Fundamental of Electroencephalogram (EEG)

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Introduction

- The electroencephalogram (EEG) was first measured in humans by Hans Berger in 1929. Berger was the first to record the electrical activity of the human brain.
- Electrical impulses generated by nerve firings in the brain can be measured by electrodes placed on the scalp.
- The EEG gives a coarse view of neural activity and has been used to non-invasively study the physiology of the brain.
- He was the first to record an epileptic seizures.
- EEG activity is quite small signal, measured in microvolt (µV) with the main frequencies of interest up to approximately 30 Hertz (Hz).
Signal range: 2µV (brain death) – several hundred µV.

The frequency bands in EEG:

1- Delta (<4 Hz): deep sleep stages of normal adults.

2- Theta (4-8 Hz): normal infants and children as well as during drowsiness and sleep in adults.

3- Alpha (8-14 Hz): mostly below 50 µV, normal adults during relaxed and mentally inactive wakefulness.

4- Beta (14-30 Hz): mostly below 30 µV, It is enhanced by expectancy states and tension.

5- Gamma (>30 Hz): Usually, it is not of clinical and physiological interests and therefore often filtered out in EEG recordings.
Physiological Artifacts
Non-Physiological Artifacts
EEG machine consists of the following components:

1- Electrodes.
2- Amplifiers.
3- Filters.
4- Recording unit.
Analog EEG System

Head Box

Input Select Switches

Differential Amplifier

Low Frequency Filter

High Frequency Filter

Notch Filter

PA

Calibration Pulse
Digital EEG system

Head Box

Ch 1

Fixed Band pass Filter

Ch n

Ref

Fixed Band pass Filter

GND

Mux

A/D Converter

Computer
**EEG electrode**

- **Electrode**: means whereby the electrical activity of the brain communicated to the input circuit of the amplifier in the EEG machine, **Metal** is the material of which the electrode is composed.
- **Electrolyte**: may be conducting solution (gel or paste) or may be fluid of living tissue as when electrode inserted below skin. It is salt solution, principally sodium chloride. This means that current flow within brain becomes electron flow in the electrodes and electrode wires.

To understand how electrical current pass through *metal-electrolyte interface*. we must know some basic of electrical properties of electrolyte:

- **Ions** is particles in solution that bear an electrical charge. The fact that ions are free to move in the solution, so if applied voltage between two points in the solution, an electric current can be made to flow in it.
The current carried by ions in the solution in the same way that current is carried by the loosely bound electrons in a metallic conductor and this is appropriate with electrode potentials.

Metal – electrolyte interface:
It is the junction where flow of ions is converted into flow of electrons. It is the place where an electrochemical phenomenon is converted into purely electrical phenomenon.
Types of electrodes

Types of EEG Electrodes

Needle

Surface

Flat

Cup
Two identical pieces of felt cutting into circles big enough fit onto the suction cups. Silver wire is bent around the two pieces of felt into a U-shape.

**Electrode Design**

- Flat electrode
- Cup electrode
Electrodes are placed on the scalp in special positions. These positions are identified by the recorders who measure the head using the International 10/20 System.

There are two different types of EEG signals depending on where the signal is taken in the head: scalp or intracranial. For scalp EEG, electrodes are placed on the scalp with good mechanical and electrical contact. In intracranial EEG (IEEG), the EEG signal is obtained by special electrodes implanted in the brain surface during a surgery.
The brain (cerebrum) is formed of two cerebral hemispheres, right and left.

Each cerebral hemisphere is formed of four lobes:
1- Frontal lobe: contains motor area.
2- Parietal lobe: contains sensory area.
3- Temporal lobe: contains area of hearing & memory.
4- Occipital lobe: contains area of vision.
Major External Parts of the Human Brain (Underside View)

- Frontal Lobe
- Olfactory Bulb
- Temporal Lobe
- Pons
- Cerebellum

Cranial Nerves Shown in BLUE

- Longitudinal fissure
- Frontal lobe
- Parietal lobe
- Occipital lobe
EEG system cover all parts of brain by placing electrode on all part of head.

There are two system of electrode placement:
1- 10-20 international system: includes 21 electrodes.
2- 10-10 international system: includes 64 electrodes.
10-20 international system of electrode placement

electrode placement system, where Fp is Prefrontal, F is Frontal, C is Central, T is Temporal, P is Parietal, O is Occipital, A is Ear.
10-10 international system of electrode placement
Basic Differential Amplifier

Differential amplifiers measure the voltage difference between the two signals at each of its inputs.
Electrode Montages

- The pattern of connections between the electrodes and the recording channels is known as a montage.

- There are two basic types of EEG montage:

  1- Referential: The potential difference is measured between an active electrode and an inactive reference electrode.
2- Bipolar: The potential difference is measured between two active electrodes.
Four EEG channels of bipolar montage
FOURIER THEOREM

Any wave can be thought of (decomposed) as a number of sinusoidal waveforms that vary in amplitude, frequency and phase.
Filter

IDEAL FILTER.
Function of a filter

Filtering is the operation that results in zero amplitude for the waves at frequencies that we don't want to contribute to our final waveform.
Low Pass Filter

Unfiltered

Filtered

Adding

Adding

High frequency “noise” is not contributing to this waveform.
High Pass Filter

Unfiltered

Adding

Adding

Low frequency “noise” is not contributing to this waveform.
Band - Pass Filter

![Diagram showing high pass and low pass filters with transition bands and roll-off points.](image-url)
Notch filter

A band pass filter around the power lines frequency (50 or 60 Hz).
Types of FILTERS

• **Analog**: A piece of hardware, a resistor and a capacitor coupled together.
  - Is applied before the analog-to-digital conversion.
  - ON-LINE

• **Digital**: A software algorithm.
  - Is applied after the analog-to-digital conversion.
  - OFF-LINE
Thank You