PHASE MODULATION

ECE 321 – ANALOGUE COMMUNICATION

Wednesday, 12 November 2025

WHAT IS ANGLE MODULATION?

1. **Angle Modulation** is a technique where the angle of a carrier signal is varied in accordance with the message signal.
2. **There are two types of phase modulation:**
   a) **Frequency Modulation (FM):** The instantaneous frequency of the carrier is varied linearly with the message signal.
   b) **Phase Modulation (PM):** The instantaneous phase of the carrier is varied linearly with the message signal.
3. **Key Advantage over AM:** Angle modulation techniques are highly resistant to amplitude noise and signal fading.

PRINCIPLE OF PHASE MODULATION

1. Assume the carrier wave is:

$$c(t) = A_c * \cos(2\pi f_c t + \varphi)$$

1. In PM, the phase φ is made proportional to the message signal m(t).
2. Mathematical expression:
   a) Instantaneous Phase, $\theta_i(t) = 2\pi f_c t + k_p m(t)$

      Where:

      - k_p is the phase sensitivity of the modulator (rad/volt).
      - m(t) is the modulating signal

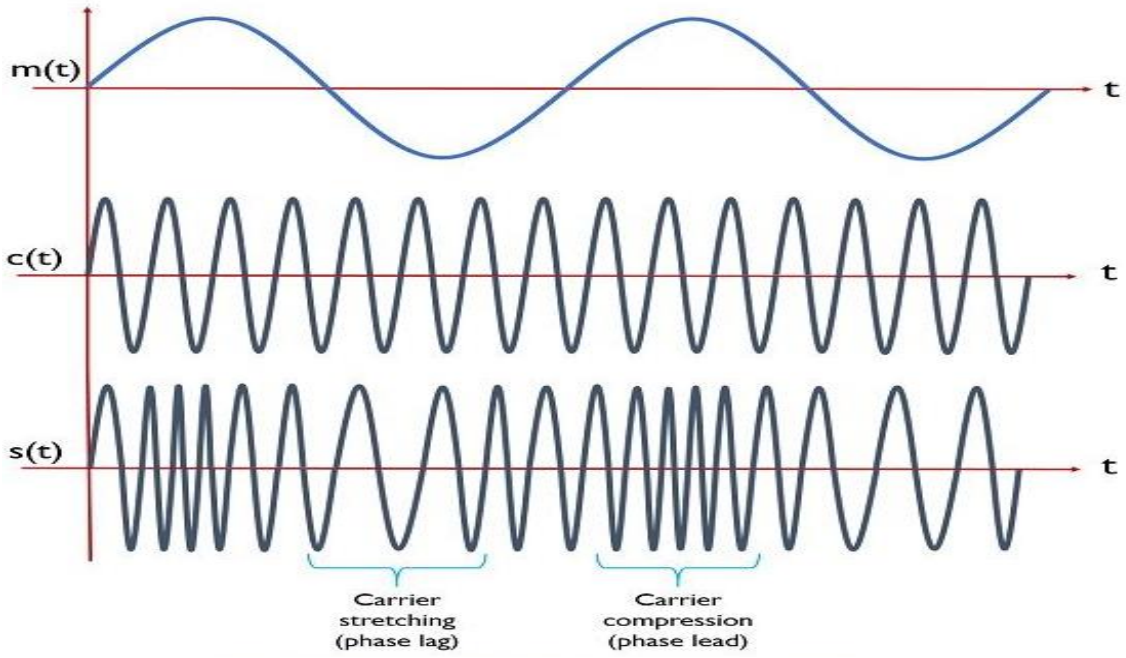
   b) PM Waveform:

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

VISUALIZING PM WHERE m(t) IS SINE WAVE

Message Signal: $m(t) = A_m * \sin(2\pi f_m t)$

PM Wave: $s(t) = Ac * \cos(2\pi f_c t + k_p A_m \sin(2\pi f_m t))$

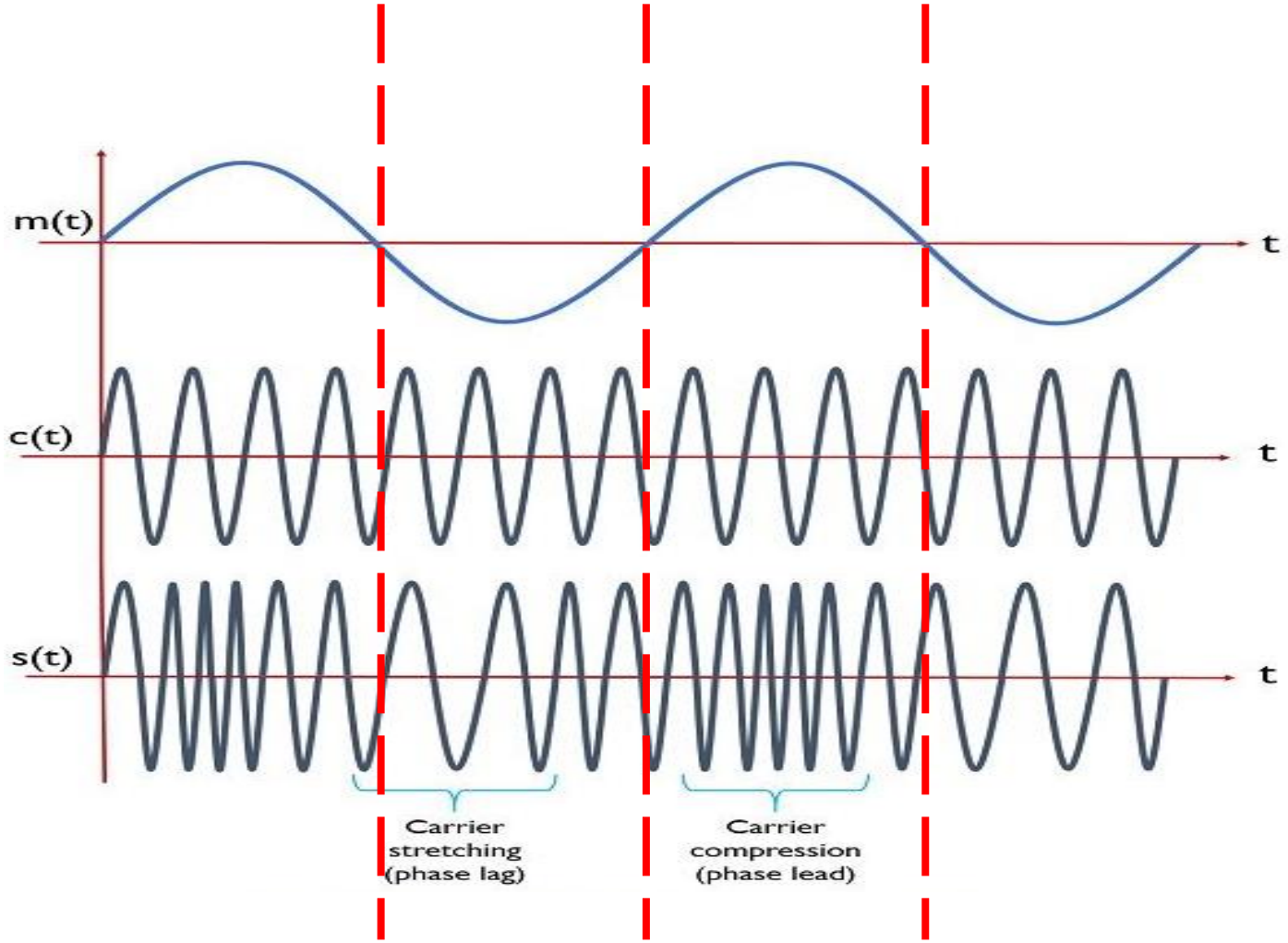


Key Observation:

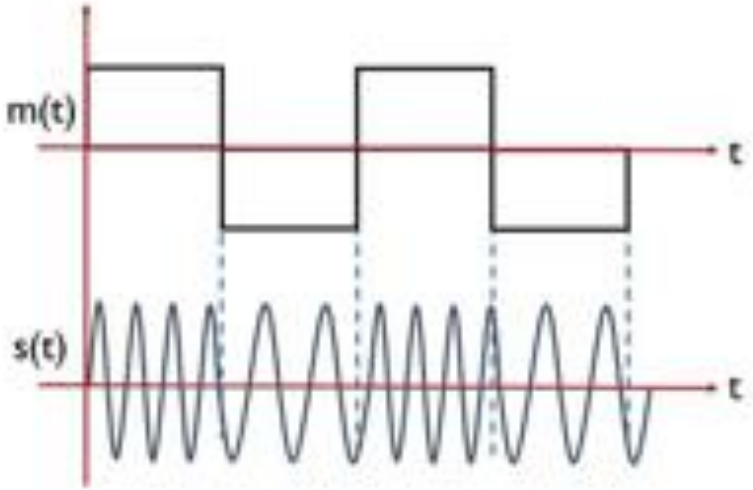
Where m(t) is at its positive peak, the carrier phase is *advanced*.
Where m(t) is at its negative peak, the carrier phase is *retarded*.
The zero-crossings of the carrier are *shifted* in time.

Message Signal: $m(t) = A_m * \sin(2\pi f_m t)$

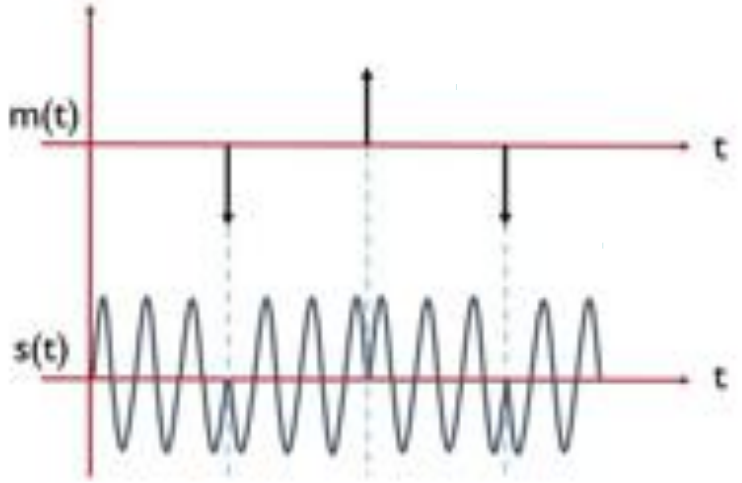
PM Wave: $s(t) = A_c * \cos(2\pi f_c t + k_p A_m \sin(2\pi f_m t))$



VISUALISATION OF PM WAVEFORMS - SQUAREWAVE



(a) Square-wave Frequency Modulation



(b) Square-wave Phase Modulation

1. When the signal moves from positive to negative amplitude then negative phase reversal exists.
2. When the message signal shows movement from negative to positive amplitude then positive phase reversal takes place.

MODULATION INDEX OF PHASE MODULATION(PM)

1. **Modulation index (β)** is a dimensionless quantity that represents the peak phase deviation, i.e the maximum phase change of the carrier signal from its unmodulated value.
2. **Message Signal:** $m(t) = A_m * \sin(2\pi f_m t)$
3. **PM Wave:** $s(t) = A_c * \cos(2\pi f_c t + k_p A_m \sin(2\pi f_m t))$
4. **Peak Phase Deviation (Δθ):** The maximum phase shift caused by the message signal.

$$\Delta\theta = k_p max|m(t)|$$

5. **Modulation Index** $\beta = \Delta\theta = k_p max|m(t)|$ (in radians)
6. **Crucial Point:** In PM, the modulation index (β) is **directly proportional to the amplitude of the message signal** and is independent of its frequency.

GENERATING PHASE MODULATED SIGNAL

- **Method 1: Direct Method (VCO-based)**
  - Use a Voltage-Controlled Oscillator (VCO).
  - Since $f_i(t) \propto \frac{dm(t)}{d}$ for PM, we must first **integrate the message signal** before applying it to the VCO.
  - **Block Diagram:**
    m(t) → [Integrator] → [VCO] → s_pm(t)

ADVANTAGES OF PM

1. **Constant Envelope:** The amplitude A_c remains constant.
   a) Allows use of efficient **Class C power amplifiers** in transmitters.
   b) Resilient to amplitude noise and fading.
2. **Superior Noise Performance:** Compared to AM, it offers a better signal-to-noise ratio (SNR) at the receiver output, especially in wideband configurations.
3. **Trade-off Flexibility:** Allows trading bandwidth for improved noise performance.

DISADVANTAGES OF PM

- **Disadvantages:**
  - Requires more complex receivers than AM.
  - Typically requires a wider bandwidth than AM for the same message signal.
  - Circuits for generation and demodulation are more complex.

APPLICATIONS OF PM

- **Wireless Communications:** Used in GSM, Bluetooth, and Wi-Fi (often in its digital form, Phase-Shift Keying - PSK).
- **Satellite Communication:** Due to its noise resilience.
- **Digital Modulation:** BPSK, QPSK, and QAM are all descendants of the basic PM concept.

SUMMARY

1. **Definition:** PM varies the carrier's phase linearly with the message signal m(t).
2. **Waveform:** $s(t) = A_c\cos(2\pi f_c t + k_p m(t))$
3. **Modulation Index:** $\beta = k_p * \max|m(t)|$ (Amplitude-dependent, frequency-independent).
4. **PM & FM Link:** PM can be generated via an FM modulator with a pre-emphasized (integrated) message signal.
5. **Bandwidth:** $B \approx 2(\beta_{pm} + 1)f_m$ (Carson's Rule).
6. **Key Strength:** Constant envelope provides noise resistance and power amplifier efficiency.
7. **Foundation:** PM is the direct analog precursor to the vast family of digital PSK modulations used today.