Modulation

Lesson 13

4CT.5

Modulation

- Let's look at two Kinds of Modulation
  - Amplitude Modulation

$$f(t)=A(t)\ cos\ \omega t$$

  - Angle Modulation

$$f(t)=Acos[\ f(t)]$$

  - Where $A(t)$ and $f(t)$ contain the information portion of $f(t)$ and this information is found in either the amplitude and angle of the carrier, respectively.

Band Limited Signals

- A signal $m(t)$ is band limited (BL) when

$$\Im[m(t)] = M(j\omega) \equiv 0; \text{ for } |\omega| > \omega_M$$

that is, *m(t)* is limited to the band of frequencies below ω_M

- Examples:
  - Voice is BL.
  - Video is BL
- We can always obtain a BL signal by passing a signal through a Low Pass filter

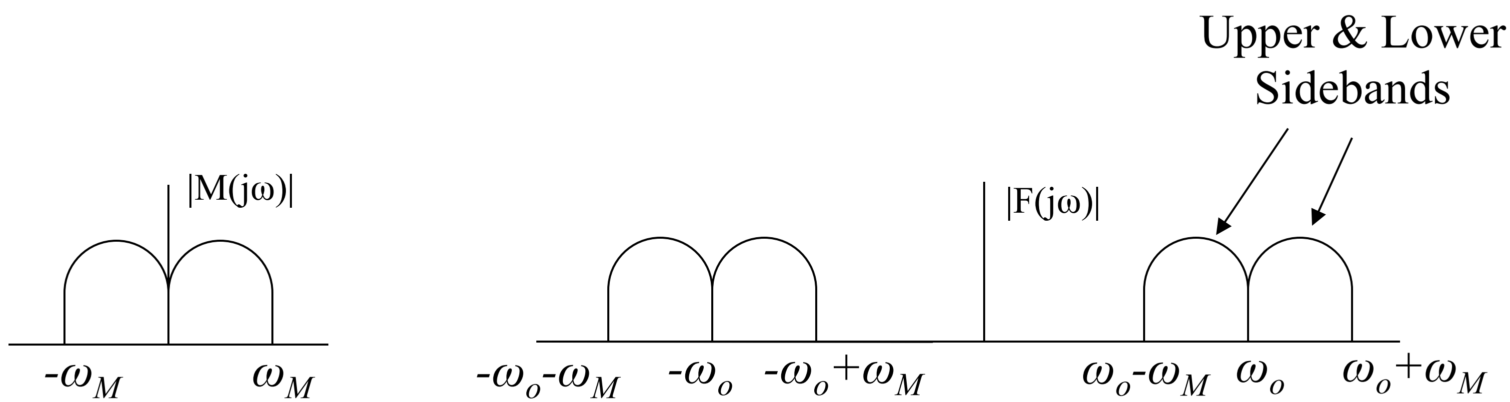
Amplitude Modulation

Recall if $\Im[m(t)] = M(j\omega)$, then

$$\Im[m(t)e^{j\omega_o t}] = M[j(\omega - \omega_o)]$$

$$\Im[f(t)] = \Im[m(t)\cos\omega_o t] = \frac{1}{2}\{M[j(\omega - \omega_o)] + M[j(\omega + \omega_o)]\}$$

If $m(t)$ is BL, then $m(t)\cos(\omega t)$ is also BL

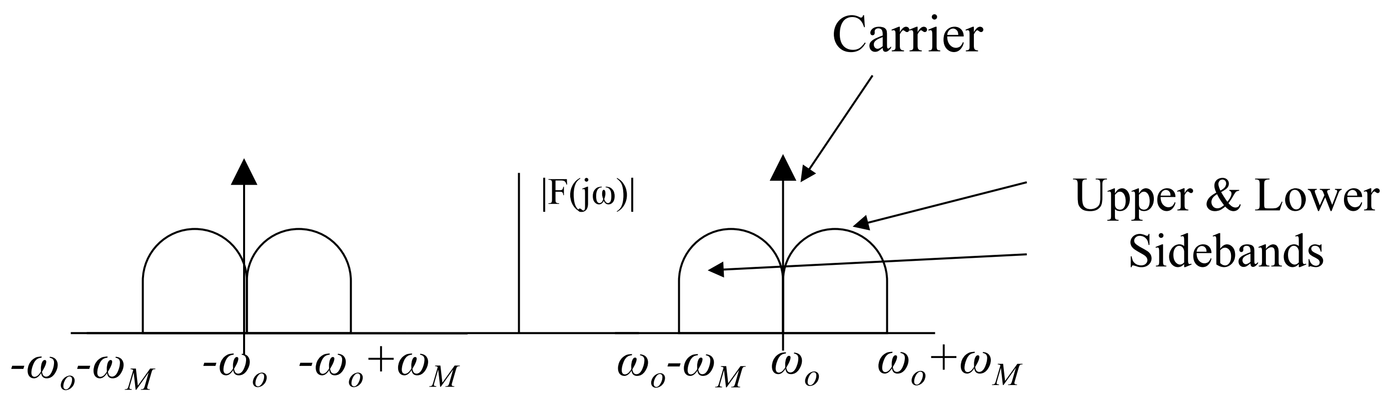


AM Radio Signal

Define: $f(t) = K[1 + m(t)]\cos\omega_o t$, assuming $|m(t)| < 1$ and $m(t)$ is BL $< \omega_M$

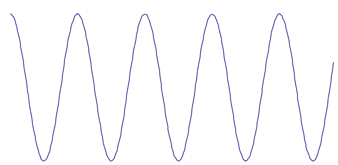
$$\Im[f(t)] = \Im[K\{1 + m(t)\}\cos\omega_o t]$$

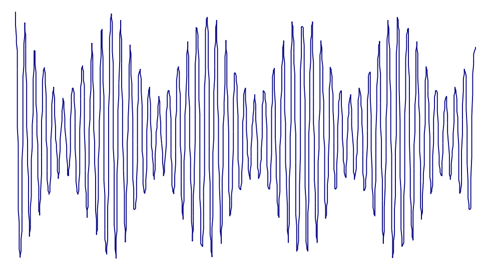
$$= K\pi\{\delta(\omega - \omega_o) + \delta(\omega + \omega_o)\} + \frac{K}{2}\{M[j(\omega - \omega_o)] + M[j(\omega + \omega_o)]\}$$



AM Continued

- If $\omega_M << \omega_o$, that is $m(t)$ varies slower than the carrier frequency, we have the following signal:

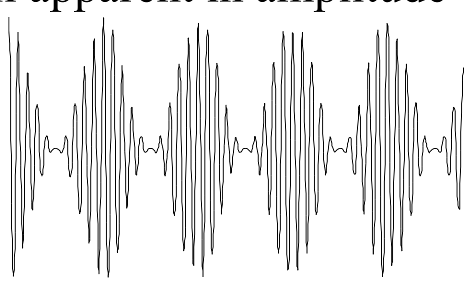




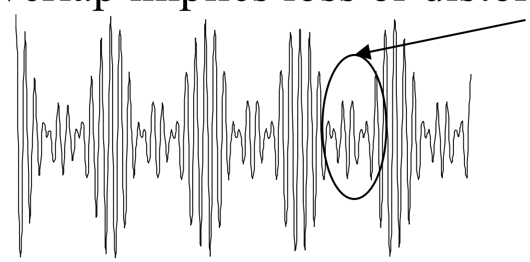
AM signal for $\omega_o / \omega_M = 10$ and $|m(t)| = 25\%$

Original signal still apparent in amplitude

$|m(t)| = 100\%$



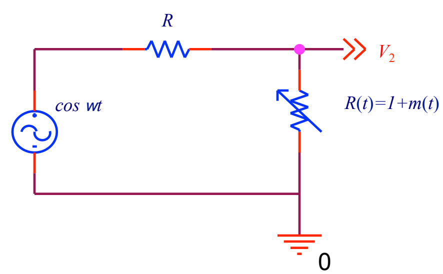
Overlap implies loss or distortion of information

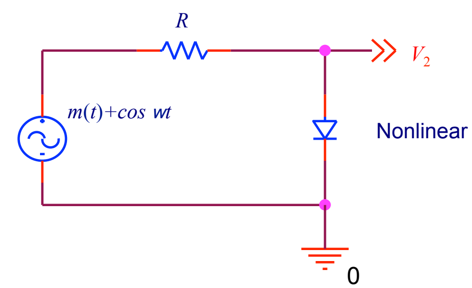


$|m(t)| = 200\%$

Construction of an AM Signal & Reconstruction of m(t)

- Construction (Modulation): Multiplication of $1+m(t)$ and $\cos \omega_o t$ using a variable parametric device or nonlinear modulator
  - Linear Modulators
  - Square Law Modulators





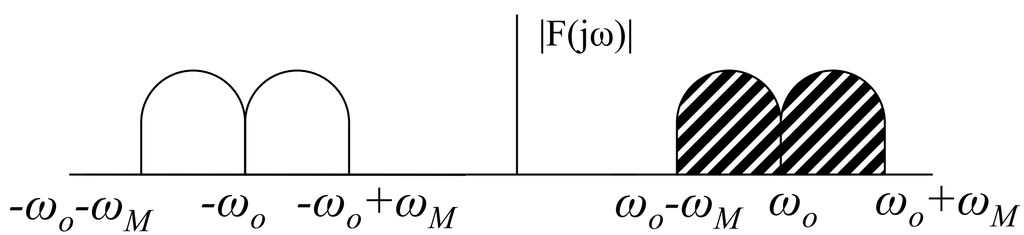
- Reconstruction of m(t) (Demodulation):
  - Multiplication of AM signal with the carrier signal
  - Filter out $m(t)$
  - Halfwave rectification followed by envelope detection.

Reconstruction

- Multiplication of AM signal with carrier:

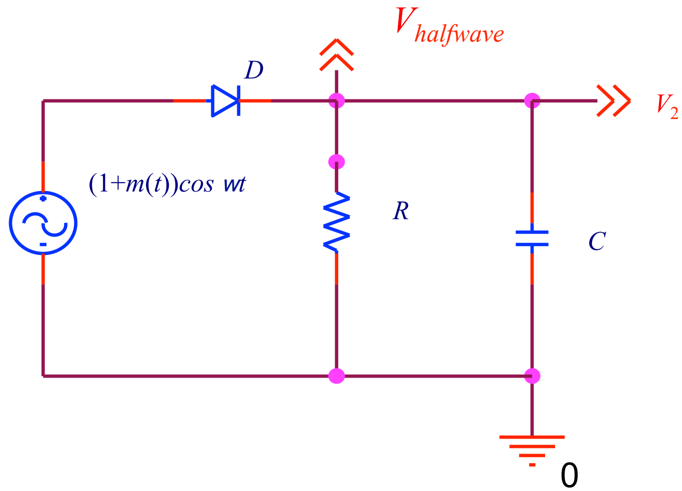
$$f(t)\cos\omega_o t = [1+m(t)]\cos\omega_o t \times \cos\omega_o t = [1+m(t)]\cos^2\omega_o t$$
$$= [1+m(t)] + [1+m(t)]\cos 2\omega_o t$$

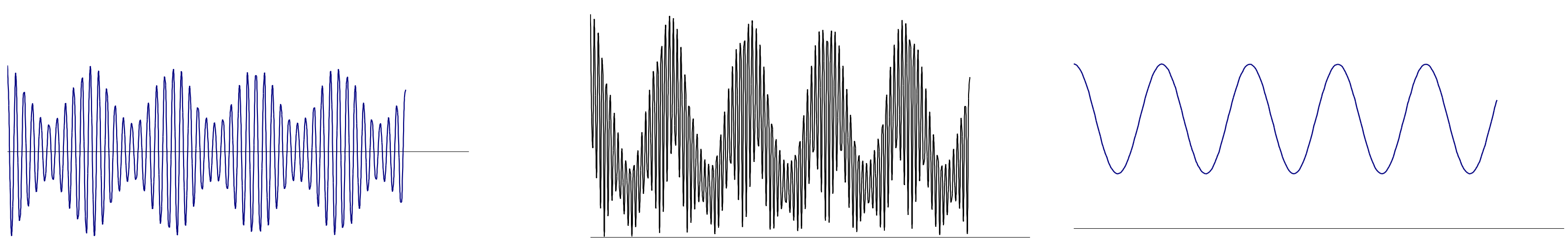
- Filter out sidebands of AM



- Halfwave Rectification and Envelop Detection

Halfwave Rectification and Envelope Detection

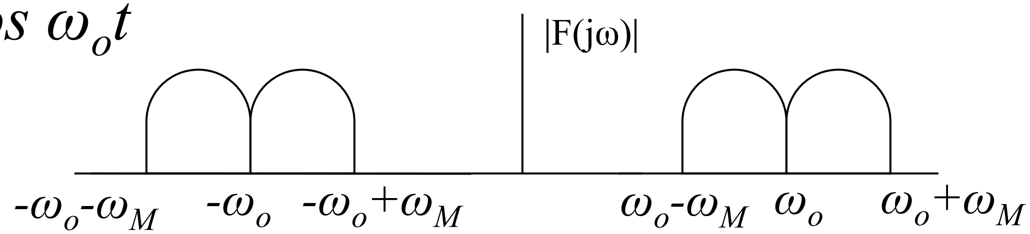




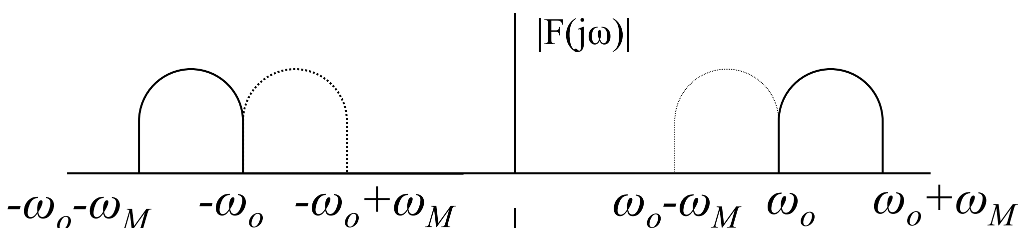
V_1=[1+m(t)]cos wt $V_{halfwave}$ V_2

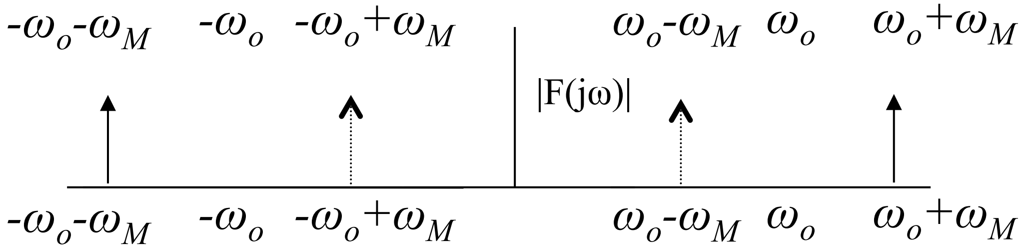
Other AM Signals

- To use less energy:
  - Double Side Band Suppressed Carrier (DSBSC), send $m(t) \cos \omega_o t$



  - Single Side Band Suppressed Carrier (SSBSC), [for simplicity assume $m(t) = \cos \omega_s t$], send $\cos(\omega_o + \omega_s)t$





Homework

- Problem (1)
  - The signal $f(t)=(1+m_o cos\ t)cos100t$ is applied to a series RLC circuit where L=10 h, C=10 mF, R=10k W. Calculate $v(t)$, the voltage across the resistance.
- Problem (2)
  - The SSBSC version of $f(t)$ is applied to the same circuit. Calculate $v(t)$.