# EE-2025 Fall-99

**Lecture 23**

**Amplitude Modulation (AM)**

**29-Nov-99**

# Info: Web-CT, Lab, HW

- Calendar: Final Exams
  - 11am section–Period 9, Weds, 12/15
  - 12pm section–Period 13, Fri, 12/17
  - NO switching allowed
- Prob Set #13 – due 3–Dec
- Reading Assignment
  - Read Chapter 13 of Notes.

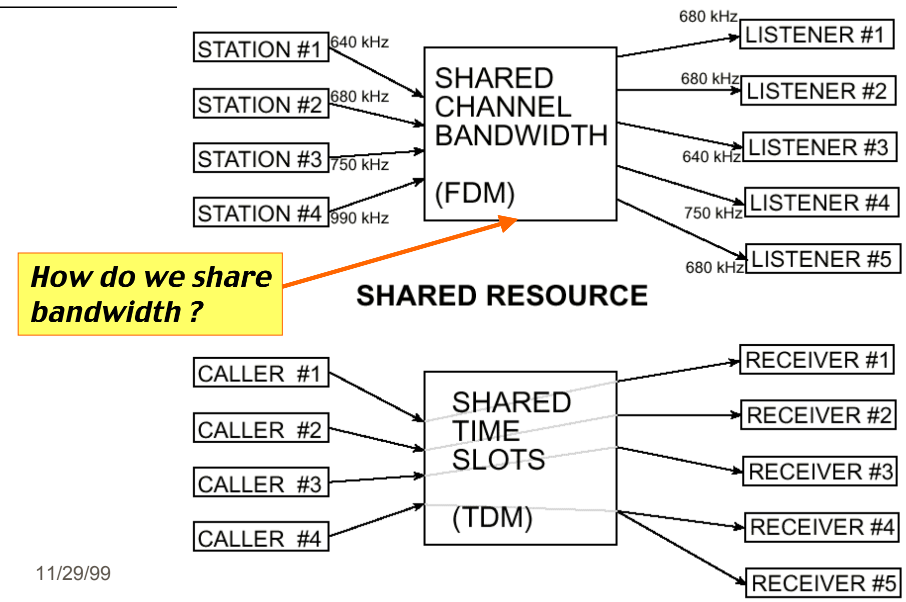


# LECTURE OBJECTIVES

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



# The way communication systems work



## 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***

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



## Table of FT Properties

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

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

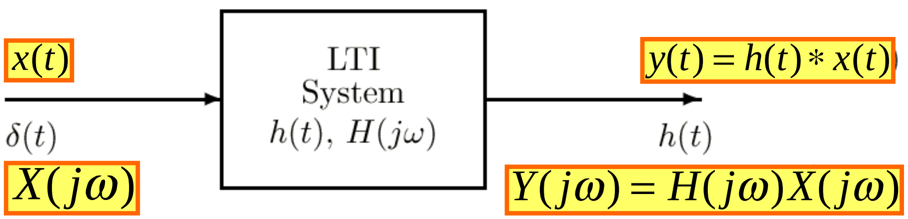
$$x(t)e^{j\omega_0 t} \Leftrightarrow X(j(\omega-\omega_0))$$

***Differentiation Property***

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



## Convolution Property




- **Convolution in the time-domain**

$$y(t)=h(t)*x(t)=\int_{-\infty}^{\infty}h(\tau)x(t-\tau)d\tau$$

**corresponds to MULTIPLICATION in the frequency-domain** $Y(j\omega)=H(j\omega)X(j\omega)$



## Frequency Shifting Property

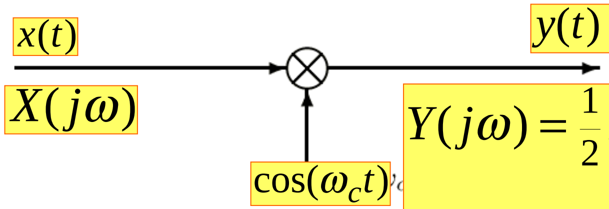
$$x(t)e^{j\omega_0 t} \Leftrightarrow X(j(\omega-\omega_0))$$

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

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

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

## Amplitude Modulator




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

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



$$y(t) = x(t)\cos(\omega_c t) \Leftrightarrow$$

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

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

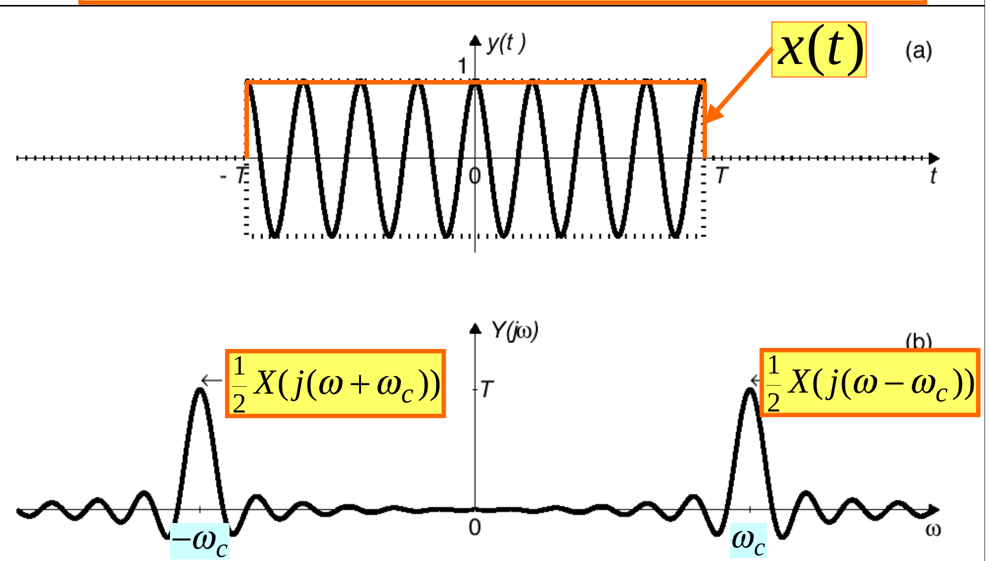
$$y(t) = x(t)\cos(\omega_c t) \Leftrightarrow$$

$$Y(j\omega) = \frac{\sin((\omega - \omega_c))}{(\omega - \omega_c)} + \frac{\sin((\omega + \omega_c))}{(\omega + \omega_c)}$$



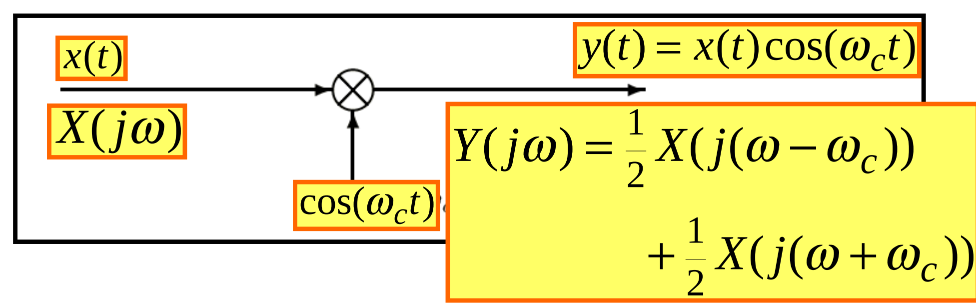
$$y(t) = x(t)\cos(\omega_c t) \Leftrightarrow$$

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






## DSBAM Modulation

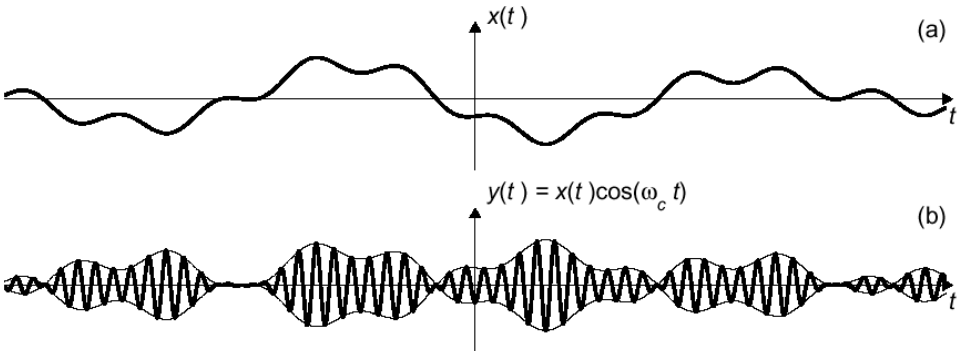



$$Y(j\omega) = \frac{1}{2}X(j(\omega - \omega_c)) + \frac{1}{2}X(j(\omega + \omega_c))$$

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

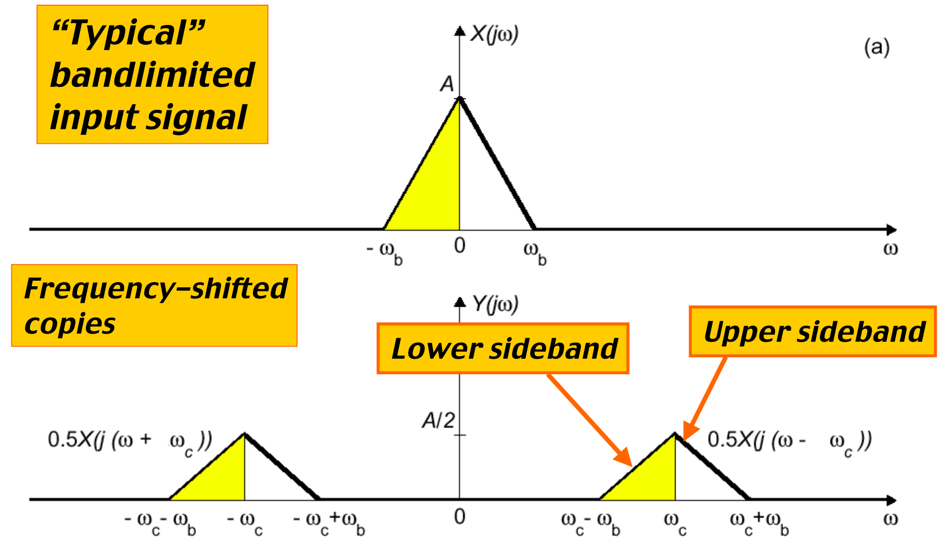
# DSBAM Waveform

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



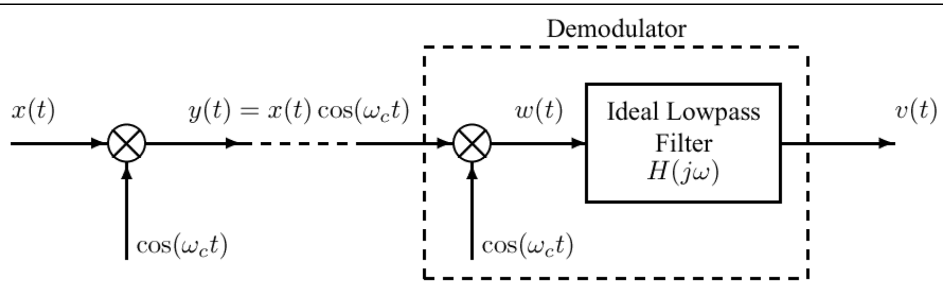



# Double Sideband AM (DSBAM)






# DSBAM Demodulation



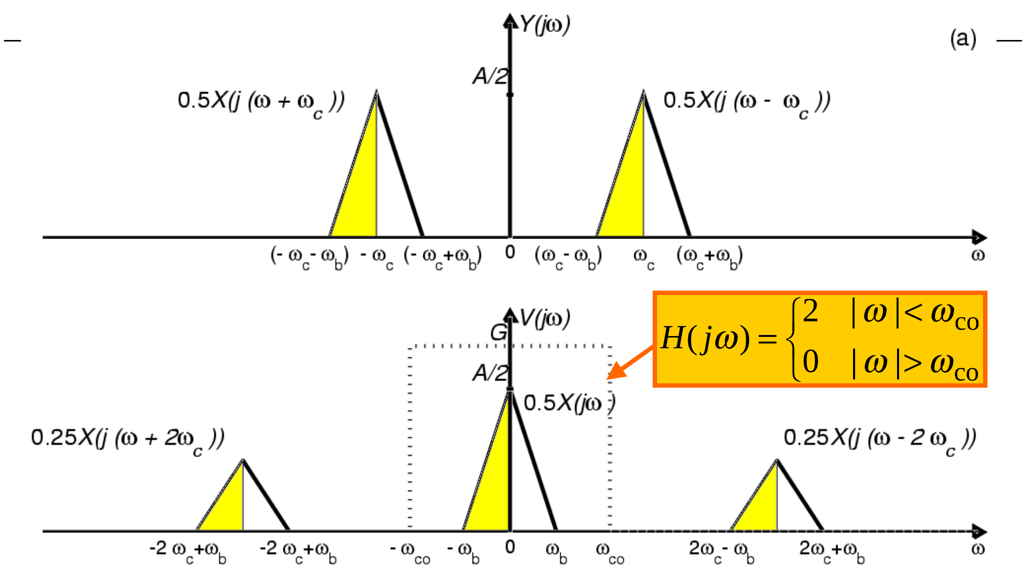

$$w(t) = x(t)[\cos(\omega_c t)]^2 = \frac{1}{2}x(t) + \frac{1}{2}x(t)\cos(2\omega_c t)$$

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

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



# DSBAM Demodulation




$$H(j\omega) = \begin{cases} 2 & |\omega| < \omega_{co} \\ 0 & |\omega| > \omega_{co} \end{cases}$$

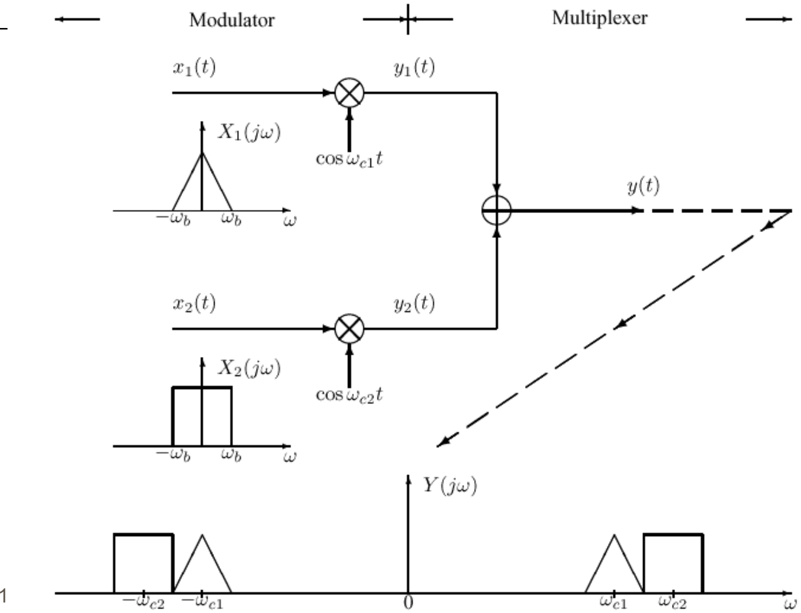
$$V(j\omega) = H(j\omega)W(j\omega) = X(j\omega) \text{ if } \omega_b < \omega_{co} < 2\omega_c - \omega_b$$

# 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)

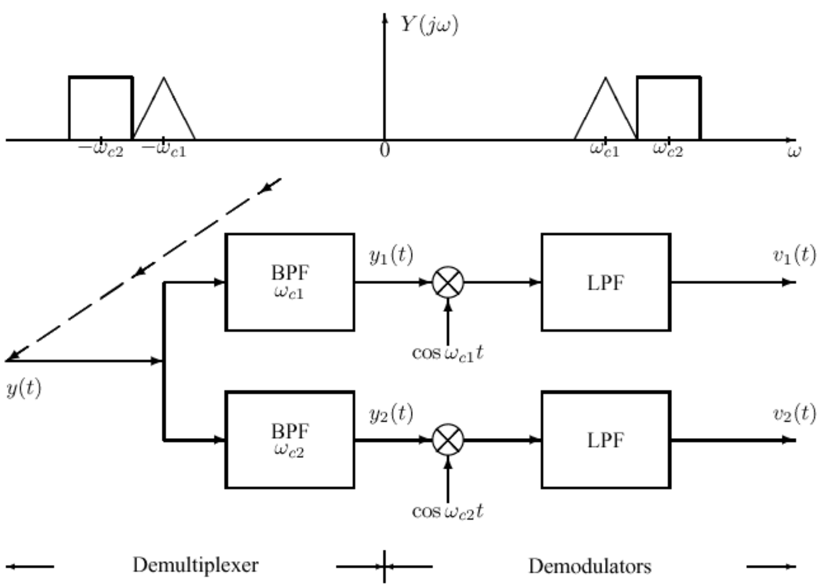


# FDM Block Diagram






# Frequency-Division De-Mux






# Bandpass Filters for De-Mux