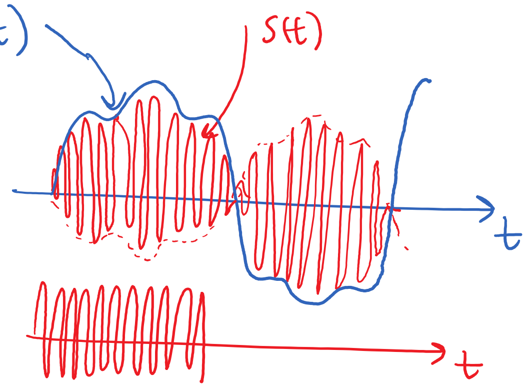
ECE 513 - Lecture 2

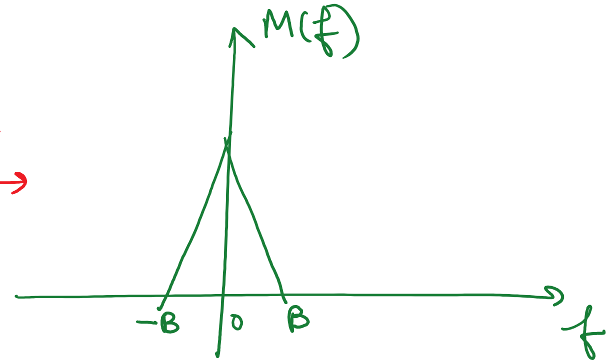
Thursday, August 23, 2018 9:30 AM

Analog Modulation $\longrightarrow$ AM $\rightarrow$ amplitude modulation
FM $\rightarrow$ frequency "

message



$f_c = 100\,MHz$



$B = 1\,kHz$

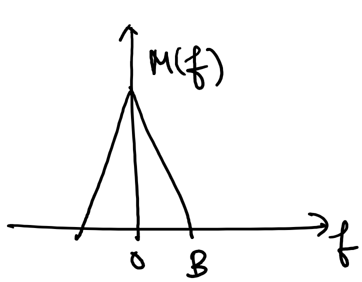
Carrier $\Rightarrow$ $A_c \cos(\omega_c t) = A_c \cos(2\pi f_c t)$

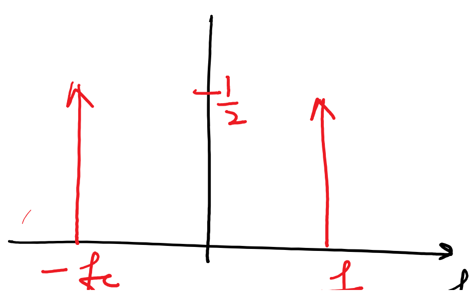
modulated signal

$$s(t) = \underbrace{m(t)}_{\rightarrow M(f)} \cdot \underbrace{A_c \cos \omega_c t}_{\rightarrow}$$

$$s(t) \xrightarrow{\mathcal{F}} S(f)$$

$$* \quad \cos \omega_c t = \frac{1}{2}\left[e^{j\omega_c t} + e^{-j\omega_c t}\right] \xrightarrow{\mathcal{F}} \frac{1}{2}\left[\delta(f - f_c) + \delta(f + f_c)\right]$$

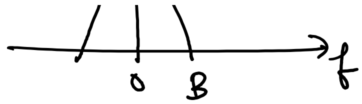


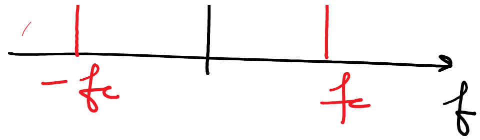


$\delta(t) \xrightarrow{\mathcal{F}} 1$

$1 \xrightarrow{\mathcal{F}} \delta(f)$

$e^{j\omega_c t} \xrightarrow{\mathcal{F}} \delta(f - f_c)$



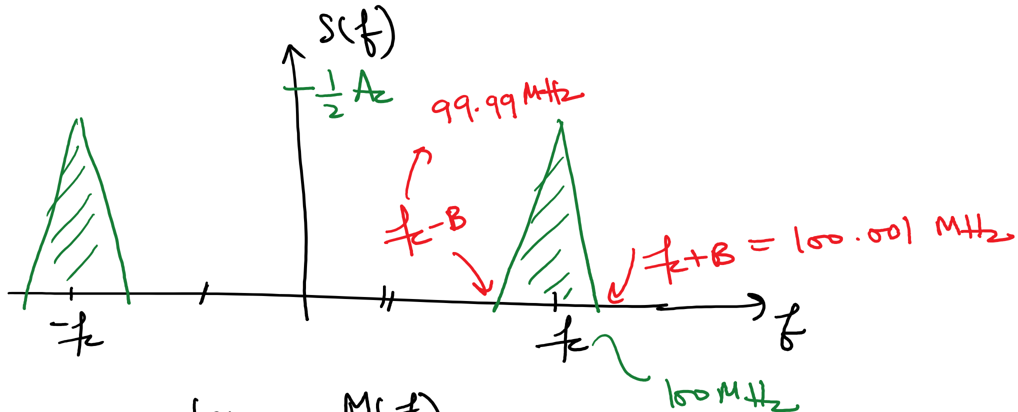


$$e^{j\omega_c t} \xrightarrow{\mathcal{F}} \delta(f-f_c)$$

$$m(t)\cdot A_c\cos(\omega_c t) \xrightarrow{\mathcal{F}} M(f) \circledast \frac{A_c}{2}\left[\delta(f-f_c)+\delta(f+f_c)\right]$$

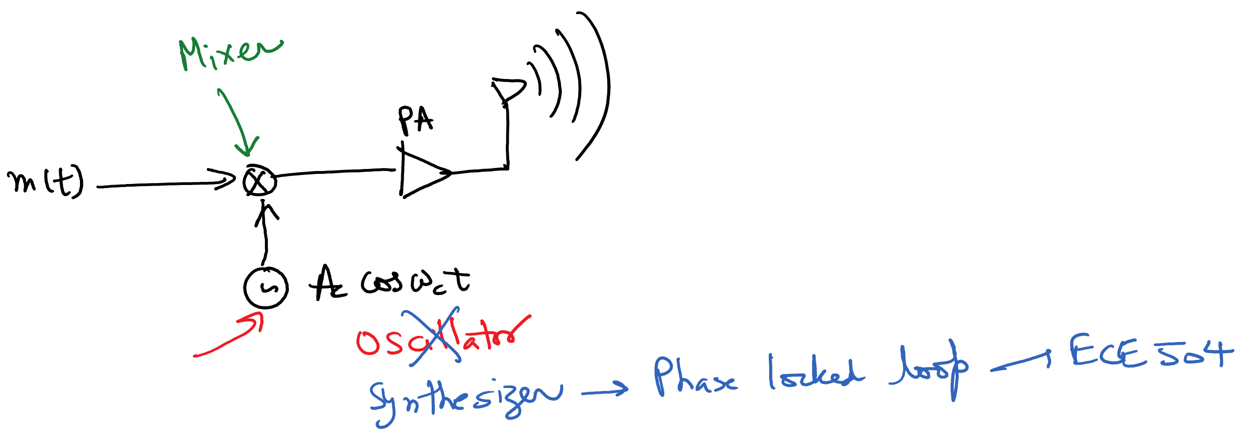
$$= \frac{A_c}{2}\left[M(f-f_c)+M(f+f_c)\right]$$

Modulation or Upconversion

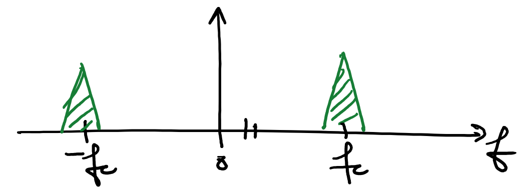


real $m(t) \rightarrow$ Symmetric $M(f)$

real $s(t) \rightarrow$ Asymmetric $S(f)$



Demodulation:



$\cos^2\theta = \frac{1+\cos 2\theta}{2}$

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

$$v(t) = s(t)\cdot A_2\cos\omega_c t = A_2 A_c\, m(t)\cos^2\omega_c t$$

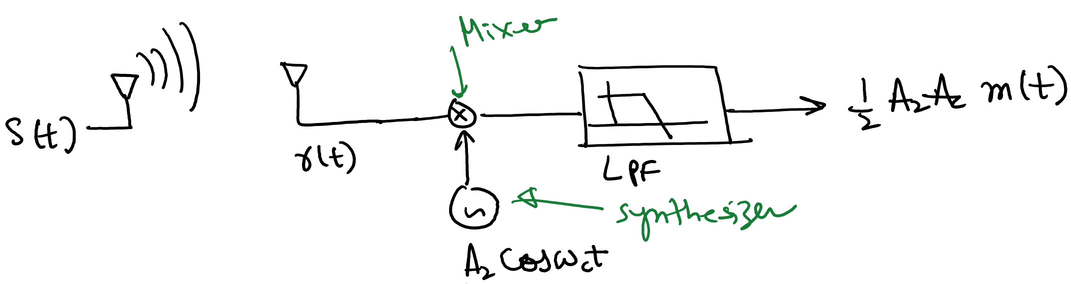
$$= \frac{1}{2}A_2 A_c\, m(t)\left[1+\cos(2\omega_c t)\right]$$

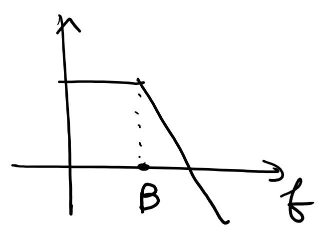
$$= \frac{1}{2}A_2 A_c\left[m(t) + m(t)\cancel{\cos}(2\omega_c t)\right]$$

$$\xrightarrow{\text{LPF}} \frac{1}{2}A_2 A_c\cdot m(t)$$

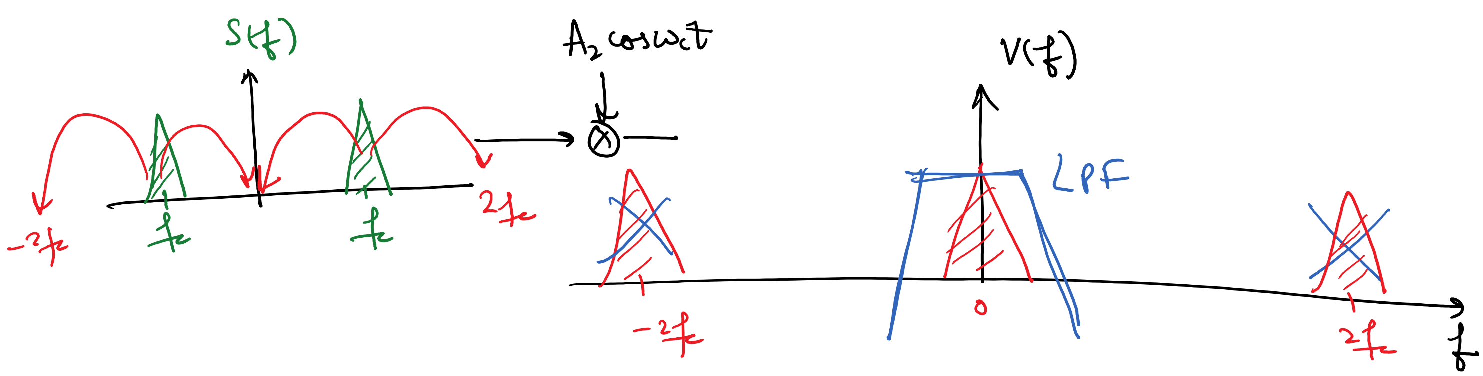
image

Synchronous Detection





Need a local synthesizer that is synchronized with the carrier at TX



Thursday, August 23, 2018 10:29 AM

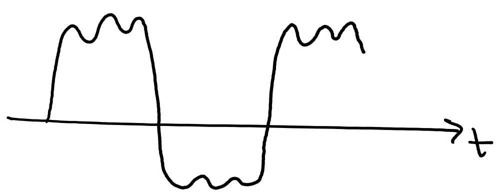
AM Radio

$$s(t) = A_c \cancel{m(t)} \cos(\omega_c t)$$

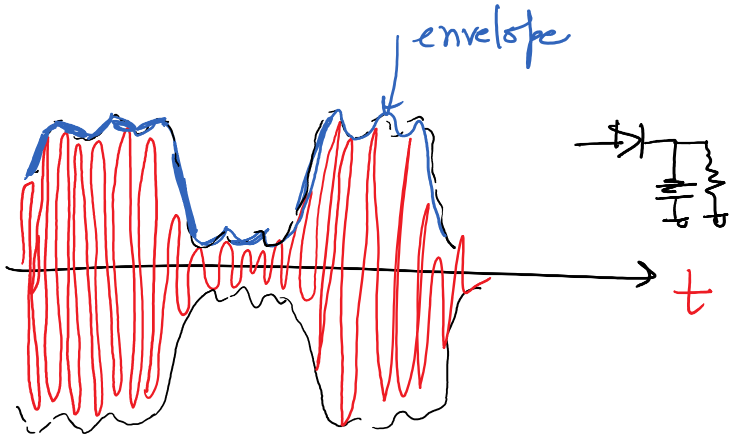
$$s(t) = A_c[1 + \underbrace{k_a}_{\text{modulation index}} m(t)] \cos(\omega_c t)$$

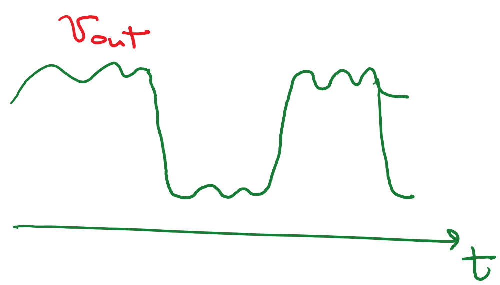
$$|k_a m(t)| < 1$$

m(t)

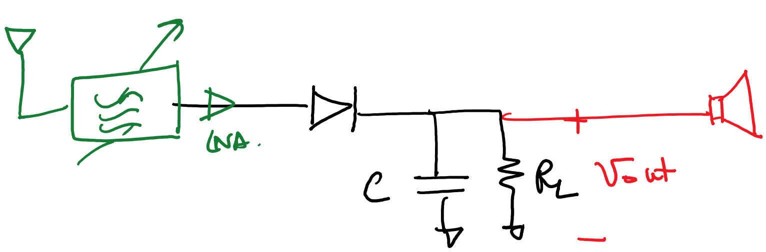


s(t)





Envelope Detection

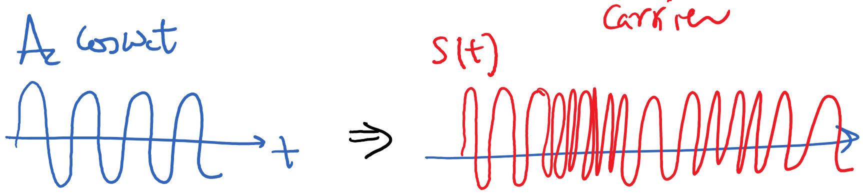


$\phi(t)$

FM Modulation

$$s(t) = A_c \cos\left(2\pi f_c t + 2\pi k_m \int_{-\infty}^{t} m(t)\,dt\right)$$

Information is in the phase of the carrier



Let $A_c = 1$

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

$$\triangleq m(t)\cos\omega_c t$$

$$e^{j\omega_c t} = \cos\omega_c t + j\sin\omega_c t$$

$$s(t) = \mathrm{Re}\{m(t)\, e^{j\omega_c t}\}$$

$$m(t) = \mathrm{Re}\{s(t)\, e^{-j\omega_c t}\}$$

In general

$$s(t) = \mathrm{Re}\{m(t)\, e^{j\omega_c t}\}$$ when $m(t)$ can be complex

$$m(t) = m_I(t) + j\, m_Q(t)$$

In-phase　　Quadrature phase

$$= \mathrm{Re}\{[m_I(t) + j\, m_Q(t)][\cos\omega_c t + j\sin\omega_c t]\}$$

$$s(t) = \underbrace{m_I(t)}\cos\omega_c t - \underbrace{m_Q(t)}\sin\omega_c t$$