device, which records the electrical activity of the brain. The data acquisition process requires proper setup and calibration of the EEG device to ensure accurate signal capture. This involves placing electrodes on the scalp according to standardized positions, such as the international 10-20 system, to consistently capture brain wave patterns associated with different sleep stages.

**Initial Data Handling**

Once the raw EEG data is collected, it needs to be segmented into manageable parts for further processing. Typically, the EEG recordings are divided into 30-second epochs or segments. Each segment represents a window of brain activity that will be analyzed to classify the sleep stages. This segmentation is crucial as it aligns with the standard practice in sleep research and facilitates consistent feature extraction and analysis.

**Data Preprocessing and Cleaning**

1. **Artifact Removal:**

The raw EEG data often contains various artifacts and noise, such as those from eye movements, muscle activity, or external electrical sources. These artifacts can significantly affect the performance of the classification model. Therefore, an essential preprocessing step is to remove or minimize these artifacts. Techniques such as Independent Component Analysis (ICA) or wavelet decomposition can be used to isolate and remove these noise components from the EEG signals.

**2. Filtering:**

The next step is to apply band-pass filtering to the EEG signals. EEG signals are composed of different frequency bands (delta, theta, alpha, beta, and gamma), each associated with specific brain activities and sleep stages. Band-pass filters help isolate these frequency bands by allowing only signals within a specific frequency range to pass through while attenuating the others. For sleep stage classification, the typical frequency range of interest is between 0.5 Hz and 50 Hz.

1. **Normalization:**

Normalization is applied to the EEG data to ensure that all the signals have a uniform scale. This step is crucial for improving the convergence of deep learning models. Min-max normalization or z-score normalization are common techniques used to scale the EEG data values.

**4. Segmentation and Labeling:**

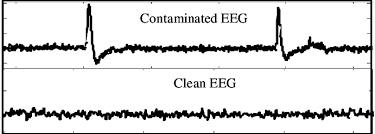
After filtering and normalization, the EEG signals are segmented into overlapping or non-overlapping windows of fixed duration (e.g., 30 seconds). Each segment is then labeled according to the corresponding sleep stage, as annotated by sleep specialists or automated scoring systems. The labels typically include stages such as wake (W), rapid eye movement (REM), and non-REM stages (N1, N2, N3).

**5. Feature Extraction:**

Feature extraction involves transforming the raw EEG data into a set of features that can be used for classification. In this approach, a multi-resolution convolutional neural network (MRCNN) is employed to extract both low and high-frequency features from different frequency bands of the EEG signals. The MRCNN consists of multiple convolutional layers with varying kernel sizes to capture features across different temporal scales.

**6. Adaptive Feature Recalibration (AFR):**

The extracted features are then passed through an adaptive feature recalibration (AFR) module, which models the inter-dependencies among the features and enhances the most relevant ones for sleep stage classification. The AFR uses a residual squeeze and excitation block to adaptively recalibrate the features, improving the representation and subsequent classification performance.

Through these preprocessing and cleaning steps, the EEG data is transformed into a refined and feature-rich format, ready for input into the attention-based deep learning model for sleep stage classification.

**Figure 4.1: Data Cleaning**