ROHINI
COLLEGE OF ENGINEERING AND TECHNOLOGY
Approved by AICTE and affiliated to Anna University Chennai (An ISO Certified Institution)
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DEPARTMENT OF BIOMEDICAL ENGINEERING

BM3491 Biomedical Instrumentation

UNIT-II BIOSIGNAL CHARACTERISTICS

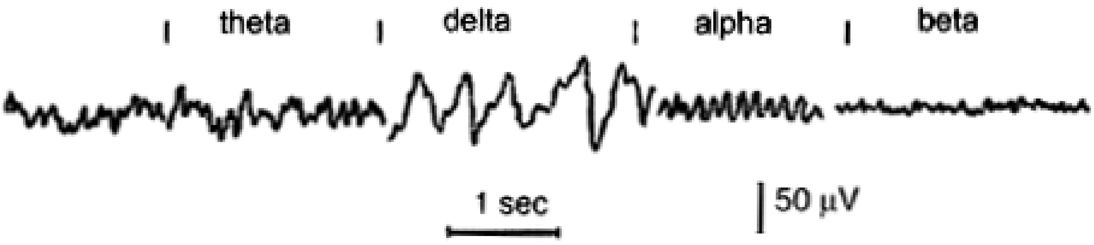
2.3 Electroencephalogram

2.3.1 Introduction:

The electroencephalogram (EEG) is a recording of the electrical activity of the brain from the scalp. The recorded waveforms reflect the cortical electrical activity. Signal intensity: EEG activity is quite small, measured in microvolts (mV). Signal frequency: the main frequencies of the human EEG waves are:

- **Delta**: has a frequency of 3 Hz or below. It tends to be the highest in amplitude and the slowest waves. It is normal as the dominant rhythm in infants up to one year and in stages 3 and 4 of sleep. It may occur focally with subcortical lesions and in general distribution with diffuse lesions, metabolic encephalopathy hydrocephalus or deep midline lesions. It is usually most prominent frontally in adults (e.g. FIRDA - Frontal Intermittent Rhythmic Delta) and posteriorly in children e.g. OIRDA - Occipital Intermittent Rhythmic Delta).
- **Theta**: has a frequency of 3.5 to 7.5 Hz and is classified as "slow" activity. It is perfectly normal in children up to 13 years and in sleep but abnormal in awake adults. It can be seen as a manifestation of focal subcortical lesions; it can also be seen in generalized distribution in diffuse disorders such as metabolic encephalopathy or some instances of hydrocephalus.
- **Alpha**: has a frequency between 7.5 and 13 Hz. Is usually best seen in the posterior regions of the head on each side, being higher in amplitude on the dominant side. It appears when closing the eyes and relaxing, and disappears when opening the eyes or alerting by any mechanism (thinking, calculating). It

is the major rhythm seen in normal relaxed adults. It is present during most of life especially after the thirteenth year.



- **Beta**: beta activity is "fast" activity. It has a frequency of 14 and greater Hz. It is usually seen on both sides in symmetrical distribution and is most evident frontally. It is accentuated by sedative-hypnotic drugs especially the benzodiazepines and the barbiturates. It may be absent or reduced in areas of cortical damage. It is generally regarded as a normal rhythm. It is the dominant rhythm in patients who are alert or anxious or have their eyes open.

2.3.2 Electrodes : [10-20 Electrode System]

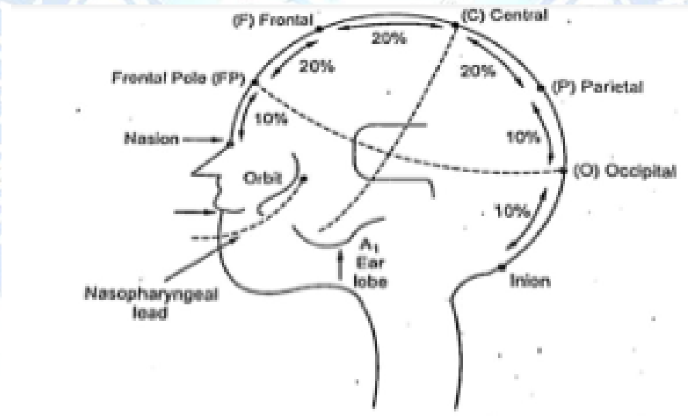
Small metal discs called electrodes are placed on the scalp in special positions. These positions are identified by the recordist who measures the head using the International 10/20 System. This relies on taking measurements between certain fixed points on the head. The electrodes are then placed at points that are 10% and 20% of these distances.

i. The 10-20 system or International 10-20 system is an internationally recognized method to describe and apply the location of scalp electrodes in the context of an EEG test or experiment.
ii. This method was developed to ensure standardized reproducibility so that a subject's studies could be compared over time and subjects could be compared to each other. This system is based on the relationship between the location of an electrode and the underlying area of cerebral cortex.
iii. The letter of the electrode stands for the general brain region that the electrode covers. From front to back, the electrode letter labelling is as follows: Fp (pre-frontal or frontal pole), F (frontal), C (central line of the brain), T (temporal), P (parietal), and O (occipital). Electrodes lying between these lines combine

multiple letters, ordered from front to back. This applies to the higher-density systems, which is further explained in the next section. In addition, the letters M and A are sometimes used to refer to the mastoids or earlobes respectively. Typically, these locations are included to serve as a (offline) reference for signal analysis.

iv. In figure, "10" and "20" refer to the fact that the actual distances between adjacent electrodes are either 10% or 20% of the total front-back or right-left distance of the skull.

v. On the surface of the brain, the voltage about 10 mv. Due to the propagation through skull bone they are attenuated from 1 to 100μv which are picked by EEG electrodes. The frequency ranges from 0.5 to 3000Hz and the resistance range from few 1000Ω to nearly 100Ω depending on electrode used.



vi. The brain waves are the summation of neural depolarisation in the brain due to stimuli from the five senses. They are Frontal, parietal, temporal. Frontal pole and occipital lobes of the brain. The above figure shows the electrode placement system of five senses with distance.

vii. The 10-20 system allows for equal inter-electrode spacing and the electrode placements to be proportional to skull shape and size. Knowledge of this system and the method behind it allows for a consistent and replicable method of recording EEG. This system is used in various applications, including sleep studies, EEG exams, and other EEG research and clinical studies.

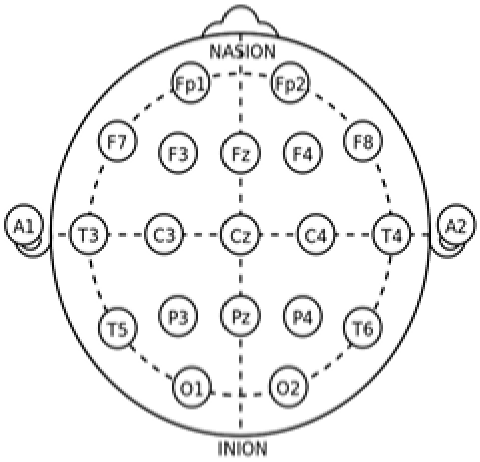


Figure.1.Arrangement Of 10:20 Electrode System

Electrode placement along imaginary line between inion and nasion,

- ✓ Fpz – 10% of distance between nasion-inion
- ✓ Fz – 20% of distance between nasion-inion
- ✓ Cz – Centre point of nasion-inion and right earlobe-left earlobe
- ✓ Pz – 20% of distance between nasion-inion
- ✓ Oz – 10% of distance between nasion-inion

Electrode placement along imaginary line between right earlobe and left earlobe,

- ✓ T3 – 10% of distance between right and left earlobe
- ✓ C3 – 20% of distance between right and left earlobe
- ✓ Cz – Already placed [centre point of nasion-inion and right and left earlobe]
- ✓ C4 – 20% of distance between right and left earlobe
- ✓ T4 – 10% of distance between right and left earlobe

Electrode placement between Fpz and Oz passing through T3

- ✓ Fp1 – 10% of distance between Fpz and Oz
- ✓ F7 – 20% of distance between Fpz and Oz
- ✓ T3 – already placed (10% distance between right and left lobe at the left)
- ✓ T5 – 20% of distance between Fpz and Oz
- ✓ O1 – 10% of distance between Fpz and Oz

Electrode placement between Fpz and Oz through T4,

- ✓ Fp2 – 10% of distance between Fpz and Oz
- ✓ F8 – 20% of distance between F¬pz and Oz
- ✓ T4 – already there (10% distance between right and left earlobe at the right)
- ✓ T6 – 20% distance between Fpz and Oz
- ✓ O2 – 10% distance between Fpz and Oz

Electrode placement between Fp2 and O2 through C4,

- ✓ F4 – 25% of distance of Fp2 and O2
- ✓ C4 – 20% of distance between right and left earlobe (already present) (right side)
- ✓ P4 – 25% of distance between Fp2 and O2

Electrode placement between Fp1 and O1 through C3,

- ✓ F3 – 25% of distance between Fp1 and O1
- ✓ C3 – 20% of distance between right and left earlobe (already present) (left side)
- ✓ P3 – 25% of distance between Fp1 and O1

Electrode gel:

i. It acts as a malleable extension of the electrode, so that the movement of the electrodes cables is less likely to produce artifacts.

ii. The gel maximizes skin contact and allows for a low-resistance recording through the skin.

iii. The electrolytic gel is injected into each cavity until a small amount comes out the hole in the mount. With a moderate amount of downward pressure, the syringe with a blunt needle is rapidly rocked back and forth.

EEG montages

i. Montage means the placement of the electrodes. Montages are specific arrangements of channels; a channel is a pair of electrodes.

ii. The EEG can be monitored with either a bipolar montage or a referential one. Bipolar means that you have two electrodes per one channel, so you have a reference electrode for each channel.

iii. The referential montage means that you have a common reference electrode for all the channels. EEG machines use a differential amplifier to produce each channel or trace of activity. Each amplifier has two inputs.

iv. An electrode is connected to each of the inputs. Differential amplifiers measure the voltage difference between the two signals at each of its inputs. The resulting signal is amplified and then displayed as a channel of EEG activity.

EEG Electrodes-unipolar, bipolar and average mode:

i. Monitoring the electroencephalogram is an effective method of diagnosing many neurological illnesses and diseases, such as epilepsy, tumour, cerebrovascular lesions, ischemia and problems associated with trauma.

ii. It is also effectively used in the operating room to facilitate anaesthetics and to establish the integrity of the anaesthetized patient's nervous system.

iii. This has become possible with the advent of small, ***computer-based EEG analyzers***. Consequently, routine EEG monitoring in the operating room and intensive care units is becoming popular.

iv. EEG electrodes are ***smaller in size*** than ECG electrodes.

v. They may be applied separately ***to the scalp*** or may be mounted in special bands, which can be placed on the patient's head. In either case, ***electrode jelly*** or paste is used to improve the electrical contact.

vi. If the electrodes are intended to be used under the skin of the scalp, ***needle electrodes*** are used. They offer the advantage of reducing movement artefacts.

vii. EEG electrodes give high skin contact impedance as compared to ECG electrodes.

viii. Good ***electrode impedance*** should be generally below 5 kilohms. Impedance between a pair of electrodes must also be balanced or the difference between them should be less than 2 kilohms.

ix. EEG preamplifiers are generally designed to have a very high value of input impedance. EEG may be recorded by picking up the voltage difference between an active electrode on the scalp with respect to a reference electrode on the ear lobe or any other part of the body.

x. This type of recording is called '***monopolar***' recording. However, '***bipola***r' recording is more popular wherein the voltage difference between two scalp electrodes is recorded. Such recordings are done with multi-channel electroencephalographs. EEG signals picked up by the surface electrodes are usually small as compared with the ECG signals. They may be several hundred microvolts, but 50 microvolts peak-to-peak is the most typical. The brain waves, unlike the electrical activity of the heart, do not represent the same pattern over and over again. Therefore, brain recordings are made over a much longer interval of time in order to be able to detect any kind of abnormalities.

Bipolar

In a bipolar measurement, the potential difference between a pair of electrodes is amplified by one amplifier channel.

Unipolar

In a unipolar setup, there will be one reference electrode, and the potential difference between this electrode (connected to Vin-) and every other electrode on the head (connected to Vin+ on separate amplifiers) will be measured.

In a unipolar measurement the output signals are formed by several input electrodes that are all amplified against one so called reference. This reference can be an electrode (the common reference electrode), or a calculated internal reference potential consisting of two or more electrode signals. This is never done by one amplifier channel, but always in a multichannel set-up (with a minimum of two channels). This type of recording is often used when measuring EEG or multichannel ECG. A new field of unipolar measurements is the high density surface EMG, where for instance 128 channels are measured using so called grid electrodes. As a result of the above, two types of unipolar amplifier principles can be distinguished:

- The common reference amplifier
- The average reference amplifier

The ***common reference amplifier*** amplifies the signal of each unipolar electrode against the signal from one common electrode, which is thus present in each of the outputs.

In EEG, a variant of this is sometimes used by amplifying each unipolar electrode against the mean of the two ear-electrodes, the so called 'linked-ears'. In the ***average reference amplifier*** there is no electrode that acts as the reference for the measurement system. Instead, each of the unipolar electrodes is amplified against the average of all the connected unipolar electrodes.

The average reference principle has several advantages over the common reference principle.

The first one is very obvious: if the reference electrode is bad (or worse yet, falls off entirely), it does not invalidate the entire recording. Also, from an amplifier-technical point of view, it is beneficial not to have one electrode ‘distributed’ over all input channels. The average-reference principle, as employed by TMSi, can be seen as the multi-channel counterpart of the well know instrumentation amplifier that has been used in electrophysiology for decades.

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