Benemérita Universidad Autónoma de Puebla

Taller: Análisis y Procesamiento de Señales EEG
3er WORKSHOP CEMMAC

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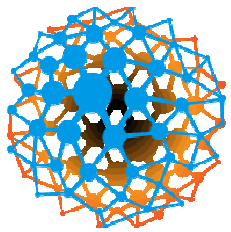
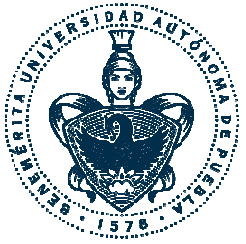
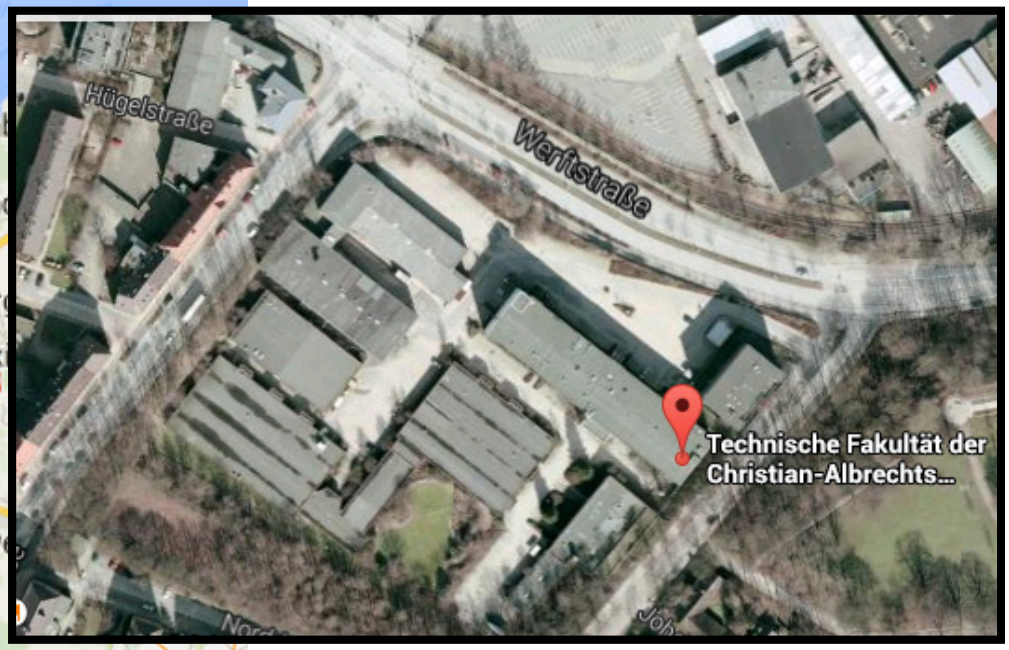
27-Septiembre-2018



CEMMAC



Kiel



www.tf.uni-kiel.de
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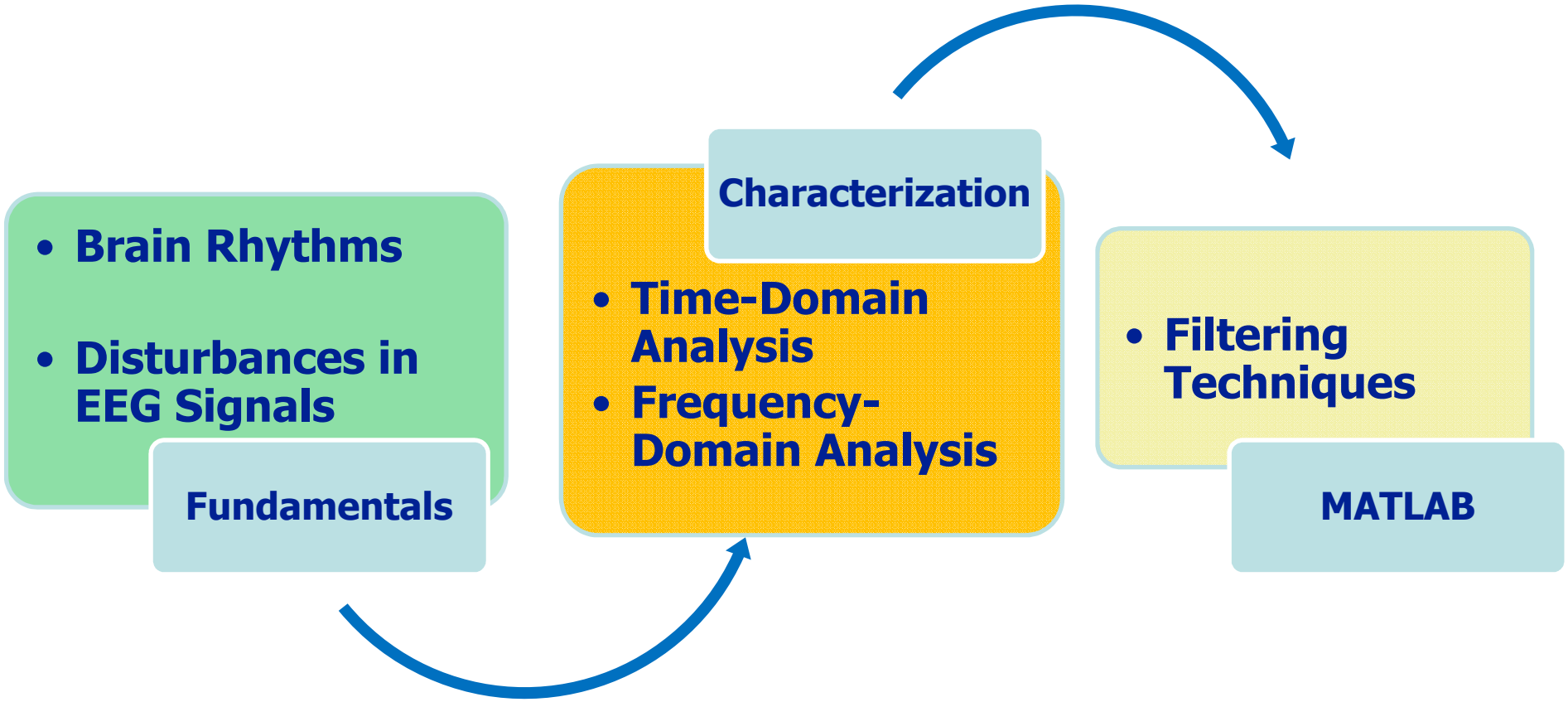
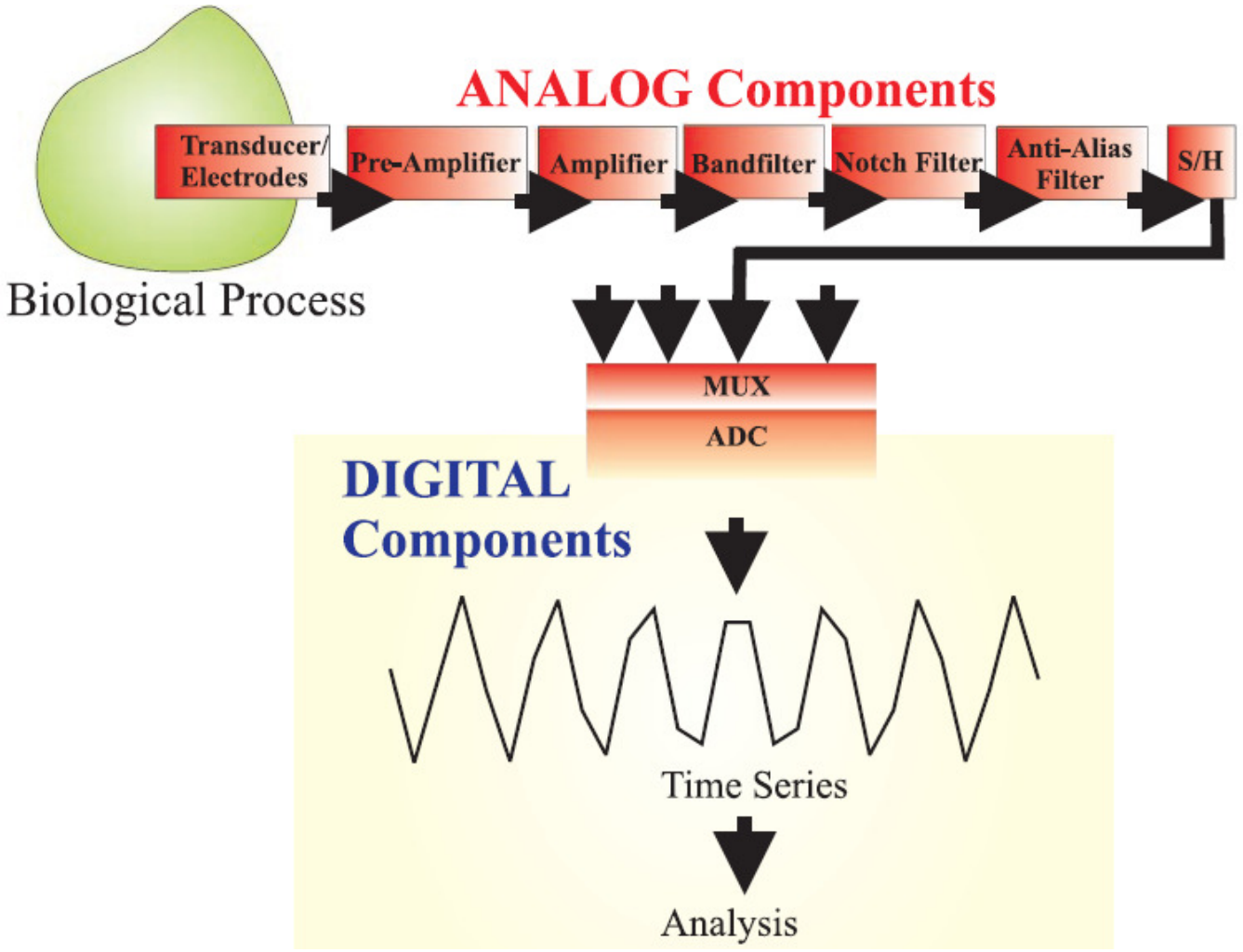
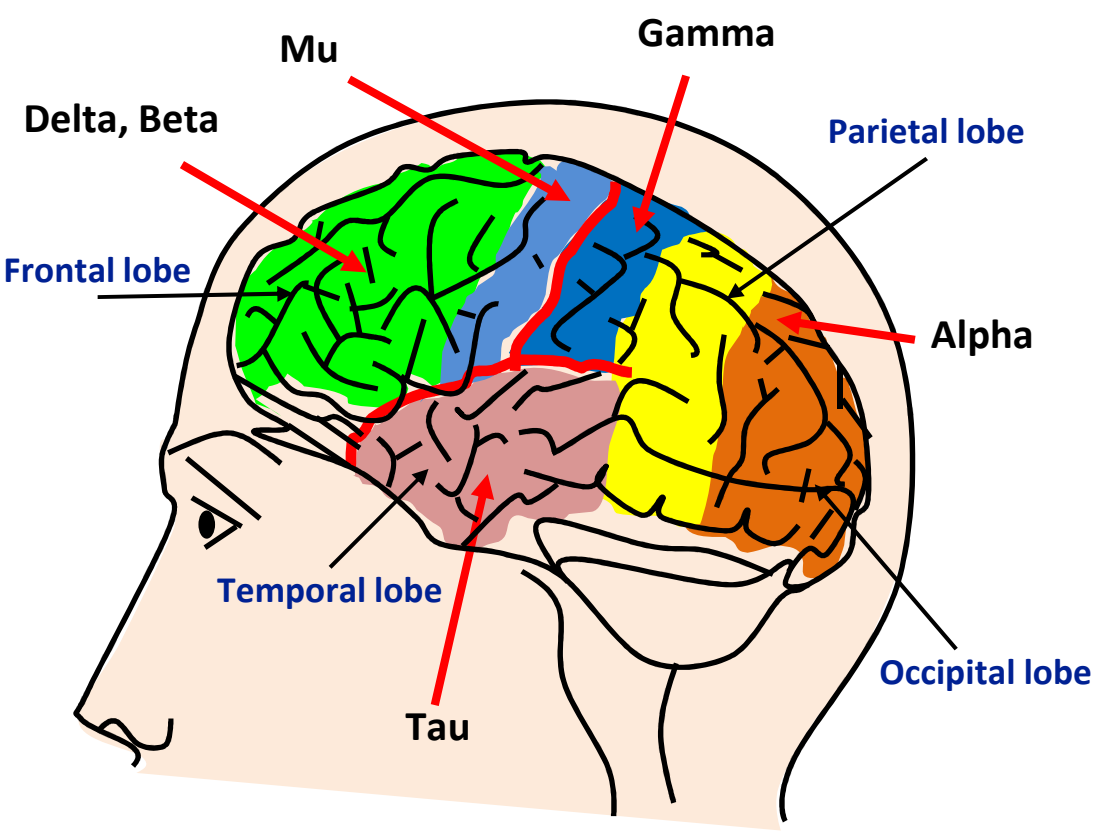
Outline

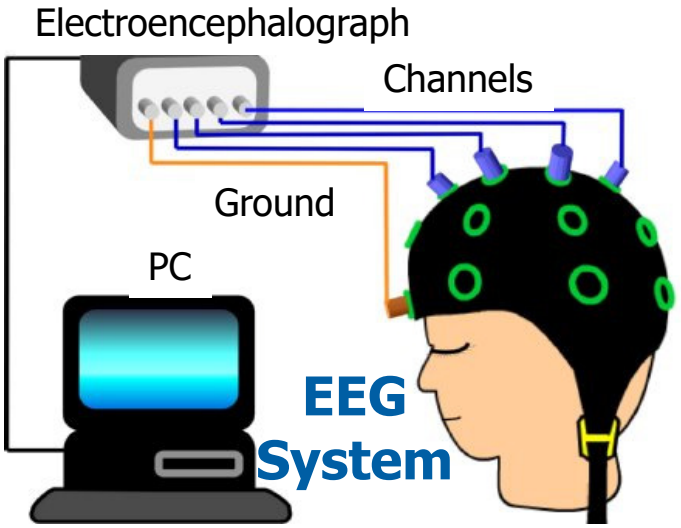

Brain Rhythms
Disturbances in EEG Signals
Fundamentals
Characterization
Time-Domain Analysis
Frequency-Domain Analysis
Filtering Techniques
MATLAB

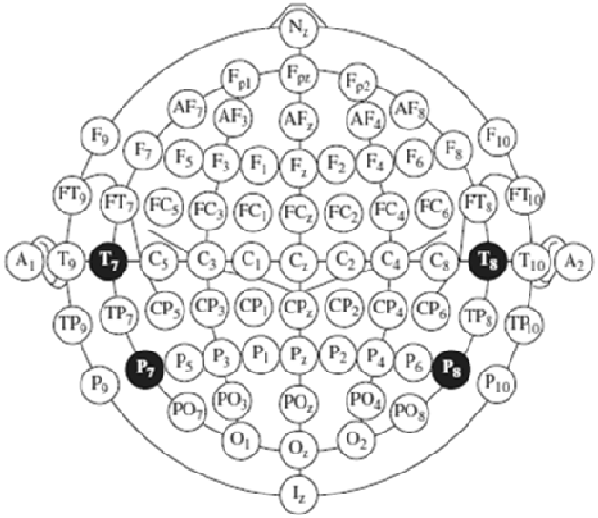
Fundamentals



Brain Rhythms

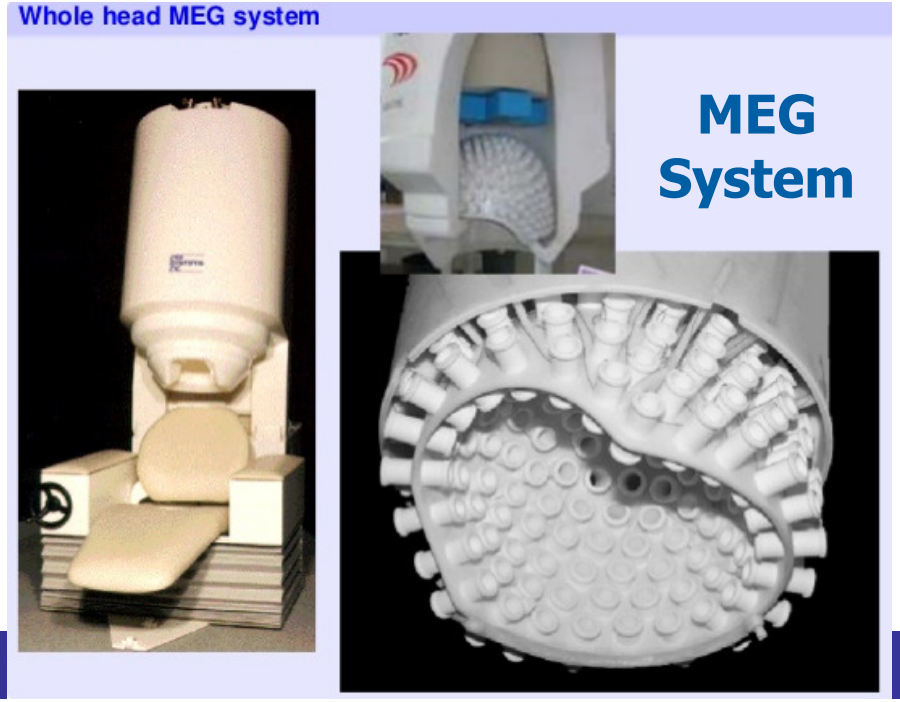






- 10-20 International System.
- F: Frontal
- P: Parietal…

Brain Rhythms



Disturbances in EEG Signals

- Artifacts: Sequence with higher amplitude and different shape than the undistorted signal sequences.

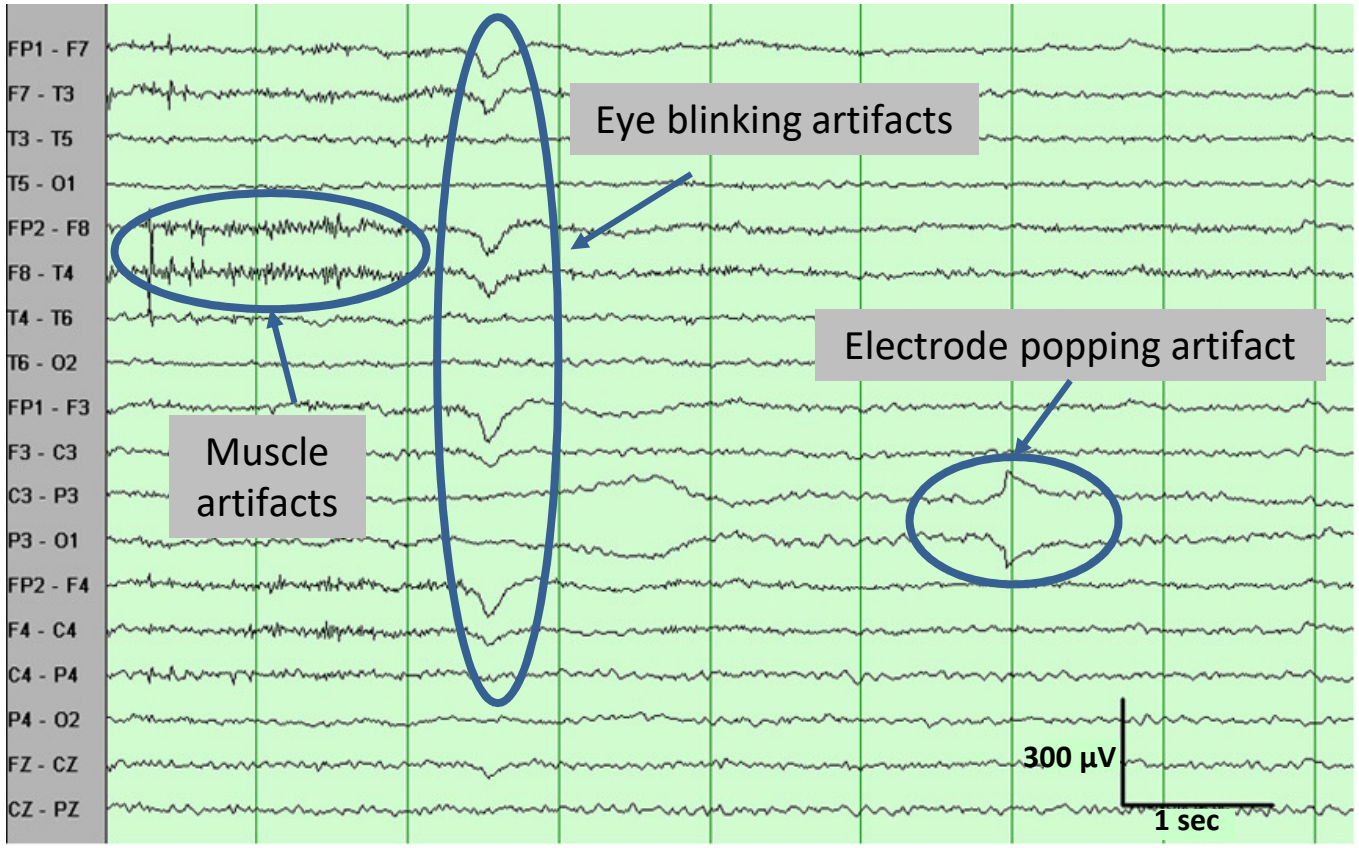
Artifacts can be:

  - Patient related (Physiologic):Heart beat, ocular and muscle movements.

  - Technical (Extraphysiologic): Power-line, electrode-popping.

Disturbances in EEG Signals

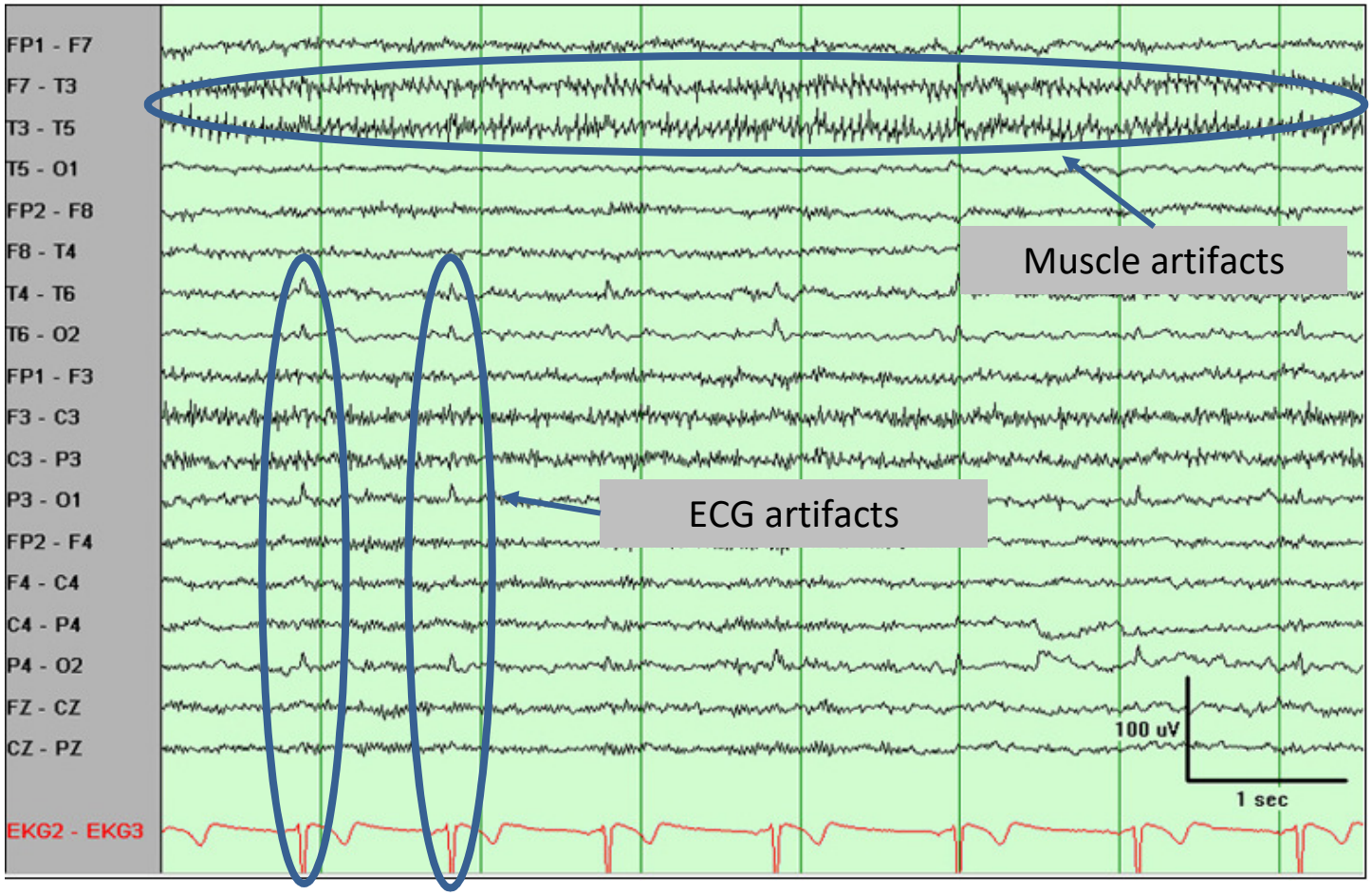
Examples of physiological and technical artifacts



- Each signal represents the difference in voltage between the two corresponding electrodes

Disturbances in EEG Signals

Examples of physiological artifacts



Images taken from: http://emedicine.medscape.com/article/1140247

CHARACTERIZATION

Time-Domain Analysis

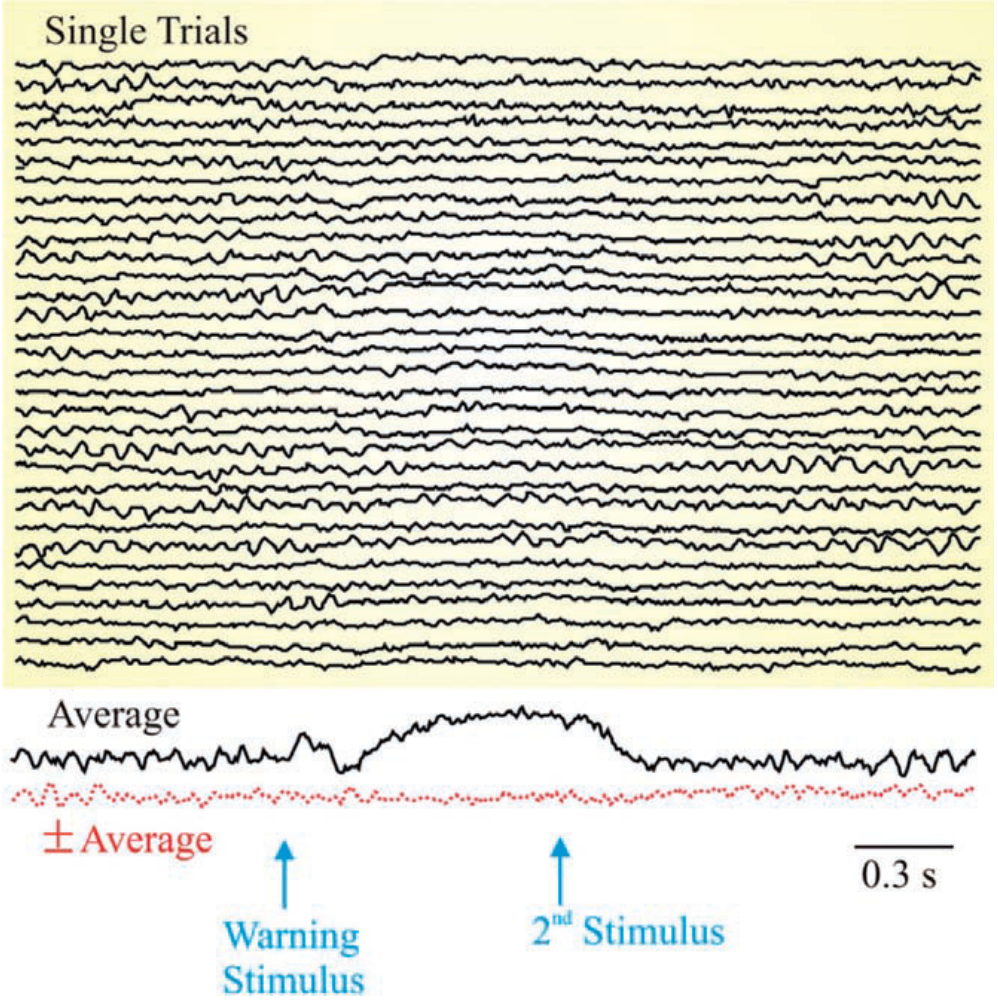
1.- Mean value, standard deviation, variance.

2.- Zero-crossings: Intervals, Frequencies, maxima, minima.

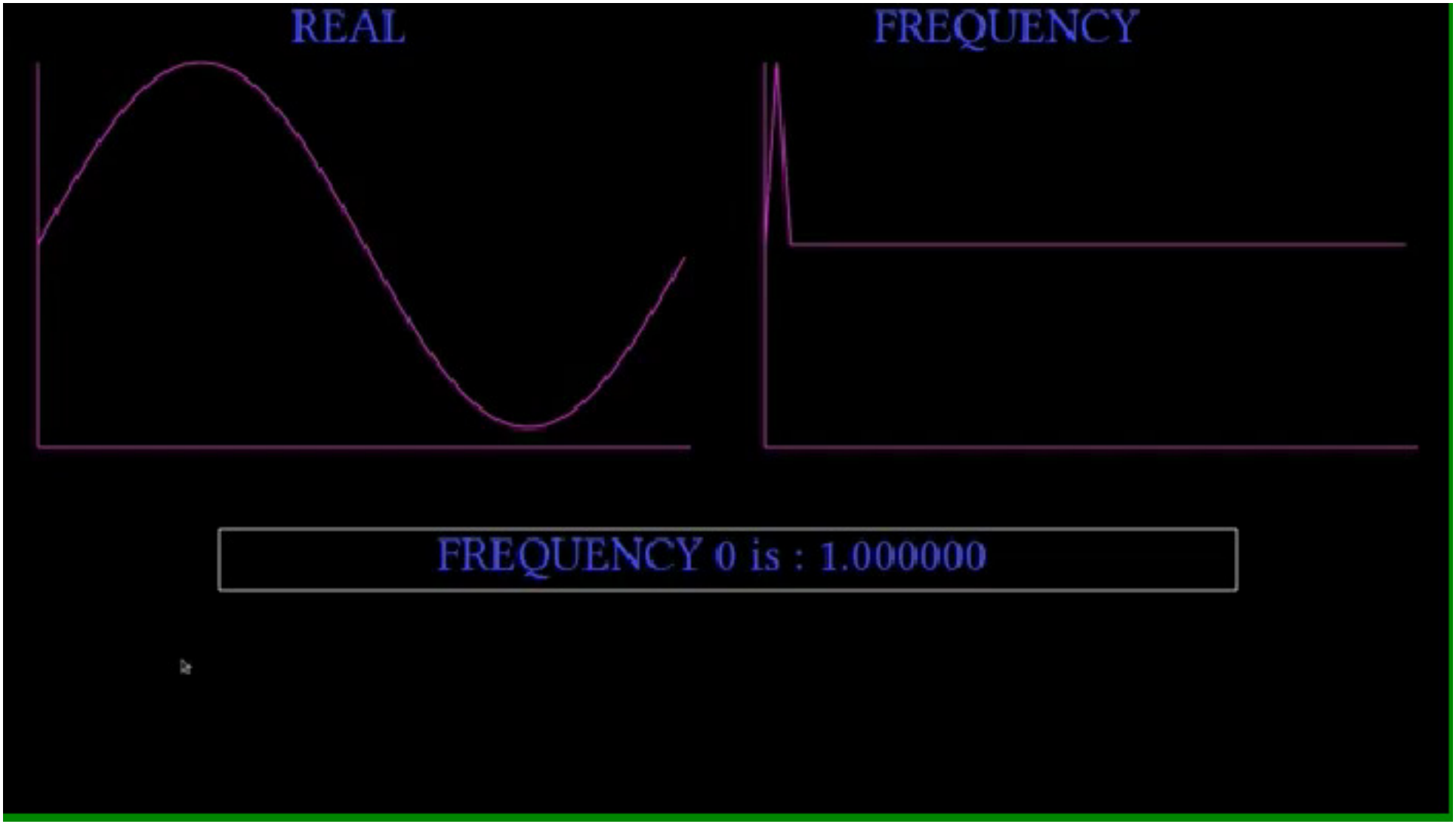
3.- Peak detection: Spikes, ECG.

4.- Signal filtering.

5.- Autocorrelation, cross-correlation.



Frequency-Domain Analysis



Amplitude spectrum→fft in Matlab→From time to frequency domain.

Power spectrum→ $P_x(\omega) = |F(\omega)|^2 = F(\omega)F^*(\omega)$

Only the half of the values is plotted, i.e., half of the fft result is used.

Cross spectrum → $P_{xy}(\omega) = |X(\omega)Y(\omega)|$ → Fourier Transform of the cross-correlation. It is used to determine in which frequencies there are some similarities in the signals.

In Matlab→ cpsd.

Coherence→$C_{xy}(f) = \frac{|G_{xy}(f)|^2}{G_{xx}(f)G_{yy}(f)}$ → from 0 to 1

In Matlab→ mscohere.

Frequency-Domain Analysis

When the signals are non-stationary (as in the case of EEG signals), we should divide them into segments (Windows), and then compute the Fourier Transform in each one.

The Windows should be overlapped to smoth the edges→Short-Term Fourier Transform (STFT).

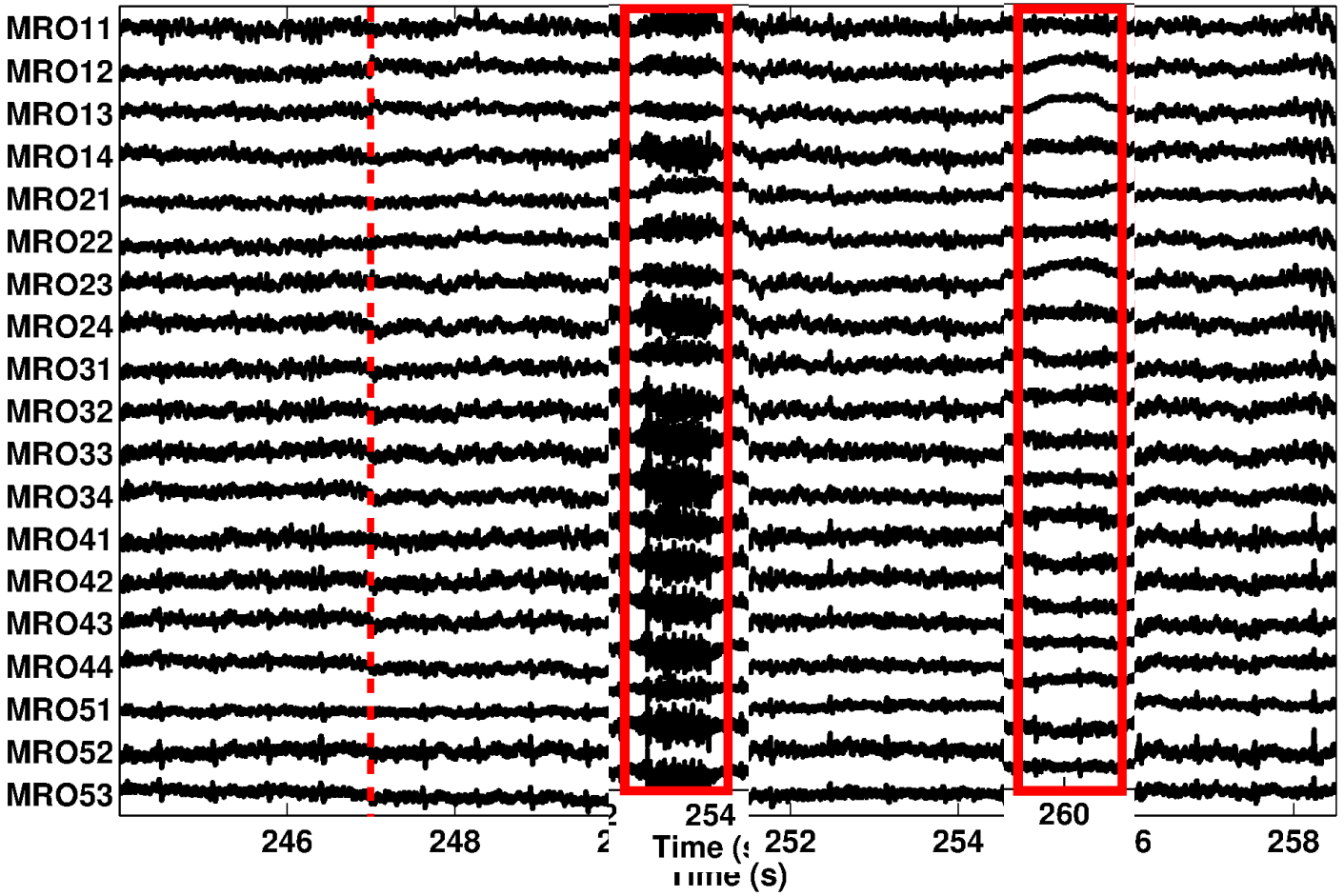
In Matlab→ spectrogram

Mathematically, the STFT is defined as

$$X(m,\omega) = \sum_{n=-\infty}^{\infty} x(n)w(n-m)e^{-j\omega n}$$

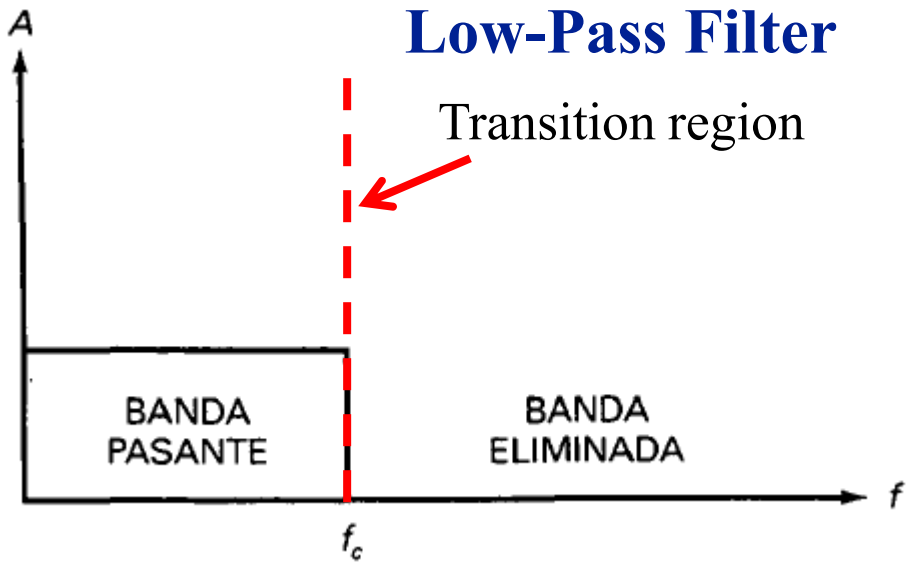
FILTERING TECHNIQUES

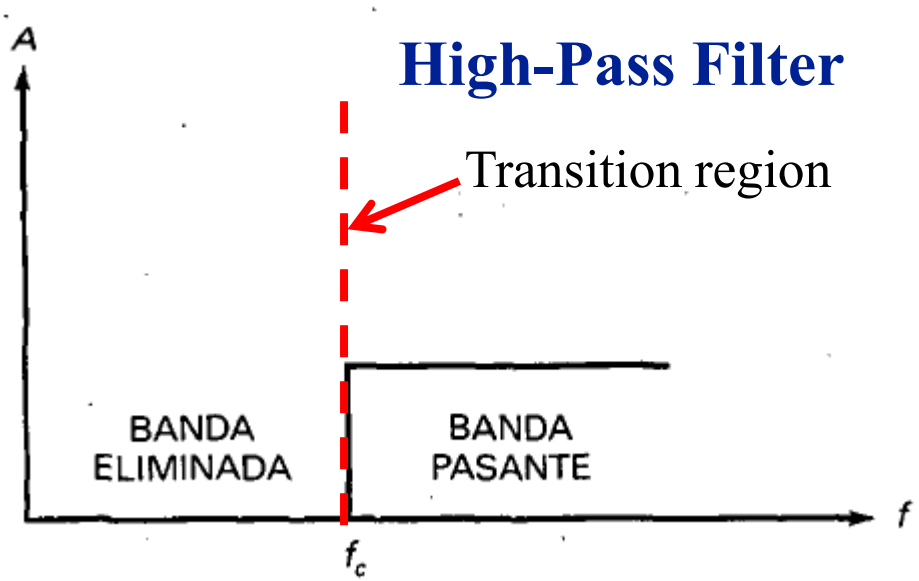
Complete or Partial Removal of Electrode Signals

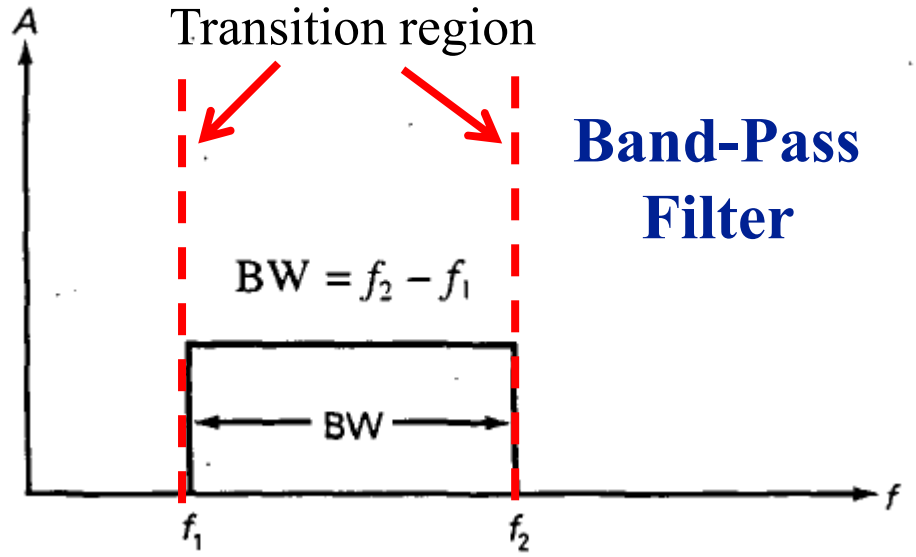


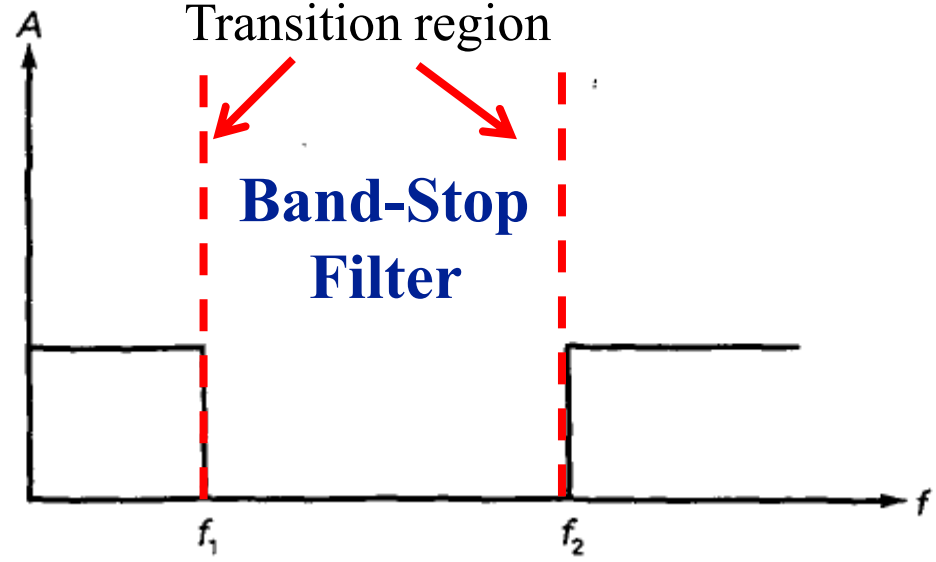
- Disadvantage: Loss of infomation, an expert is needed.

Digital Filters

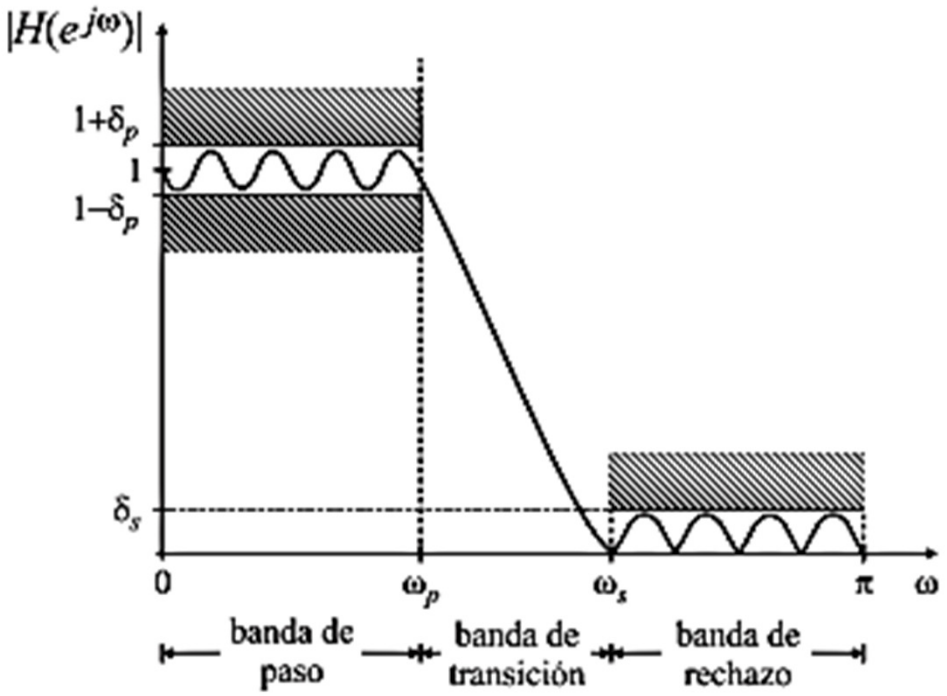






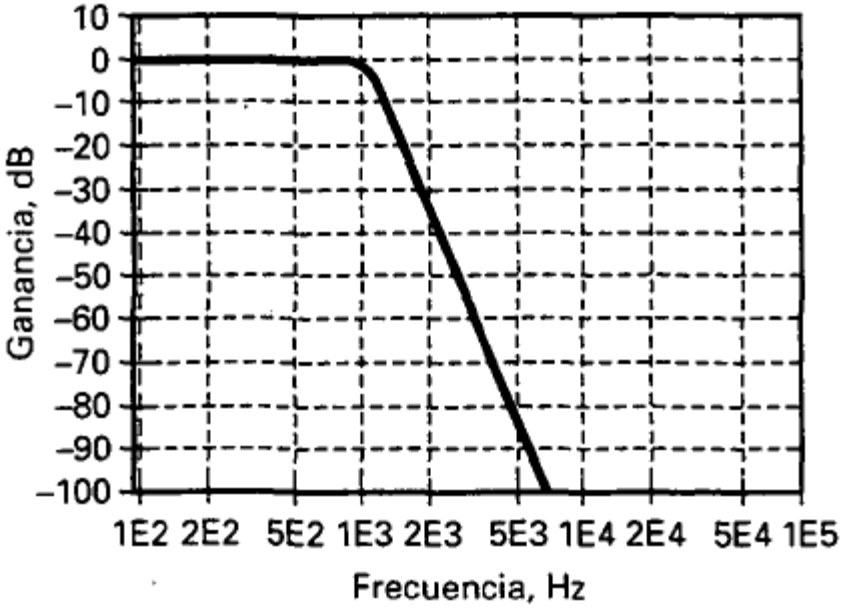


Digital Filters



desviación en la banda de paso: δ_p,
desviación en la banda de rechazo: δ_s,
frecuencia de corte de la banda de paso: ω_p,
frecuencia de corte de la banda de rechazo: ω_s.

Butterworth



$n = 6$; A_p=2.5 dB; f_c=1 kHz.

Advantage: Fast decay.

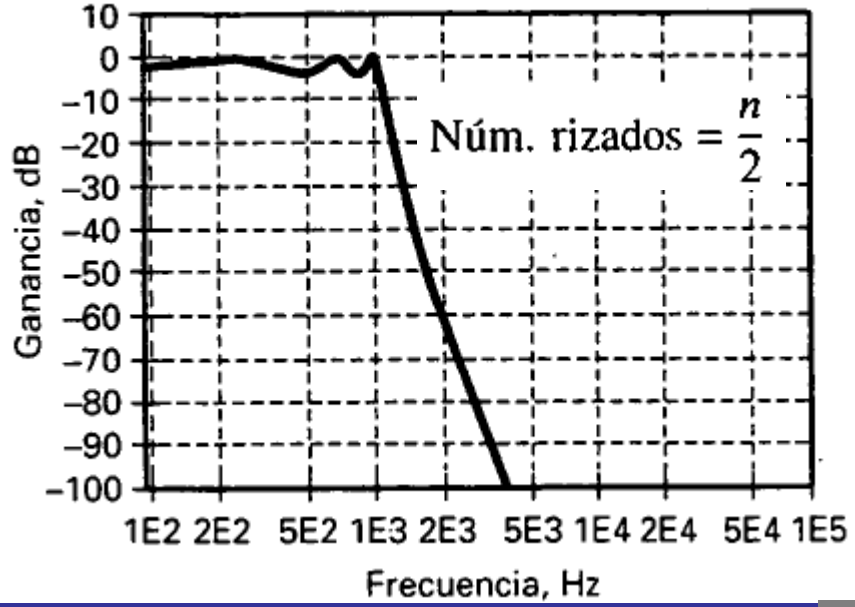
Disadvantage: Ripples in passband.

Advantage: Flat response in passband.

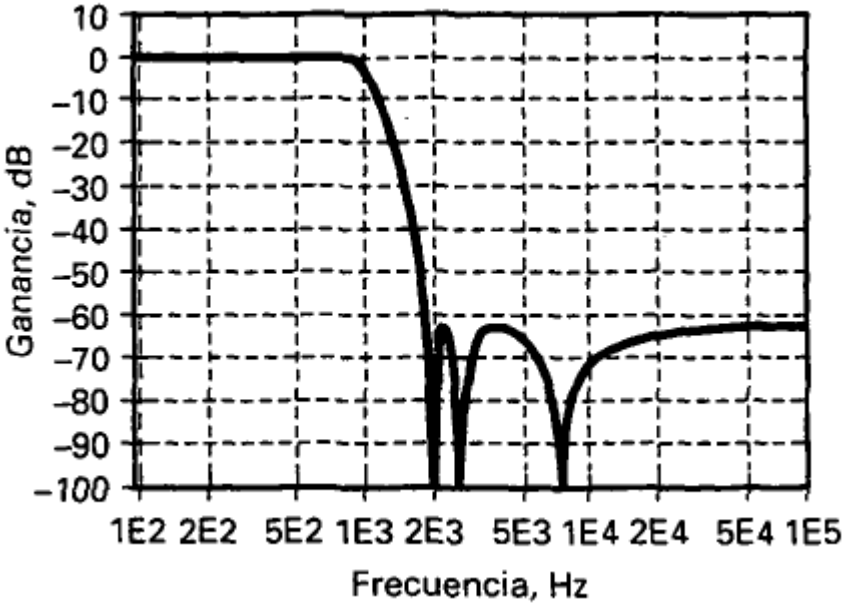
Disadvantage: Slow decay.

Slope = 20n dB/decade = 6n dB/octave

Chebyshev I



Chebyshev II

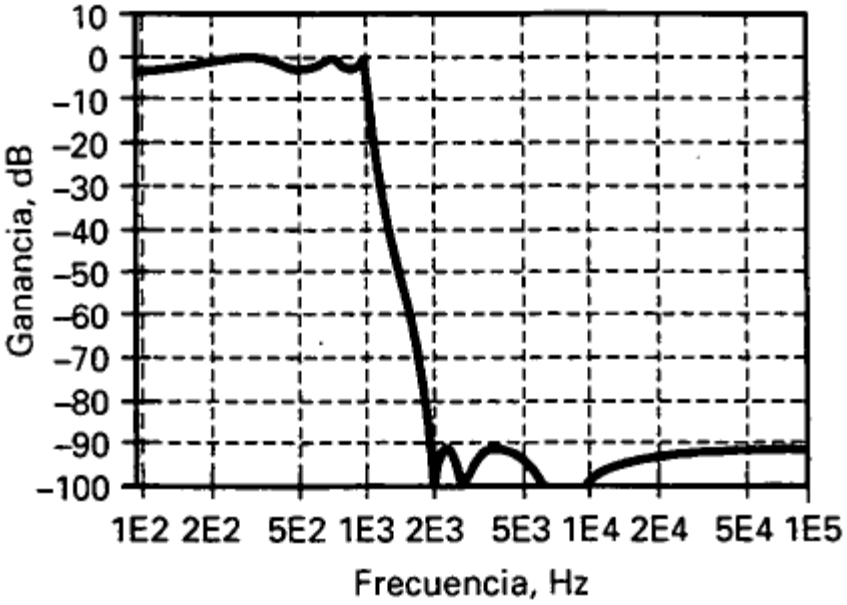


$n = 6$; A_p=2.5 dB; f_c=1 kHz.

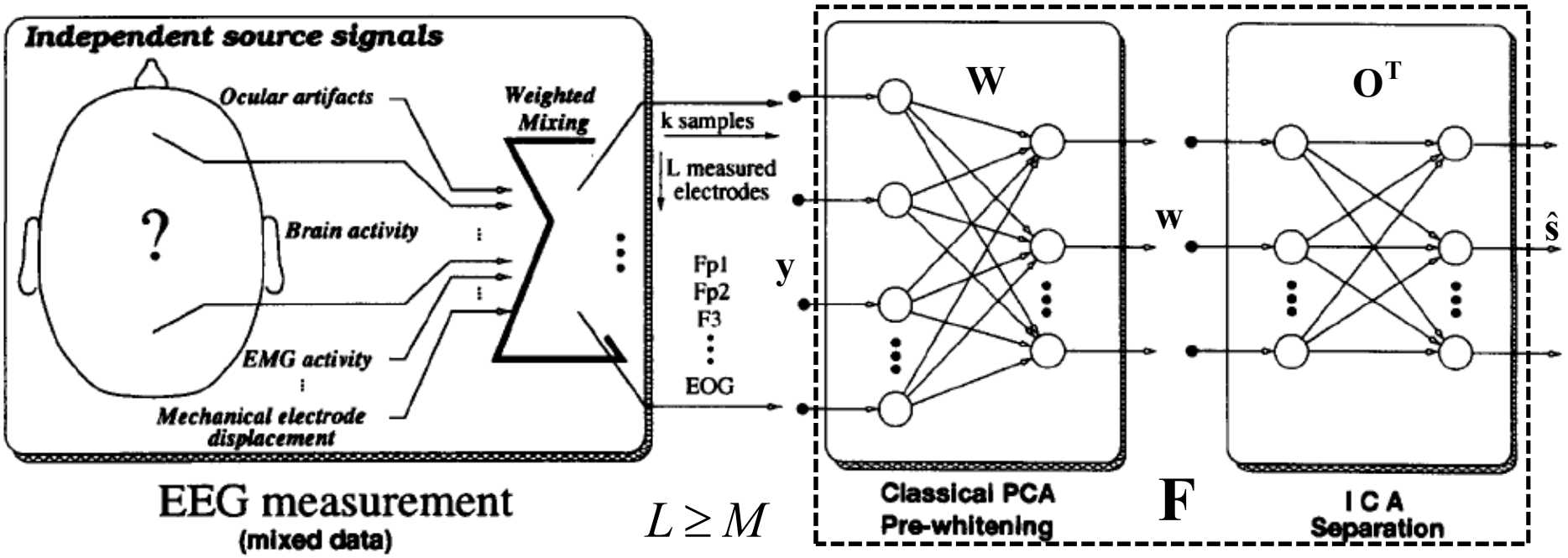
- Ripples in passband and stopband.
- More efficient design → Less order than others.

- Flat response in passband.
- Fast attenuation.
- Ripples in stopband.

Elliptic



Independent-Component Analysis (ICA)



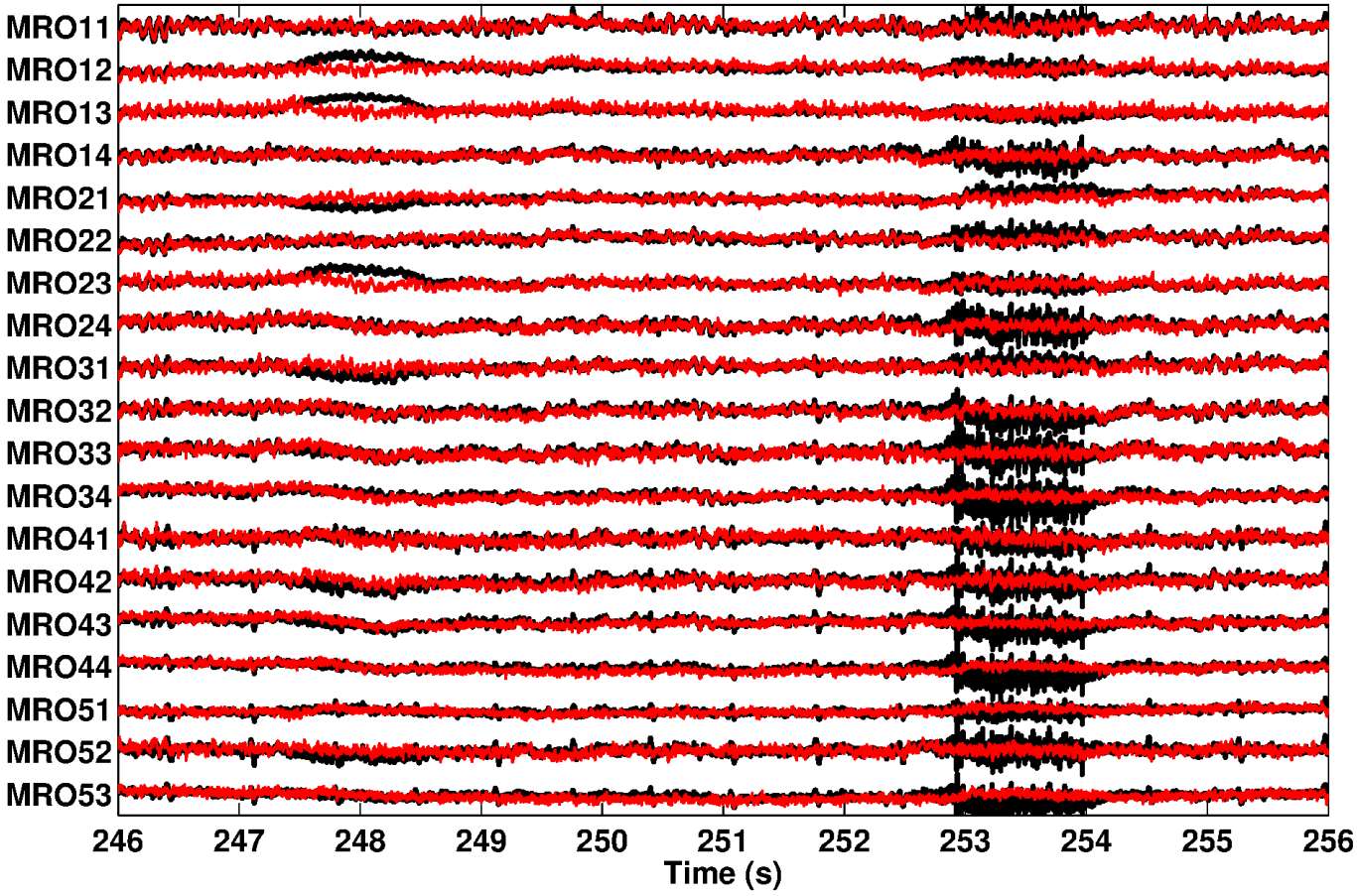
FastICA

$$\mathbf{y}_k = \mathbf{C}\mathbf{s}_k$$

$$\hat{\mathbf{s}}_k = \mathbf{F}\mathbf{y}_k = \mathbf{O}^{\mathrm{T}}\mathbf{w}_k$$

Image taken from: R. Vigário, "Extraction of ocular artefacts from EEG using independent component analysis", Electroencephalography and clinical Neurophysiology, 1997.

Independent-Component Analysis (ICA)



- Disadvantages: Muscle artifacts are not well-separated
  The number of components cannot be larger than the number of electrodes

PROCESSING EEG SIGNALS WITH MATLAB

Thank you!!!

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