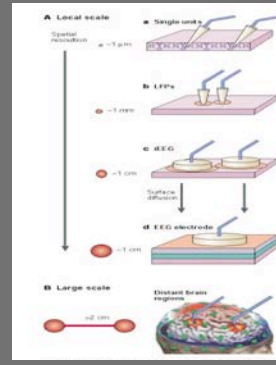


Neurociencia de Sistemas

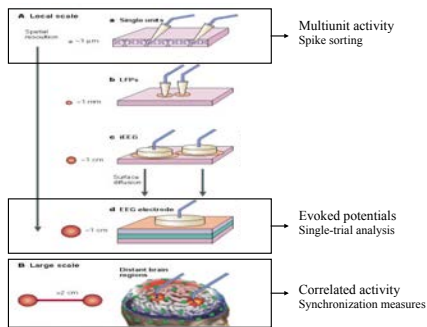
- Clase 1. Introducción
- Clase 2. Registros extracelulares y Spike sorting.
- Clase 3. Procesado de información visual.
- Clase 4. Percepción y memoria.
- Clase 5. Decodificación - Teoría de la información.
- Clase 6. Electroencefalografía - Análisis de tiempo-frecuencia y Wavelets.
- Clase 7. Potenciales evocados - Análisis de ensayo único.
- Clase 8. Dinámica no-lineal - Sincronización.

Scales of Brain activity



From Varela et al, Nature Reviews Neuroscience, 2001

Scales of Brain activity



From Varela et al, Nature Reviews Neuroscience, 2001

EEG

Measure of average electrical activity of the brain at different sites

Advantages

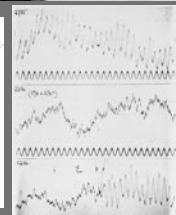
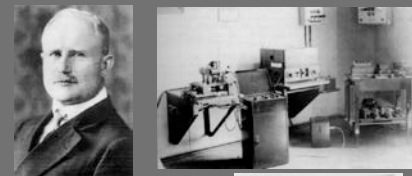
- Non-invasive
- Relatively cheap
- Easy to record
- Good temporal resolution
- Clinical use
- Used for the study of sensory and cognitive processes in humans.

Disadvantages

- Poor spatial resolution
- Indirect measure of neuronal activity
- Very low SNR
- Artifacts



Hans Berger (1873-1941)



Lord Adrian (1889-1977)

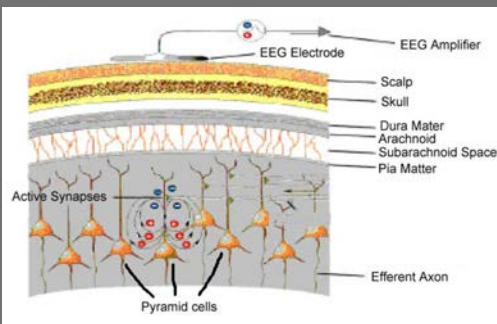
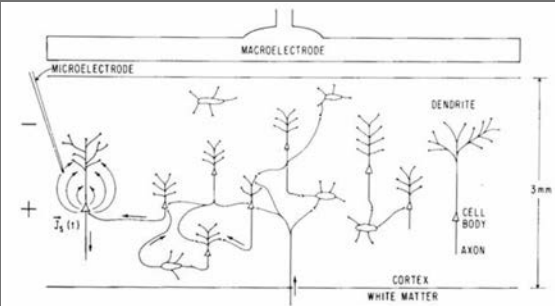
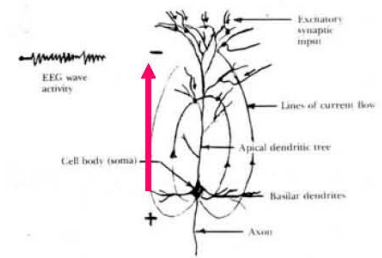


Grey Walter

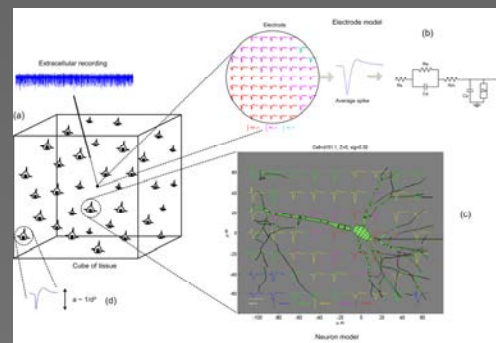
Scalp EEG

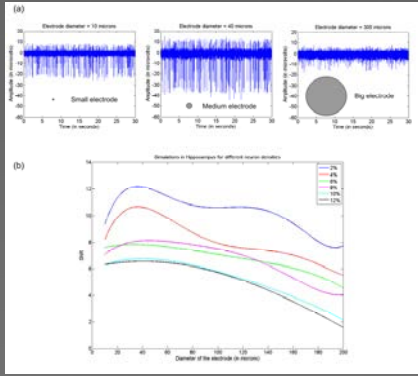


Origin of the EEG signal

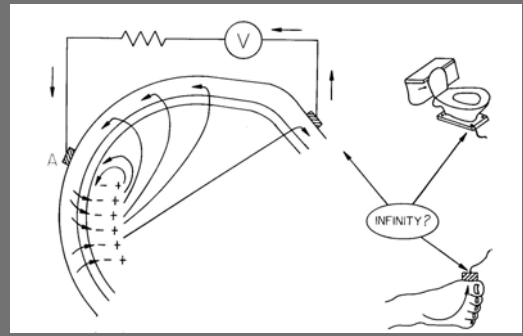


NeuroCube

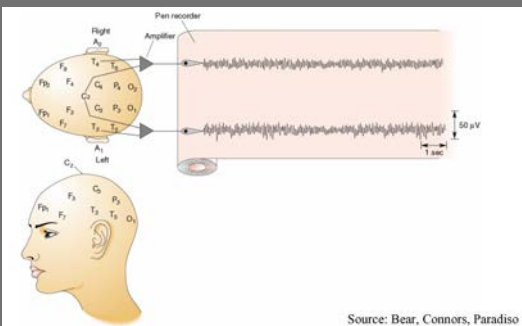




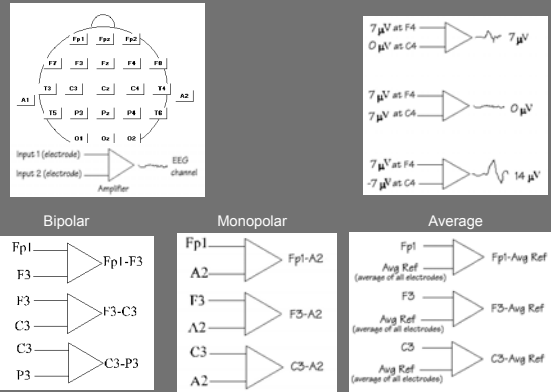
References



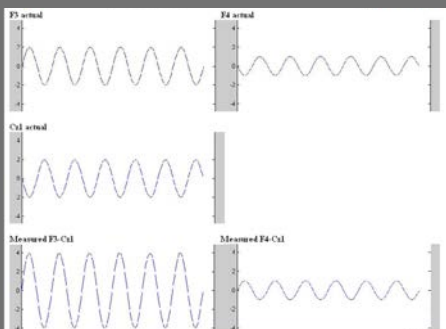
EEG Recording



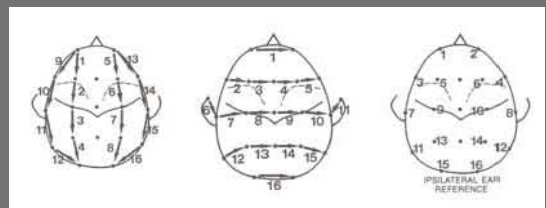
References



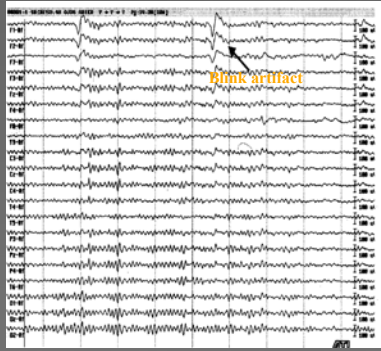
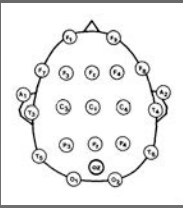
Problems with active references



Montages

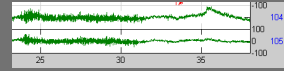


10-20 system

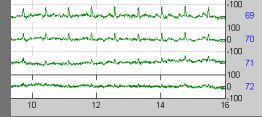


Artifacts

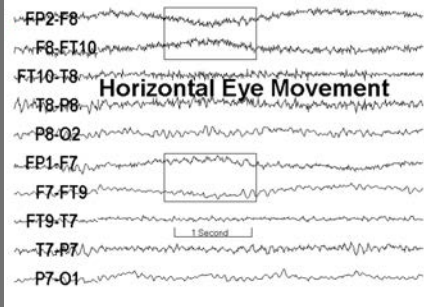
Muscular activity



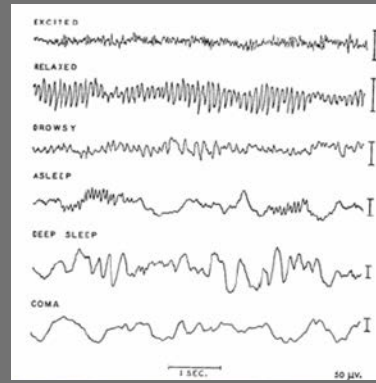
EKG



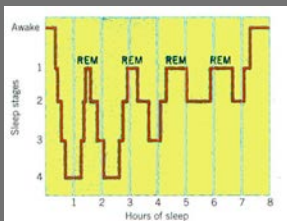
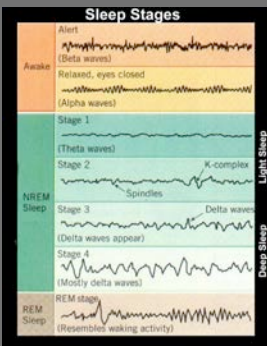
Horizontal Eye Movement



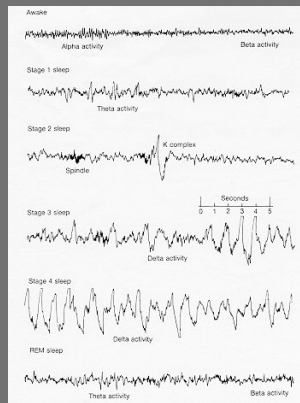
Types of EEG activity



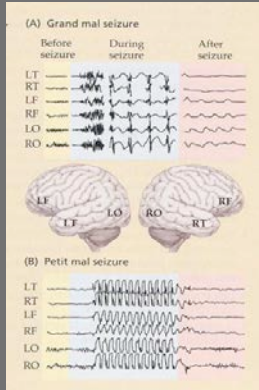
Sleep stages



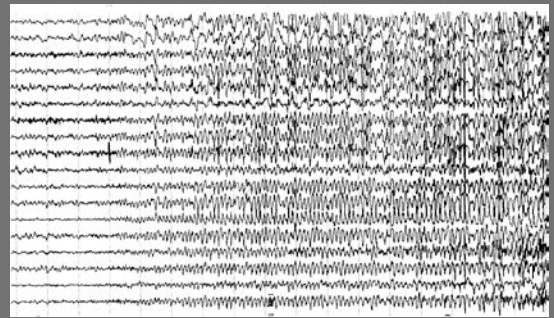
Sleep stages



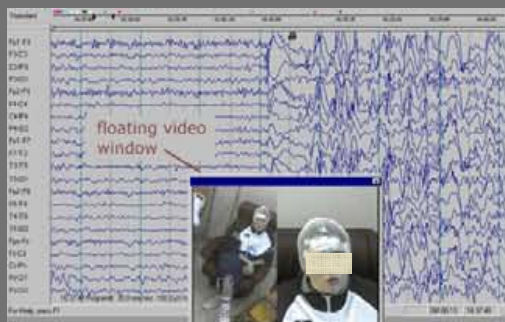
EEG During Epileptic Seizures



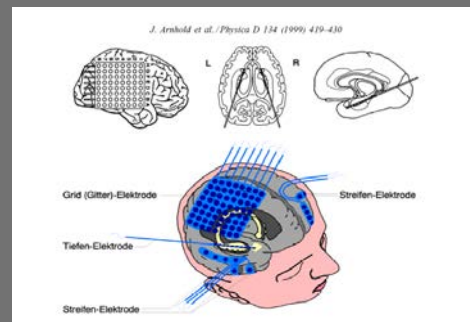
Grand Mal Seizure



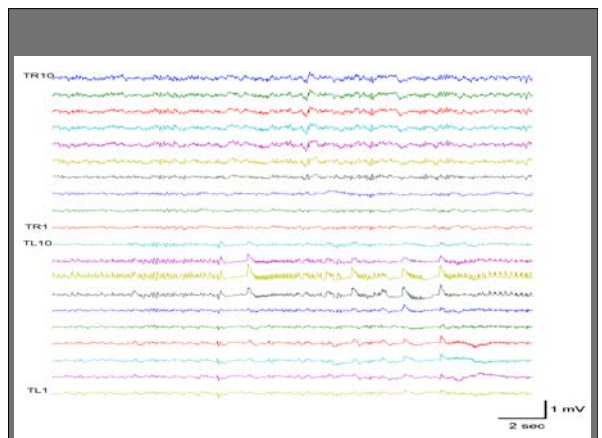
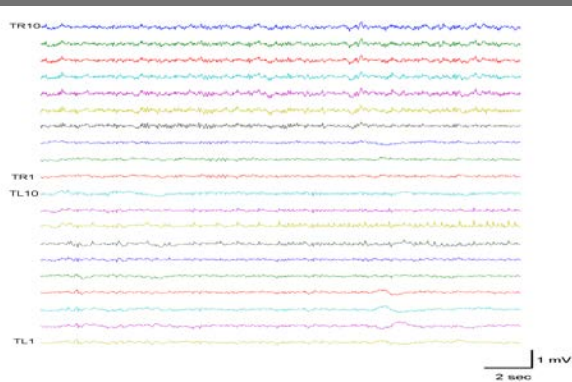
Video-EEG

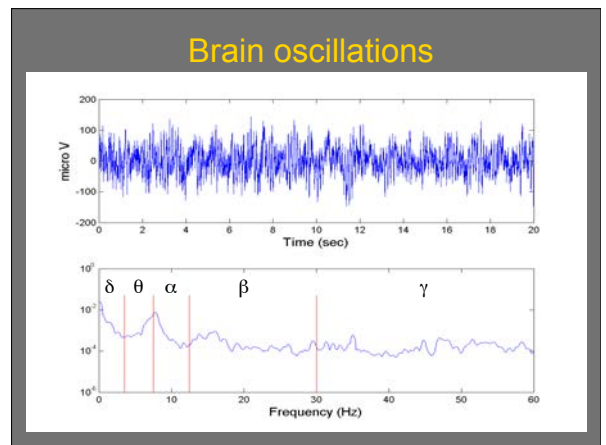
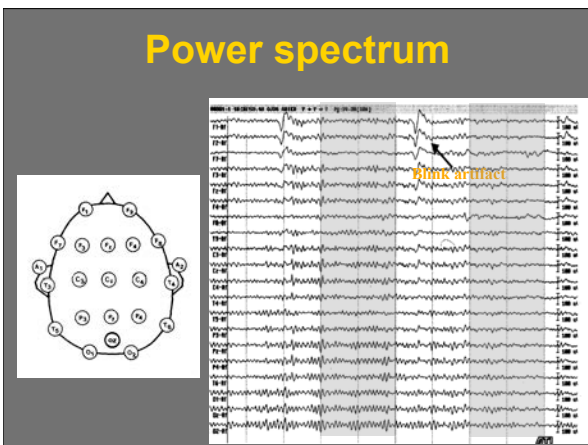
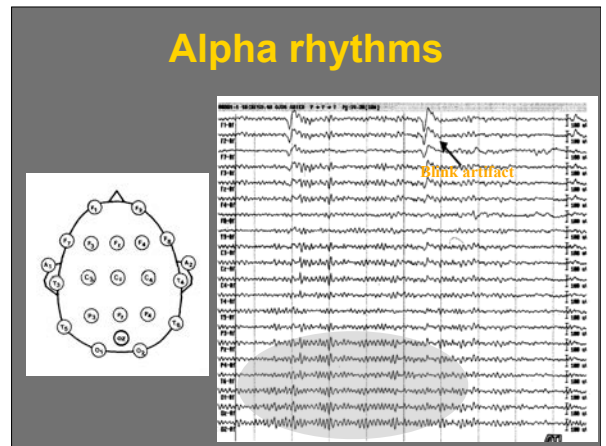
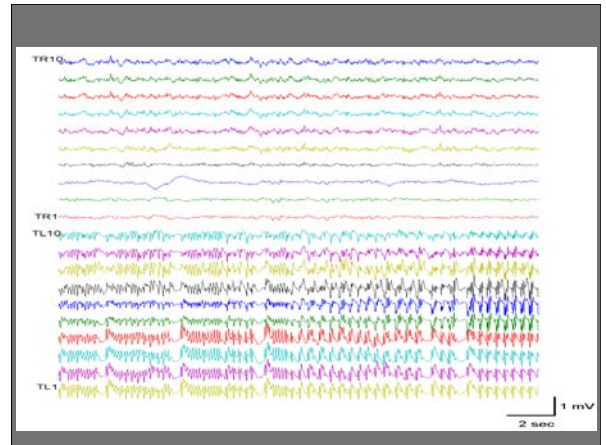
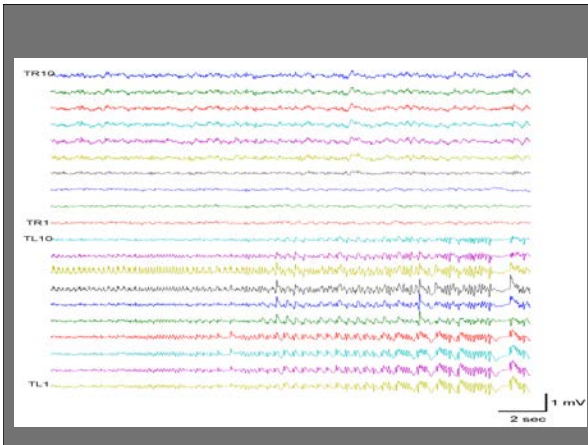


Intracranial recordings

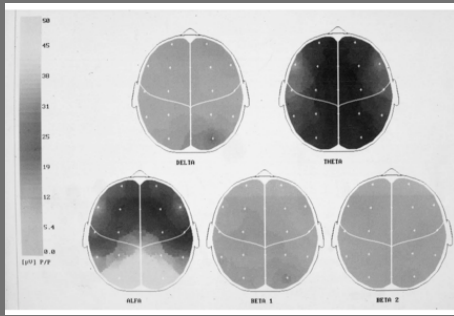


EEG of an epileptic patient

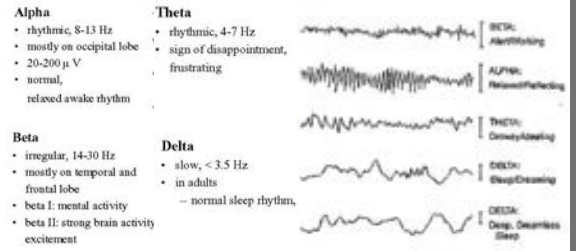




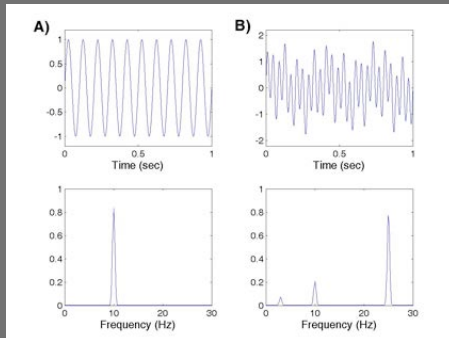
Topographic mapping



Brain oscillations



Fourier Transform

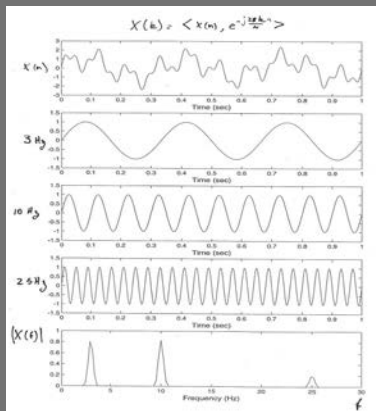


Fourier Transform

$$X(\omega) = \int_{-\infty}^{+\infty} x(t) e^{-j\omega t} dt$$

$$X(\omega) = \langle x(t), e^{-j\omega t} \rangle$$

$$x(t) = \frac{1}{2\pi} \int_{-\infty}^{+\infty} X(\omega) e^{j\omega t} d\omega$$

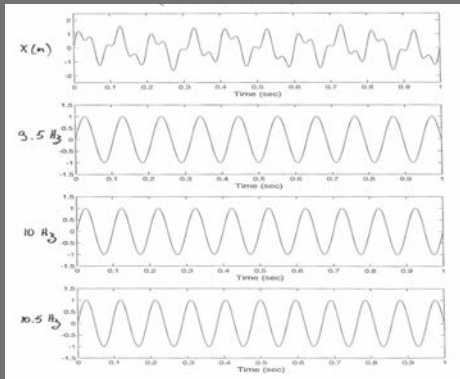


Frequency resolution and Nyquist frequency

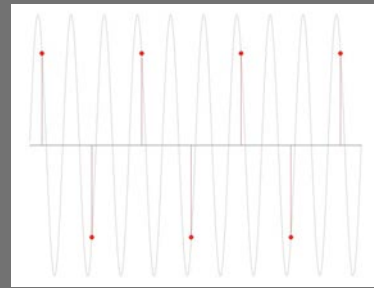
$$\Delta f = \frac{1}{N \Delta t} = \frac{1}{T}$$

$$f_N = \frac{1}{2\Delta t} = \frac{f_s}{2}$$

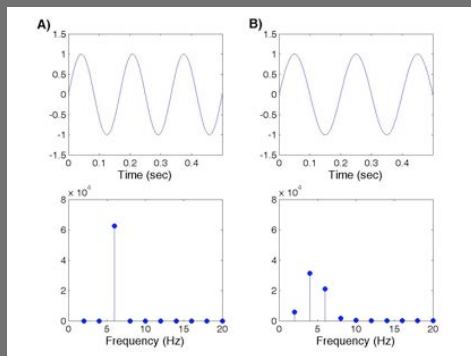
Frequency resolution



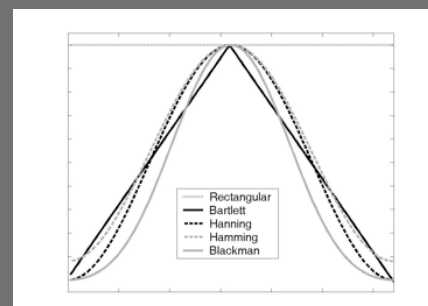
Aliasing



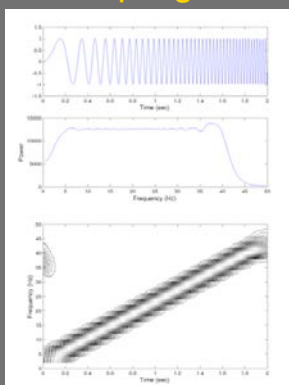
Leakage



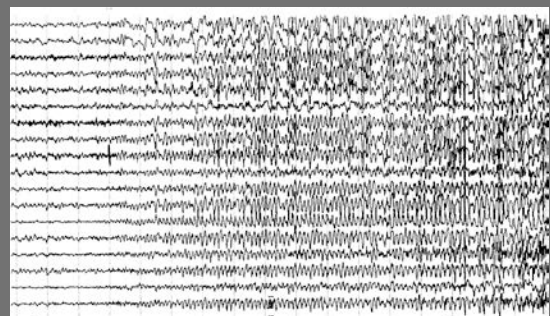
Windowing



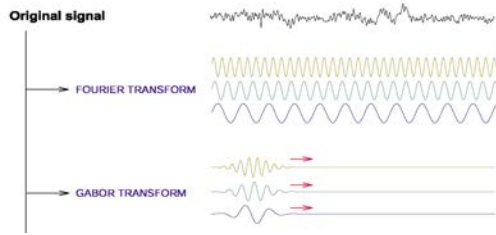
Chirp signal



Grand Mal Seizure



Gabor Transform



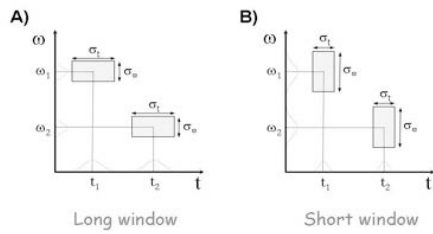
Gabor Transform

$$G_{\alpha}(\omega, t) = \langle x(t'), g_{\alpha}(t'-t) e^{-j\omega t'} \rangle$$

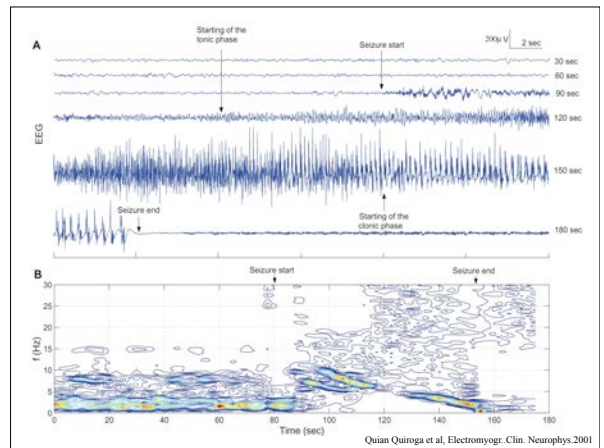
$$g_{\alpha}(t) = \left(\frac{\alpha}{\pi}\right)^{1/4} e^{-\frac{\alpha}{2} t^2}$$

$$x(t) = \frac{1}{2\pi} \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} G_D(f, t') g_D(t-t') e^{j\omega t} d\omega dt'$$

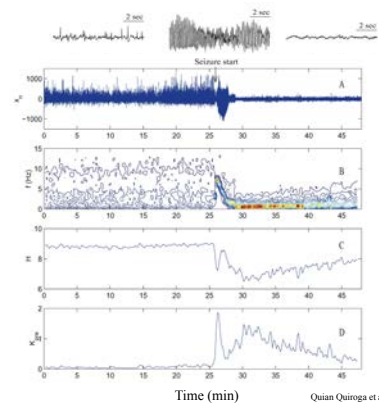
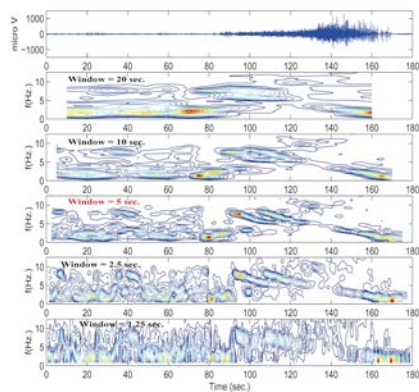
Uncertainty Principle



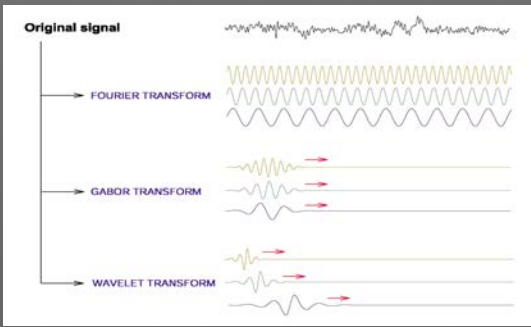
$$\sigma_t \sigma_{\omega} \geq \frac{1}{2}$$



Effect of the window size

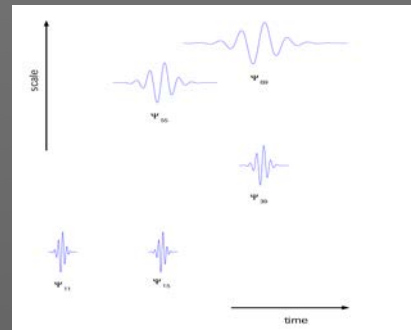


Wavelets



$$W_\psi X(a,b) = \langle x(t), \psi_{ab} \rangle = |a|^{-1/2} \int_{-\infty}^{\infty} x(t) \psi\left(\frac{t-b}{a}\right) dt$$

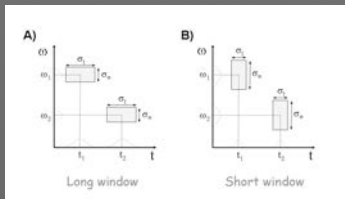
Wavelet function



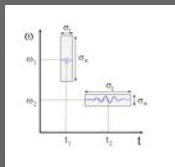
$$\psi_{a,b}(t) = |a|^{-1/2} \psi\left(\frac{t-b}{a}\right)$$

Uncertainty Principle

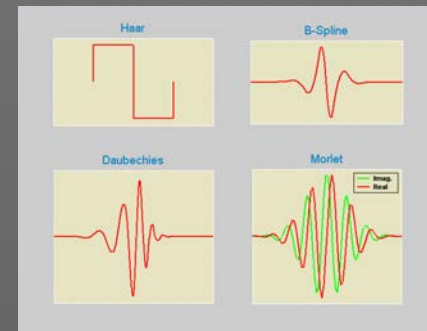
Gabor



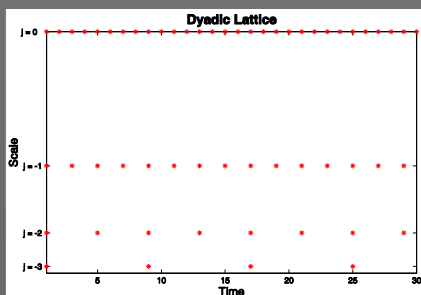
Wavelets



Wavelet function

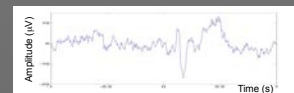


Dyadic wavelet transform (DWT)

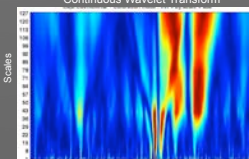


$$\psi_{a,b}(t) = |a|^{-1/2} \psi\left(\frac{t-b}{a}\right)$$

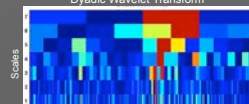
$$\{a_j = 2^j, b_{j,k} = 2^j k, j, k \in \mathbf{Z}\}$$



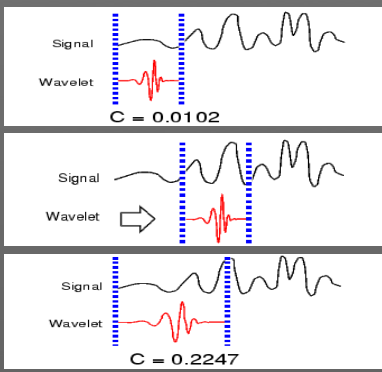
Continuous Wavelet Transform



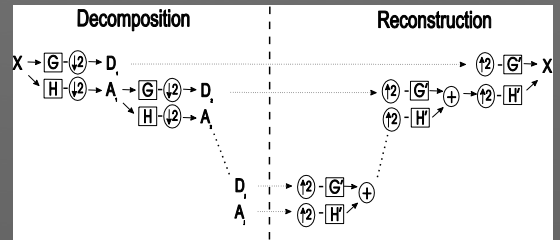
Dyadic Wavelet Transform



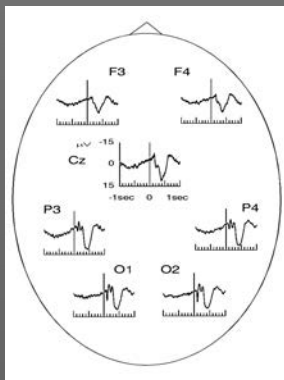
How to calculate the DWT



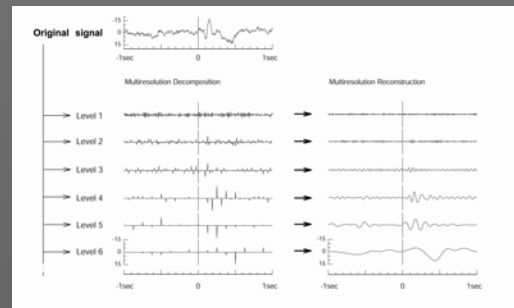
Multiresolution decomposition



Visual evoked potentials



Multiresolution decomposition



Challenges in EEG analysis

- Seizure prediction
- Seizure localization
- Spatial analysis
- Automatic sleep classification
- Automatic spike detection and classification
- Integration with imaging techniques
- Quantification of transient oscillations
- Biofeedback
- Source localization

Clase 6. Electroencefalografía – Análisis de tiempo-frecuencia y Wavelets.

Wavelet Transform in the analysis of the frequency composition of evoked potentials.
Quiñan Quiroga R, Sakowicz O, Basar E and Schürmann M.
Brain Research Protocols, 8: 16-24; 2001.

Imaging Brain Function With EEG: Advanced Temporal and Spatial Analysis of Electroencephalographic Signals
Walter Freeman and Rodrigo Quiñan Quiroga
Springer; 2013.

Niedermeyer and Lopes da Silva.
Electroencephalography. (La biblia de EEG!)