# UNIT II ANALOG COMMUNICATION

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# Objective

1. To understand the need for modulation and its types .

2. Mathematical representation of Amplitude modulation (AM)-Time domain and frequency domain concepts

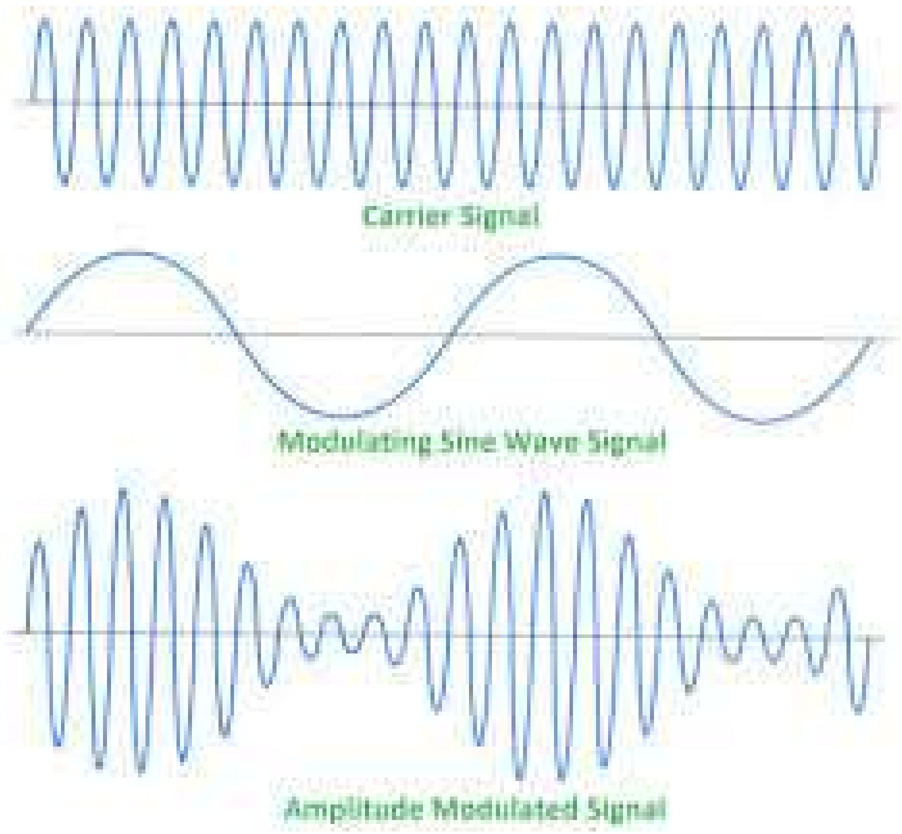
3. Mathematical representation of Complex modulating signal

4. To introduce modulation index in AM.

# Modulation

- Modulation: This involves changing the characteristic of the carrier in accordance with the amplitude of the message signal.
- Types: Amplitude modulation (AM),
  Frequency modulation (FM) and
  Phase modulation (PM)
- AM definition: This involves changing the amplitude of the carrier in accordance with the amplitude of the message signal.

# Pictorial Representation (Time domain) of AM



# Mathematical Analysis

- Let us take modulating signal as

$$e_m = E_m \cos 2\pi f_m t \qquad (1.1)$$

- where $e_m$ represents message signal. $E_m$ represents amplitude of the message signal. $f_m$ is frequency of the modulating signal.
- Similarly, the carrier signal is denoted by,

$$e_c = E_c \cos 2\pi f_c t \qquad (1.2)$$

- where $e_c$ represents the carrier signal. $E_c$ represents the amplitude of carrier signal. $f_c$ is carrier frequency.

- Then the modulated signal is given by

$$e_{AM} = [E_c + E_m \cos 2\pi f_m t]\cos 2\pi f_c t \qquad (1.3)$$

$$= E_c\left[1 + \frac{E_m}{E_c}\cos 2\pi f_m t\right]\cos 2\pi f_c t \qquad (1.4)$$

- **Modulation index (m):** It is the ratio of the amplitude of the message signal to the amplitude of the carrier signal.

$$m = \frac{E_m}{E_c} \qquad (1.5)$$

- Hence equation (1.4) becomes,

$$e_{AM} = E_C\left[1 + m\cos 2\pi f_m t\right]\cos 2\pi f_c t$$

- Now multiply $E_c \cos 2\pi f_c t$ with the contents inside the bracket.

$$e_{AM} = E_c \cos 2\pi f_c t + mE_c \cos 2\pi f_c t \cos 2\pi f_m t \qquad (1.6)$$

- Apply, $Cos\ A\, Cos\ B = \frac{1}{2}\left[Cos\ (A+B) + Cos\ (A-B)\right]$ formula to the second term in the summation.

$$e_{AM} = E_c \cos 2\pi f_c t + {mE_c}/{2}\left\{\cos 2\pi\left(f_c + f_m\right)t + \cos 2\pi\left(f_c - f_m\right)t\right\}$$

(1.7)

- This is a signal made up of three signal components

i) A carrier at frequency $f_c$ Hz

ii) Upper side frequency at $f_c + f_m$ Hz and

iii) Lower side frequency at $f_c - f_m$ Hz

- The ***bandwidth*** of AM (the difference between the highest and the lowest frequency) is

$$Bandwidth = \left(f_c + f_m\right) - \left(f_c - f_m\right) = 2 f_m Hz \qquad (1.8)$$

- Where $f_m$ is the maximum frequency of the modulating signal.

# Pictorial Representation (Frequency domain) of AM

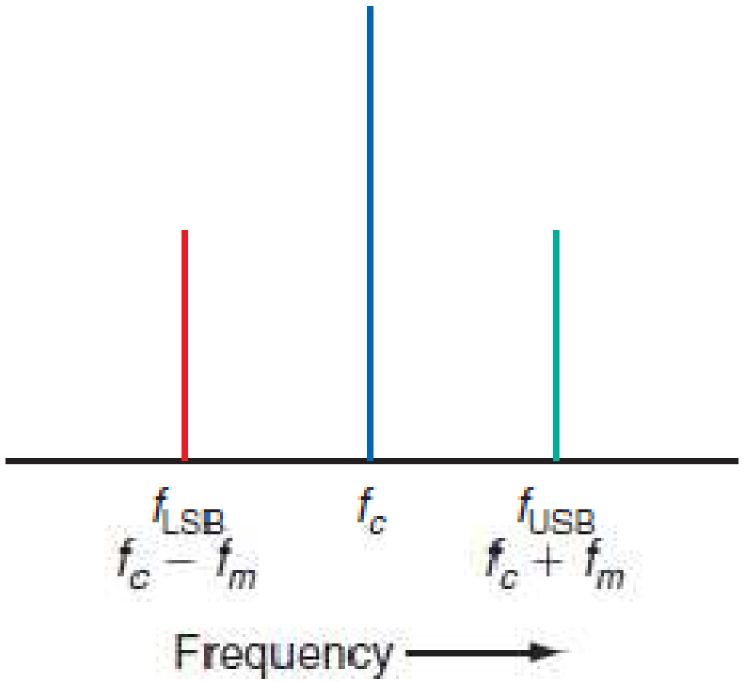
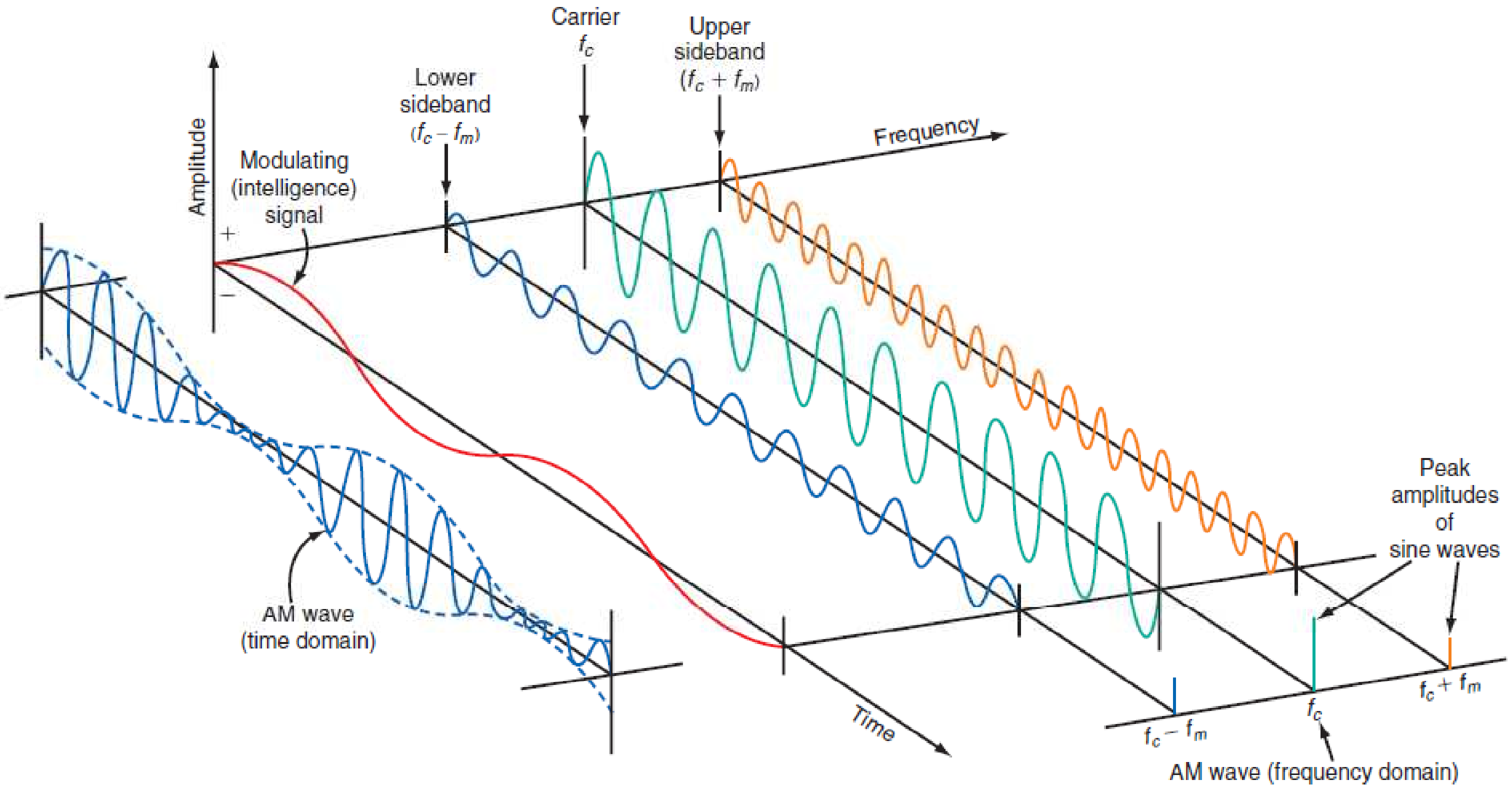



Fig: Frequency domain representation of AM

- Fig. suggests that, frequency spectrum consists of
- i) $E_c \cos 2\pi f_c t$ -carrier frequency $f_c$ with the amplitude of $E_c$
- ii) side band at $(f_c + f_m)$ and $(f_c - f_m)$ with the amplitude of $mE_c/2$.

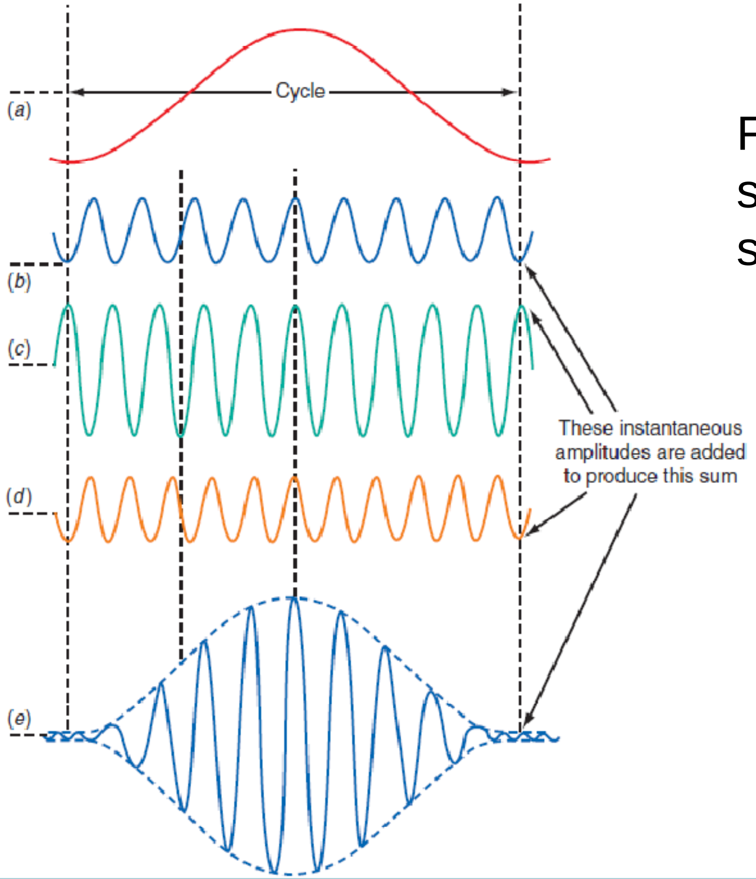
# Relation between Time and Frequency domain of AM

- From the figure below, its clear that modulated signal in time domain is only the aggregate of the modulating signal, the carrier signal, the upper sideband signals and the lower sideband signal.



# Relation between Time and Frequency domain of AM

- In other words, AM wave is the algebraic sum of the carrier, the upper and the lower sideband frequencies. It is shown in figure below




Fig, where a) modulating signal b) carrier signal c) and d) upper and lower sideband signals and e) composite AM wave

# Modulation of complex modulating signal

- In the previous analysis, simple cosine or sinusoidal signal has been considered as the message signal. In real life scenario, the modulating signal is like a complex signal. In other words, the modulating signal is the sum of two or more cosine or sinusoidal signals. Hence, the method of modulation of a complex signal with high frequency carrier is discussed What is the spectrum for modulated signal? What is the bandwidth? What is the modulation index for complex modulating signal? These are questions to be answered.

# Mathematical Analysis

- Let us consider modulating signal $x(t)$ as, sum of two signals, i.e.

  $x(t) = x_1(t) + x_2(t)$ where $x_1(t)$ and $x_2(t)$ are given as,

  $x_1(t) = E_{m1}\cos 2\pi f_{m1}t$ and $x_2(t) = E_{m2}\cos 2\pi f_{m2}t$ , where $E_{m1}$ is amplitude of $x_1(t)$, $f_{m1}$ is frequency of $x_1(t)$. Similarly $E_{m2}$ is amplitude of $x_2(t)$ , $f_{m2}$ is frequency of $x_2(t)$.
- Now the carrier signal is represented as, $e_c = E_c \cos 2\pi f_c t$

  where $e_c$ represents the carrier signal. $E_c$ represents the amplitude of carrier signal. $f_c$ is the carrier frequency.
- Then the modulated signal is given as,

  $e_{AM} = E_{AM} \cos 2\pi f_c t$ ,

- Here the amplitude of the modulated signal $E_{AM}$ is given as,

$$E_{AM} = E_c + E_{m1} \cos 2\pi f_{m1} t + E_{m2} \cos 2\pi f_{m2} t$$

Now substitute vale of $E_{AM}$ in above equation,

$$e_{AM} = \left(E_c + E_{m1} \cos 2\pi f_{m1} t + E_{m2} \cos 2\pi f_{m2} t\right) \cos 2\pi f_c t$$

$$= E_c \left(1 + \frac{E_{m1}}{E_c} \cos 2\pi f_{m1} t + \frac{E_{m2}}{E_c} \cos 2\pi f_{m2} t\right) \cos 2\pi f_c t$$

- Now Modulation index 1= $m_1 = \dfrac{E_{m1}}{E_c}$
- Modulation index 2= $m_2 = \dfrac{E_{m2}}{E_c}$

- Hence the total modulation index is $m = \sqrt{m_1^2 + m_2^2}$
- Therefore the modulated signal can written as,

$$e_{AM} = E_c\left(1 + m_1 \cos 2\pi f_{m1} t + m_2 \cos 2\pi f_{m2} t\right)\cos 2\pi f_c t$$

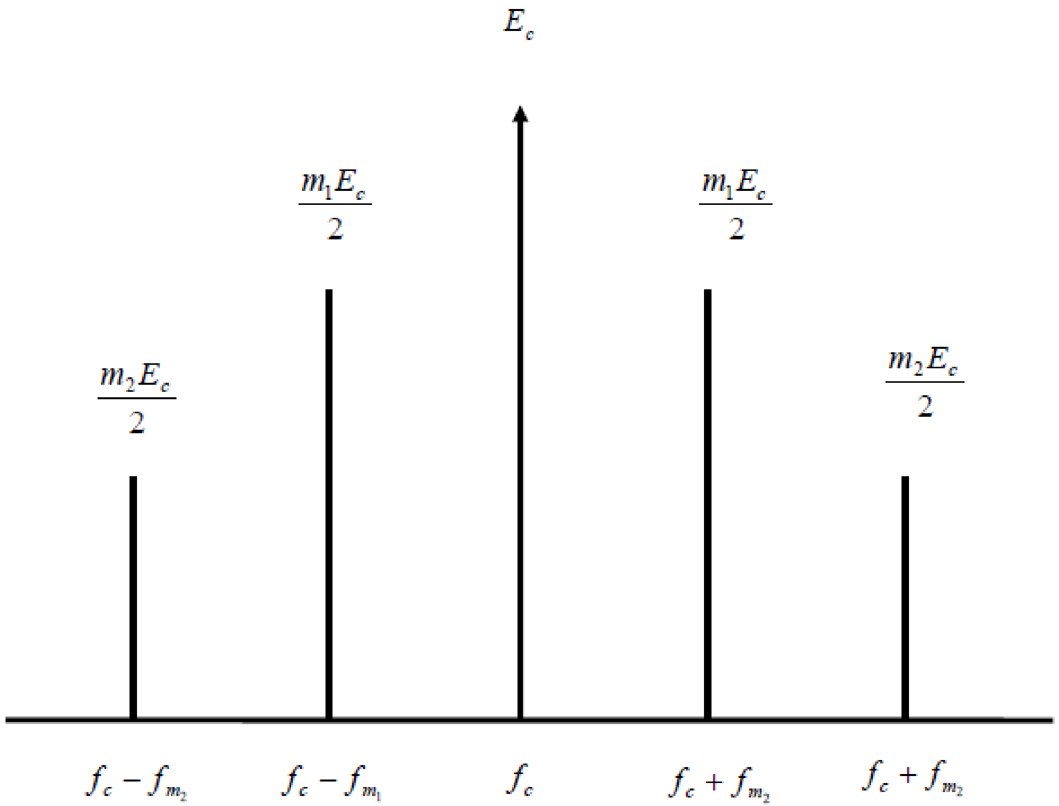
$$e_{AM} = \left(E_c \cos 2\pi f_c t + m_1 E_c \cos 2\pi f_c t \cos 2\pi f_{m1} t + m_2 E_c \cos 2\pi f_c t \cos 2\pi f_{m2} t\right)$$

Apply the Cos A and Cos B formula to $\cos 2\pi f_c t \cos 2\pi f_{m1} t$ and $\cos 2\pi f_c t \cos 2\pi f_{m2} t$ . So, becomes,

- Therefore,

$$e_{AM} = \left(E_c \cos 2\pi f_c t + \frac{m_1 E_c}{2}\left[\cos 2\pi\left(f_c + f_{m1}\right)t + \cos 2\pi\left(f_c - f_{m1}\right)t\right] + \frac{m_2 E_c}{2}\left[\cos 2\pi\left(f_c + f_{m2}\right)t + \cos 2\pi\left(f_c - f_{m2}\right)t\right]\right)$$

- The final modulated signal in frequency domain is implied as consisting of
- Carrier signal $E_c \cos 2\pi f_c t$
- Upper sideband at $f_c + f_{m1}$ and $f_c + f_{m2}$
- Lower sideband at $f_c - f_{m1}$ and $f_c - f_{m2}$



# Bandwidth

$$Bandwidth = 2 \times f_{m(\max)}$$

Where $f_{m(\max)}$ is maximum frequency of modulating signal.