EE-2025 Spring-2000

Lecture 20

Amplitude Modulation (AM)

3-April-00

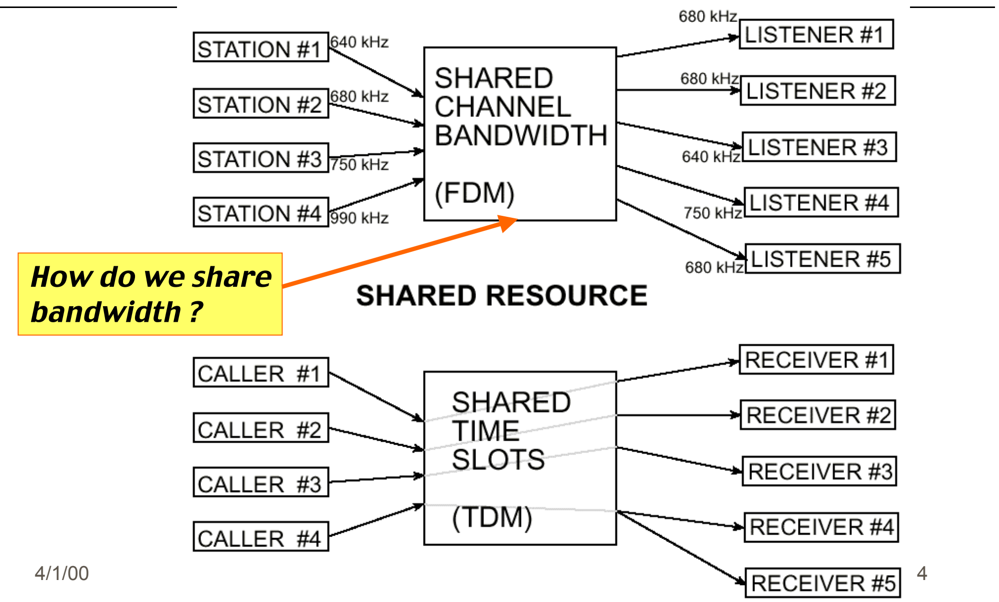
Info: Web-CT, Lab, HW

- Calendar:
  - Quiz #3 is Friday 7–April
  - Covers Z–Transform, Impulses, Convolution and FT.
- Review Session: Thursday @ 7 pm
- Prob Set #10 – due this week
  - Solution will be posted Thursday
- Reading Assignment
  - Read Chapter 13 of Notes.

LECTURE OBJECTIVES

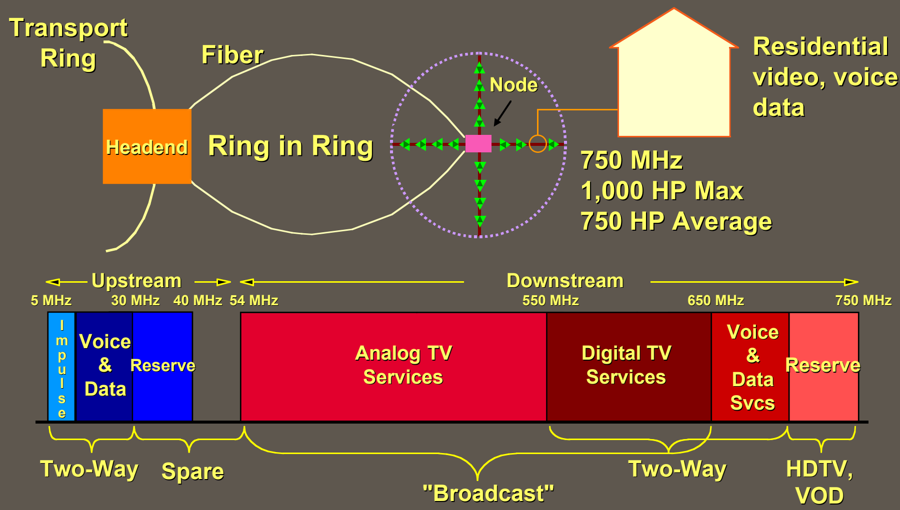
- Review of FT properties
  - Convolution <––> multiplication
  - Frequency shifting
- Sinewave Amplitude Modulation
  - AM radio
- Frequency–division multiplexing
  - FDM

The way communication systems work



From a Network Perspective,,,

Cox Cable Strategy: Broadband



HFC Full Service Network in Residential Areas

Table of Easy FT Properties

Linearity Property

$$ax_1(t)+bx_2(t) \Leftrightarrow aX_1(j\omega)+bX_2(j\omega)$$

Delay Property

$$x(t-t_d) \Leftrightarrow e^{-j\omega t_d}X(j\omega)$$

Frequency Shifting

$$x(t)e^{j\omega_0 t} \Leftrightarrow X(j(\omega-\omega_0))$$

Scaling

$$x(at) \Leftrightarrow \frac{1}{|a|}X(j(\frac{\omega}{a}))$$

Table of FT Properties

$$x(t)*h(t) \Leftrightarrow H(j\omega)X(j\omega)$$

$$x(t)p(t) \Leftrightarrow \frac{1}{2\pi}X(j\omega)*P(j\omega)$$

$$x(t)e^{j\omega_0 t} \Leftrightarrow X(j(\omega-\omega_0))$$

Differentiation Property

$$\frac{dx(t)}{dt} \Leftrightarrow (j\omega)X(j\omega)$$

Frequency Shifting Property

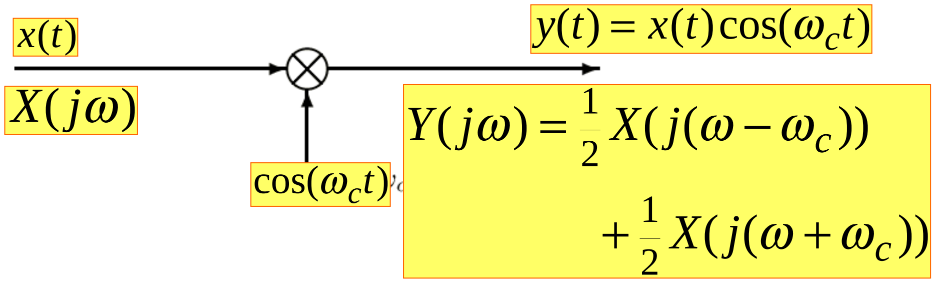
$$x(t)e^{j\omega_0 t} \Leftrightarrow X(j(\omega-\omega_0))$$

$$\int_{-\infty}^{\infty} e^{-j\omega_0 t}x(t)e^{-j\omega t}dt = \int_{-\infty}^{\infty} x(t)e^{-j(\omega-\omega_0)t}dt$$

$$= X(j(\omega-\omega_0))$$

$$y(t)=\frac{\sin 7t}{\pi t}e^{j\omega_0 t} \Leftrightarrow Y(j\omega)=\begin{cases}1 & \omega_0-7<\omega<\omega_0+7\\ 0 & elsewhere\end{cases}$$

Amplitude Modulator



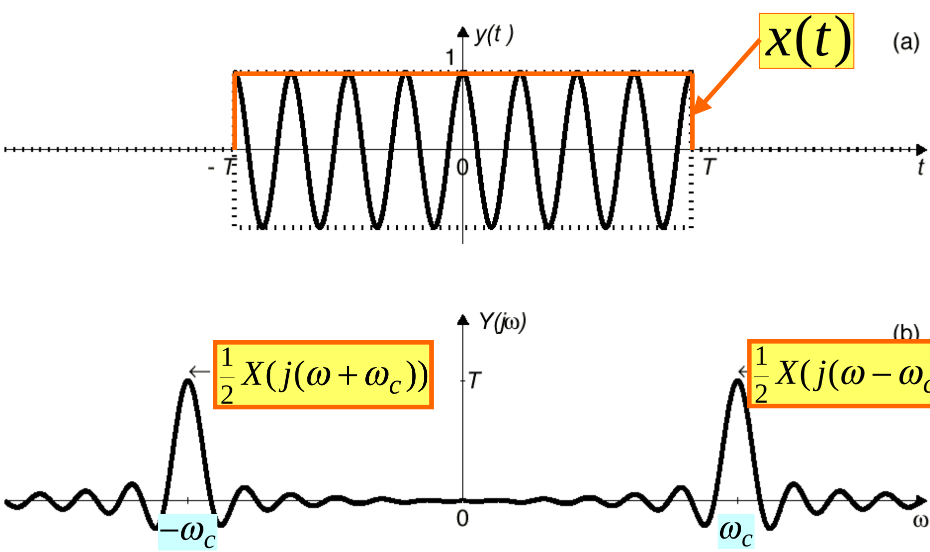
- ***x(t)*** **modulates the amplitude of the cosine wave. The result in the frequency-domain is two shifted copies of *X(jω)*.**

$$y(t) = x(t)\cos(\omega_c t) \Leftrightarrow$$
$$Y(j\omega) = \frac{1}{2}X(j(\omega-\omega_c)) + \frac{1}{2}X(j(\omega+\omega_c))$$

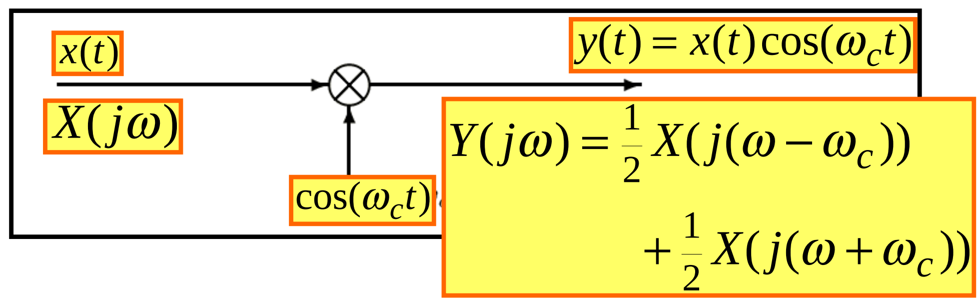
$$x(t) = \begin{cases} 1 & |t| < T \\ 0 & |t| > T \end{cases} \Leftrightarrow X(j\omega) = 2\frac{\sin(\omega T)}{(\omega)}$$

$$y(t) = x(t)\cos(\omega_c t) \Leftrightarrow$$
$$Y(j\omega) = \frac{\sin((\omega-\omega_c))}{(\omega-\omega_c)} + \frac{\sin((\omega+\omega_c))}{(\omega+\omega_c)}$$

$$y(t) = x(t)\cos(\omega_c t) \Leftrightarrow$$
$$Y(j\omega) = \frac{1}{2}X(j(\omega-\omega_c)) + \frac{1}{2}X(j(\omega+\omega_c))$$



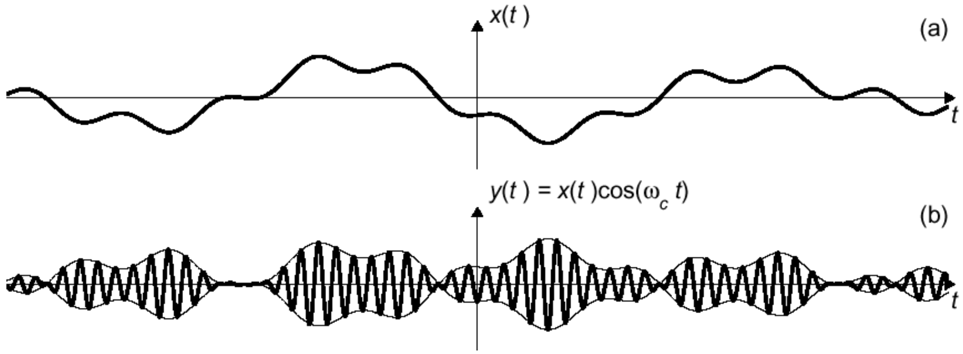
DSBAM Modulator



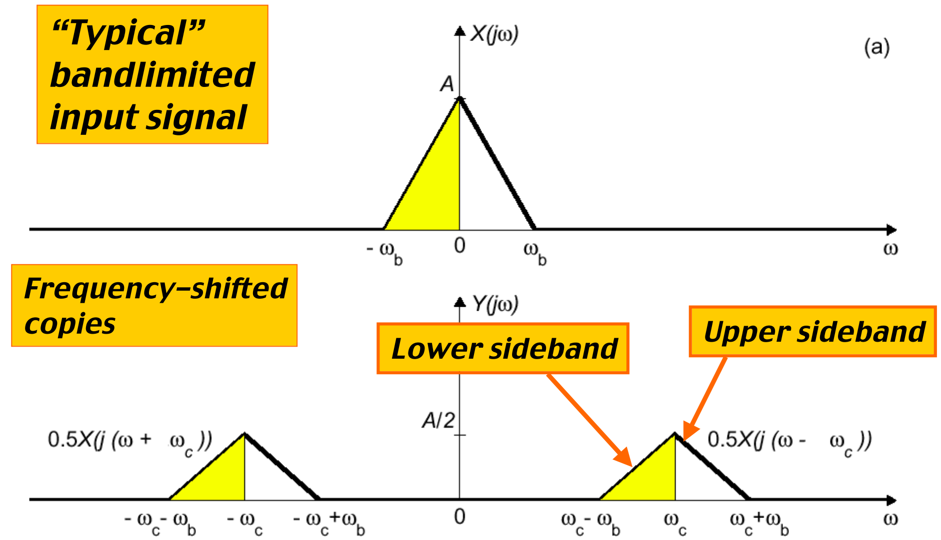
- **If *X(jω)*=0 for |ω|>ω_b and $\omega_c > \omega_b$, the result in the frequency-domain is two shifted and scaled exact copies of *X(jω)*.**

DSBAM Waveform

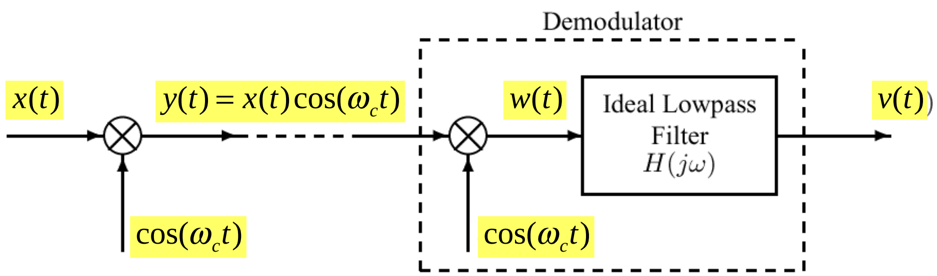
- In the time–domain, the envelope of sinewave peaks follows |*x(t)*|



Double Sideband AM (DSBAM)



DSBAM Demodulator

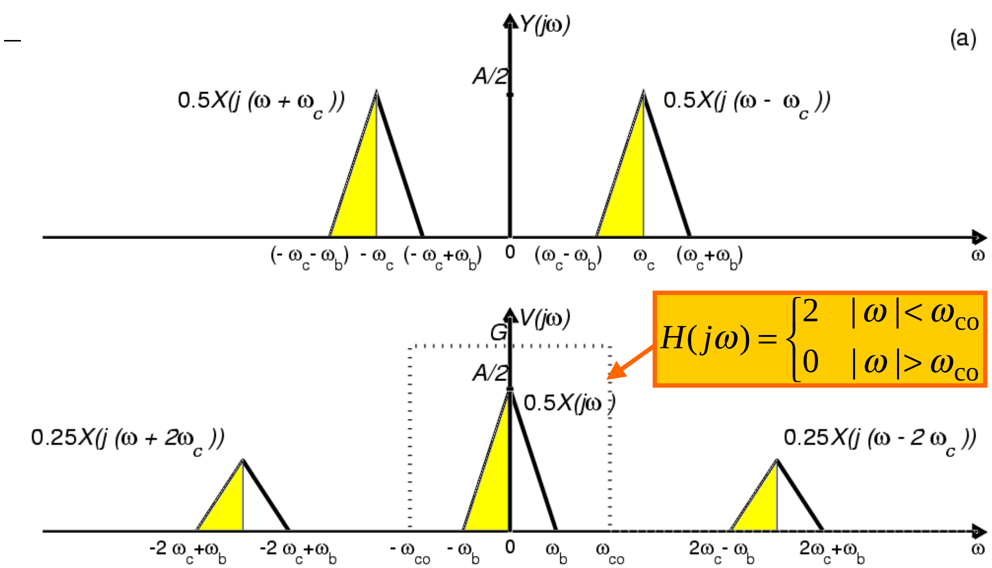


$$w(t) = x(t)[\cos(\omega_c t)]^2 = \frac{1}{2}x(t) + \frac{1}{2}x(t)\cos(2\omega_c t)$$

$$W(j\omega) = \frac{1}{2}X(j\omega) + \frac{1}{4}X(j(\omega - 2\omega_c)) + \frac{1}{4}X(j(\omega + 2\omega_c))$$

$$V(j\omega) = H(j\omega)W(j\omega)$$

DSBAM Demodulation



$$V(j\omega) = H(j\omega)W(j\omega) = X(j\omega) \;\text{ if }\; \omega_b < \omega_{co} < 2\omega_c - \omega_b$$

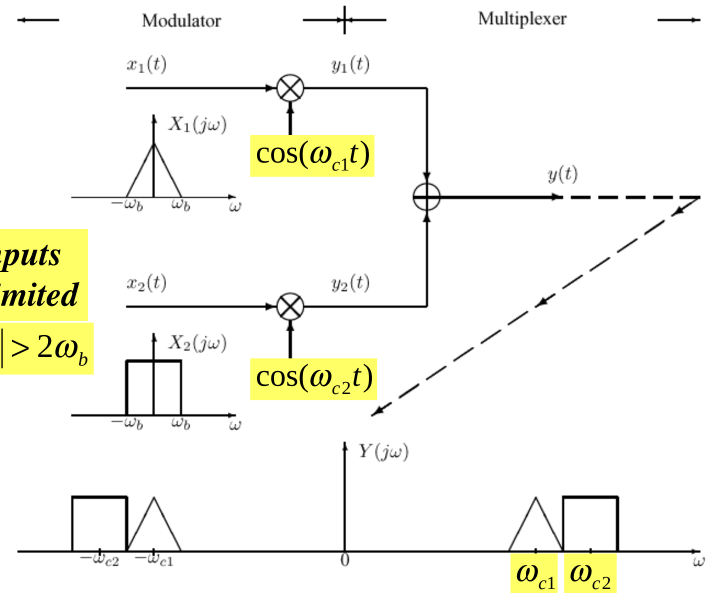
Frequency-Division Multiplexing (FDM)

- Shifting spectrum of signal to higher frequency:
  - Permits transmission of low-frequency signals with high-frequency EM waves
  - By allocating a frequency band to each signal multiple **bandlimited** signals can share the same channel
  - AM radio: 530–1620 kHz (10 kHz bands)
  - FM radio: 88.1–107.9 MHz (200 kHz bands)

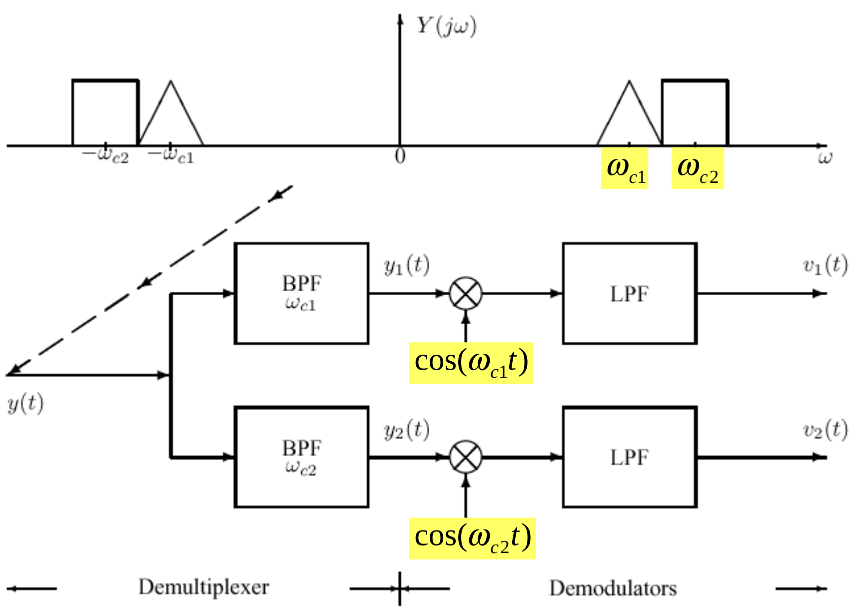
FDM Block Diagram

Spectrum of inputs must be bandlimited

Need $|\omega_{c2} - \omega_{c1}| > 2\omega_b$



Frequency-Division De-Mux



Bandpass Filters for De-Mux