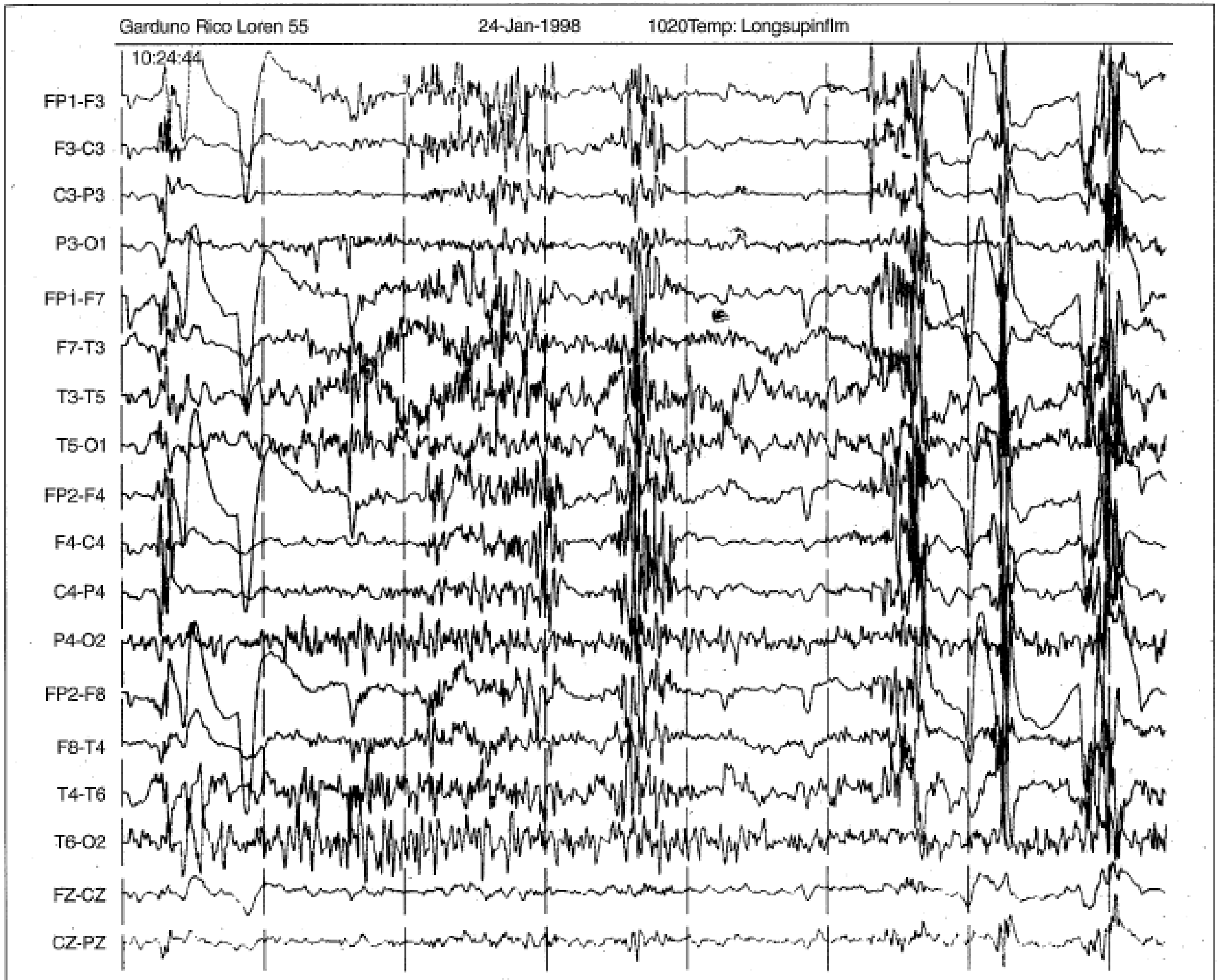
EE 791 Lecture 7 Measures of EEG Dynamic Properties

Mar 2, 2015

Epilepsy EEG Signal



6. Record of a subject with seizure activity during sleep. The system detects the initial three spikes in 1 sec at the start of the seizure. At this moment, the alarm is activated.

Computer Analysis

- Infinite number of ways to transform data
- Central Question: <u>not</u> what can EEG do for mathematics but <u>rather</u> what can mathematics do for EEG
- One objective to compress data into a more recognizable form
- Data in various time and spatial scales
- Common staring point is spectral analysis, i.e. frequency analysis for each site

Pitfalls

- Assuming that few isolated sources generate different EEG patterns
- Assuming brain has only a limited number of degrees of freedom when interpreting measures of chaotic dynamics
- Clinicians suspicious of mathematical processing of EEG
- Some mathematicians or physical scientists sell computer methods high on sophistication but low on benefits.
- Require knowledge of signal sources, volume conduction, neural dynamics and limitations of recording system

Fundamental Assumptions

- Higher brain functions originate within cell assemblies that change in the 10 to 100 ms timescale.
- Cell assemblies can range from local networks to networks ranging in size to brain dimensions
- Large-scale cortical and scalp potentials are believed to be generated by millisecond scale modulation of synaptic current sources at the surfaces of cortical neurons
- This is superimposed on longer timescale background modulations of the network structures
- Scalp potential at any electrode is therefore the linear some of weighted volume dipole moments from many mesosources, weighting dependent on properties of volume conductor and distance

Spectral Analysis

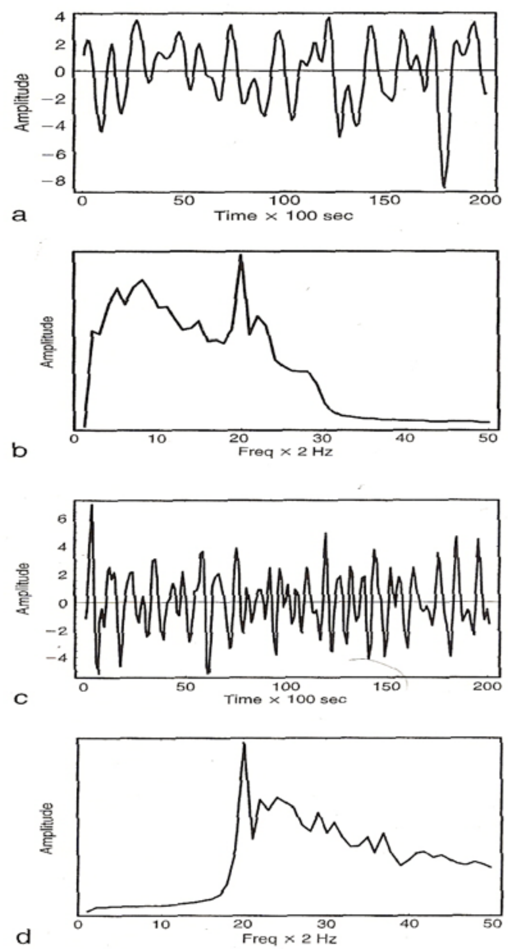


Figure 9-1 (a) A two-second simulated waveform composed of many frequency components producing an average of 14.2 zero crossings per second (7.1 Hz). (b) The amplitude spectrum of waveform (a) obtained by averaging the spectra of 31 two-second epochs. (c) A two-second simulated waveform producing an average of 30.2 zero crossings per second (15.1 Hz). (d) The amplitude spectrum of waveform (c) obtained by averaging the spectra of 31 two-second epochs.

Effect of Under-sampling

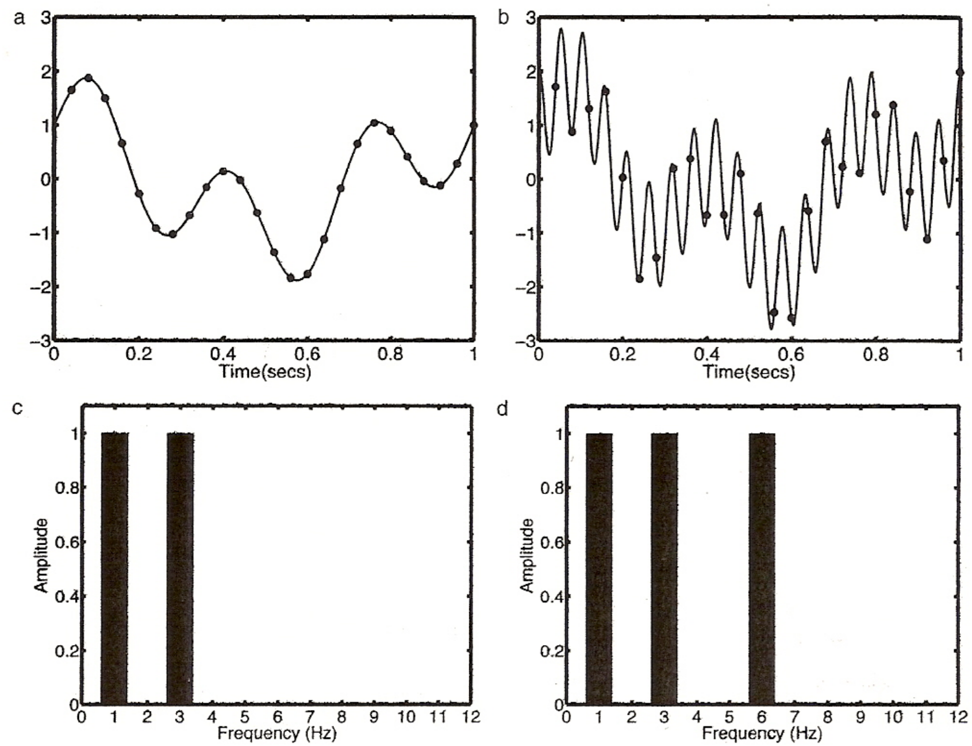


Figure 9-2 (a) A 1 s simulated waveform composed of 1 and 3 Hz sine waves of equal amplitude. The composite waveform is sampled every 40 ms as indicated by the gray dots. (b) A 1 s simulated waveform composed of a 1 Hz, 3 Hz, and 19 Hz sine waves of equal amplitude. Sampling every 40 ms (gray dots) aliases the signal because peaks and troughs of the 19 Hz oscillation are missed. (c) Amplitude spectrum obtained by applying the FFT to the signal (a) sampled every 40 ms. The 1 Hz and 3 Hz components have amplitude 1. (d) Amplitude spectrum obtained by applying the FFT to the signal of example (b) sampled every 40 ms. This aliased signal has an additional component at 6 Hz due to aliasing of the 19 Hz component.

Effect of Spectral "Leaking"

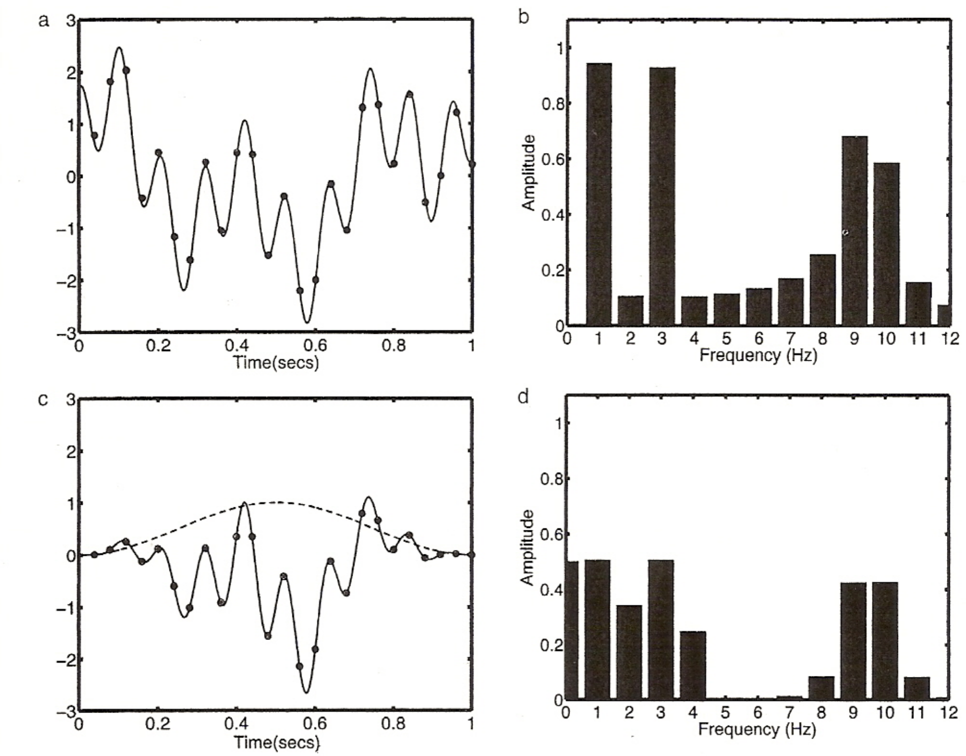


Figure 9-3 (a) A 1 s simulated waveform composed of 1 Hz, 3 Hz, and 9.5 Hz sine waves of equal amplitude sampled every 40 ms as indicated by the gray dots. (b) Amplitude spectrum of the signal shown in (a). The 1 Hz and 3 Hz sine waves are clearly identified, but the 9.5 Hz signal appears mainly at 9 and 10 Hz and is smeared throughout the spectrum. (c) A Hanning window function, shown by the dashed lines, is applied to the data of (a). The windowed data are shown by the solid lines. (d) The amplitude spectrum after windowing shows that the 9.5 Hz oscillation appears mainly in the 8–11 Hz bins. However, the 1 Hz and 3 Hz oscillations are now smeared due to loss of frequency resolution.

Time Domain Spectral Analysis

- Spectral analysis provides a means to assess statistical properties of the stochastic process
- A single window EEG spectrum is only one measure of this process
- Require averaging to obtain statistics
- Assume EEG wide sense stationary over entire signal of analysis (mean and power spectrum invariant with shifts in time)
- Power vs amplitude spectrum
- Sum of all positive and negative power spectral components is equal to variance of signal (Parseval's theorem)
- Power in μV^2 with magnitudes depending on Δf

Frequency Resolution Effects

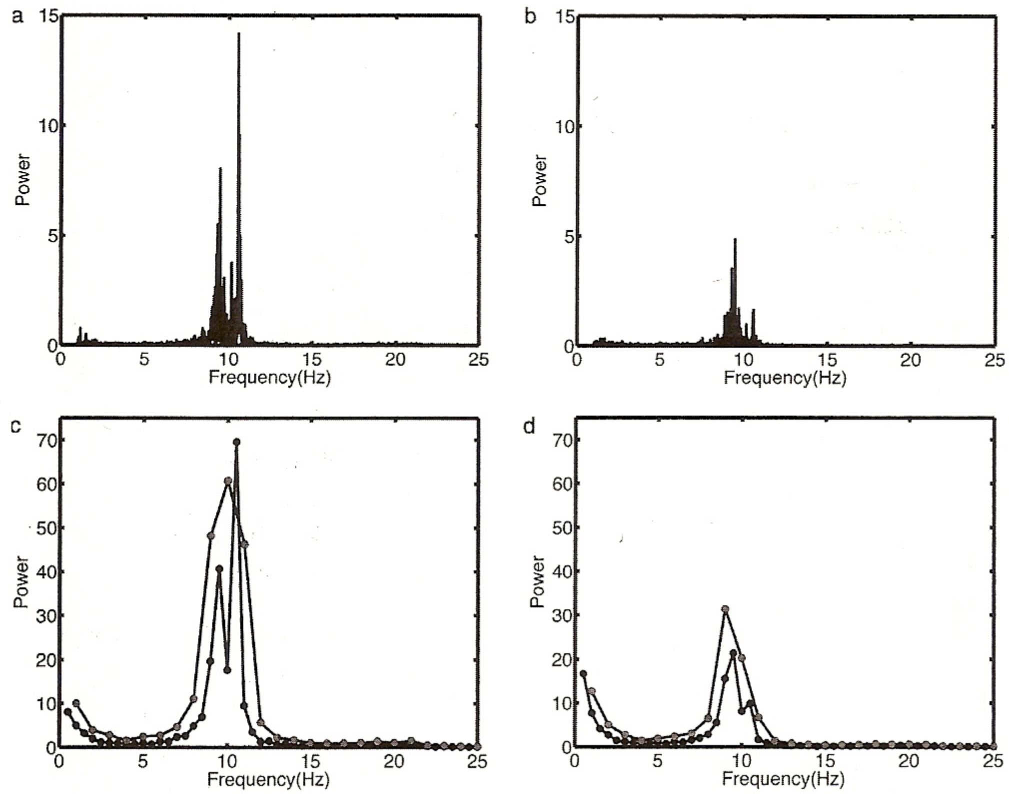


Figure 9-4 Example EEG power spectra from a single subject (female, 22 years). The subject is at rest with *eyes closed*. (a) Power spectrum of a midline occipital channel with epoch length $T = 60$ s and $K = 1$ epochs. The power spectrum appears to have two distinct peaks, one below 10 Hz and one above 10 Hz. (b) Power spectrum at a midline frontal channel with epoch length $T = 60$ s and $K = 1$ epochs. Here only the peak below 10 Hz is prominent. (c) Power spectra of a midline occipital channel calculated with two different choices of epoch length T and number of epochs K. The gray circles indicate the power spectrum with $T = 1$ s and $K = 60$ epochs. The black circles indicate the power spectrum with $T = 2$ s and $K = 30$ epochs. (d) Power spectra of a midline frontal channel calculated as in (c).

Dipole Synchronization Effects

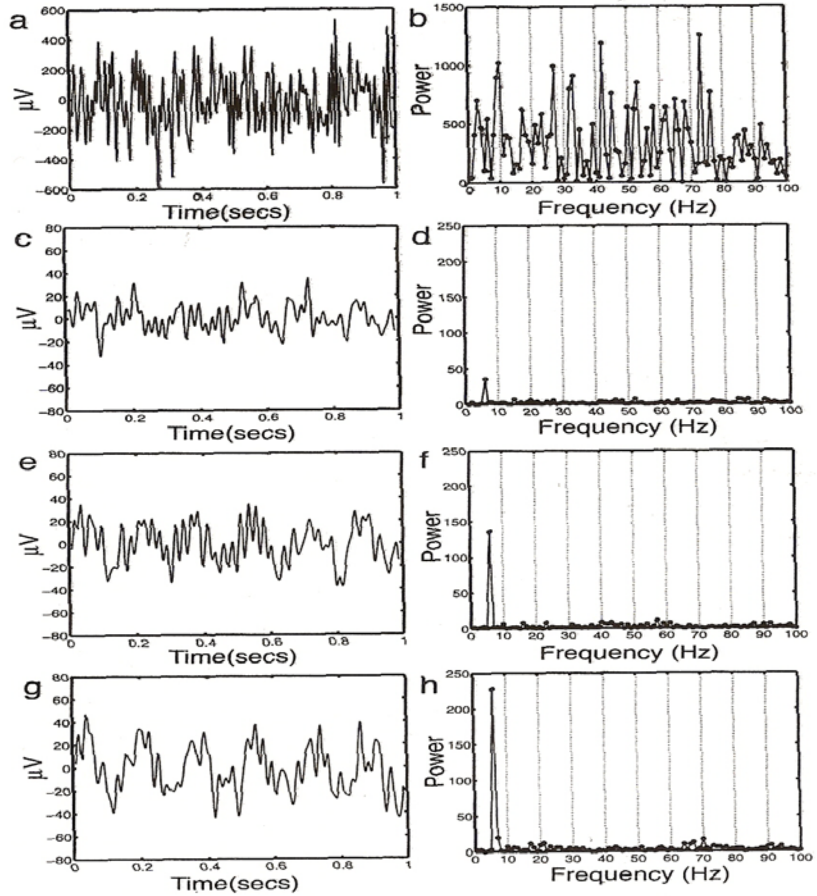


Figure 9-6 Simulated data. (a) time series of a dipole mesosource **P**(**r**, t) composed of a 15 μV sine wave added to Gaussian random noise with standard deviation 150 μV. The Gaussian random noise was low-pass filtered at 100 Hz. The sine wave has variance (power) equal 1% of the noise. (b) Power spectrum of the time series shown in (a). The power spectrum has substantial power at frequencies other than 6 Hz. (c) Time series recorded by an electrode on the outer sphere (scalp) of a 4-sphere model above the center of a dipole layer of diameter 3 cm. The dipole layer is composed of 32 dipole sources **P**(**r**, t) with time series constructed similar to (a) with independent Gaussian noise (uncorrelated) at each dipole source. Scalp potential was calculated for a dipole layer at a radius $r_z = 7.8$ cm in a

Summary of Source Diameter and Strength

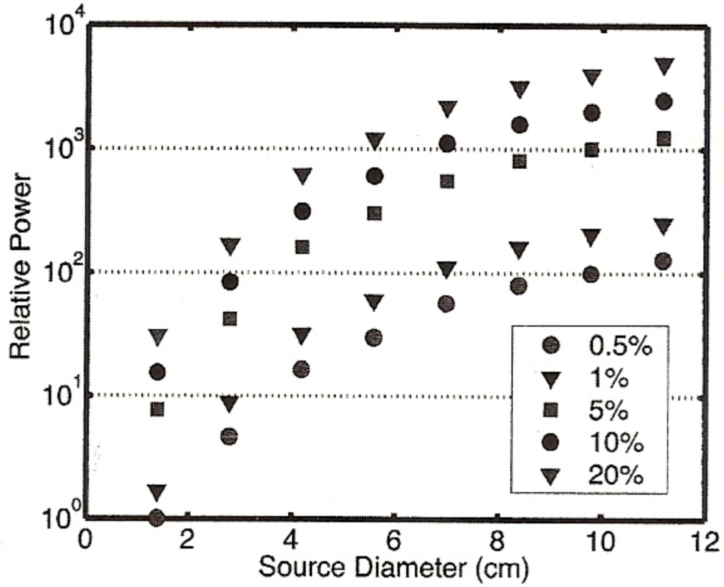


Figure 9-7 A simulated summary of the dependence of scalp power on the size and strength of a synchronous dipole layer, based on the simulation of fig. 9-6. Both source strength and source size independently contribute to the power at a scalp electrode. Source strength is expressed as the ratio of the power of sinusoid to the power of noise in the source activity and labeled with different symbols as indicated by the legend. Source diameter varies from 1.5 to 11.4 cm. Power is expressed relative to the power of the smallest dipole layer with weakest strength.