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 od 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

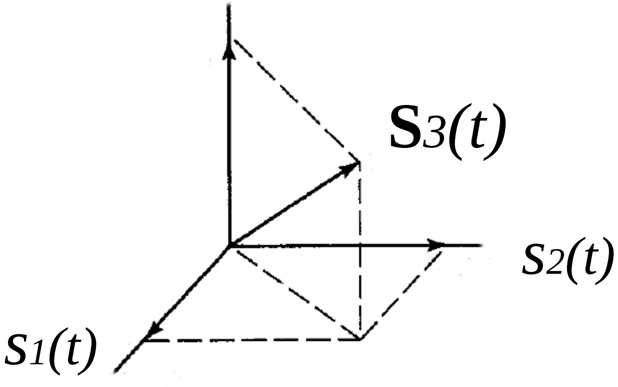
Signals

- An electromyogram of uterus (30 min)

Multichannel signals

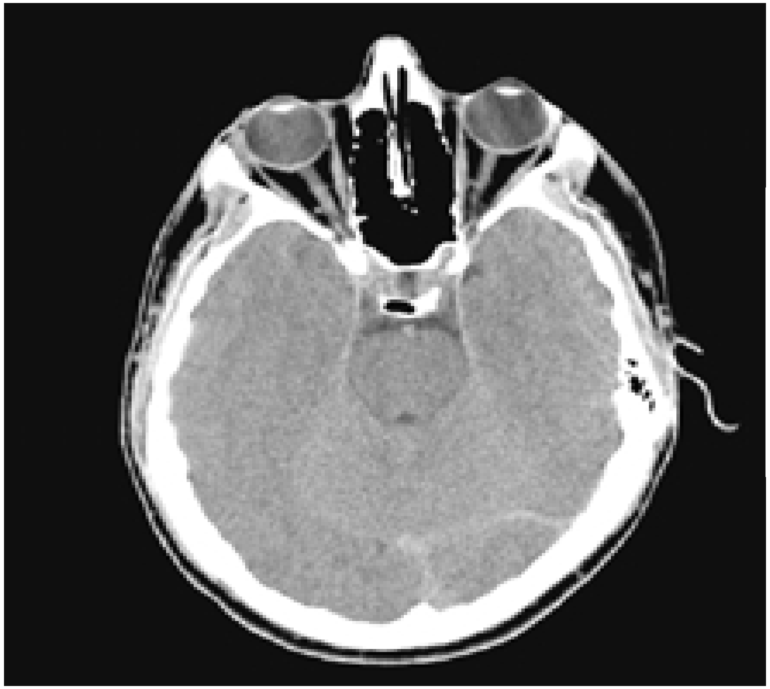
- Three-channel electrocardiogram

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



Multidimensional signals

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



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

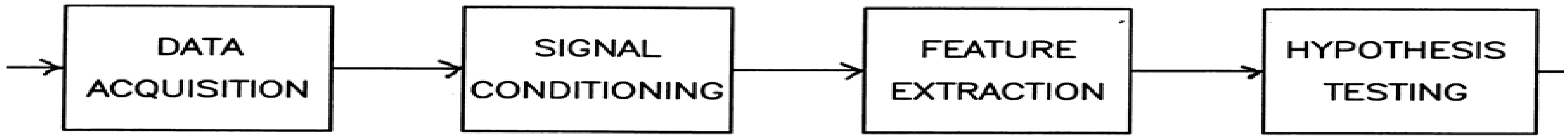
(Gonzales, Woods)

Signal processing selectively eliminates information

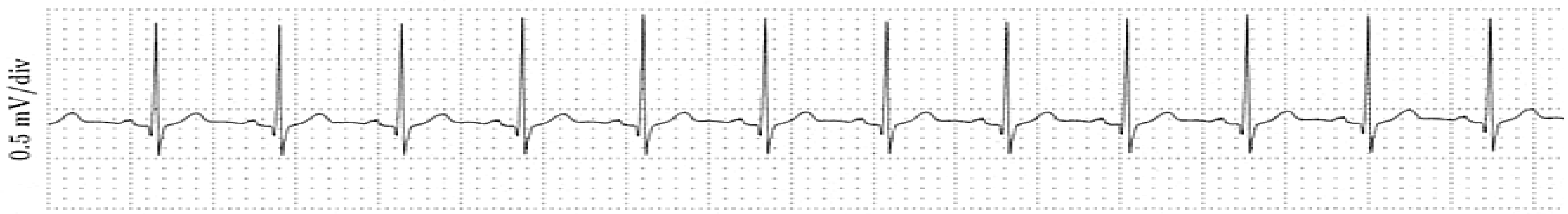
- A signal conveys the information of interest as well as irrelevant information (50/60 Hz power line interference, motion artifacts)
- What constitutes information of interest depends on the specific application (arrhythmia detection, transient ischaemia detection)
- The purpose of signal processing 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

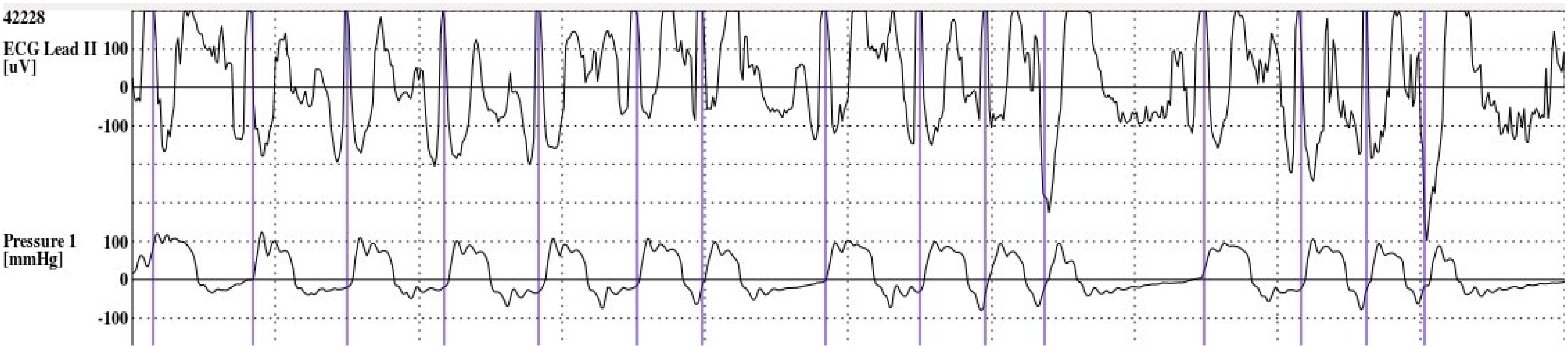
Stages in biomedical signal and image processing

- 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?)

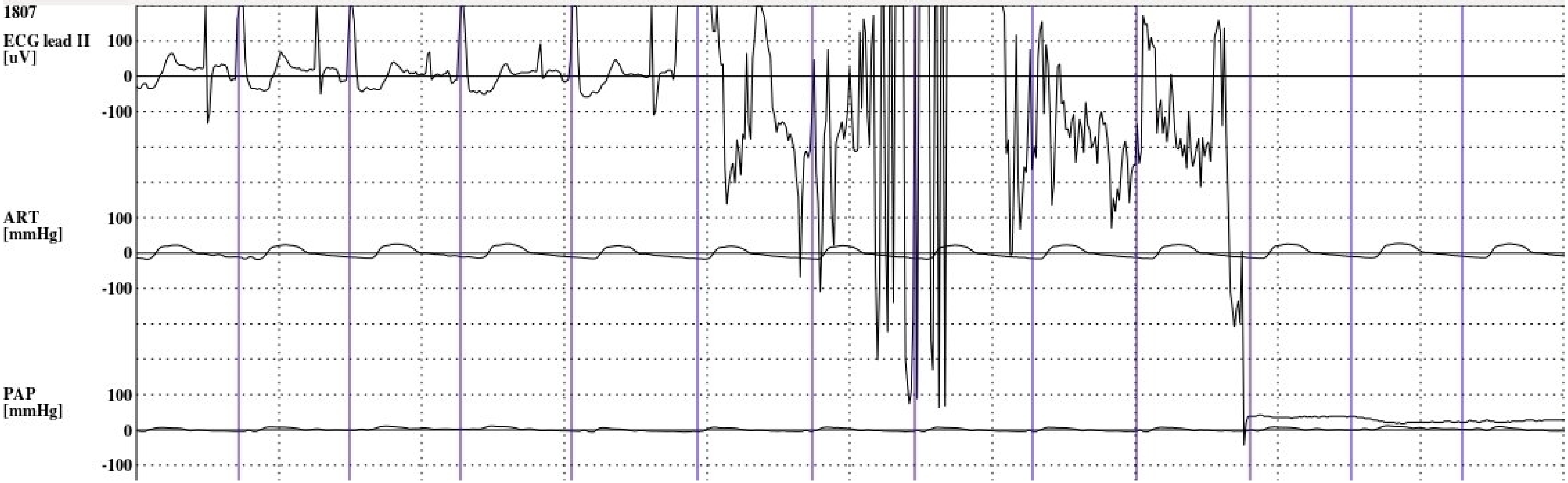


Examples of electrocardiogram (ECG)

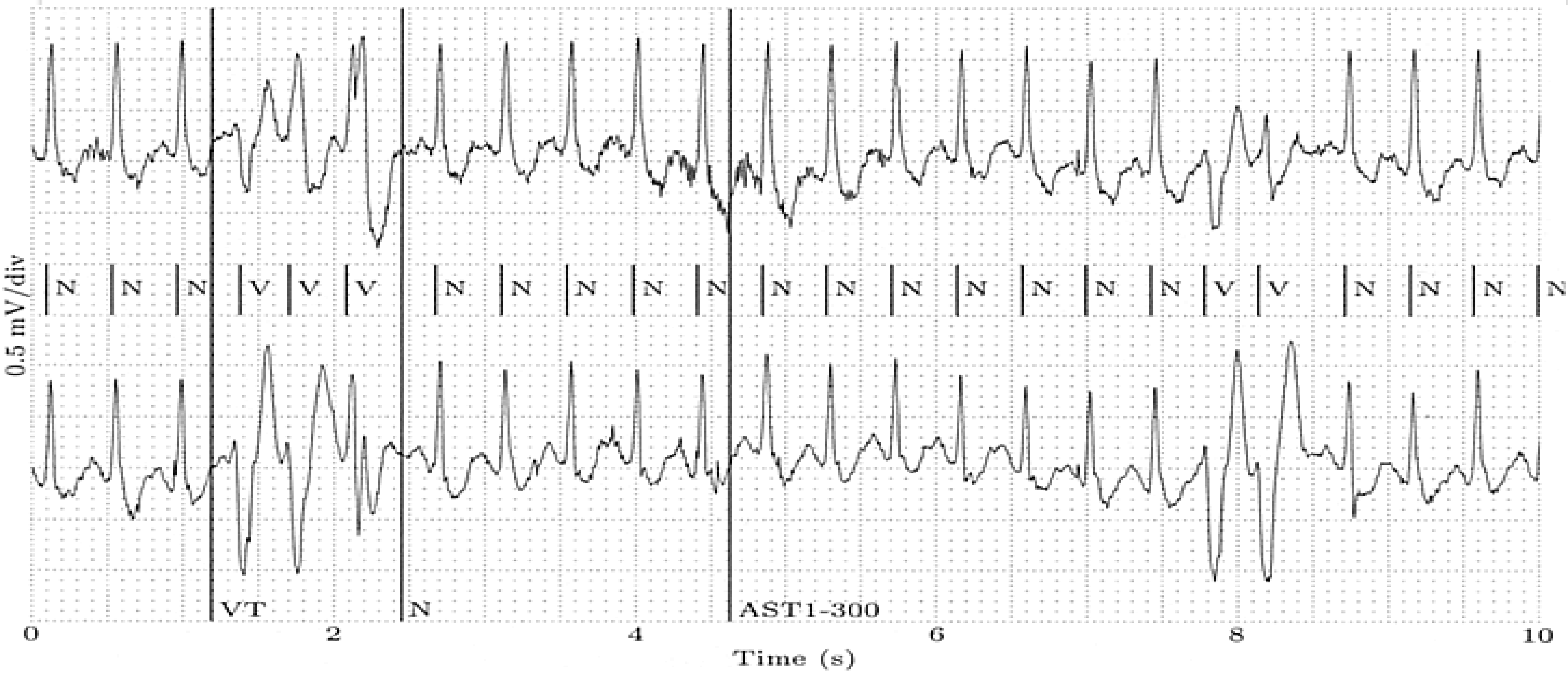




Examples of electrocardiogram (ECG)



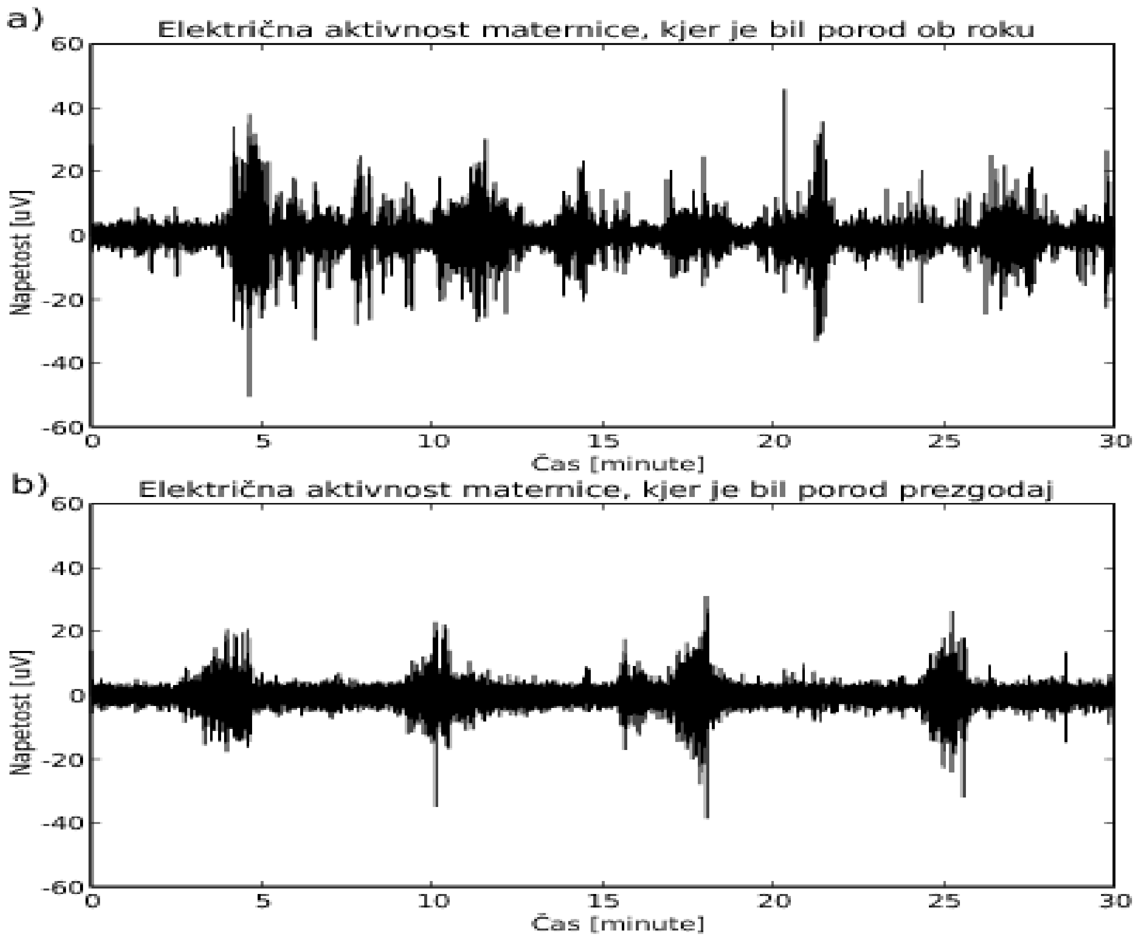
Electrocardiogram with arrhythmias



(Sornmo, Laguna)

Electrocardiogram with myocardial ischaemia

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



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Example of computed tomography (CT) image

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

Example of computed tomography (CT) image

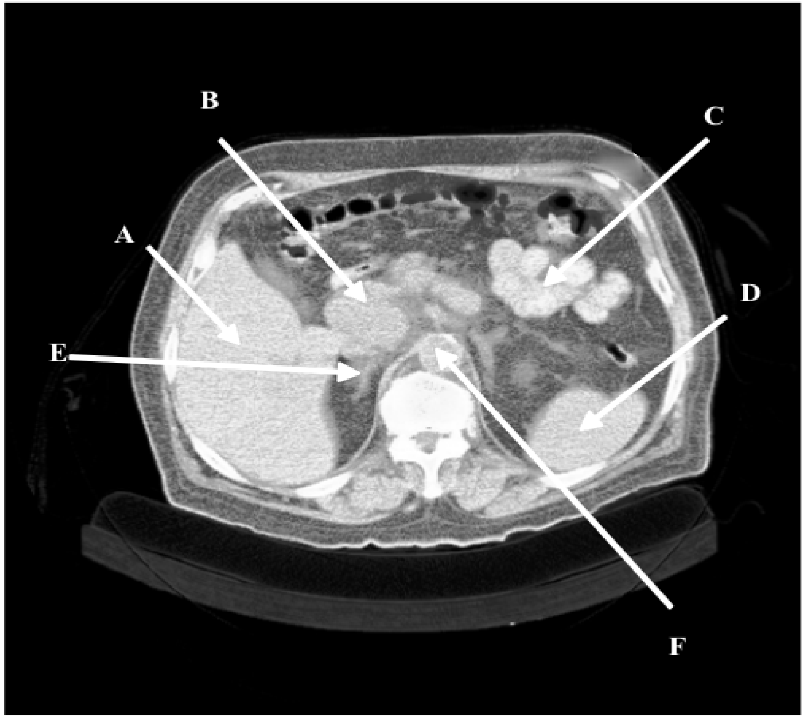


Figure 4.4: Contrast enhanced, helical CT scan through the abdomen and the head of the pancreas obtained with a reconstruction width of 8 mm (equal to slice thickness). A = liver; B = head of pancreas with tumor; C = bowel; D = spleen; E = right adrenal; F = aorta.

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

Continuous-time sinusoidal signals

- Cosine signal

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

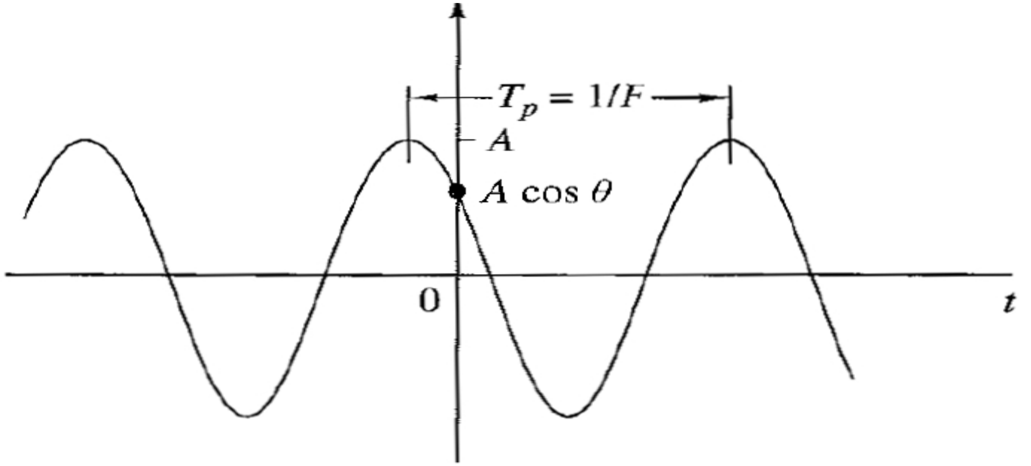
A is the amplitude

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*], $Hz = 1/s$



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

- An electromyogram of uterus (30 min)

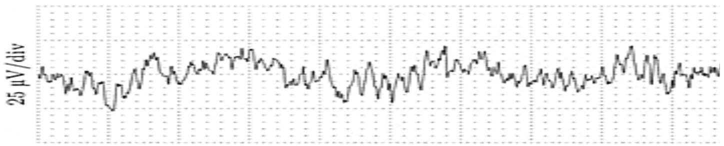
- A segment of signal may be represented as a sum of several sinusoids of different amplitudes and frequencies:

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

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

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

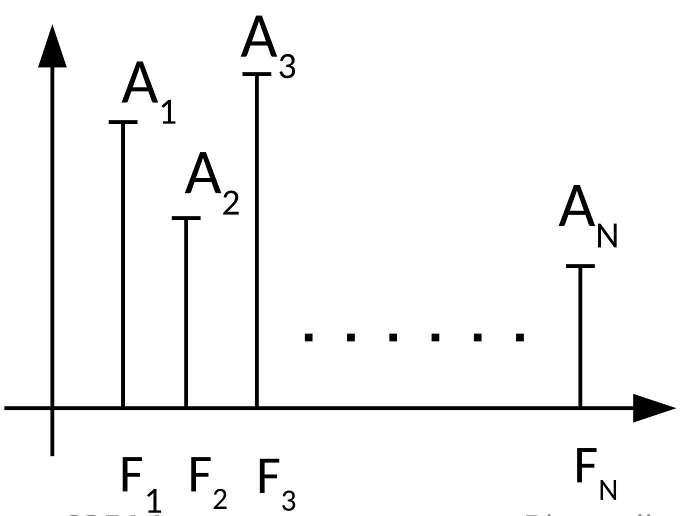
- A segment of signal can be represented as a sum of sinusoids with different amplitudes and frequencies, which are shifted among each other



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

- where {*A* i}, {*F* i}, in {*Θ* i} are sets of amplitudes, frequencies and phases
- What is frequency spectrum?

Amplitude spectrum



$F_2 = 2.F_1$

$F_3 = 3.F_1$

$\vdots$

$F_N = N.F_1$

Phase spectrum