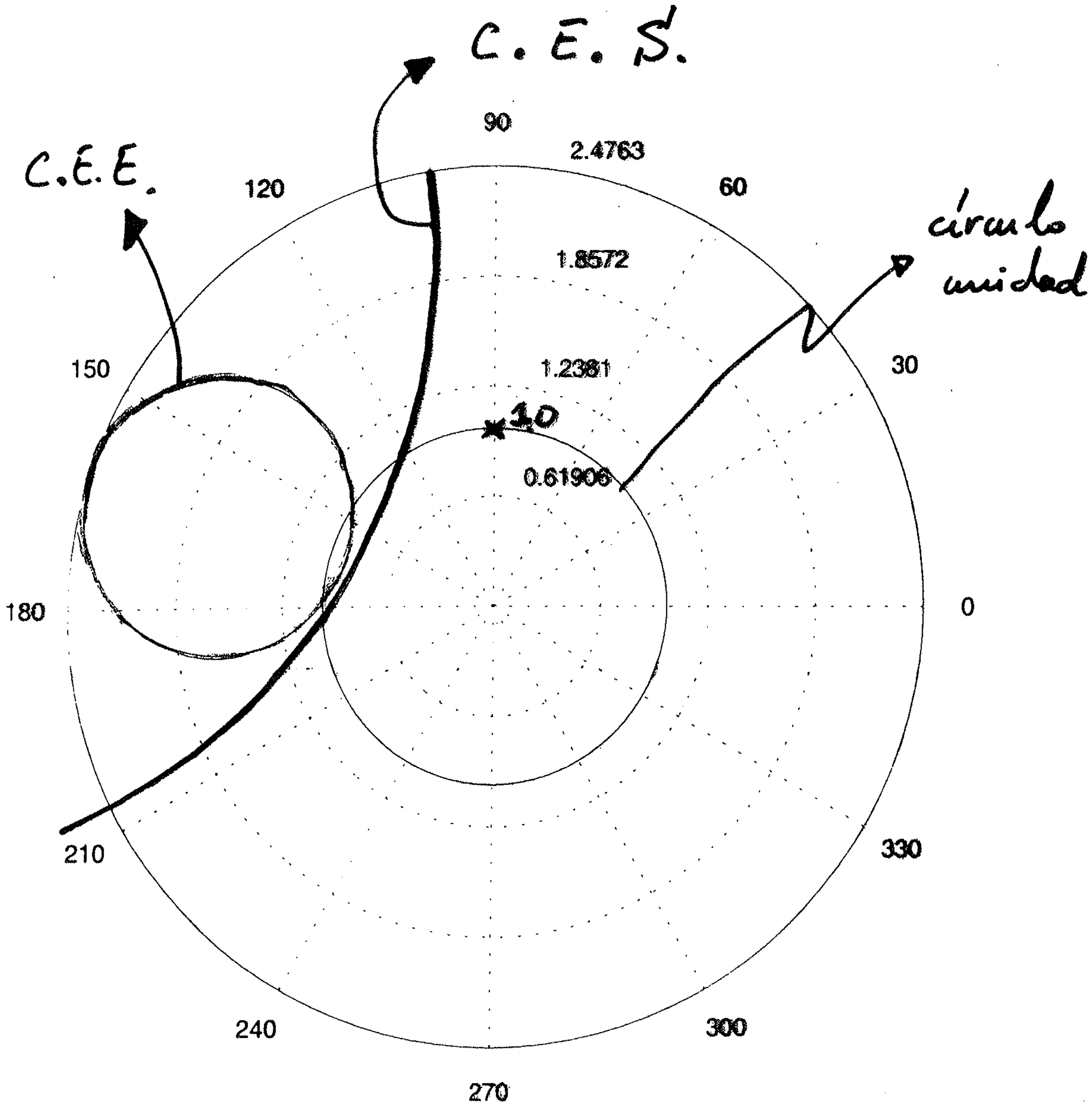
$f_{ini} = f_0 - 0'005 f_0$
$f_{fin} = f_0 + 0'005 f_0$

$$\Gamma(\omega) = \frac{\beta}{\beta + 1 + j\, Q_u \cdot \frac{\omega^2 - \omega_0^2}{\omega \cdot \omega_0}} \cdot e^{-j\, 2 \cdot \theta(\omega)}$$

$$\theta(\omega) = \left[\theta_0 - 0'005\theta_0 , \ldots , \theta_0 + 0'005\theta_0\right]$$

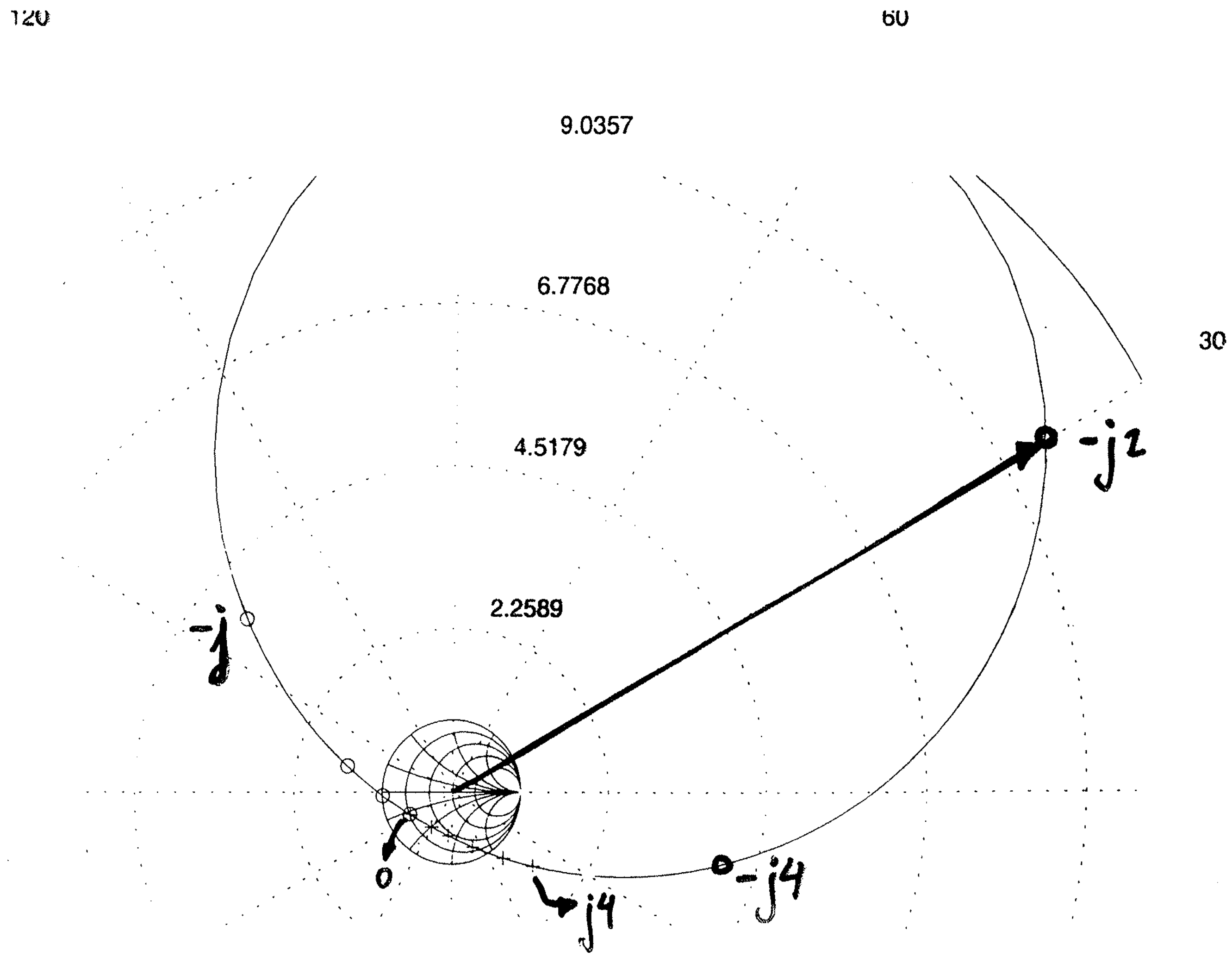
$\theta = \beta \cdot l = \omega \cdot l$

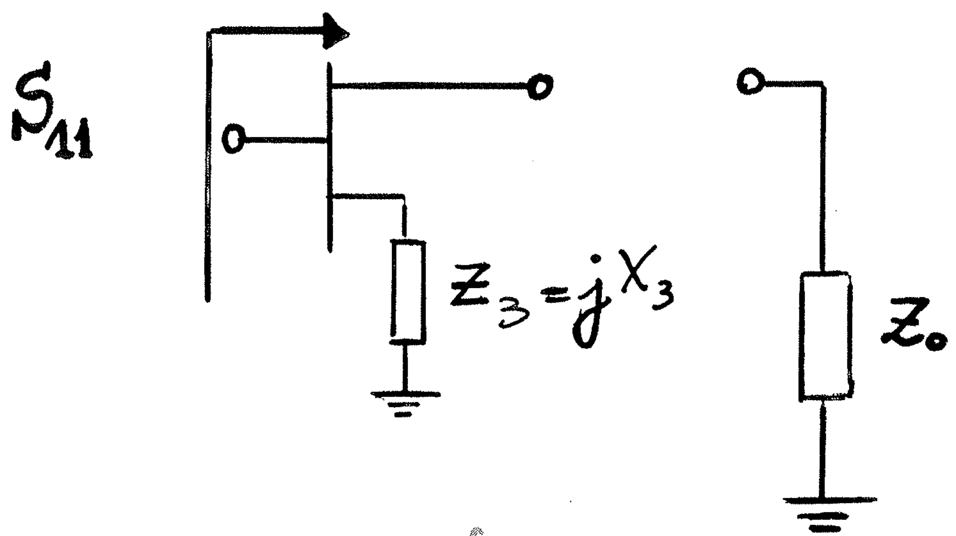
* Curvas Estabilidad del ATF36077



* Influencia de impedancia serie en "fuente"

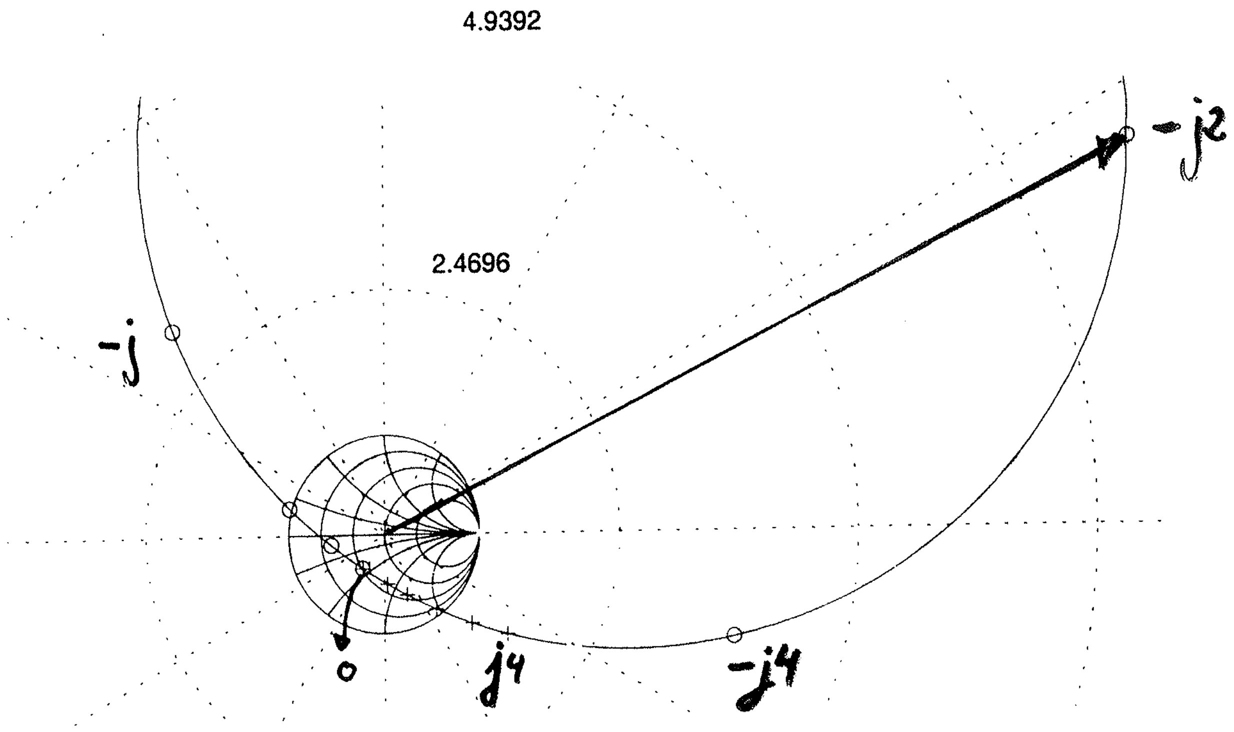
Plano Γ_{in} : $S_{11} = S_{11}(jX_3)$

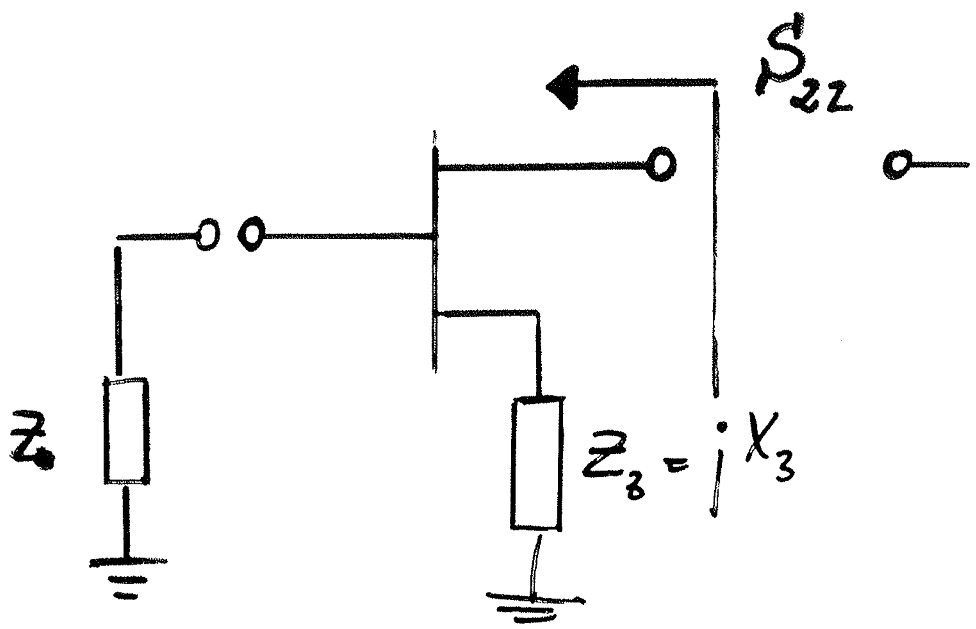




* Influencia de impedancia serie en "fuente"

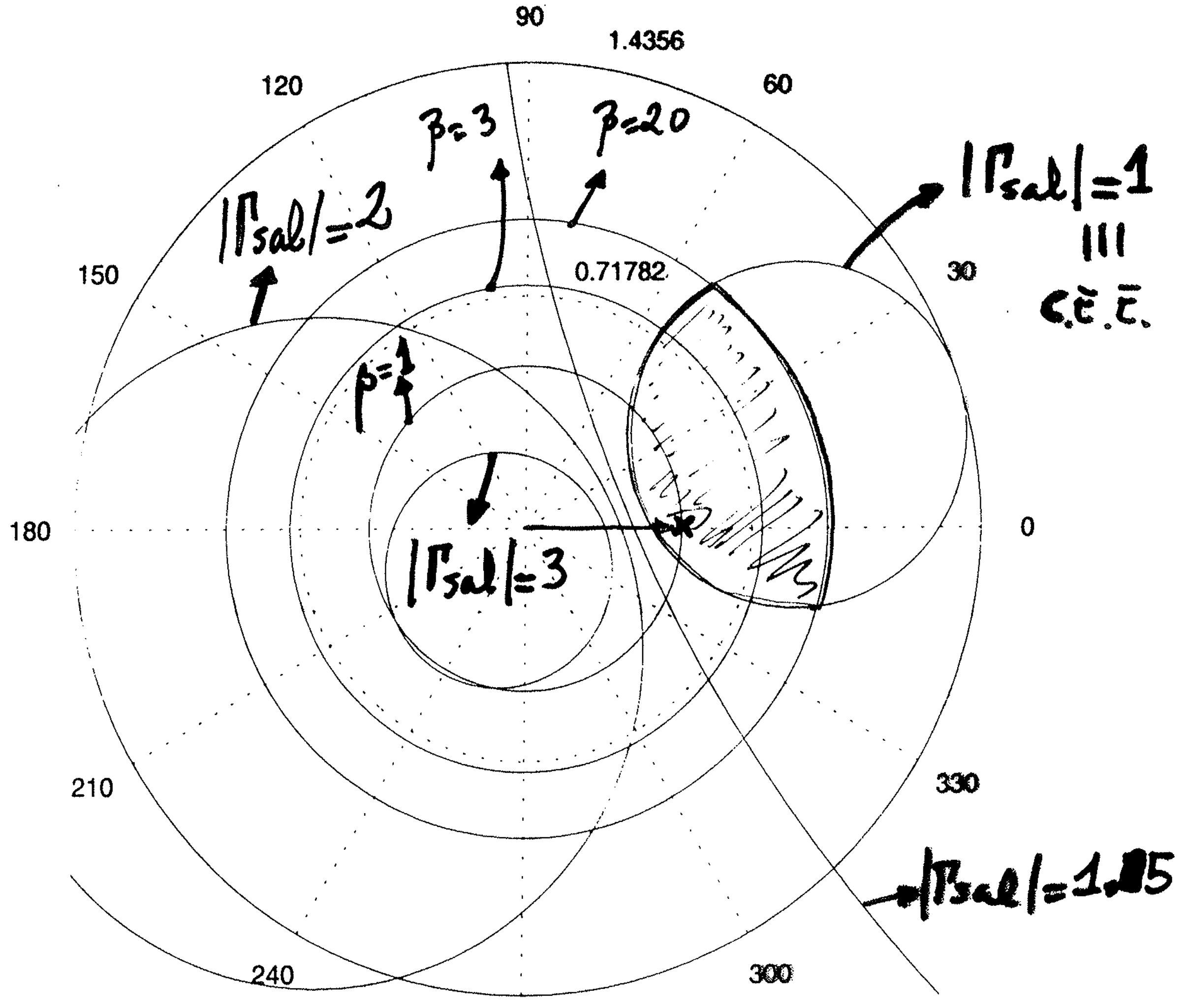
Plano Γ_{sal}: $S_{22} = S_{22}(jX_3)$

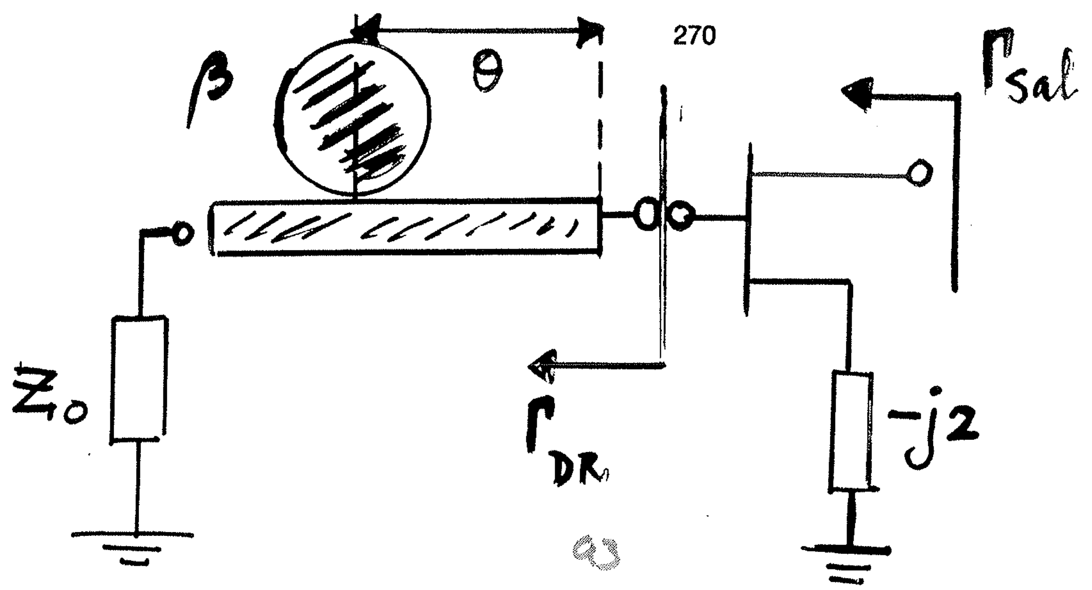




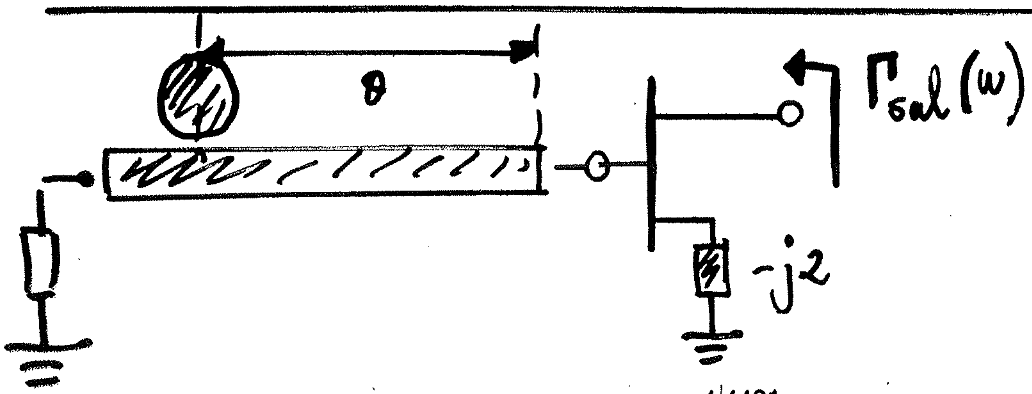
* # Selección del Resonador Dieléctrico

Plano DR

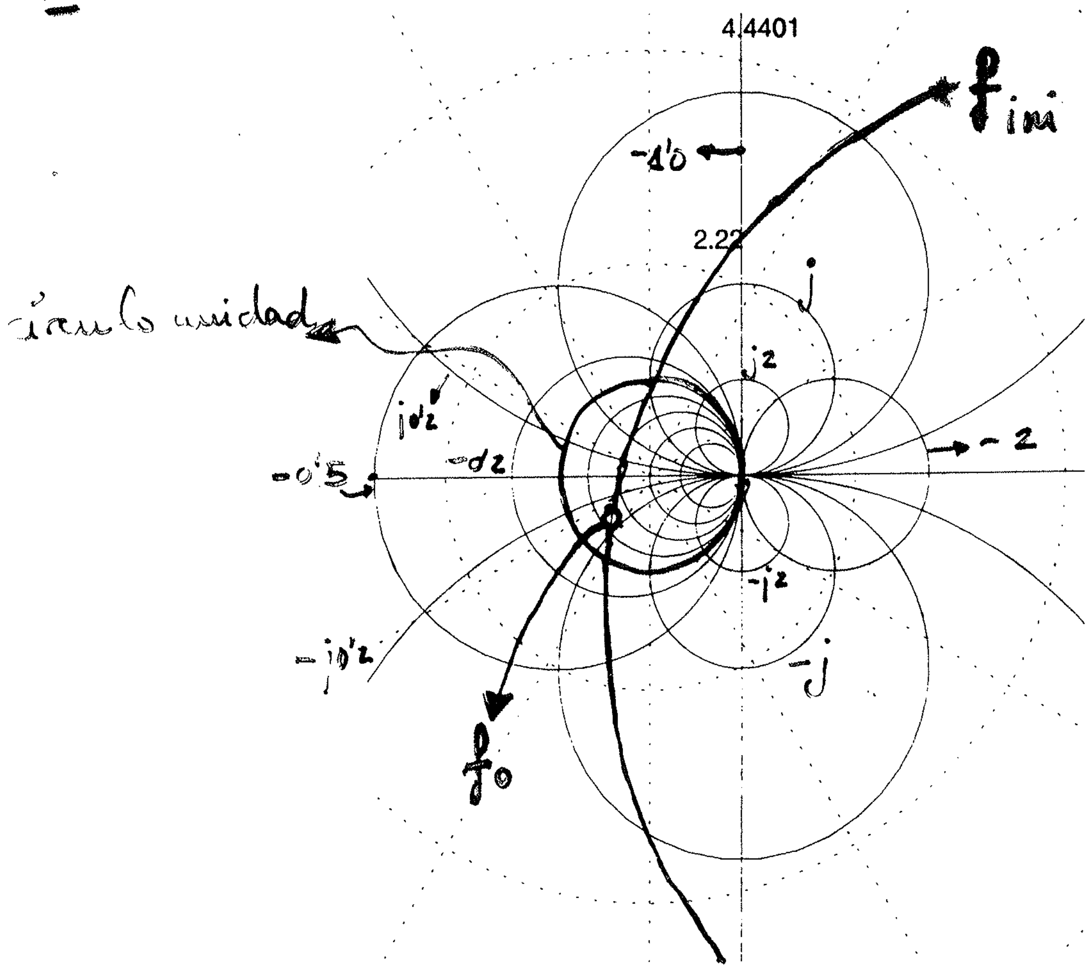




* Determinación del tramo de línea 'θ':



Dato DR:
$Q_u = 1000$
$\beta = 1$; $f_0 = 10'56$



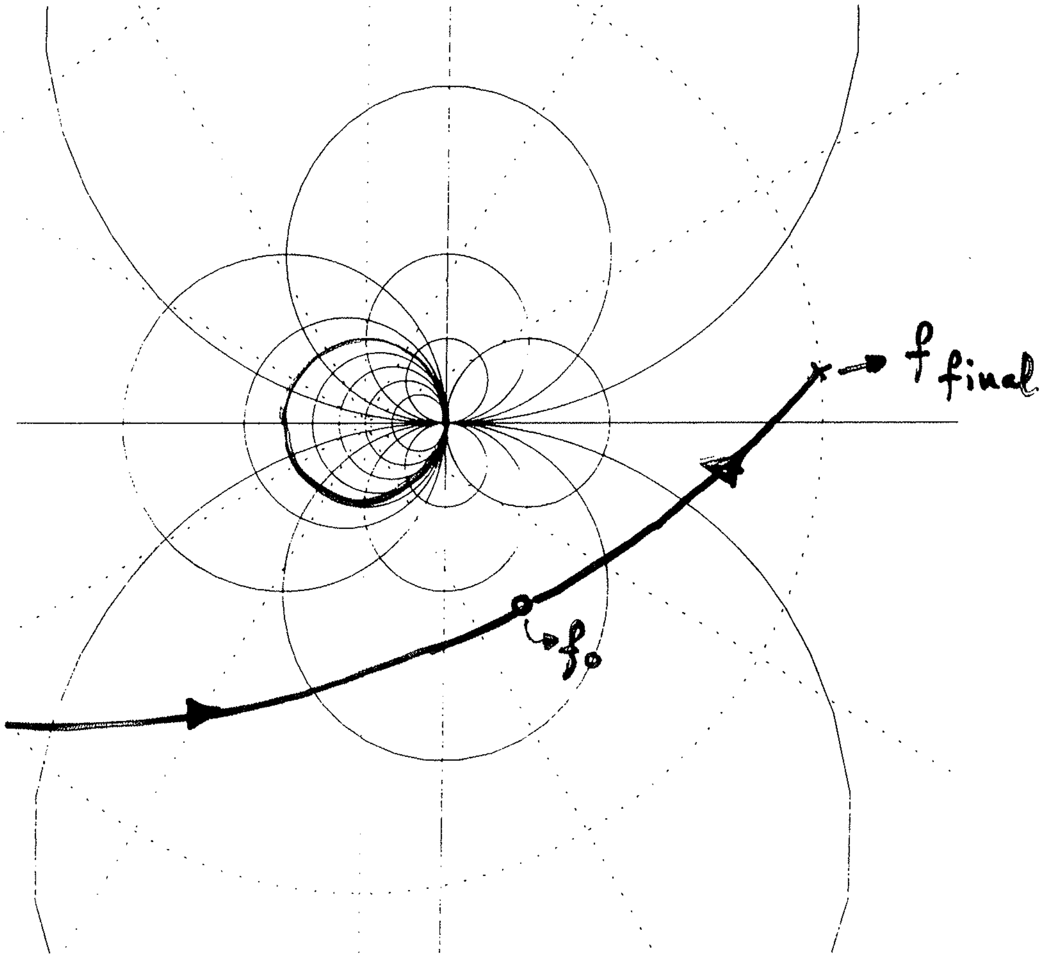
θ = 0°

240

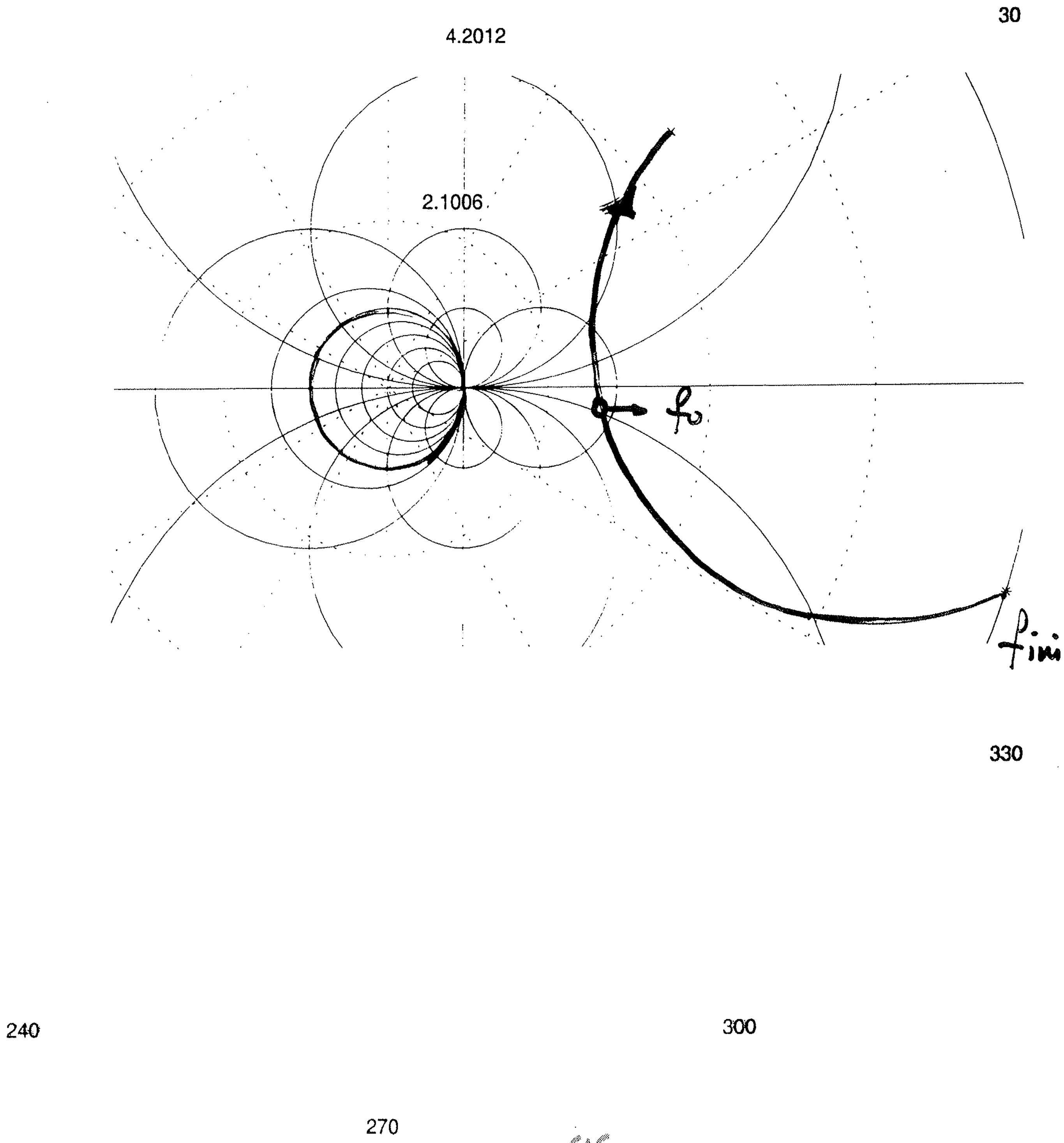
300

$\theta = 45°$

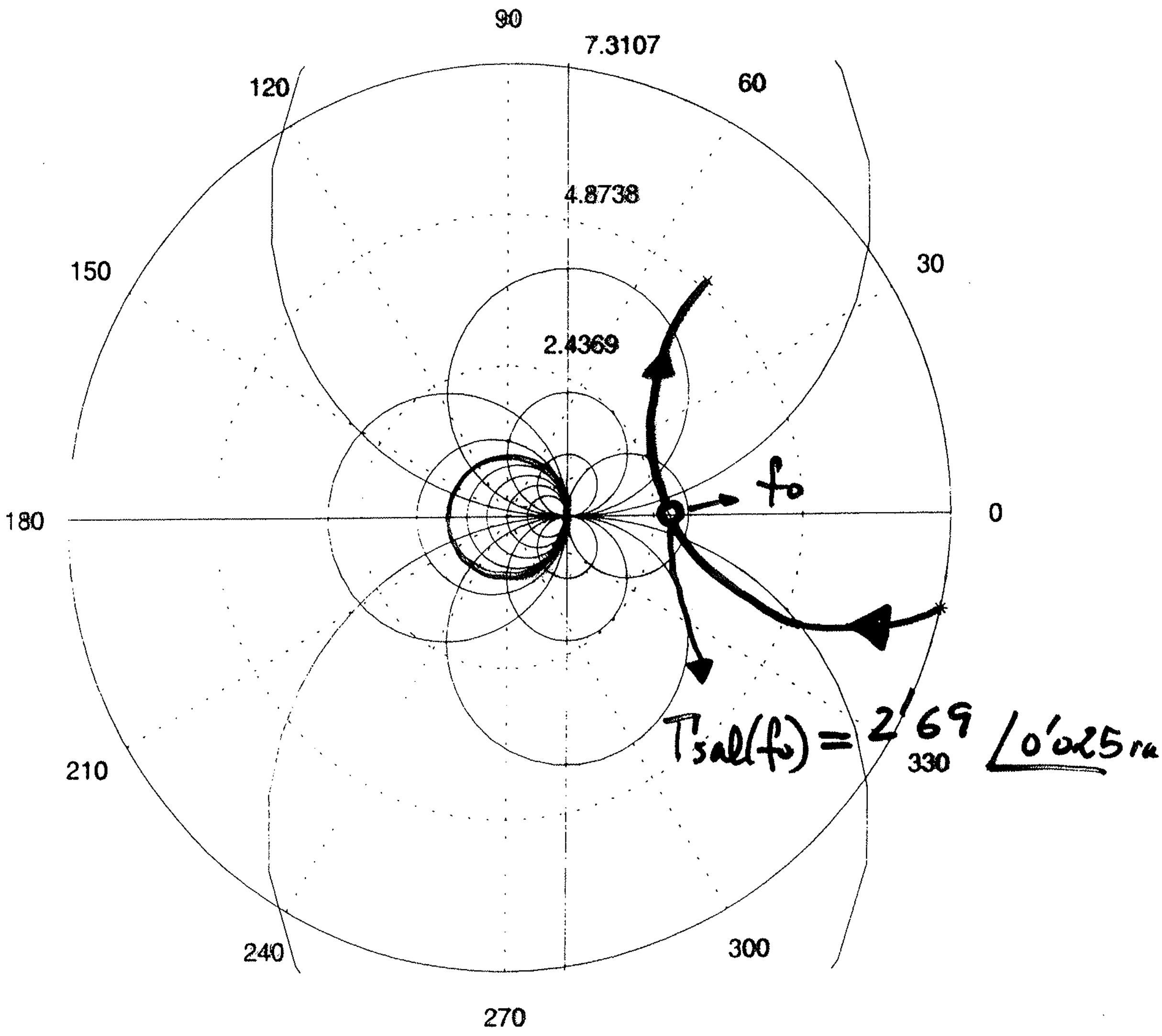
5.5779



$\boxed{\theta = 90^\circ}$



$\boxed{\theta = 98^\circ}$



$$\Gamma_{sal}(w_0) = \frac{Z_{sal} - Z_0}{Z_{sal} + Z_0} = 2'69 \angle 0'025 \Rightarrow \boxed{Z_{sal} = -109'1 + j\,2'35}$$