



INTRODUCTION TO BIOMEDICAL SIGNAL AND IMAGE PROCESSING

- Signals convey information
- Signals
- Multichannel signals
- Multidimensional signal
- Signal processing selectively eliminates information
- Stages in biomedical signal and image processing
- Examples of electrocardiogram (ECG)
- Electrocardiogram with arrhythmias
- Electrocardiogram with myocardial ischaemia
- Electromyogram (EMG) of a term and pre-term delivery
- Example of computed tomography (CT) image
- Continuous-time sinusoidal signals
- A segment of signal as a sum of sinusoids (spectrum)

Signals convey information

- A **signal** is a function of one or several variables that carries useful information
- A signal is **biological** if it is recorded from a living system and conveys information about the state or behavior of that system
- **One-dimensional signals** depend on a single variable such as time
- **Multichannel signals** are simultaneous, taken from different points of a system and depend on a single variable such as time
- **Multidimensional signals (images)** depend on several variables such as spatial coordinates

Signals

- An electromyogram of uterus (30 min)

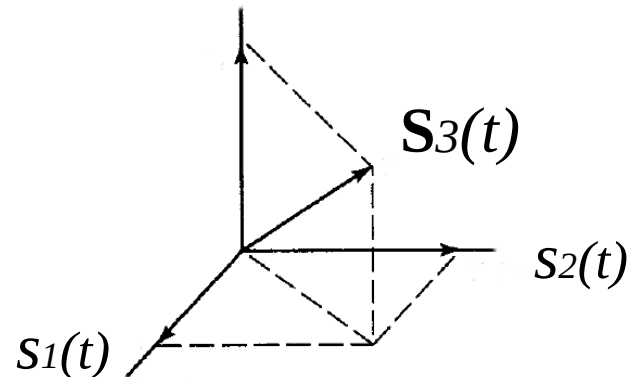


Multichannel signals

- Three-channel electrocardiogram

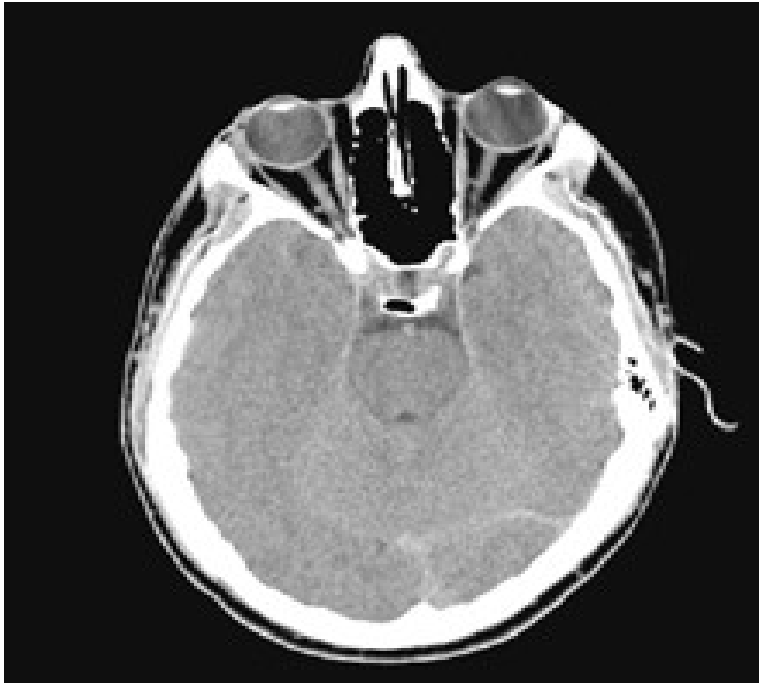


$$\mathbf{S}_3(t) = \begin{bmatrix} s_1(t) \\ s_2(t) \\ s_3(t) \end{bmatrix}$$



Multidimensional signals

- Multidimensional signals (images) $f(x, y)$ depend on several variables such as spatial coordinates (x, y)



$$f(x, y) = \begin{bmatrix} f(0, 0) & f(0, 1) & \cdots & f(0, N - 1) \\ f(1, 0) & f(1, 1) & \cdots & f(1, N - 1) \\ \vdots & \vdots & & \vdots \\ f(M - 1, 0) & f(M - 1, 1) & \cdots & f(M - 1, N - 1) \end{bmatrix}$$

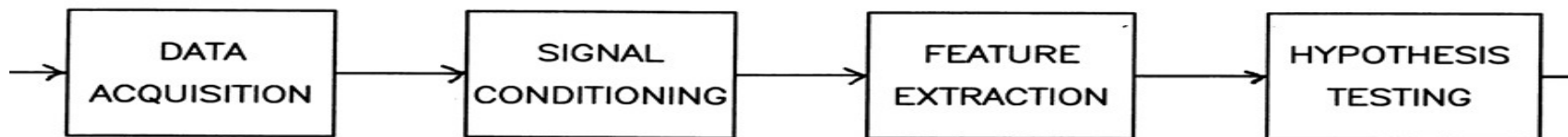
(Gonzales, Woods)

Signal processing selectively eliminates information

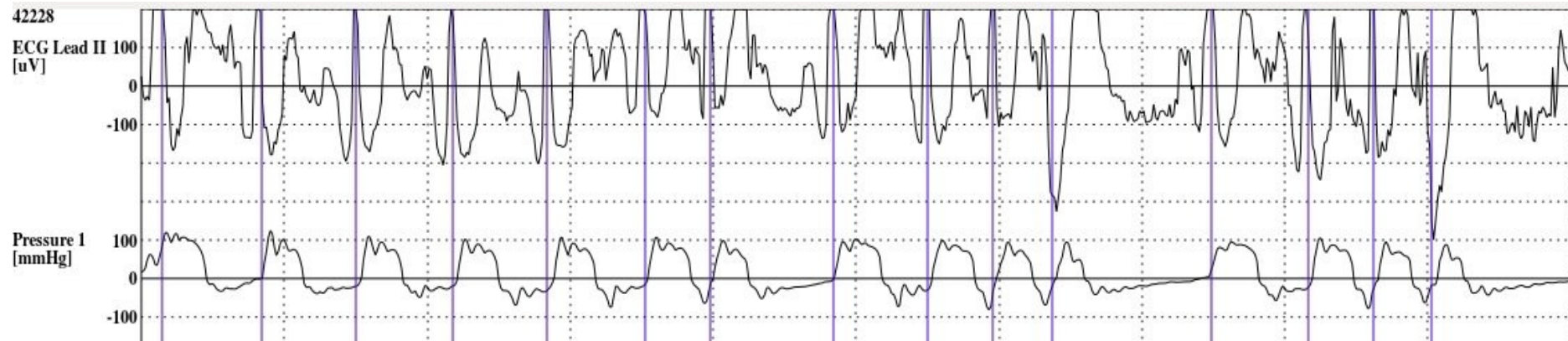
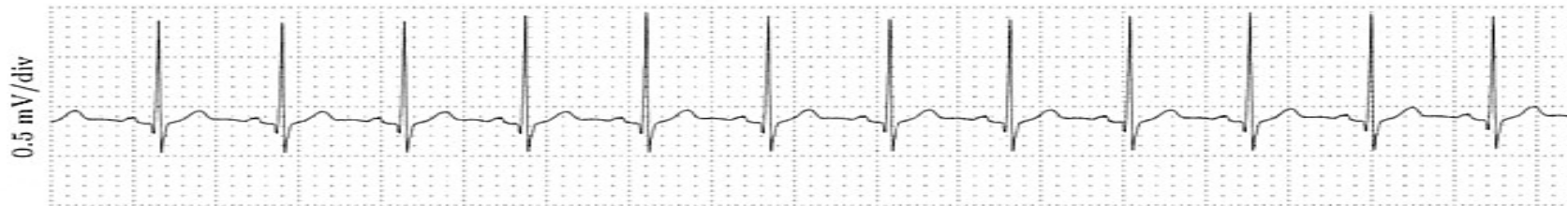
- A signal conveys the information of interest as well as irrelevant information (50/60 Hz power line interference, motion artifacts)
- What constitutes information of interest depends on the specific application (arrhythmia detection, transient ischaemia detection)
- The purpose of **signal processing** is to selectively eliminate irrelevant information from a signal to make the information of interest more easily accessible to a human observer or a computer system
- It is not possible to add information to a given signal, only to eliminate it

Stages in biomedical signal and image processing

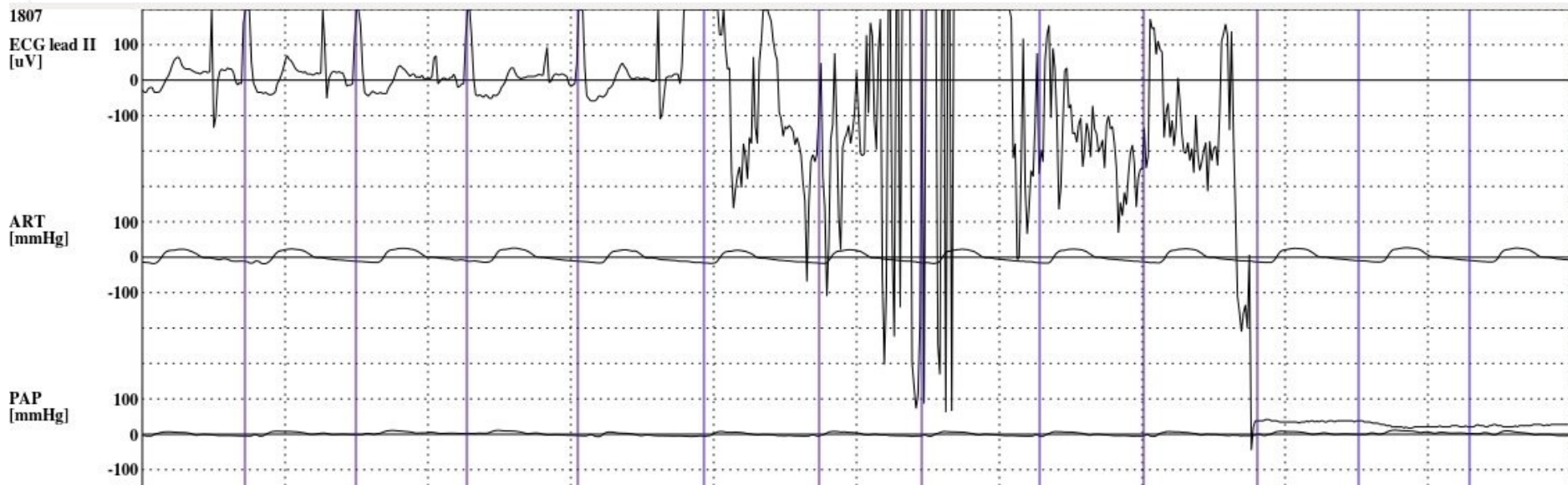
- **Data acquisition** (to capture the signal and encode in a form suitable for computer processing, to avoid losing information about the signal)
- **Signal conditioning** (to eliminate extraneous components such as noise: general techniques, the same dimensionality of the signal)
- **Feature extraction** (identifying and measuring a small number of parameters or features that best characterize the information of interest: signal- and application-specific techniques, much lower dimensionality – e.g. KL coefficients, edge detection)
- **Hypothesis testing, decision making** (Clinical applications, what course of actions has to be taken? E.g.: Does a patient show a specific pathology in heart beats based on ECG? Does a patient have a tumor based on a brain scan?)



Examples of electrocardiogram (ECG)

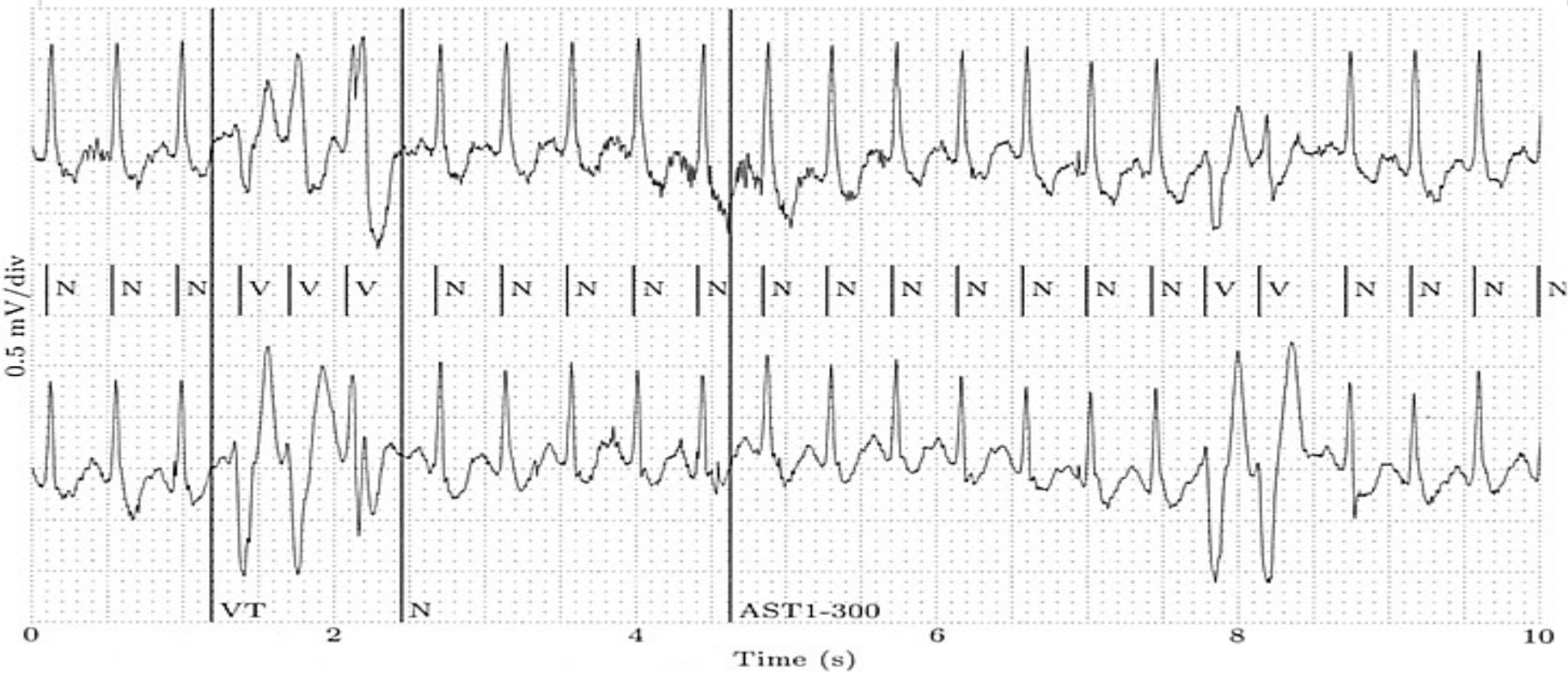


Examples of electrocardiogram (ECG)





Electrocardiogram with arrhythmias

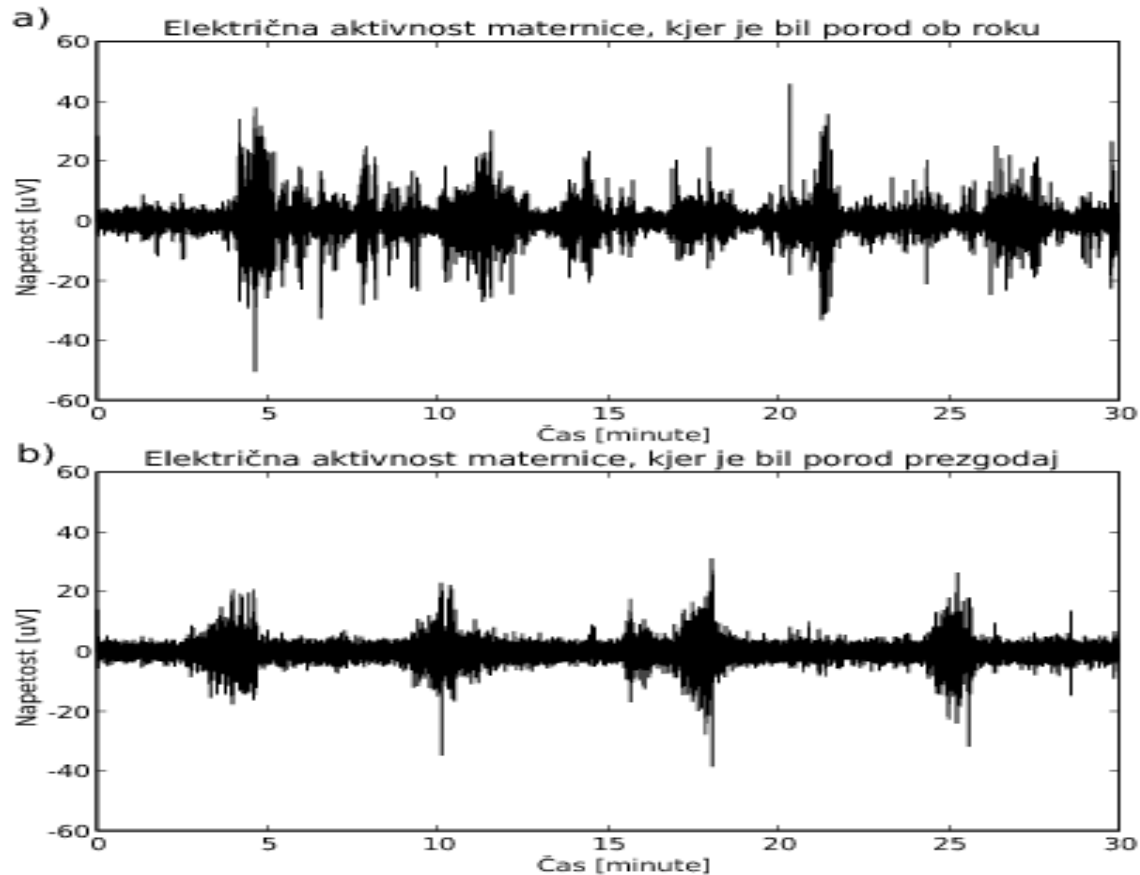


(Sornmo, Laguna)

Electrocardiogram with myocardial ischaemia



Electromyogram (EMG) of a term and pre-term delivery



Example of computed tomography (CT) image



(Suri, Wilson, Laxmanarayan, Handbook of Biomedical Image Analysis)

Example of computed tomography (CT) image

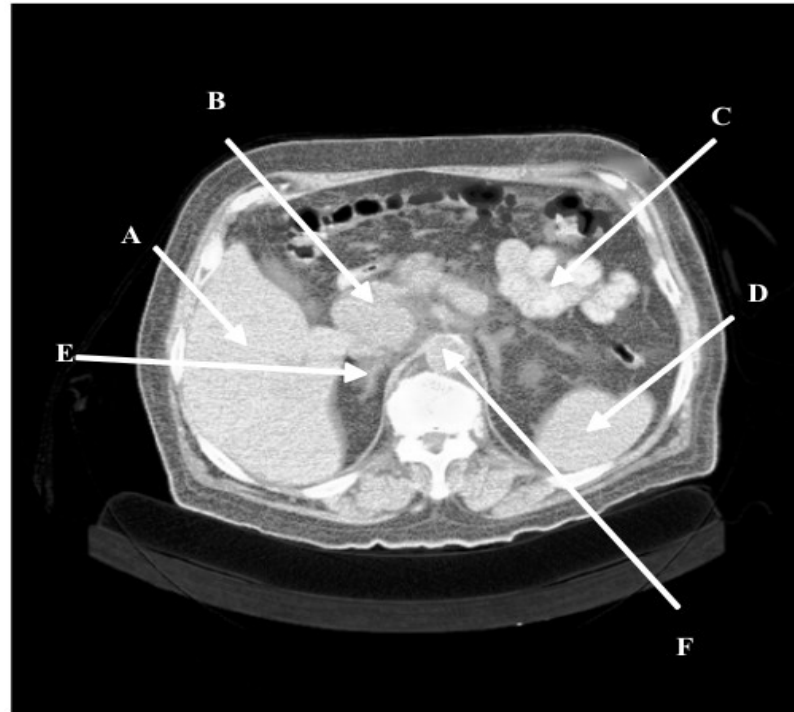


Figure 4.4: Contrast enhanced, helical CT scan through the abdomen and the head of the pancreas obtained with a reconstruction width of 8 mm (equal to slice thickness). A = liver; B = head of pancreas with tumor; C = bowel; D = spleen; E = right adrenal; F = aorta.

(Suri, Wilson, Laxmanarayan, Handbook of Biomedical Image Analysis)

Continuous-time sinusoidal signals

- Cosine signal

$$x_a(t) = A \cos(\Omega t + \theta), \quad -\infty < t < \infty$$

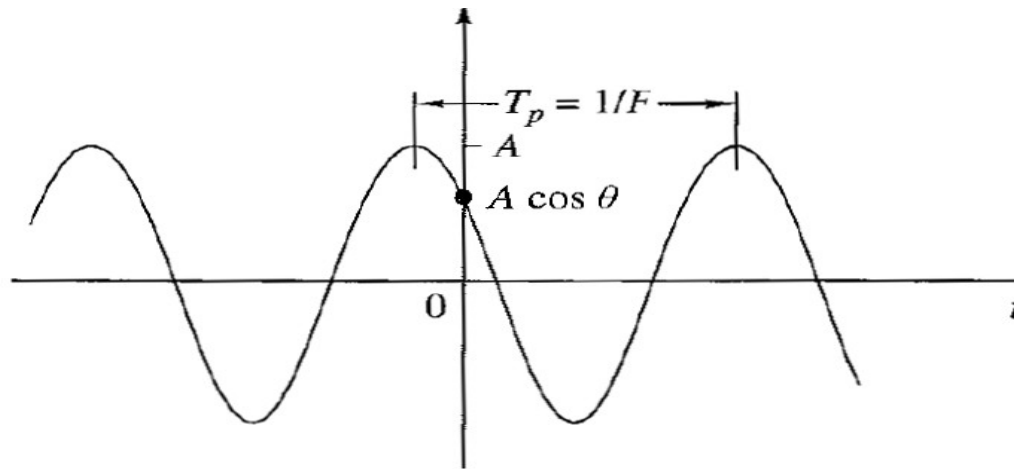
A is the amplitude

Ω is the frequency in radians per second [rad/s], $\Omega = 2 \pi F$

θ is the phase in radians [rad]

T_p is the duration of one cycle in seconds [s]

$F = 1 / T_p$ is the frequency in cycles per second or Hertz [Hz], $\text{Hz} = 1/\text{s}$



A segment of signal as a sum of sinusoids (spectrum)

- An electromyogram of uterus (30 min)



- A segment of signal may be represented as a sum of several sinusoids of different amplitudes and frequencies:

$$\sum_{i=1}^N A_i(t) \sin(2\pi F_i(t)t + \Theta_i(t))$$

- where $\{A_i(t)\}$, $\{F_i(t)\}$, and $\{\Theta_i(t)\}$ are the sets of amplitudes, frequencies and phases