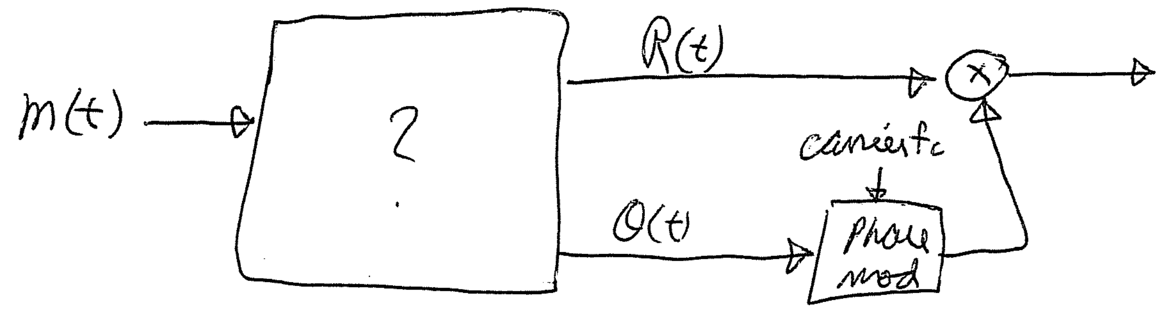
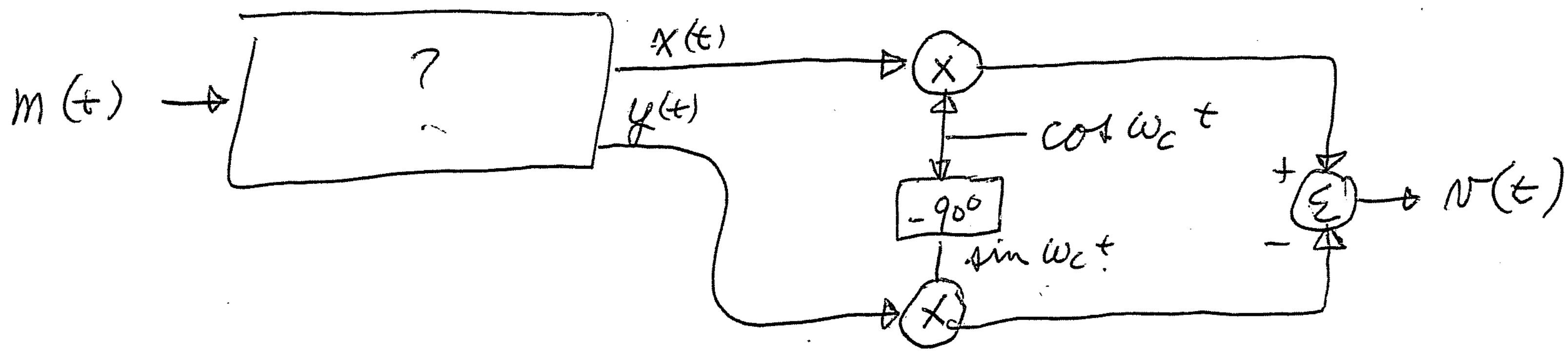
EE511: Lecture 20; Quadrature Modulation
Quadrature Detection and Costas Receiver

Generalized Transmitter



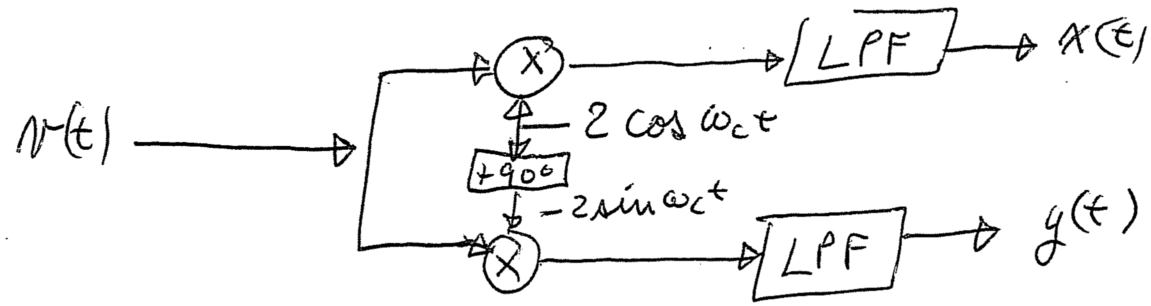
$v(t) = R(t)\cos(\omega_c t + \theta(t))$

Quadrature Generation

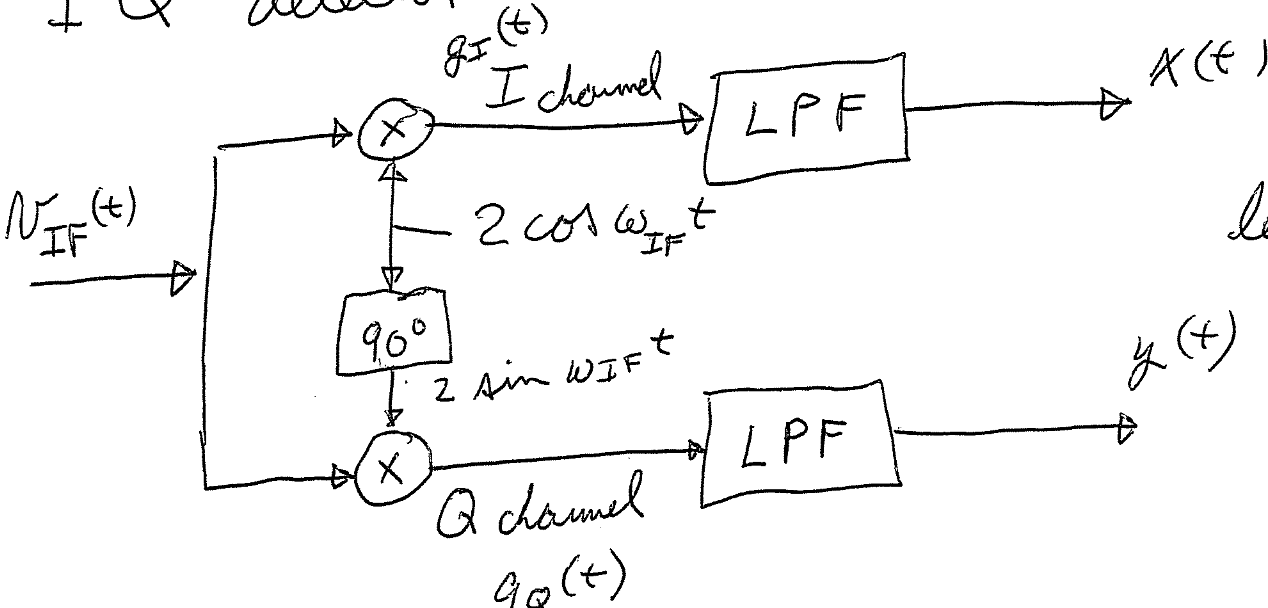


$$v(t) = x(t)\cos\omega_c t - y(t)\sin\omega_c t$$

~~Quad~~ Quadrature Detection



IQ detector

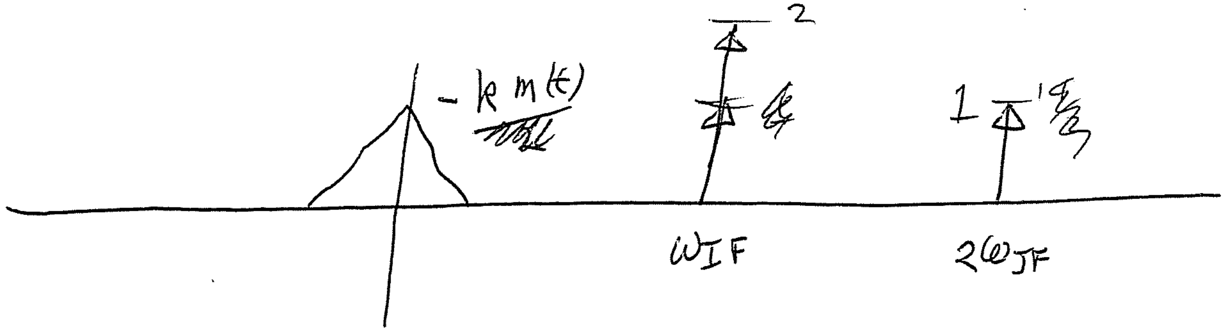


let $v_{IF}(t) = \cancel{}$
$= 1$

Ex:

$$g_I(t) = (2\cos\omega_{IF} t)(1 + k\, m(t) \cos\omega_{IF} t)$$

$$= (2\cos\omega_{IF} t + \cancel{} + k\, m(t) \underbrace{\cos^2 \omega_{IF} t}_{\frac{1 + \cos 2\omega_{IF} t}{2}})$$



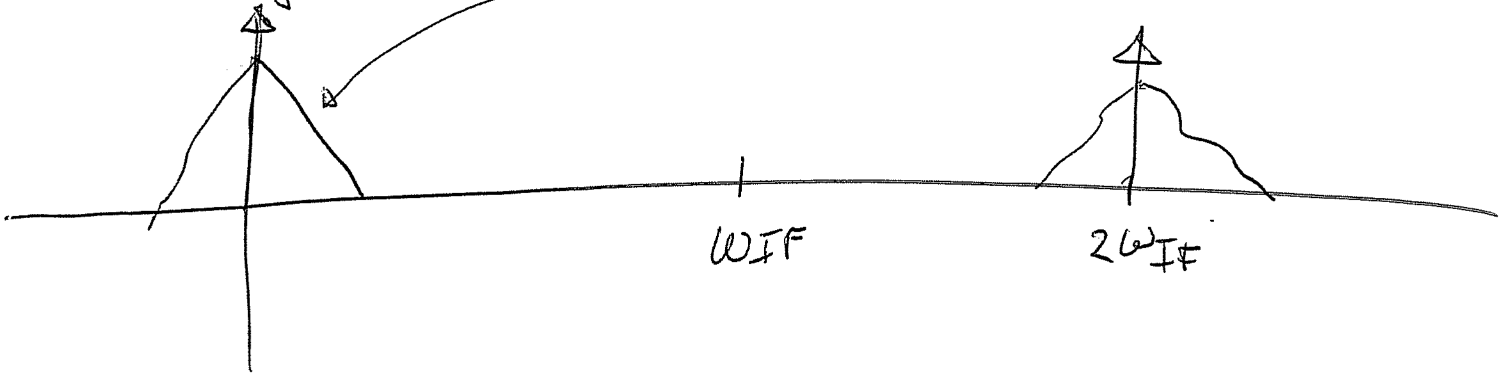
let $v_{IF}(t) = AM$

Ex! $g_I(t) = (2\cos\omega_{IF}t)(1 + k\,m(t))\cos\omega_{IF}t$

$$= (1 + k\,m(t))(1 + \cos 2\omega_{IF}t)$$

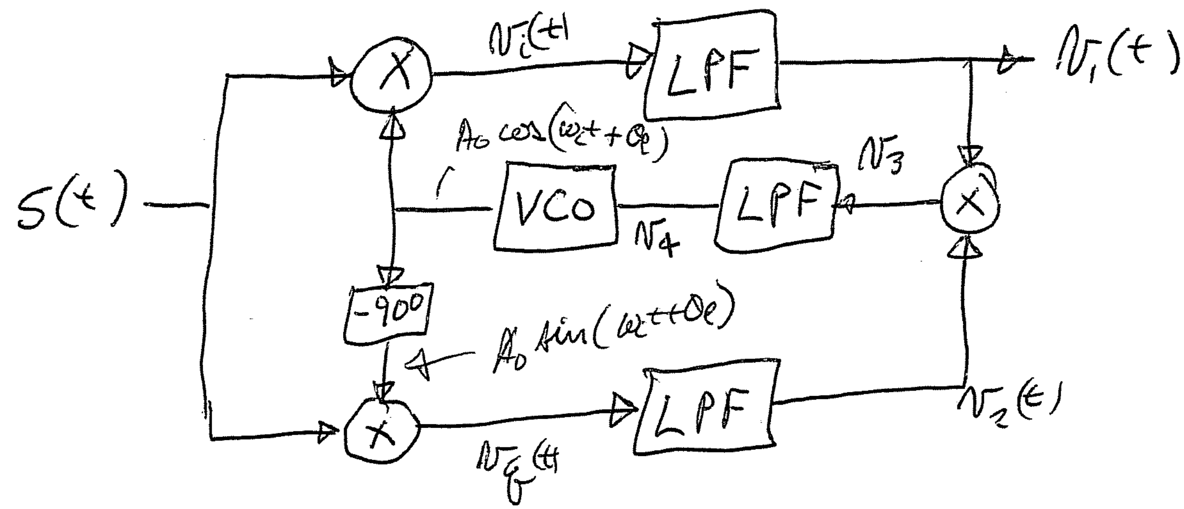
$$G_I(f) = \delta(f) + \mathcal{F}(\cos 2\omega_{IF}t) + k\,M(f) + \mathcal{F}\{\cos 2\omega_{IF}t\}$$

$k\,M(f) *$



Costas Receiver

Previous PLL only returned a dc level proportional to the carrier frequency. Phase info. was lost or ambiguous



let $s(t) = A_c \, m(t) \cos \omega_c t$

$$v_i(t) = s(t) A_0 \cos(\omega_c t + \theta_e) = A_c A_0 \, m(t) \cos \omega_c t \cos(\omega_c t + \theta_e)$$

$$= \frac{A_c A_0}{2} m(t) \left[\cos \theta_e + \cos(2\omega_c t + \theta_e) \right]$$

$$v_1(t) = \frac{A_c A_o}{2} m(t) \cos\theta_e$$

likewise for

$$v_2(t) = \frac{A_c A_o}{2} m(t) \sin\theta_e$$

$$v_3(t) = v_1(t)\, v_2(t) = \frac{A_c^2 A_o^2}{4} m^2(t) \underbrace{\cos\theta_e \sin\theta_e}_{\frac{1}{2}\left[\sin 2\theta_e + \cancel{\sin 0}^{\,0}\right]}$$

$$= \frac{A_c^2 A_o^2}{8} \sin 2\theta_e \left(m^2(t)\right)$$

$m^2(t) =$ dc + higher frequencies

$$\text{st } V_4(t) \approx K \sin 2\theta_e \Big\}\ \text{VCO control voltage}$$

For $\theta_e = 0$ then $v_1(t) = \frac{1}{2} A_0 A_c m(t)$

Phase shift keying where $m(t)$ is ~~to~~ 1 or -1

$$m(t) \cos 2\pi f_c t = \cos\left(2\pi f_c t + \left(\frac{m(t)-1}{2}\right)\pi\right)$$

so if $m(t) = 1$, $\cos 2\pi f_c t = \cos(2\pi f_c t + 0)$

and if $m(t) = -1$, $-\cos 2\pi f_c t = \cos(2\pi f_c t - \pi)$