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Department of Electronics and Communication Engineering

EC3354 Signals and Systems

Unit 1 – Classification of Signals and Systems

Presented by

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Introduction

❖ **What is Signal?**

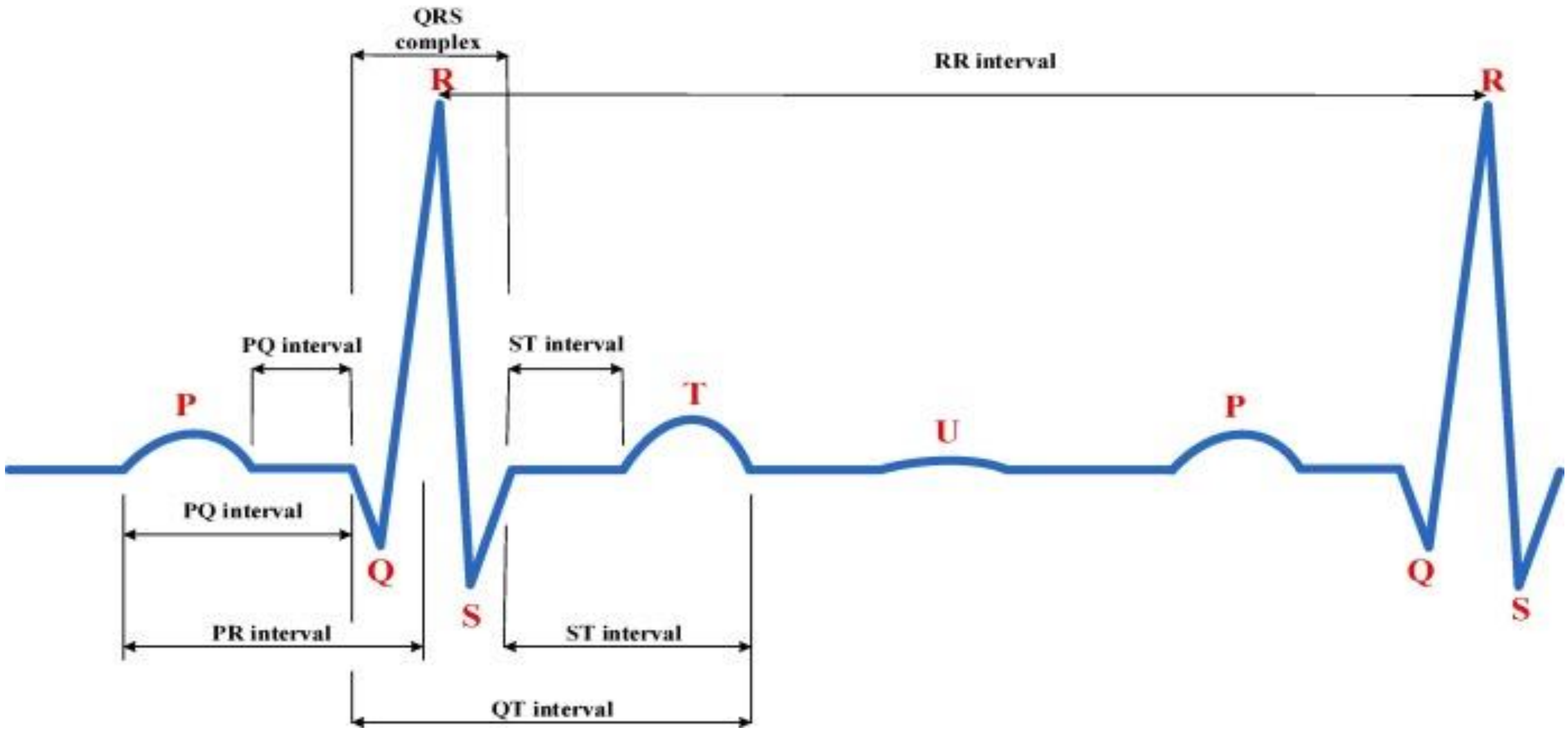
Theoretical Approach

Signal is a physical quantity that varies with independent variable like time, space, etc.

Signal carries information in the form of text, data, audio, video, etc.

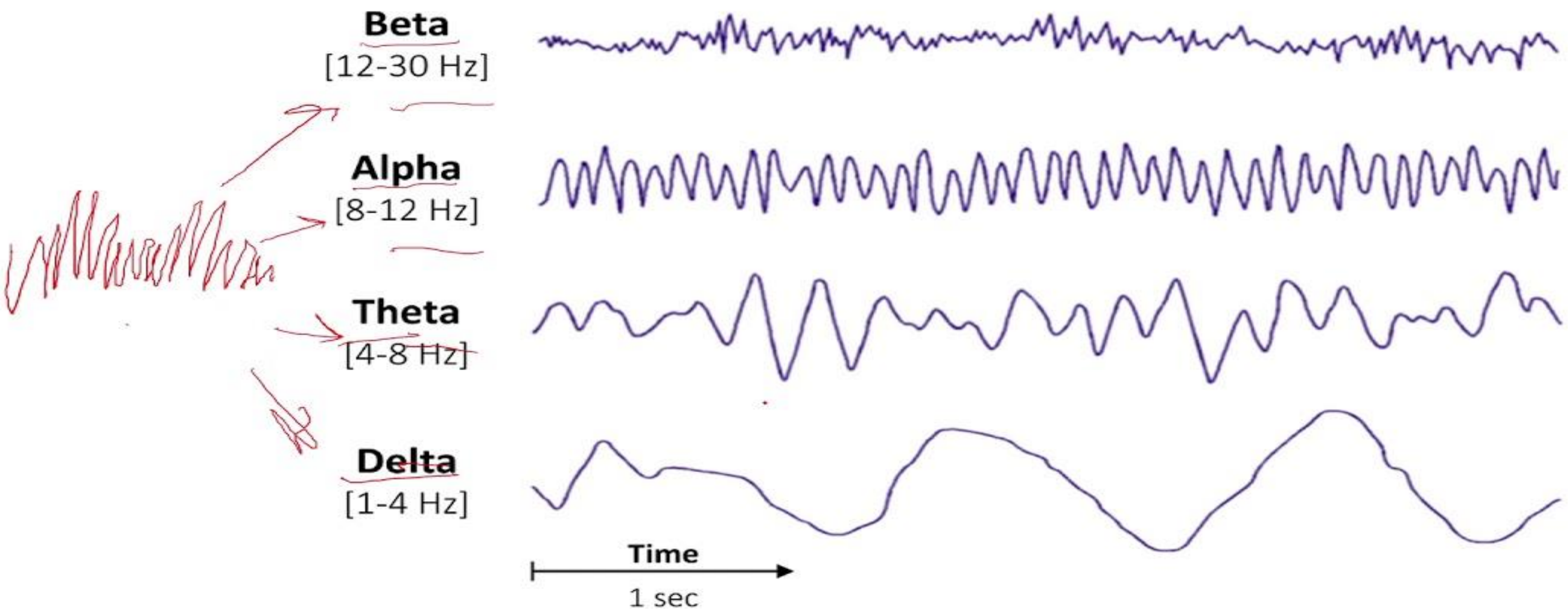
❖ **Examples: ECG Signal, EEG Signal, TV Signal, Speech Signal, Photographs**

ECG Signal Image



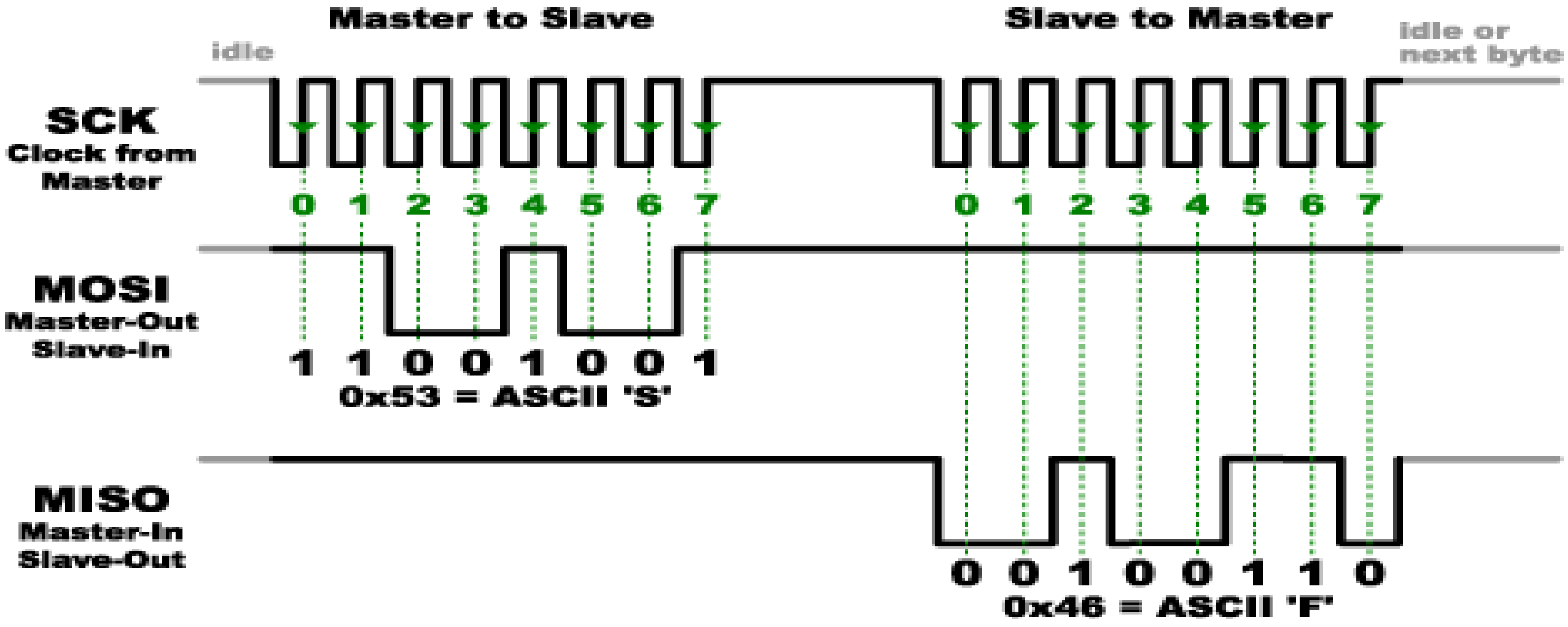
EEG Signal Image

EEG Frequency Bands



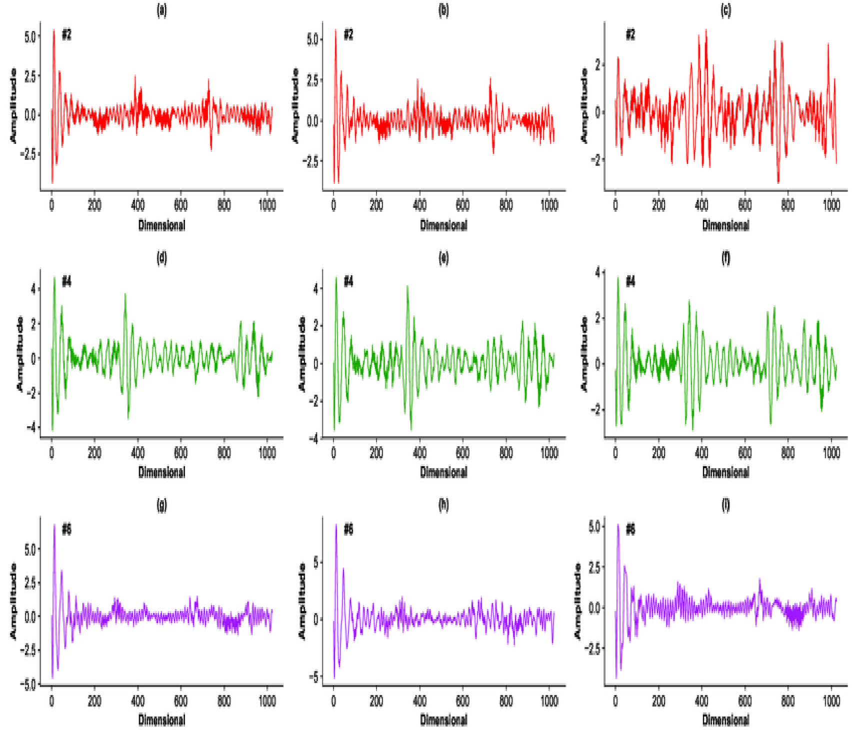
Signal Examples

Data



Signal Examples

Audio



Image

Text

Nature of fault	Signal	Features
1. Unbalance	$x, x^{(1)}$	rms, peak
2. Misalignment	$x, x^{(1)}$	rms, peak
3. Bent shaft	$x, x^{(1)}$	rms, peak
4. Damaged rolling element bearings	$x^{(2)}, x^{(3)}, x^{(4)}$	peak, rms, crest factor, kurtosis, l_p norm
5. Mechanical looseness	$x, x^{(1)}$	rms, peak
6. Damaged or worn gears	$x^{(2)}, x^{(3)}, x^{(4)}$	peak, rms, l_p norm

Introduction

Signal Definition: A practical approach

Signal Definition and Classification of Signals

❖ What is signal?

Practical Approach

→ signal comprises of frequency components

i) Low frequency components

It carries required (or) relevant (or) repeated (or) wanted information.

ii) High frequency components

It lies at the edges of a signal. It gives security (or) protection to the low frequency components.

Some frequency components present along with low frequency components, which gives disturbance to the low frequency components. Such frequency components are referred as high frequency components.

Classification of Signals

- Signals can be broadly classified into two categories:

1. Continuous-Time (CT) Signals: Defined at every instant of time.

2. Discrete-Time (DT) Signals: Defined only at discrete points in time.

Example:

CT: Analog audio signal, temperature over time.

DT: Digital audio, sampling data points.

Continuous-Time (CT) vs Discrete-Time (DT) Signals

- **Continuous-Time (CT) Signals**:
  - Defined for all real values of time (t).
  - Examples: Sinusoids, exponential functions.
- **Discrete-Time (DT) Signals**:
  - Defined only at discrete intervals (e.g., integers or specific time steps).
  - Examples: Sampled data, sequence of numbers.

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Periodic and Aperiodic Signals

- **Periodic Signals**:

Repeats at regular intervals.

Mathematically, $x(t)=x(t+T)x(t)$.

- Examples: Sine waves, square waves.
- **Aperiodic Signals**:

Do not repeat at regular intervals.

Examples: Pulse signals, transient signals.

Deterministic and Random Signals

- **Deterministic Signals**:
  - Can be precisely described by a mathematical expression.
  - Examples: Sinusoids, exponential functions.
- **Random Signals**:
  - Cannot be exactly described; they are unpredictable and are characterized by probabilistic behavior.
  - Examples: Noise signals, random walks.

Energy and Power Signals

- Energy Signals:
  - Signals with finite energy, $E = \int |x(t)|^2 dt$.
  - Examples: Pulse signals, transient signals.
- Power Signals:
  - Signals with finite, non-zero power, $P = \lim_{T \to \infty} \frac{1}{2T} \int_{-T}^{T} |x(t)|^2 dt$.
  - Examples: Continuous sinusoids, periodic signals.

Classification of Systems

- **Continuous-Time (CT) Systems**: Operate on continuous-time signals.
- **Discrete-Time (DT) Systems**: Operate on discrete-time signals.
- **Example:** Analog filter vs digital filter.

Classification of CT & DT Systems Based on Properties

- **Linear vs Nonlinear Systems**:
  - Linear: Satisfy superposition principle (addition of signals and scaling).
  - Nonlinear: Do not satisfy superposition.
- **Time-Variant vs Time-Invariant Systems**:
  - Time-Invariant: System behavior doesn’t change over time.
  - Time-Variant: System behavior changes with time.
- **Causal vs Non-Causal Systems**:
  - Causal: Output depends only on present and past input.
  - Non-Causal: Output depends on future inputs.
- **Stable vs Unstable Systems**:
  - Stable: Bounded input leads to bounded output (BIBO stability).
  - Unstable: Can produce unbounded output even for bounded input.

Summary

- Signals can be classified into CT and DT, periodic and aperiodic, deterministic and random, energy and power signals.
- Systems can be classified based on linearity, time-invariance, causality, and stability.
- These classifications help in analyzing and designing communication systems and signal processing algorithms.

Applications

- Understanding signal classifications is essential for:
  - Signal processing applications like filtering, modulation.
  - System design like analog and digital filters, communication systems.
  - Noise and interference analysis in communication channels.

References

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  - 2. Simon Haykin, Barry Van Veen, “Signals and Systems”, 2nd Edition, Wiley, 2002
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  - 1. B. P. Lathi, “Principles of Linear Systems and Signals”, 2nd Edition, Oxford, 2009.
  - 2. M. J. Roberts, “Signals and Systems Analysis using Transform methods and MATLAB”,McGraw- Hill Education, 2018.
  - 3. John Alan Stuller, “An Introduction to Signals and Systems”, Thomson, 2007.