Al-Mustaqbal University
Department of Medical Instrumentation Techniques Engineering
Class: Third
Subject: Medical Communication Systems
Lecturer: Prof. Dr. Bayan Mahdi Sabbar & M.Sc. Huda Wasfi Hassoon
Lecture:9

Lecture 9

Pulse Modulation

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Pulse modulation is a method of transmitting signals where information is conveyed through pulses. This technique is broadly classified into two categories: Analog Pulse Modulation and Digital Pulse Modulation. In Analog Pulse Modulation, analog information is transmitted by varying certain characteristics of the pulses, such as their amplitude, duration, or position. On the other hand, Digital Pulse Modulation involves transmitting information by encoding it into discrete digital pulses. Pulse modulation, as a whole, serves as an effective means of transmitting both analog and digital information, depending on the specific type employed.

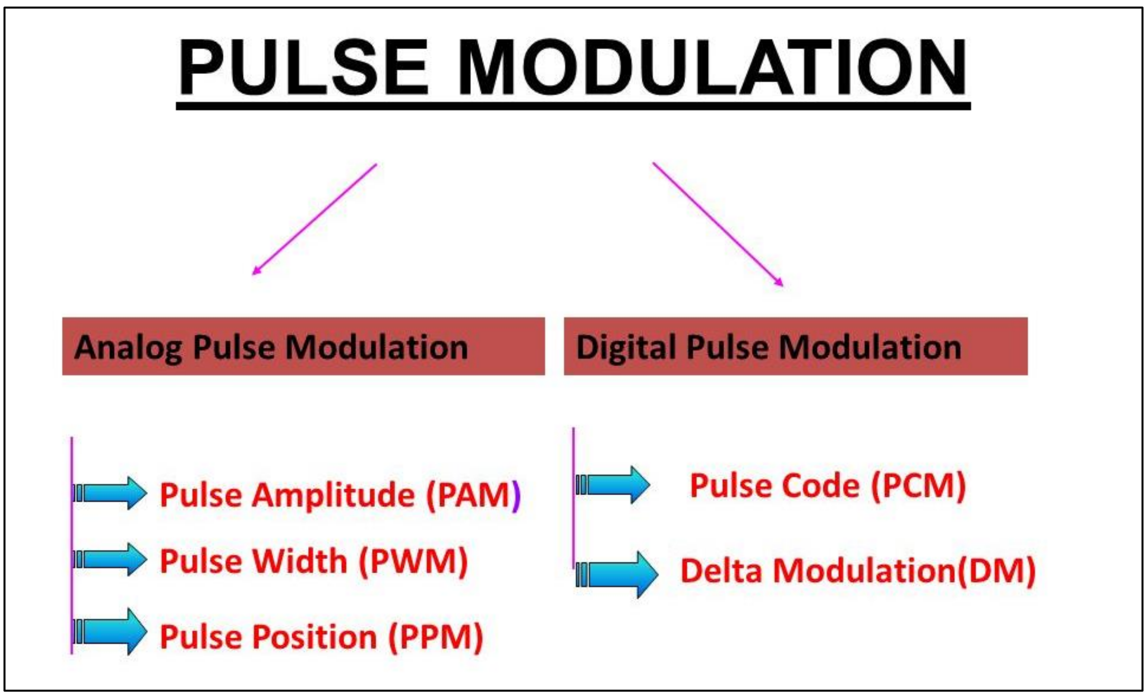

Figure 1: Types of Pulse Modulation.

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Pulse Amplitude Modulation (PAM)

Pulse Amplitude Modulation (PAM) is a modulation technique where the amplitude of each pulse is determined by the instantaneous amplitude of the modulating signal. In this method, the original signal is sampled at regular intervals, and each sample's amplitude corresponds directly to the amplitude of the signal at the specific sampling instant.

This technique is commonly used to encode information in the form of amplitude variations of the pulses. Pulse amplitude modulation is further categorized into two types based on the polarity of the message signal:

1. **Single-Polarity-PAM:**
   In this type of PAM, all pulse amplitudes are kept positive by adding a fixed DC bias to the modulating signal. This ensures that the signal does not cross the zero level, maintaining a unipolar characteristic.

2. **Double-Polarity-PAM:**
   In double polarity PAM, the pulses can have both positive and negative amplitudes. The modulating signal is allowed to take its natural form, enabling the pulses to reflect the original signal's polarity, resulting in a bipolar characteristic.

This classification enables PAM to represent a variety of signal types depending on the requirements of the communication system, as shown in the diagram, which illustrates the modulating signal, pulse carrier, and the resulting PAM signals for both double-polarity and single-polarity cases.

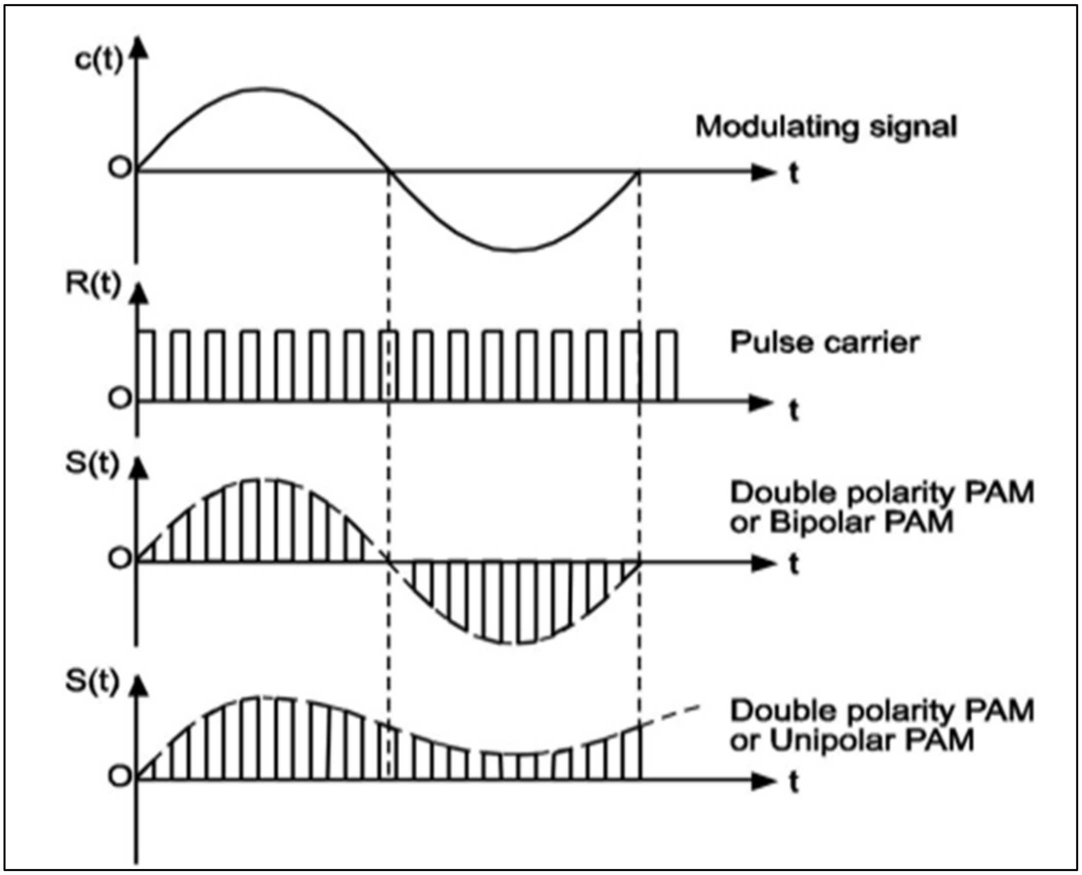

Figure 2: Pulse Amplitude Modulation (PAM)

The figure illustrates the process of **Pulse Amplitude Modulation (PAM)** in detail, where the modulating signal is represented using pulses whose amplitudes vary in proportion to the amplitude of the original signal at each sampling instant. The diagram is divided into four key sections:

1. **Modulating Signal (c(t)):**
   - This represents the original signal that carries the information to be transmitted. It is a continuous analog signal that varies over time.

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2. **Pulse Carrier (R(t)):**
   - This is a series of regularly spaced rectangular pulses. The pulse carrier serves as the foundation for the modulation process, providing the structure to sample the modulating signal.
3. **Double Polarity PAM (or Bipolar PAM):**
   - In this case, the amplitude of the pulses directly reflects both the positive and negative values of the modulating signal. The result is a bipolar waveform where the pulses take on positive and negative values depending on the amplitude of the modulating signal at the corresponding instant.
4. **Single Polarity PAM (or Unipolar PAM):**
   - In this form, the pulses only have positive amplitudes. A DC bias is added to the modulating signal to ensure the entire signal remains above the zero level. The resulting waveform is unipolar, meaning all pulse amplitudes are non-negative.

The figure effectively demonstrates the modulation process, showing how the amplitude of the modulating signal is sampled and reflected in the amplitude of the pulses in both bipolar and unipolar forms.

Based on the shape of the top of the PAM pulses, **Pulse Amplitude Modulation (PAM)** is categorized into two types:

1. Natural PAM:

- In this method, the top of each pulse follows the natural shape of the modulating signal during the sampling interval.

- The amplitude of the pulses varies smoothly, maintaining continuity with the modulating signal.
- Natural PAM provides a more accurate representation of the original signal but can be more prone to distortion due to the overlap of adjacent pulses in certain systems.

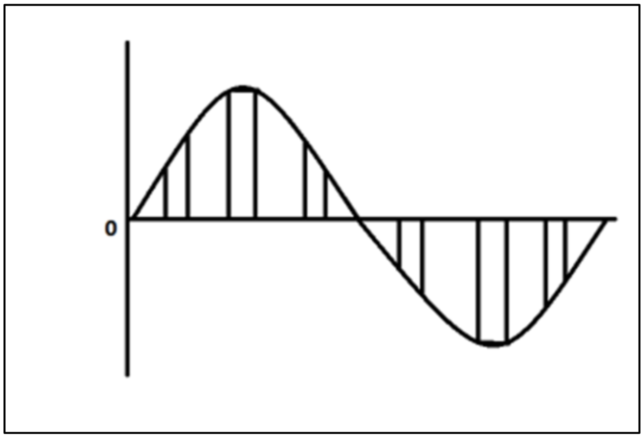

Figure 3: Natural PAM.

2. Flat-Top PAM:

- In this method, the top of each pulse is flattened and held constant for the entire duration of the pulse.
- The amplitude of the pulse is determined at the sampling instant and remains constant until the next pulse.
- Flat-top PAM is less sensitive to distortion caused by overlapping pulses, making it more suitable for digital communication systems. However, it introduces a small error known as aperture distortion because of the flat-top approximation.

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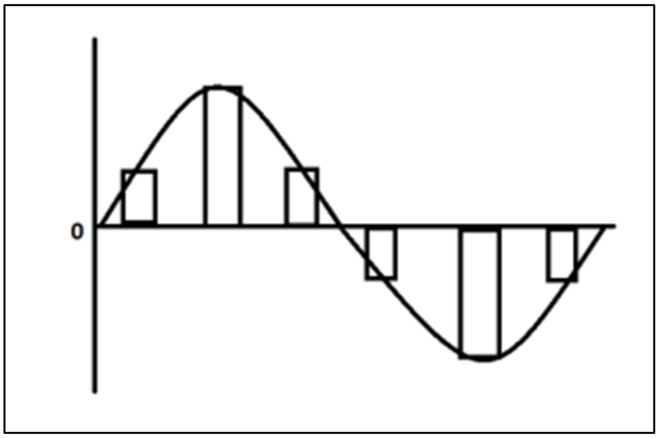

Figure 4: Flat-top PAM.

Both types are used depending on the application, with flat-top PAM being more common in modern communication systems due to its robustness and ease of implementation.

PAM modulation circuit:

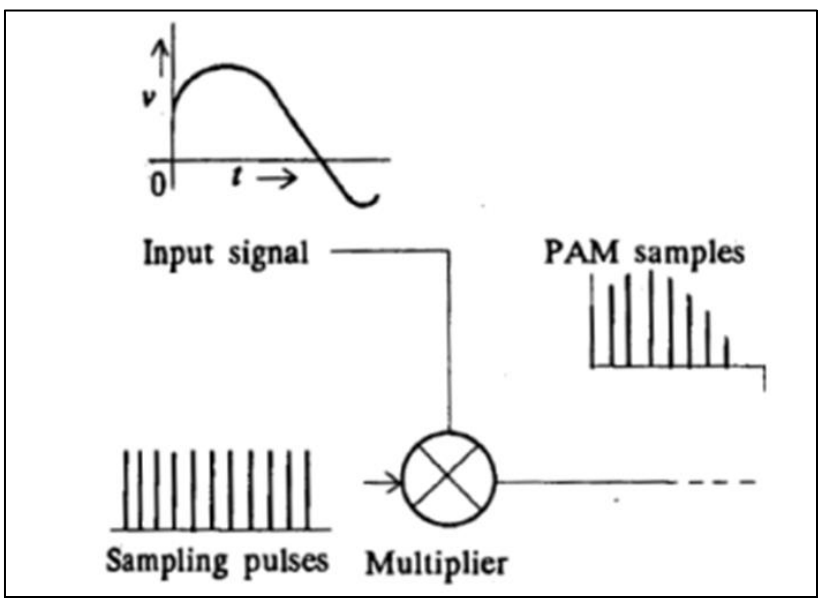

Figure 5: The Pulse Amplitude Modulated (PAM) circuit.

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The figure represents a **PAM modulation circuit** and demonstrates the process of generating Pulse Amplitude Modulated (PAM) signals.

1. Input Signal:

- This is the analog signal carrying the information to be transmitted. The signal varies continuously over time.

2. Sampling Pulses:

- These are periodic pulses used to sample the input signal. The pulses are typically rectangular in shape and are generated at regular time intervals.
- The frequency of the sampling pulses must satisfy the Nyquist sampling theorem to accurately reconstruct the input signal.

3. Multiplier:

- The multiplier is the core component of the PAM circuit. It combines the input signal with the sampling pulses.
- For every sampling pulse, the multiplier outputs a pulse whose amplitude is proportional to the instantaneous amplitude of the input signal at that moment.

4. PAM Samples (Output):

- The output is a series of pulses whose amplitudes correspond to the sampled values of the input signal. These pulses form the PAM signal, where the information from the input signal is encoded in the amplitude of each pulse.

This circuit demonstrates the essential principle of PAM: sampling the input signal at regular intervals and modulating the pulse amplitudes according to the sampled values. The resulting PAM signal can then be transmitted or processed further in communication systems.

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PAM demodulating circuit:

The figure represents a **PAM demodulating circuit**, which is used to recover the original signal from a PAM (Pulse Amplitude Modulated) signal.

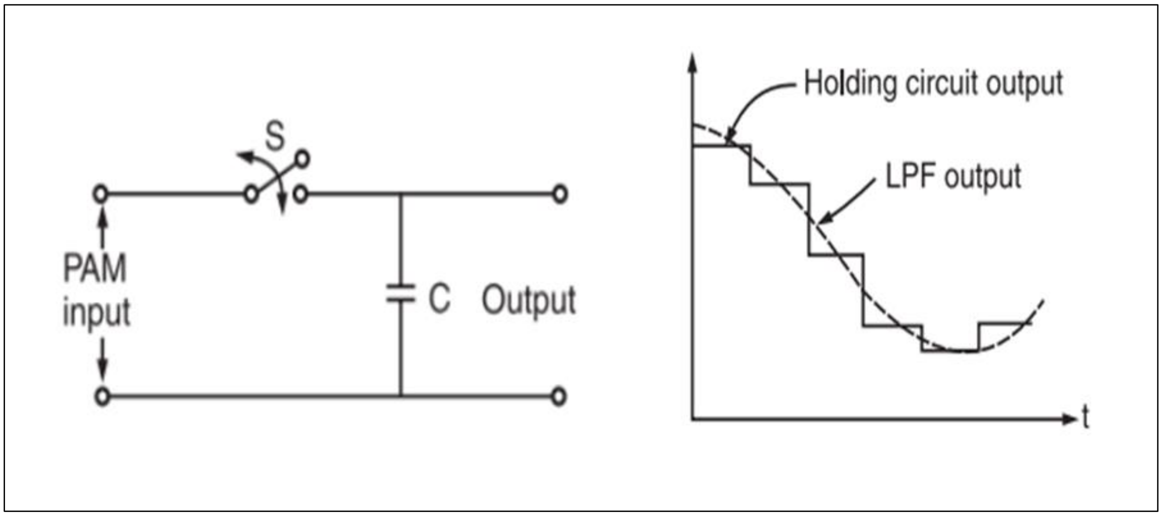

Figure 6: PAM demodulating circuit.

Circuit Components:

1. **PAM Input:**
   - The PAM signal, consisting of a series of pulses whose amplitudes correspond to the original modulating signal, is provided as the input to this circuit.
2. **Switch (S):**
   - The switch operates in synchronization with the incoming PAM pulses. Its "samples" the input pulses and passes them to the capacitor.
3. **Capacitor (C):**
   - The capacitor stores the charge corresponding to the amplitude of each pulse. This holds the signal value until the next pulse arrives, creating

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a stepped approximation of the original signal. This process is known as **"holding."**

4. **Output:**
    - The output of the circuit is a signal that approximates the original modulating signal. This is further processed to smooth out the steps and restore the continuous waveform.

Graph Explanation:

- The graph on the right shows the recovery process:
    - **Holding Circuit Output:**
        - The stepped waveform is generated as the capacitor holds the charge between successive pulses. This output is not smooth but approximates the original signal.
    - **LPF Output:**
        - A Low Pass Filter (LPF) is applied to the holding circuit output to smooth the signal and remove high-frequency components caused by the pulse sampling. The final output is a continuous signal that closely resembles the original modulating signal.

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