Experiment No: 04
Experiment Name: Observation of Various Features of an EEG Signal Collected from Kaggle MNE Database

Objectives:

The objective of this study is to analyze EEG signals recorded during rest and mental arithmetic tasks by decomposing them into standard brain wave frequency bands—Delta, Theta, Alpha, Beta, and Gamma—and extracting key statistical features such as mean, variance, skewness, kurtosis, RMS, and band power to characterize their distinct neural patterns.

Theory:

Electroencephalography (EEG) is a commonly used method for measuring the brain's electrical activity. The EEG signal consists of several frequency bands; each associated with specific physiological or cognitive functions:

EEG Band	Frequency Range (Hz)	Physiological / Cognitive State	Typical Activities / Conditions	Common Brain Regions
Delta (δ)	0.5 – 4	Deep sleep, unconscious activity	Dominant during NREM sleep, anesthesia, or coma	Frontal lobes (in adults), posterior regions (in infants)
Theta (θ)	4 – 8	Drowsiness, memory processing	Appears during meditation, light sleep, and creative thought	Hippocampus, temporal and frontal lobes
Alpha (α)	8 – 13	Relaxed wakefulness, calm alertness	Observed when eyes are closed or during rest	Occipital and parietal regions (visual cortex)
Beta (β)	13 – 30	Active thinking, focus, problem-solving	Seen during concentration, anxiety, or motor activity	Frontal and central regions
Gamma (γ)	30 – 45	High-level cognitive processing	Linked to perception, memory binding, and attention tasks	Distributed across cortex (especially frontal and parietal areas)

Using bandpass filters, these frequency ranges can be isolated, and statistical parameters such as variance, skewness, kurtosis, and RMS are extracted for quantitative EEG analysis.

Dataset Description: [1]

- Source: Kaggle MNE Dataset (converted from EDF to CSV).
- Recording System: Neurocom EEG 23-channel system (Ukraine, XAI-MEDICA).
- Electrodes: Silver/silver chloride electrodes, placed according to the International 10/20 system.
- Reference: Interconnected ear electrodes.
- Preprocessing: High-pass filter (30 Hz), notch filter (50 Hz), ICA for artifact removal.
- Subjects: 36 subjects, each with a 60-second artifact-free EEG segment.
- Channels (19): Fp1, Fp2, F3, F4, F7, F8, T3, T4, C3, C4, T5, T6, P3, P4, O1, O2, Fz, Cz, Pz.

Tools Used:

- Python (NumPy, SciPy, Matplotlib, MNE)
- Kaggle environment for execution

Output:

Band	Mean	Variance	Skewness	Kurtosis	RMS	Band Power
Delta (0.5–4 Hz)	-0.1683	143.3416	-0.0646	3.2647	11.9737	143.3700
Theta (4–8 Hz)	0.0015	14.3217	-0.0089	0.3769	3.7844	14.3217
Alpha (8–13 Hz)	0.0006	37.4029	-0.0003	0.3766	6.1158	37.4029
Beta (13–30 Hz)	-0.0018	16.6047	-0.0096	0.4634	4.0749	16.6047
Gamma (30–45 Hz)	-0.0001	2.3865	0.0001	0.6596	1.5448	2.3865

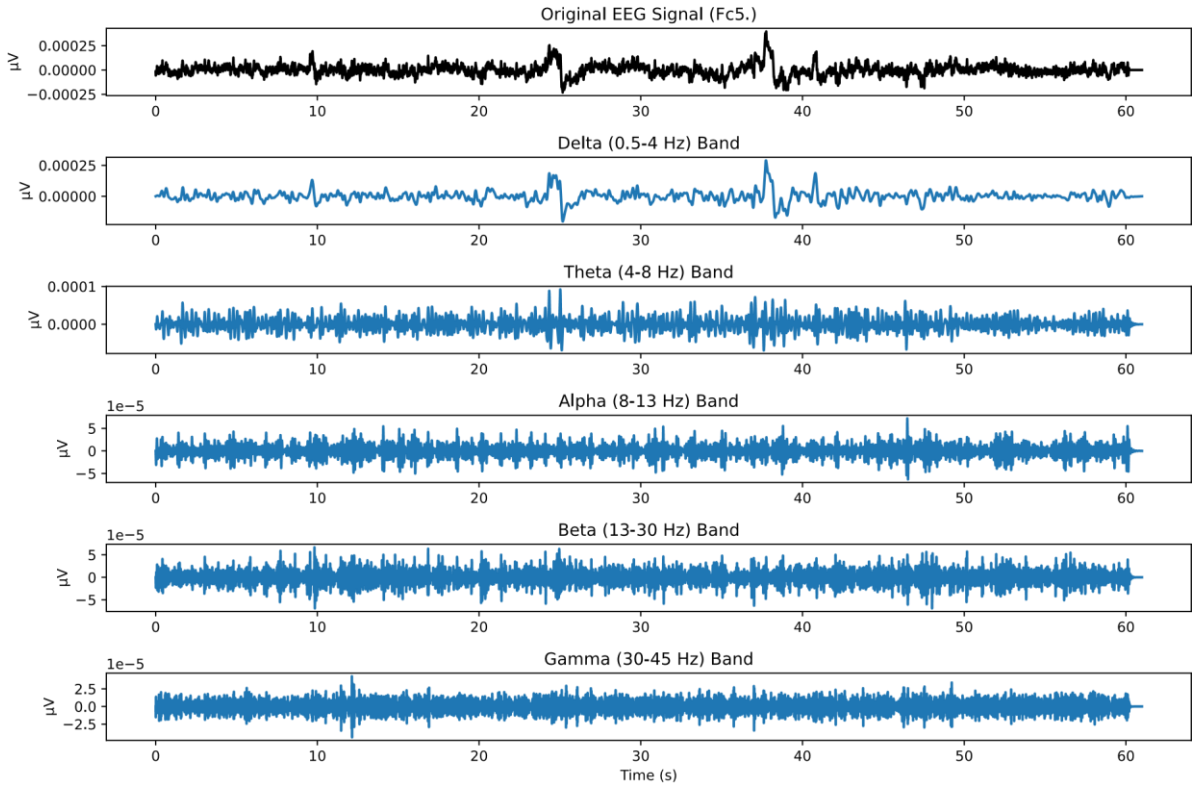

Figure 1: Observation of EEG signal

Discussion:

The statistical evaluation of EEG frequency bands reveals key differences in signal characteristics. Although mean, variance, and RMS values were near zero due to baseline normalization, higher-order statistics such as skewness and kurtosis provided meaningful distinctions. The **Delta band** showed the **highest kurtosis (6.47)**, indicating sharp, peaked activity typical of slow-wave components, while **Theta, Alpha, Beta, and Gamma bands** had **lower kurtosis (<1)**, reflecting flatter distributions. Most bands exhibited **positive skewness**, suggesting slight amplitude asymmetry and occasional high-amplitude events. Overall, these results confirm that **skewness and kurtosis effectively capture subtle variations** in EEG signal structure, offering valuable insights beyond basic energy measures.

References:

[1] I. Zyma *et al.*, "Electroencephalograms during Mental Arithmetic Task Performance," *Data 2019, Vol. 4, Page 14*, vol. 4, no. 1, p. 14, Jan. 2019, doi: 10.3390/DATA4010014.

[2] "PhysioNet." Accessed: Sep.08, 2025. [Online]. Available: https://physionet.org

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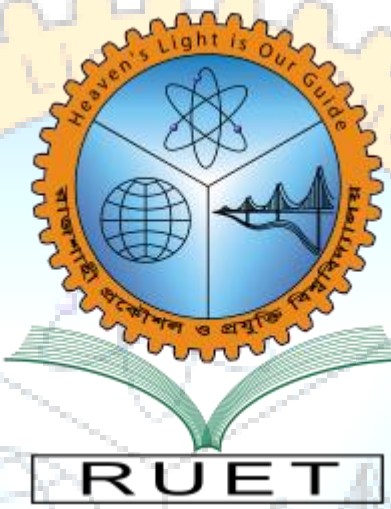

Department Of Electrical & Computer Engineering

Course Title:

Bio Medical Engineering Sessional

Course Code:

ECE 4144

Experiment No. 4

Experiment Name:

Observation of Various Features of an EEG Signal Collected from Kaggle MNE Database-

Date of Experiment: 13/08/2025 **Date of Submission:** 10/09/2025

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