FREQUENCY AND PHASE MODULATION

(ANGLE MODULATION)

ANGLE MODULATION –

When frequency or phase of the carrier is varied by the modulating signal , then it is called angle modulation

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- Frequency Modulation –
  The frequency of the carrier varies as per amplitude of modulating signal, then it is called frequency modulation (FM)
- Phase Modulation –
  The phase of the carrier varies as per amplitude of modulating signal, then it is called phase modulation (PM)
- Amplitude of the modulated carrier remains constant in both modulation systems

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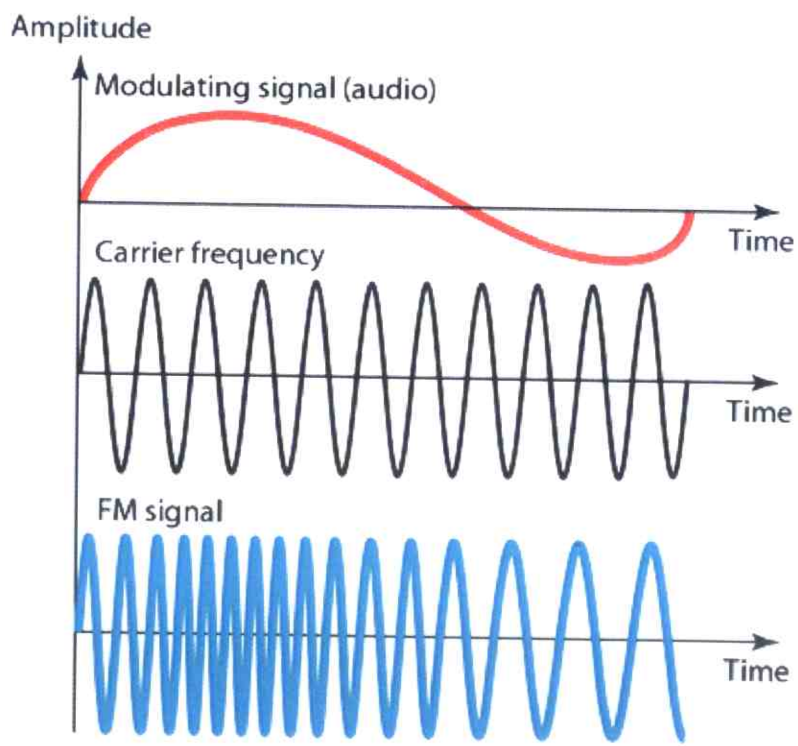
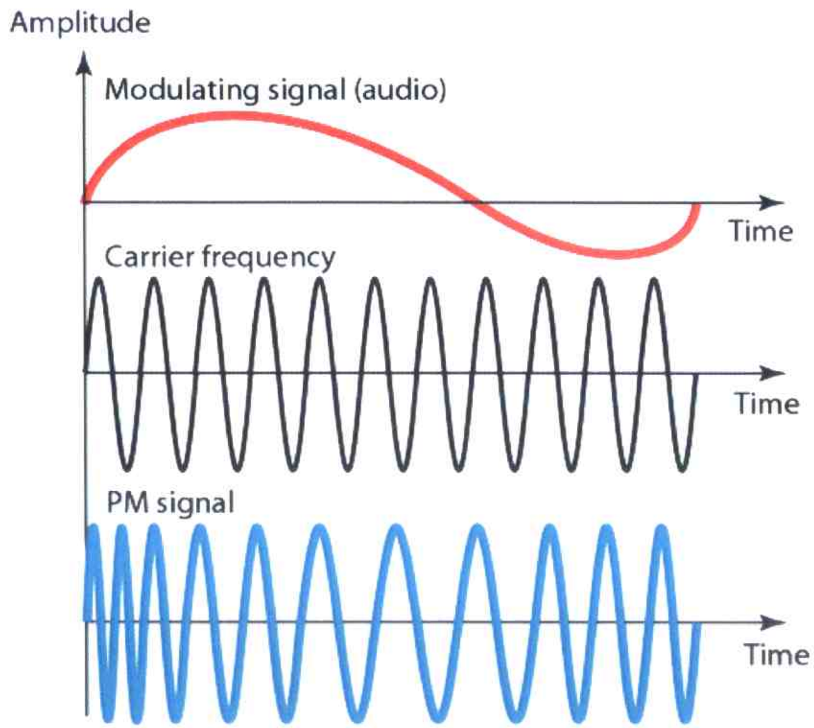
FREQUENCY MODULATION



PHASE MODULATION



Important features of angle modulation:

- It can provide a better discrimination (robustness) against noise and interference than AM.
- This improvement is achieved at the expense of increased transmission bandwidth.
- In case of angle modulation, channel bandwidth may be exchanged for improved noise performance
- Such trade-off is not possible with AM

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$$A_c \cos(2\pi f_c t + \phi_0)$$

$$A_c(t) \cos(\theta(t))$$

$$A_c(t) \cos(2\pi f_c t + \phi_0) \leftarrow \text{AM}$$

$$A_c \cos(\theta(t))$$

$$\theta(t) = 2\pi f_c t + \phi_0$$

$$f_c \longrightarrow f_{\Delta t} \triangleq \frac{\theta(t+\Delta t) - \theta(t)}{2\pi\, \Delta t}$$

$$\Delta t \rightarrow 0$$

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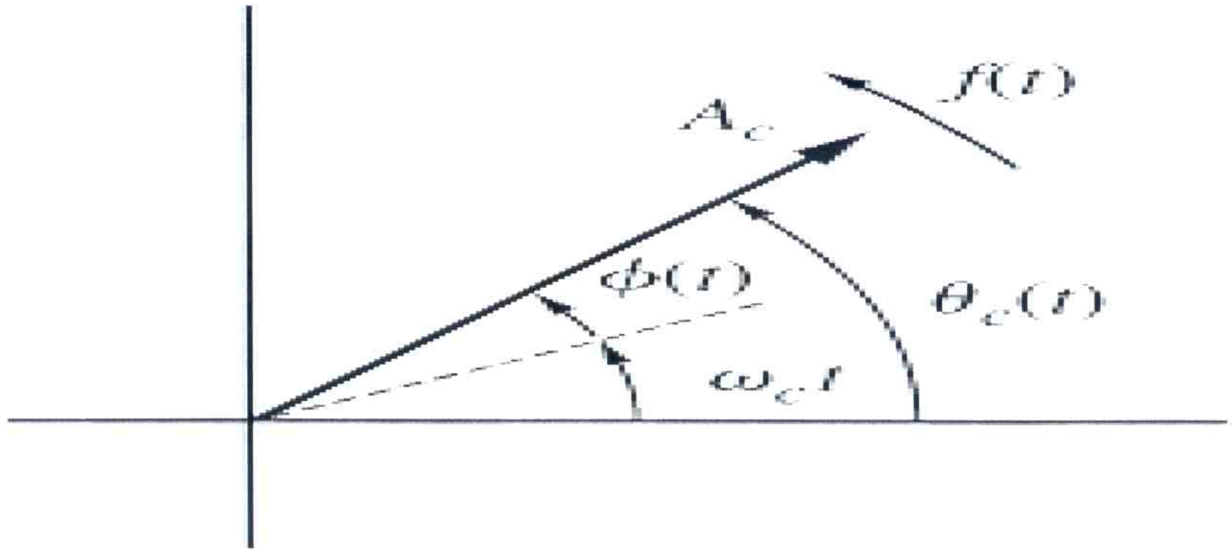
$$f_i(t) \triangleq \frac{1}{2\pi} \frac{d}{dt} \theta(t)$$

$$\theta(t) \longrightarrow \theta_i(t)$$

Rotating phasor representation of exponential modulation



Phase Modulation (PM)

$$\theta_i(t) \triangleq 2\pi f_c t + \underline{k_p m(t)}$$

message signal

$$s(t) = A_c \cos\{\theta_i(t)\}$$

phase sensitivity
rad/V

$$s(t) = A_c \cos\{2\pi f_c t + k_p m(t)\}$$

Frequency Modulation (FM)

$$f_i(t) \triangleq f_c + k_f \, \underline{m(t)}.$$

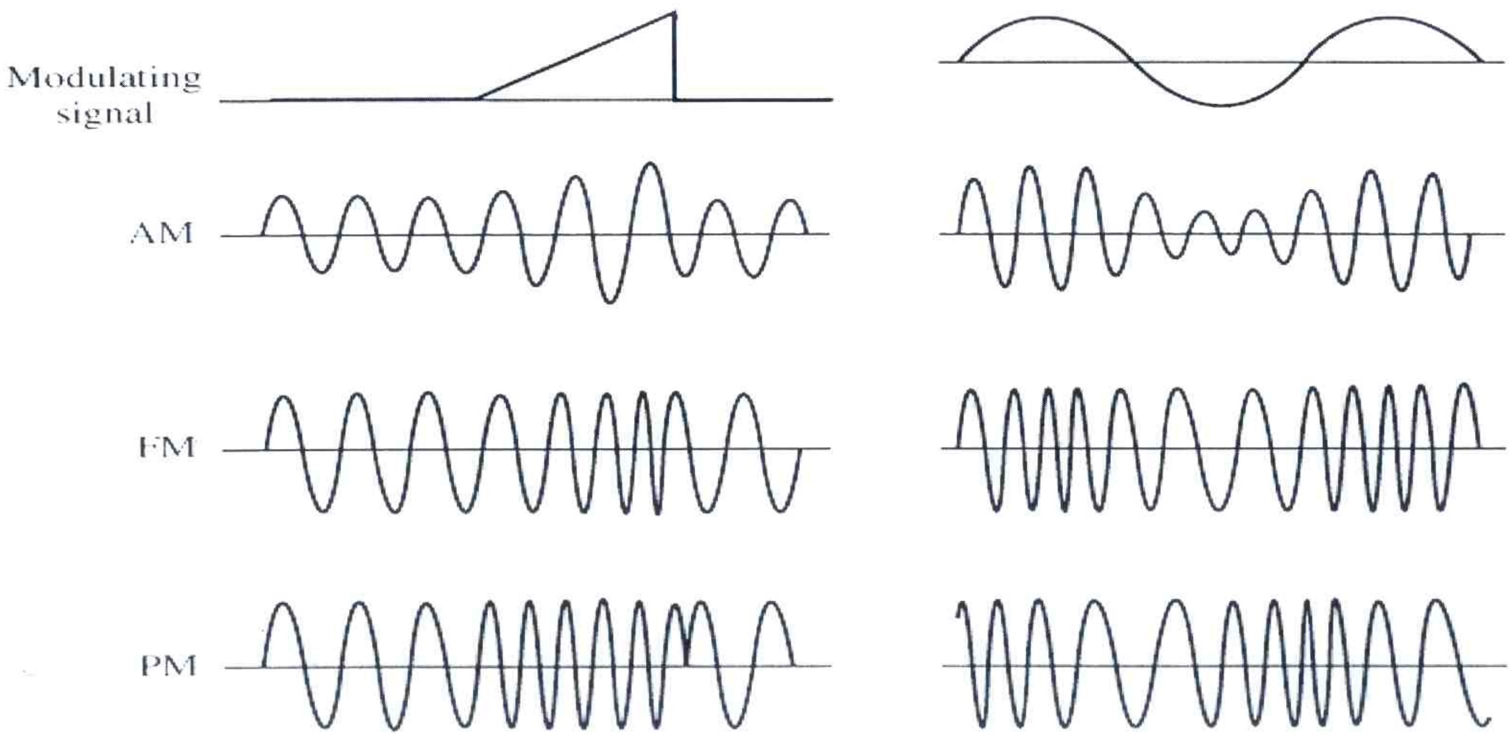
message signal

frequency sensitivity.

$$\theta_i(t) = 2\pi f_c t + 2\pi k_f \int_0^t m(\tau)\, d\tau.$$

$$s(t) = A_c \cos\left\{ 2\pi f_c t + 2\pi k_f \int_0^t m(\tau)\, d\tau \right\}$$

Illustrative AM, FM and PM waveforms



Properties of Angle Modulated Signal

(1) Constancy of Transmitted Power.

$$P_{av} = \frac{1}{2} A_c^2$$

(2) Nonlinearity of the Modulation Process

$m_1(t)$ $m_2(t)$

$m_1(t) + m_2(t)$

(3) Irregularity of Zero Crossings

(4) Visualization of Angle-Modulated waveforms

(5) BW requirement is HIGH

Illustrating the relationship between frequency modulation and phase modulation. (*a*) Scheme for generating an FM wave by using a phase modulator. (*b*) Scheme for generating a PM wave by using a frequency modulator

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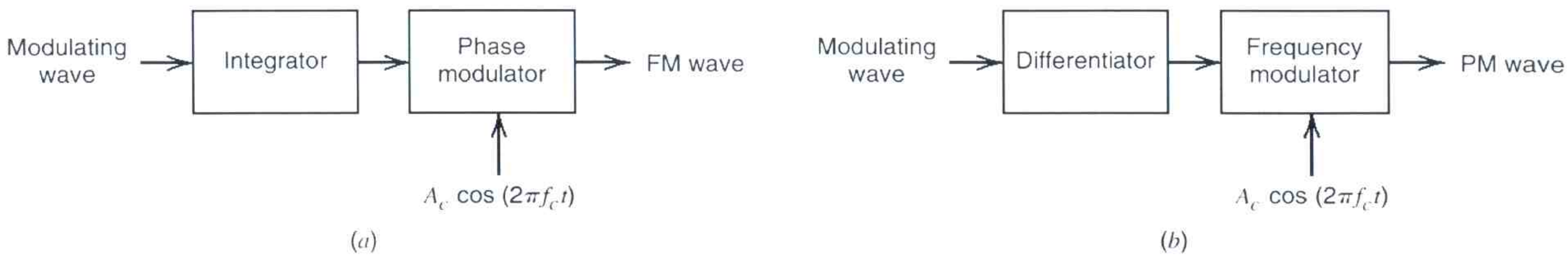

Bandwith of Angle-Modulated Signal

$$m(t) = A_m \cos(2\pi f_m t)$$

$$f_i(t) = f_c + k_f A_m \cos(2\pi f_m t).$$

$$= f_c + \underbrace{\Delta f}_{\text{frequency deviation}} \cos(2\pi f_m t)$$

$$\theta_i(t) = 2\pi \int_0^t f_i(\tau)\,d\tau = 2\pi f_c t + \frac{\Delta f}{f_m} \sin(2\pi f_m t)$$

$$\frac{\Delta f}{f_m} \triangleq \text{modulation index} \equiv \beta$$

$$S(t) = A_c \cos\left[2\pi f_c t + \beta \sin(2\pi f_m t)\right]$$

$\beta << 1$ radian $\rightarrow$ Narrowband FM

$\beta > 1$ radian $\rightarrow$ Wideband FM