Moduladores

- Modulaciones Lineales
  - AM
  - Doble Banda Lateral
  - Banda Lateral Única
  - Banda Vestigial
- Modulaciones Exponenciales
  - En fase (PM)
  - En frecuencia (FM)

Tipos de Modulación

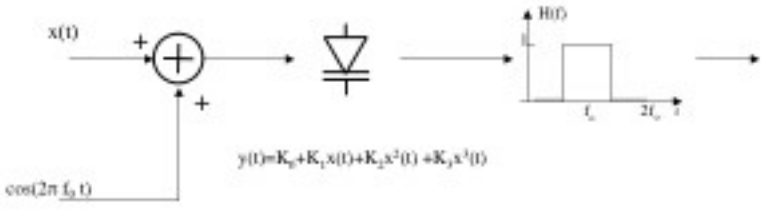
Tipo de modulación	Señal modulada	Ancho de banda
AM	$y(t) = A_p\left[1 + m\bar{x}(t)\right]\cos(w_p t)$	$2W_m$
DBL	$y(t) = A\bar{x}(t)\cos(w_p t)$	$2\ W_m$
BLU	$y(t) = A\left[\bar{x}(t)\cos(w_p t) \pm \bar{x}^*(t) sen(w_p t)\right]$	W_m
PM	$y(t) = A\cos\left[w_p t + \Delta\theta_{max}\,\bar{x}(t)\right]$	$2(\Delta\theta_{max}+1)\ W_m$
FM	$y(t) = A\cos(w_p t + 2\pi\Delta f_{max}\int_{-\infty}^{t}\bar{x}(\tau)d\tau)$	$2(\Delta f_{max}+ W_m)$
M-ASK	$y(t) = A_i\cos(w_p t)$ con $i = 1...M$	Flujo $_{bd}/\log_2 M$
M-FSK	$y(t) = A\cos\left[(w_p + 2\pi\cdot i\cdot\Delta f)\cdot t\right]$ con $i = 1...M$	$[(i+1)\cdot\Delta f+\text{Flujo}_{bd}]/\log_2 M$
M-PSK	$y(t) = A\cos(w_p t + \frac{2\pi}{M} i)$ con $i = 1...M$	Flujo $_{bd}/\log_2 M$
QAM	$y(t) = A\left[X_i(t)\cos(w_p t) \pm X_j(t)^* sen(w_p t)\right]$ con $i = 1...\sqrt{M}$ y $j = 1...\sqrt{M}$	Flujo $_{bd}/\log_2 M$

Modulación AM

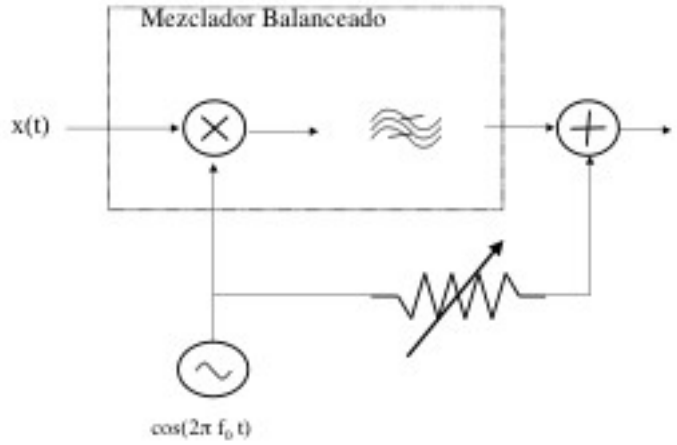
$$y(t) = A\left\{1 + \alpha\overline{x(t)}\right\} cos(\omega_0 t)$$

$$\alpha = \frac{x(t)_{max}}{A}$$

Esquemas de modulación AM

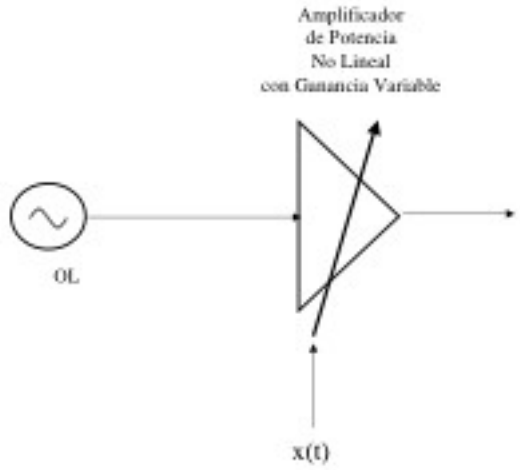


Esquemas de Modulación AM



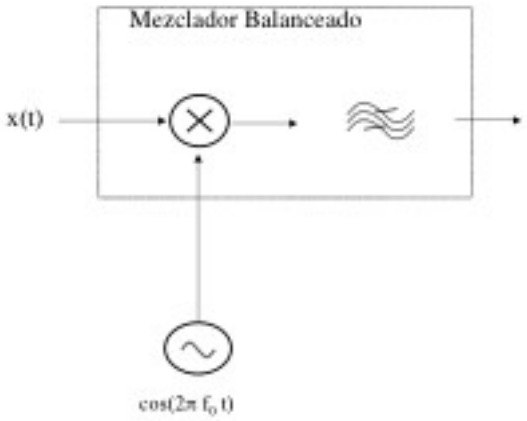
Modulación AM
Alto Nivel (En potencia)

- Uso amplificador clase C

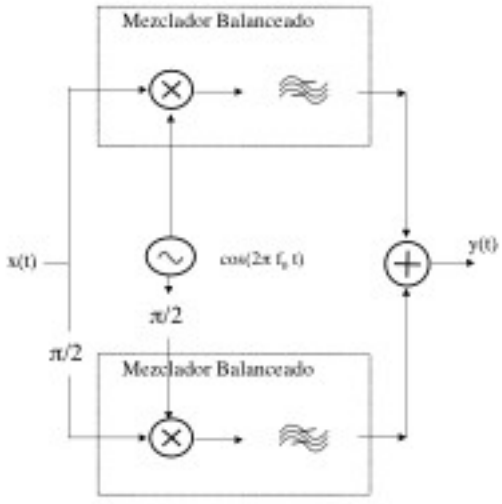


Modulador DBL

$$y(t) = Ax(t)cos(\omega_0 t)$$



Modulador BLU (SSB)



Banda Lateral Única (BLU)

$$y(t) = A\left\{x(t)cos(\omega_0 t) + \widehat{x(t)}sin(\omega_0 t)\right\}$$

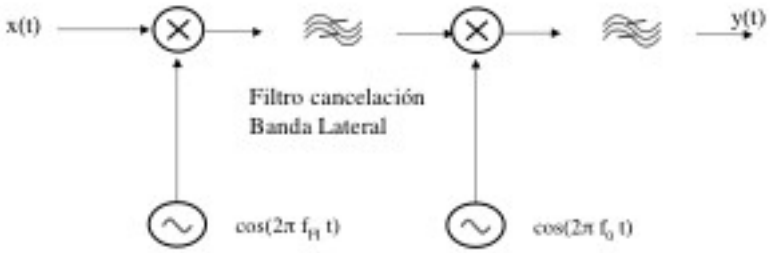
$$S(db) = 10\left\{\frac{1+R^2+2Rcos(\Delta-\Theta)}{1+R^2-2Rcos(\Delta+\Theta)}\right\}$$

$$R = \frac{\text{Amplitud Rama 1}}{\text{Amplitud Rama2}}$$

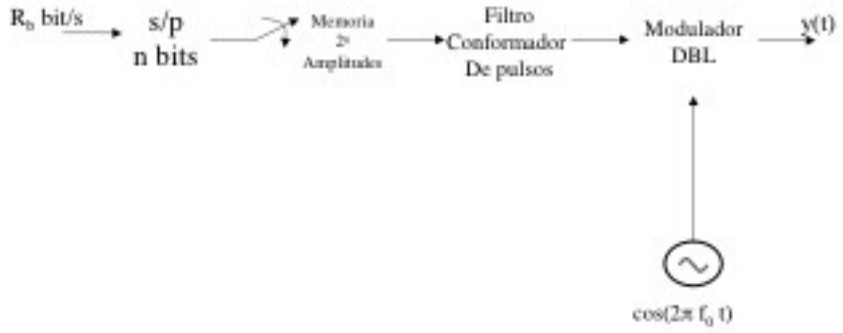
Δ = Desfase introducido en portadora

Θ = Desfase introducida por transformada Hilbert

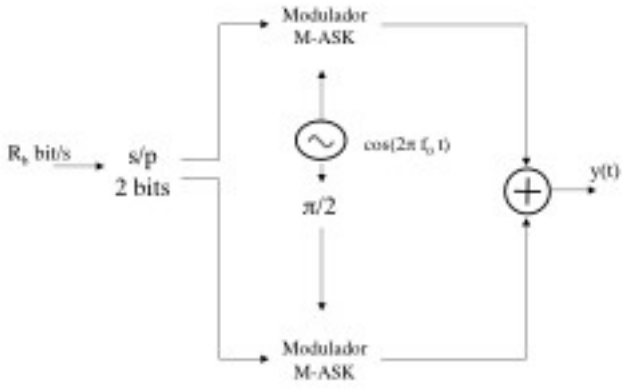
Banda Lateral Única y Banda Vestigial



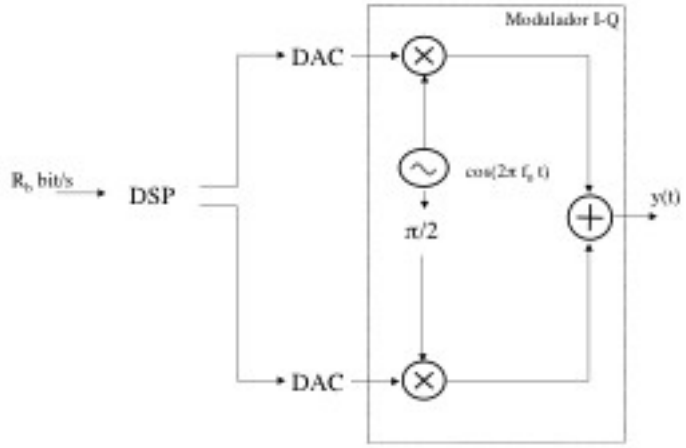
Modulacion Digital en Amplitud M-ASK



M-QAM



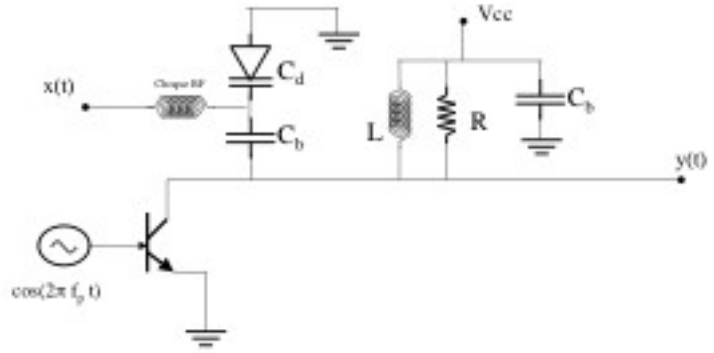
Moduladores con Síntesis Digital



Moduladores Exponenciales Modulación en Fase

$$y(t) = Acos\left(\omega_0 t + \Delta\Theta_{max}\overline{x(t)}\right)$$

Modulación en Fase
Diodo Varactor



$$
\begin{aligned}
x(t) &= V_{pol} + \overline{x(t)} \\
V_{pol} &= \text{Voltaje de polarización} \\
\overline{x(t)} &= \text{señal moduladora}
\end{aligned}
$$

$$
\begin{aligned}
\omega_0 &= \frac{1}{\sqrt{LC_d}} \\
Q &= \omega_0 C_d R \\
G &= -\frac{g_m}{\frac{1}{R} + j\omega_p C_d + \frac{1}{j\omega_p L}} \\
G &= -\frac{g_m R}{1 + jQ\left(\frac{\omega_p}{\omega_0} - \frac{\omega_0}{\omega_p}\right)}
\end{aligned}
$$

$$
\Phi = arctan\left\{Q\frac{\omega_p^2 - \omega_0^2}{\omega_p\omega_0}\right\} = arctan\left\{Q\frac{f_p + f_0}{f_0}\frac{f_p - f_0}{f_p}\right\}
$$

$$C_d = \frac{K_d}{V_d^2}$$

$$f_0 = \frac{1}{2\pi\sqrt{LC_d}} = \frac{x(t)}{2\pi\sqrt{LK_d}} = \frac{V_{pol}}{2\pi\sqrt{LK_d}} + \frac{\overline{x(t)}}{2\pi\sqrt{LK_d}}$$

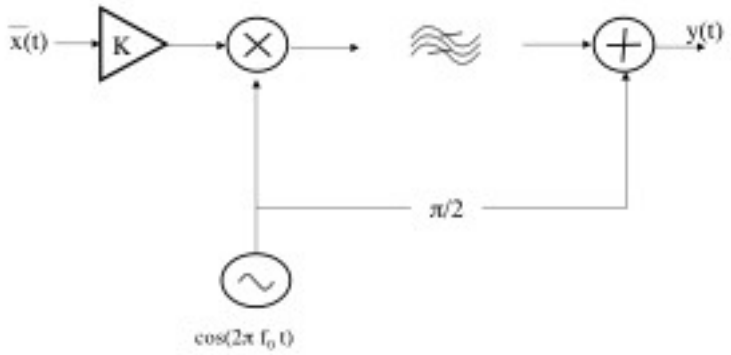
$$f_p = \frac{V_{pol}}{2\pi\sqrt{LK_d}}$$

$$f_0 = f_p + f_p \frac{\overline{x(t)}}{V_{pol}}$$

Modulador en Fase

$$\Phi(t) \approx arctan\left\{2Q\frac{\overline{x(t)}}{V_{pol}}\right\} \approx 2Q\frac{\overline{x(t)}}{V_{pol}}$$

Modulador Armstrong



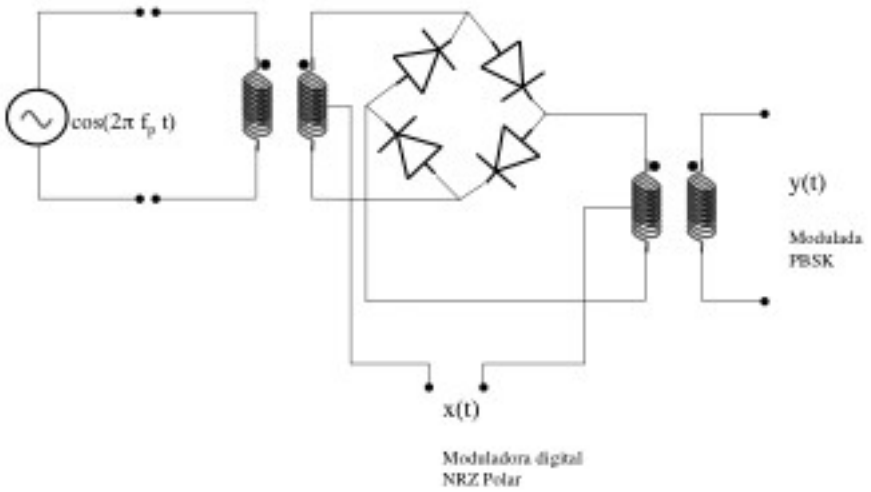
Modulador de Armstrong

$$
\begin{aligned}
y(t) &= A\sin(\omega_0 t) + AK\overline{x(t)}\cos(\omega_0 t) \\
&= A\sqrt{1 + K^2\overline{x(t)}^2}\sin\left(\omega_0 t + \arctan\left\{K\overline{x(t)}\right\}\right) \\
&\approx A\sin\left(\omega_0 t + K\overline{x(t)}\right)
\end{aligned}
$$

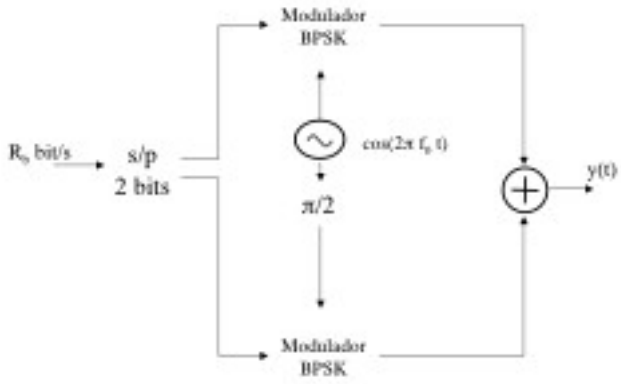
Distorsión

$$
\begin{aligned}
K\overline{x(t)} &\approx arctan\left\{K\overline{x(t)}\right\} \\
\text{Si } \overline{x(t)} = cos(\omega_m t) &\Rightarrow : \\
arctan\left\{Kcos(\omega_m t)\right\} &= \sum_{\text{n=1 impar}}^{\infty} \frac{2}{nK^n}\left[\sqrt{1+K^2}-1\right]^n cos(n\omega_m t) \\
D_{3PM} &= \frac{\left[\sqrt{1+K^2}-1\right]^2}{3K^2} \\
K &\ll 1 \\
D_{3PM} &\approx \frac{K^2}{12}
\end{aligned}
$$

Modulador BPSK



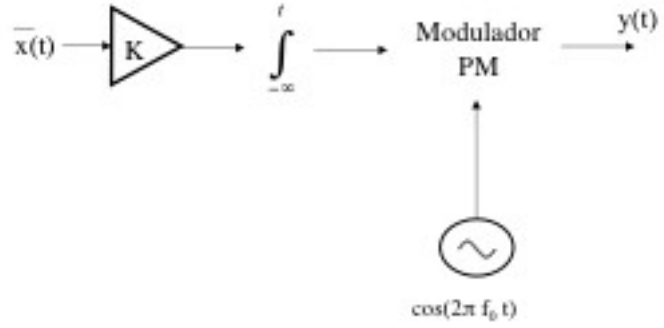
Modulador QPSK



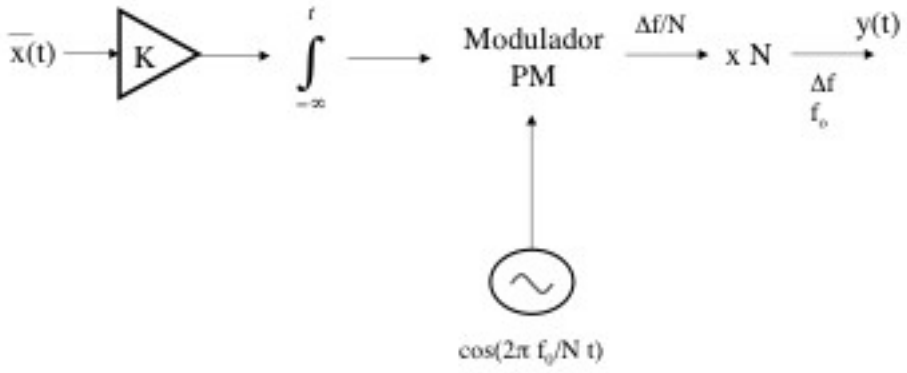
Modulación FM

$$y(t) = Acos\left(\omega_0 t + K\int_{-\infty}^{t}\overline{x(\tau)}d\tau\right)$$

Modulación FM Indirecta



Modulación Indirecta con baja desviación inicial



Modulación Directa FM
Uso VCO

- De osciladores y VCO
  - Excursión en frecuencia es inversamente proporcional al factor de calidad Q

$$\Delta f = \frac{Vc}{Q}$$

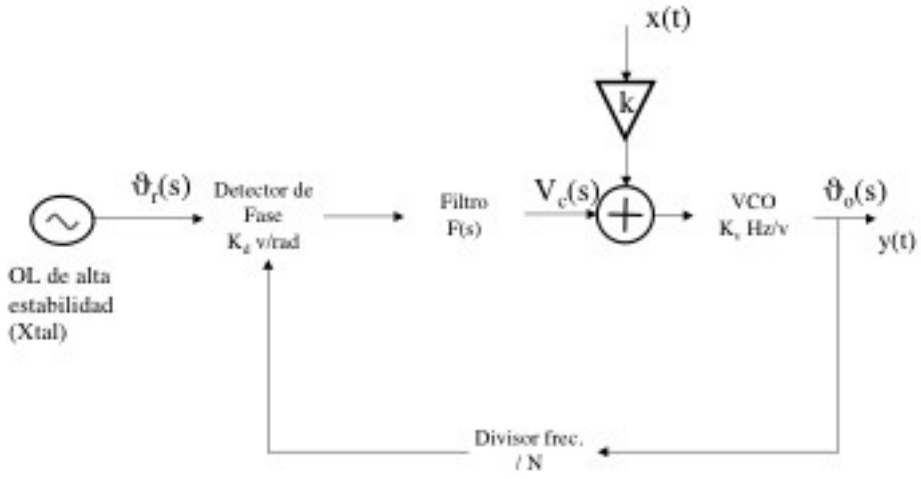
  - Inmunidad al ruido es inversamente proporcional al factor de calidad Q

$$\left|\frac{\partial \omega}{\partial \phi}\right| = \frac{\omega_0}{2Q}$$

Modulación directa de FM
Uso VCO

- Solución:
  - Uso menor desviación en frecuencia y multiplico
  - Uso de PLL para estabilizar!

Modulación Directa con PLL



Condición de PLL como Modulador FM

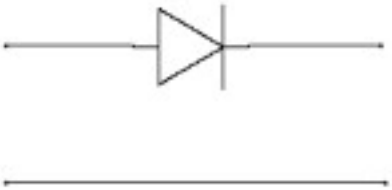
$$f_v(s) = K_m H_e(s) X_m(s) + H_{PLL}(s) f_r(s)$$

- Para usar el PLL como modulador de FM

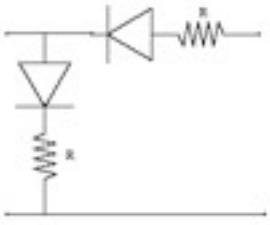
$$BW_{PLL} < f_{min_{x_m(t)}}$$

Rectificadores

Rectificadores Media Onda

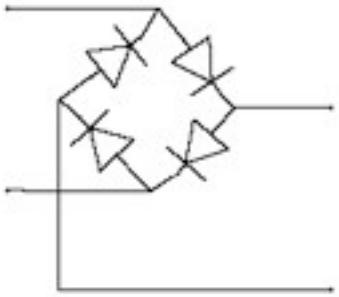


No Balanceado

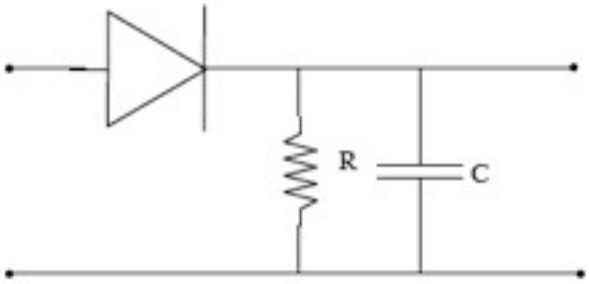


Balanceado

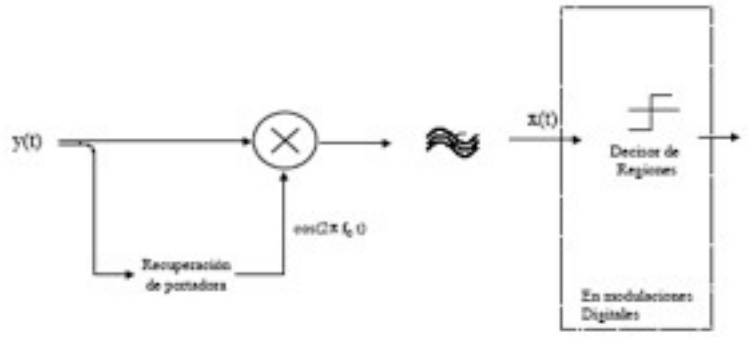
Rectificador Onda completa



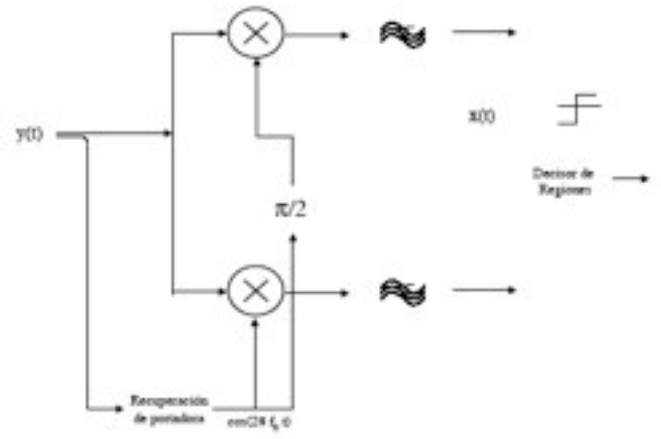
Detector de Envolvente



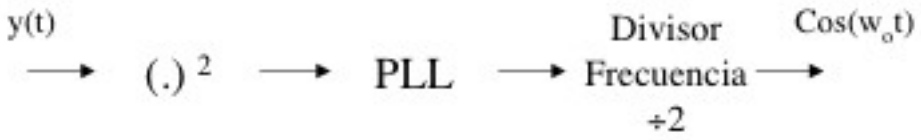
Demodulador Coherente



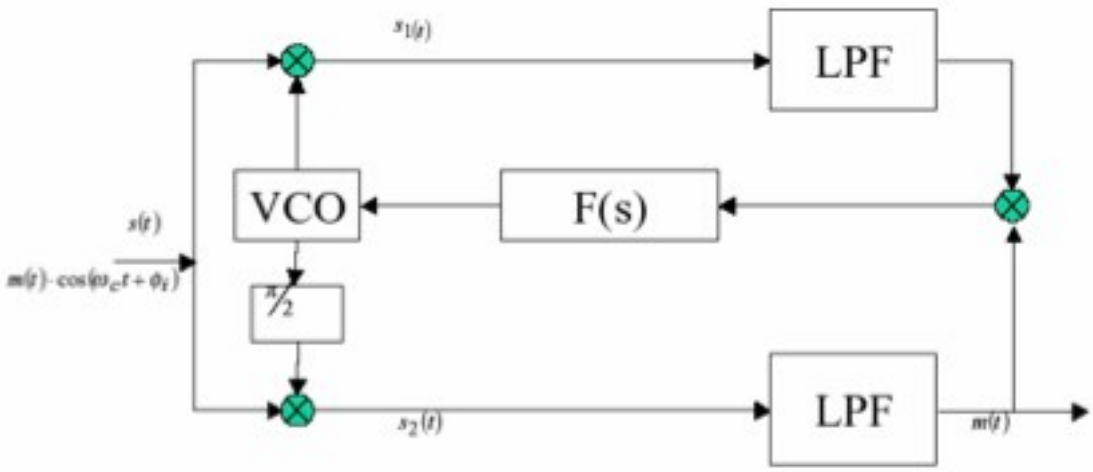
Demodulador QAM (Coherente)



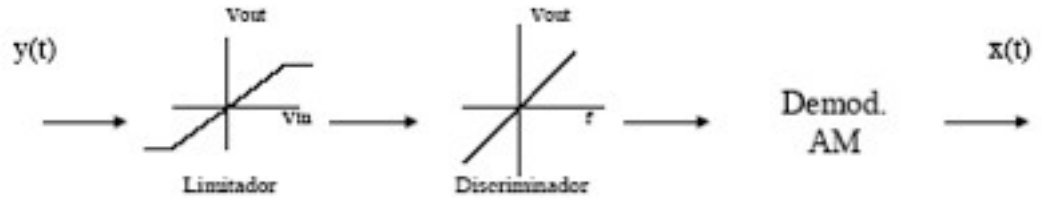
Recuperación de Portadora en DBL y ASK



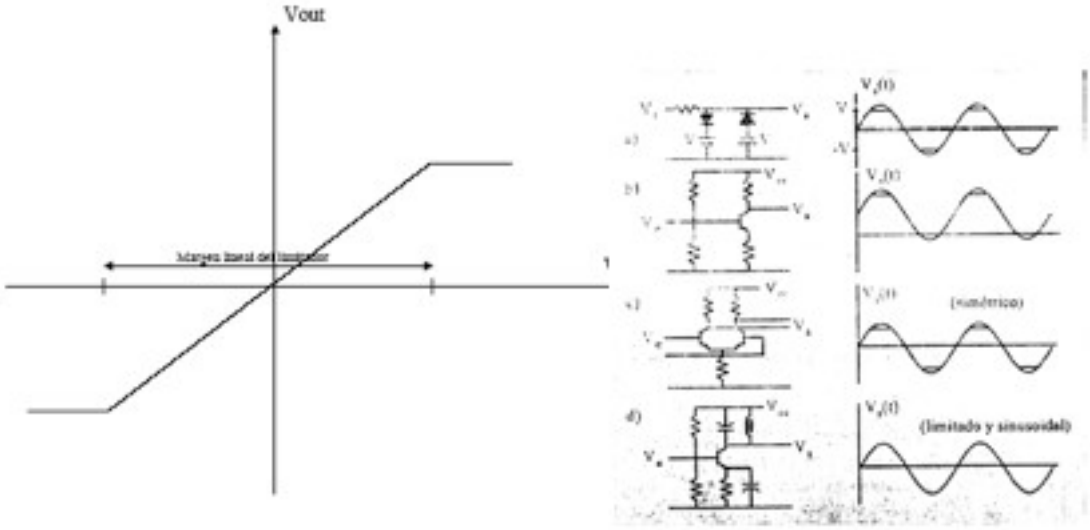
Lazo de Kostas



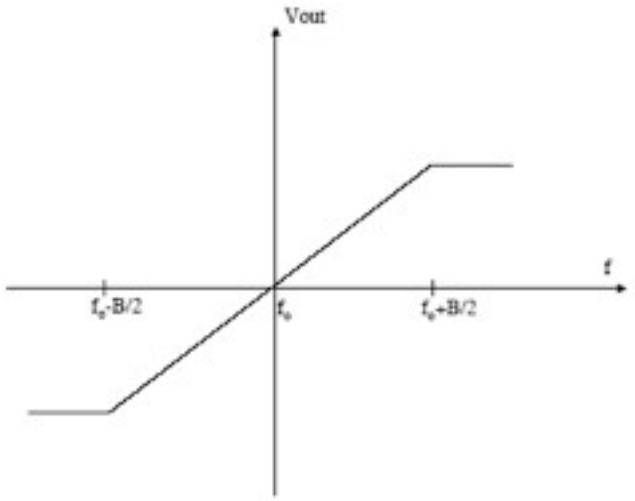
Demodulador FM No Coherente



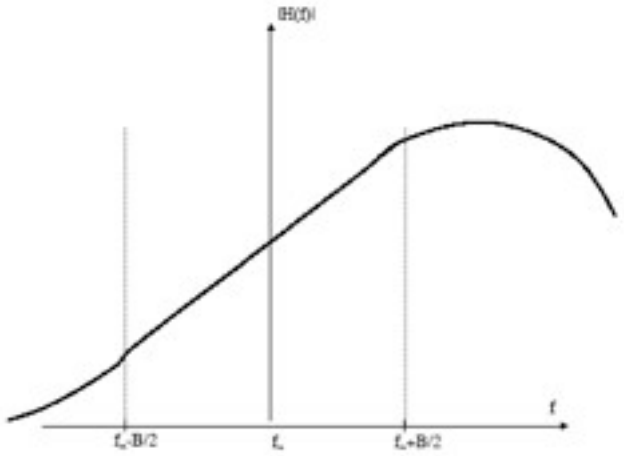
Limitador



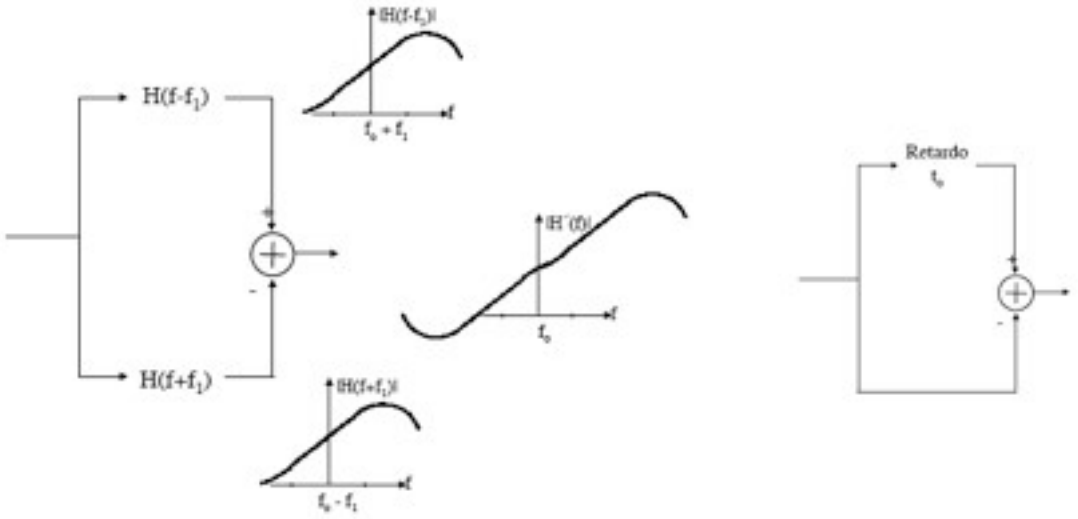
Derivador



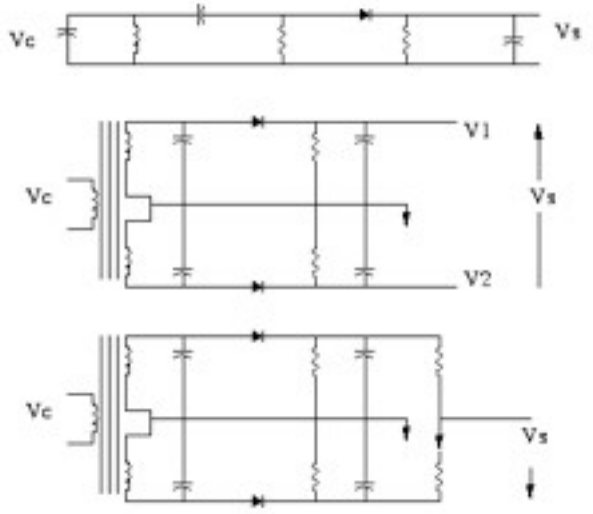
Función de Transferencia de Discriminador



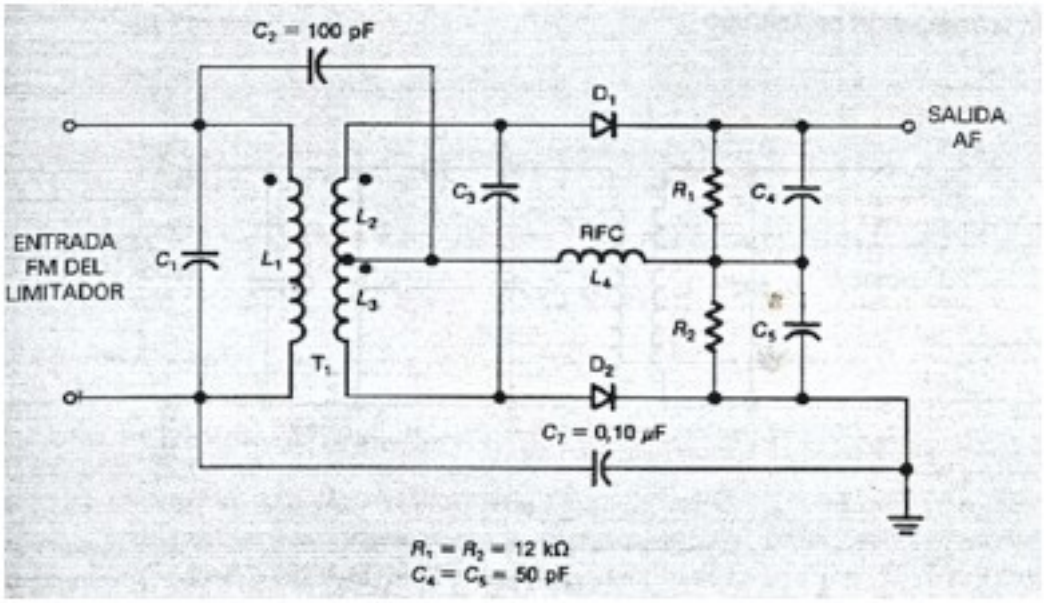
Discriminador



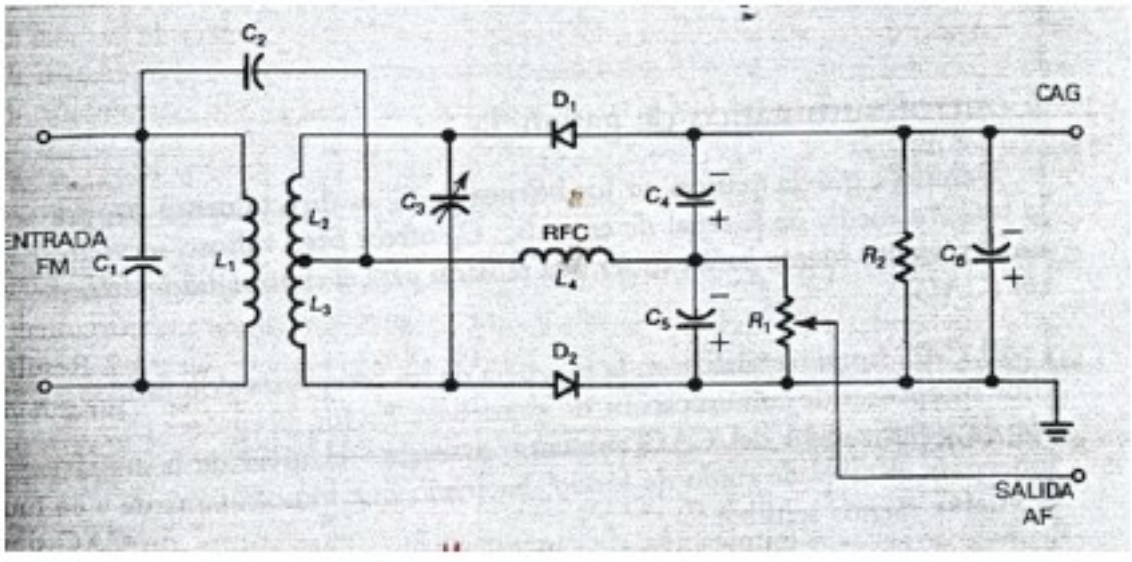
Demoduladores FM No Coherentes



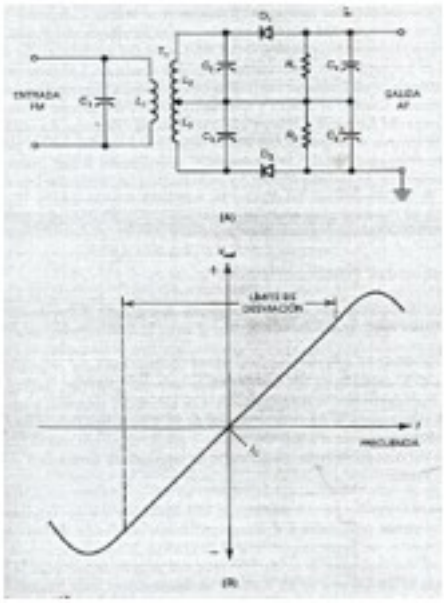
Detector Foster-Seeley



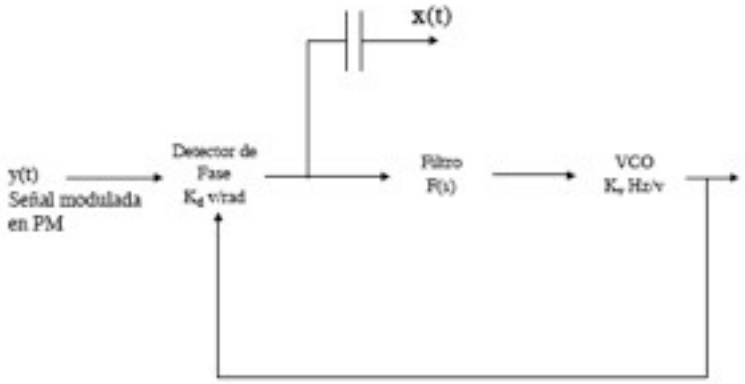
Detector FM de Relación



Detector de Doble Cuadratura

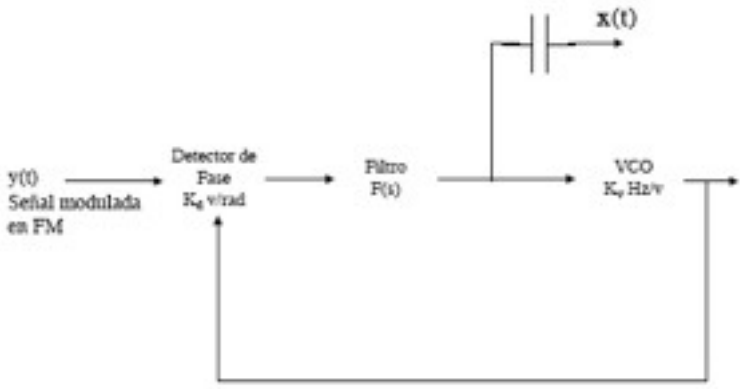


Demodulador PM (Coherente)



$$BW_{PLL} < f_{min_{x(t)}}$$

Demodulador FM Coherente (PLL)



$$BW_{PLL} > f max_{x(t)}$$