Electroencephalography

In addition to ECG measurements, biopotentials can also be recorded from the brain (electroencephalography – EEG) or from muscles (electromyography – EMG). Electroencephalography has found many clinical uses, from the investigation of epileptic fits to sleep (and vigilance) studies or the diagnosis of brain death. The EEG is the summation of neural depolarizations in the brain due to stimuli from the five senses as well as from normal brain activity. On the surface of the brain, these potentials are of the order of 10 mV; the amplitude of the EEG signal recorded with scalp electrodes, however, is 100 µV, at most, because of the attenuation caused by the skull. EEG instrumentation is much more critical because of the lower amplitude of the EEG signal. The frequency response of EEG differential amplifiers usually extends from 0.1 to 100 Hz.

EEG electrodes

The EEG is measured with Ag–AgCl electrodes which are placed in standard positions on the skull, at regular intervals along three lines: one from the nose to the back of the head, one from ear to ear and one around the circumference of the skull (see Figure 19).

![Figure 19: EEG electrode positions on the scalp](image-url)
Characteristics of the EEG

The frequency content of the EEG varies with the state of alertness and mental activity. To assist in EEG analysis, the normal EEG range of 0.5 to 30 Hz has been subdivided into five bands (note, however, that there is some degree of variation in the exact cut-offs from one system to another):

- **Delta** $\delta$ 0.5 – 4 Hz
- **Theta** $\theta$ 4 – 8 Hz
- **Alpha** $\alpha$ 8 – 13 Hz
- **Beta** $\beta$ 13 – 22 Hz
- **Gamma** $\gamma$ 22 – 30 Hz

What does the EEG look like in different brain states? Figure 20 shows the EEG through various stages (or depths) of sleep. The lower trace on Figure 20 shows that, if the subject is dreaming, the EEG exhibits rapid, low-voltage waves that resemble those obtained in alert

![Figure 20: EEG activity for various sleep stages](image)
subjects (rapid–eye–movement or REM sleep). During the transition from REM to non–
dreaming (deep) sleep, the EEG sometimes exhibits bursts of alpha–like activity, called
spindles. These are periodic waves which have a frequency between 12 and 14 Hz and an
amplitude of around 10 µV. The last between 0.5 and 1 second but no–one has yet come up
with a satisfactory explanation for their origin.

Diagnostic uses of the EEG

The main clinical purpose of the EEG is to help physicians diagnose disease. The
pathological states or diseases usually diagnosed using the EEG are brain death, epilepsy and
sleep disorders. The sustained absence of EEG signals is a clinical measure of brain death
and the EEG can also be used as one of the indicators for deciding to carry out an organ
transplant. The pathological EEG during grand mal epilepsy is characterised by high–
magnitude synchronous waves of about 10 Hz. Petit mal epilepsy exhibits a spike and slow–
wave pattern with a repetition frequency of about 3 Hz. Figure 21 shows the EEG
waveforms recorded from different sites during one such seizure.

Evoked Potentials

This is a technique whereby a stimulus, such as a light flash or loud click, is applied to the
body’s sensory system and the change in the EEG signal recorded from a particular area of
the brain. Normal EEG activity, however, masks the brains response to a single stimulus;
repetitive stimuli have to be used and the evoked response is distinguished from the
background activity by using the technique of signal averaging.

Figure 21: EEG during an epileptic seizure