

№3 lecture

Classification of Signals in Communication Systems

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Outline

1. Introduction to Signals in Communication Systems

Classification of Signals:

Analog vs. Digital Signals

Periodic vs. Aperiodic Signals

Deterministic vs. Random Signals

2. Properties of Signals:

Amplitude, Frequency, and Phase

Bandwidth and Signal-to-Noise Ratio (SNR)

3. Applications of Signal Types in Communication Systems

4. Signal Conversion and Processing

5. Summary and Key Takeaways

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Introduction to Signals in Communication Systems

Definition of Signals:

Signals are functions that convey information over time or space.

They represent physical quantities, like sound, light, or voltage, that can carry data across systems.

Role in Communication Systems:

Signals are essential in transmitting information between devices.

Communication systems utilize different types of signals depending on the application requirements (e.g., clarity, distance).

Types of Signal Forms:

Common forms include electrical, optical, and radio frequency signals.

Analog vs. Digital Signals

Analog Signals:

Continuous in time and amplitude.

Represented by sine waves with smooth variations.

Examples: Human voice, radio waves.

Formula: $s(t) = A \sin(2\pi ft + \phi)$

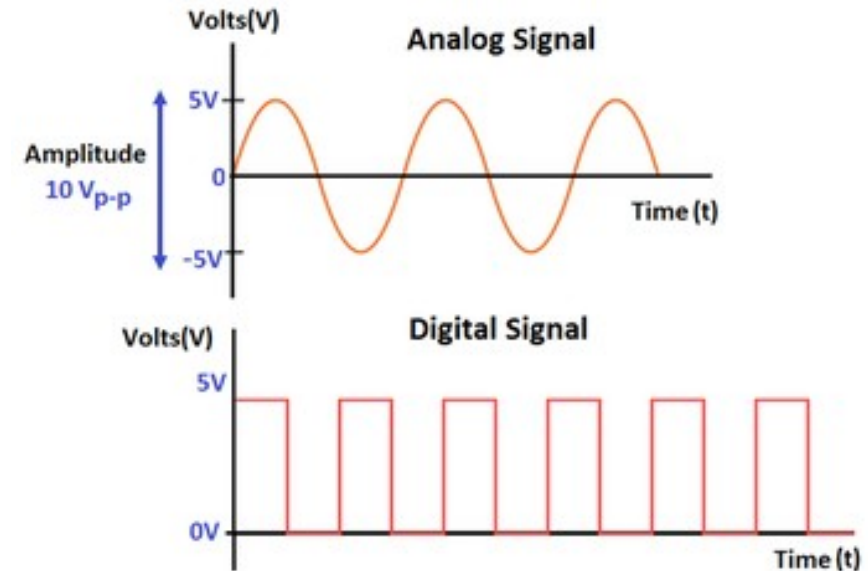
where A = amplitude, f = frequency, ϕ = phase.

Digital Signals:

Discrete in time and amplitude, represented by binary values (0s and 1s). More resilient to noise and preferred in modern digital communication.

Examples: Computer data, digital TV signals.

Comparison: Analog signals provide continuous detail, while digital signals offer noise resistance and ease of processing.



Periodic vs. Aperiodic Signals

Periodic Signals: Repeat over a defined interval, often represented by sinusoidal functions.

Common in signals that have a regular frequency component, such as certain radio waves.

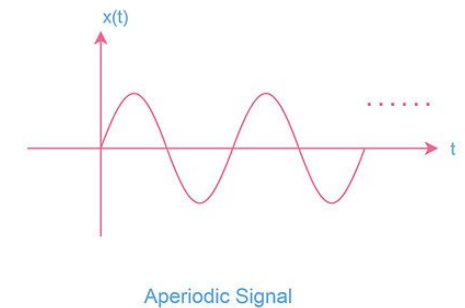
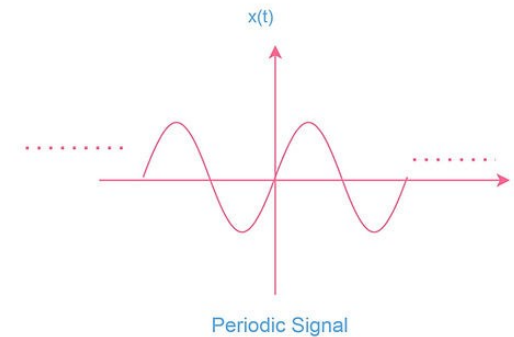
Example: Sine waves, square waves.

Aperiodic Signals: Do not repeat over time and are typically more complex.

Useful for irregular or one-time communication.

Example: Single digital pulse, random noise signals.

Applications: Periodic signals are common in broadcasting; aperiodic signals are often seen in one-time events like digital pulses.



Deterministic vs. Random Signals

Deterministic Signals: Signals with predictable and defined behavior over time. Their values can be calculated at any point based on a formula or model.

Example: Sine waves in modulation, clock signals in electronics.

Random (Stochastic) Signals: Unpredictable and vary according to random factors, described statistically. Common in real-world scenarios with environmental interference or noise.

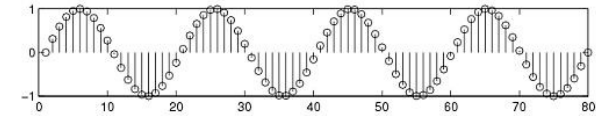
Example: Thermal noise in electronic circuits, signal noise in wireless communication.

Implications: Deterministic signals are ideal for controlled environments; random signals need statistical methods to analyze their behavior.

Deterministic signals, random signals

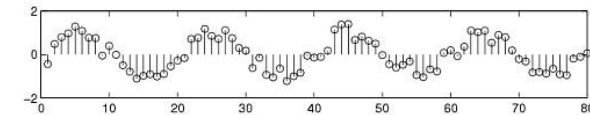
■ Deterministic signals

- There is no uncertainty with respect to its value at any time. (ex) $\sin(3t)$



■ Random signals

- There is *uncertainty* before its actual occurrence.



Properties of Signals

Amplitude: The height or strength of a signal, measured in volts or decibels.

Frequency: The rate at which a signal oscillates, measured in Hertz (Hz).

Formula: $f = \frac{1}{T}$ Frequency (where T is the period).

Phase: The position of a point in time on a waveform cycle, measured in degrees or radians.

Bandwidth: The range of frequencies a signal occupies, critical in determining data rate.

Formula: **Bandwidth = $f_{max} - f_{min}$**

Signal-to-Noise Ratio (SNR):

Measures the level of a desired signal to the background noise.

Formula: **SNR(dB) =**

Applications of Signal Types in Communication Systems

Analog Signal Applications:Used in AM/FM radio, analog telephony, and audio transmission.

Digital Signal Applications:Essential in modern communication such as internet data transfer, digital TV, and VoIP.

Periodic Signals:Applied in regular broadcast signals, clock signals for synchronous systems.

Aperiodic Signals:Useful in data packets in networking, one-time messages.

Deterministic Signals:Used in signal modulation (e.g., amplitude modulation), secure digital communications.

Random Signals:Modeled in systems with interference, such as wireless communication where signal noise is a factor.

Signal Conversion and Processing

Analog-to-Digital Conversion (ADC): Converts continuous analog signals into digital form for processing and storage.

Key Steps: Sampling (selecting data points), Quantization (assigning values). Nyquist Theorem: Sampling rate must be at least twice the signal's highest frequency to prevent aliasing.

Digital-to-Analog Conversion (DAC): Converts digital data back to analog form for transmission or playback.

Applications: Digital audio players, digital communication systems.

Signal Processing: Techniques to improve or modify signals, including filtering, modulation, and error correction.

Example: Filtering out noise in audio signals, modulating data for efficient transmission.

Summary and Key Takeaways

Signal Types: Signals can be classified into analog, digital, periodic, aperiodic, deterministic, and random types, each with distinct properties.

Signal Properties: Amplitude, frequency, phase, and SNR affect signal quality and determine the suitability of signals for various applications.

Applications: Signal types are chosen based on application requirements; for instance, digital signals are preferred for data transmission, while analog signals are useful for audio.

Conversion: ADC and DAC are essential for integrating analog signals with digital processing systems.

1. What are the key differences between analog and digital signals, and in which scenarios might each be preferred?
2. Why are periodic signals often used in broadcasting, while aperiodic signals are common in digital communication?
3. How does the Nyquist Theorem influence sampling in Analog-to-Digital Conversion?
4. Describe the importance of Signal-to-Noise Ratio (SNR) in communication systems and its impact on signal quality.
5. What are some practical applications of deterministic and random signals in real-world communication systems?