BETA Based Approach On Un-Synchronized EEG Waves in LFP Localization for Movement Disorders

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***Abstract*—The beta-based approach is a novel method to localize movement disorders using unsynchronized EEG waves in local field potential (LFP) data. The process is based on the observation that beta-band oscillations (13 - 30 Hz) in LFPs are highly correlated with movement-related activity in the basal ganglia. By analysing the unsynchronized EEG waves in the beta frequency range, this approach can detect changes in beta activity associated with movement disorders such as Parkinson's disease and dystonia. The beta-based approach uses advanced signal processing techniques, including time-frequency analysis to extract features from the LFP data. These features arethen used to identify the spatial distribution of beta activity in the brain, which can help localize the source of movement disorders. The beta-based approach is a promising tool for localizing movement disorders using LFP data. It has the potential to provide valuable insights into the underlying neural mechanisms of these disorders and could lead to the development of more effective treatments. Further research is needed to validate and refine this approach, but it represents an exciting new direction in movement disorder research.**

***Index Terms*— LFP, Beta Waves, frequency analysis, movement disorders.**

I. Introduction

Movement disorders such as Parkinson's disease and dystonia are characterised by abnormal activity in specific regions ofthe brain, particularly the basal ganglia. Local field potentials (LFPs) are a type of neural signal that reflects the electrical activity of a population of neurons in a specific brain region. Analysis of LFP data is a powerful tool for understanding the neural mechanisms of movement disorders. The main goal of this approach is to detect changes in beta activity associated with movement disorders, such as Parkinson's disease or essential tremor. By analyzing the beta waves in the LFP data, researchers aim to identify aberrant patterns or abnormalities in beta activity that could serve as biomarkers for these movement disorders. One key feature of LFPs is their oscillatory activity, which can be characterized by different frequency bands. The beta frequency band (13 - 30 Hz) is particularly relevant to movement-related activity in the basal ganglia. In healthy individuals, beta activity is suppressed during movement, but in people with movement disorders, beta activity can become abnormally synchronized and elevated, leading to movement impairments. The beta-based approach is promising for understanding movement disorders and advancing treatment options. In this project, we will provide a comprehensive review of the approach, covering its theoretical foundation, technical implementation, and its applications in movement disorder research. By examining its potential, we aim to shed light on the valuable insights the beta-based approach can offer in unravelling the neural mechanisms of movement disorders and facilitating the development of more effective treatments.

II. Literature

Little, S., & Brown, P. have elaborated that during typical motor control, beta oscillations (13–30 Hz) are modulated, which may function to favor the current motor set at the expense of new movements. There is substantial correlative evidence connecting beta activity at rest and beta alterations in response to therapy with bradykinesia and rigidity, and these oscillations are significantly increased in Parkinson's disease (PD). Studies in which either cortical or subcortical areas have been activated in the beta frequency range, causing a moderate but considerable slowdown of movements, provide some indication that this link may be mechanistically significant or causal. Recent studies, however, using high-frequency deep brain stimulation (DBS) exclusively during times of increased beta activity have shown significant clinical effects that even outperform those of continuous high-frequency conventional DBS. These studies show how a better knowledge of the pathophysiology of PD can result in more effective therapeutic strategies for this disorder and suggest that beta activity may be both qualitatively and quantitatively significant in the motor impairment of Parkinson. A. L. Crowell et al. figured out that basal ganglia-derived movement disorders can result from irregularities in synchronized oscillatory activity in a network involving the thalamus, motor cortices, and basal ganglia. Basal ganglia local field potentials recorded briefly

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externalized deep brain stimulator electrodes in humans have been the subject of extensive research. These investigations have given rise to the hypothesis that the basal ganglia-thalamocortical network exhibits distinctive changes in thebeta frequency range (13–30 Hz) in Parkinson's disease. However, the straightforward evaluation of existing theories is limited since distinct illnesses have rarely been compared utilising recordings in the same structure under the same behavioural conditions. They investigated cortical oscillations in the three most prevalent movement disorders, Parkinson's disease, primary dystonia, and essential tremor, using subdural electrocorticography to address this. In 31 participants, strip electrodes were used and temporarily implanted during standard surgery for deep brain stimulator placement to capture local field potentials from the arm region's primary motor and sensory cortices. The results obtained are (i) the primary motor cortex high beta (20-30 Hz) power is increased in Parkinson's disease during the stop phase of a movement task; (ii) the primary motor cortex broadband gamma power is increased in Parkinson's disease compared with the other conditions, and (iii) the alpha-beta peaks in the motor and sensory cortical power spectra occur at higher frequencies in Parkinson's disease than inthe other two conditions and (iv) Patients with dystonia have primary motor and sensory cortices with poor movement- related beta-band desynchronization The results are consistent with the developing theory that illness states are characterized by aberrations in synchronized oscillatory activity. This was the first investigation into the three most prevalent movement disorders' sensorimotor cortex local field potentials. A different study by R. S. Neuville et al., compared the pathological beta oscillations that occur during various motions in two subtypes of Parkinson's disease (PD): akinetic-rigid (AR) and tremor-dominant (TD). Beta oscillations, which are aberrant brain oscillations frequently seen in PD patients, are suggested tobe a factor in the disease's motor symptoms. The authors used deep brain stimulation (DBS) electrodes to capture brain activity from PD patients' subthalamic nucleus (STN) while they were at rest, doing simple hand motions and writing. The results of the AR and TD subtypes were then compared after the scientists examined the beta oscillations in the collected data.

The findings showed that during rest and handwriting movements, but not during simple hand movements, the AR subtype had considerably higher beta power and burst duration than the TD subtype. The authors hypothesize that various underlying causes of motor dysfunction in PD may be reflected in beta oscillations between the subtypes and movements.

Overall, the work offered insights into how abnormal beta oscillations affect different PD subtypes and movements, which may help create more individualised treatment plans for PD patients.

The alpha, beta, theta, and delta waves, generally referred to as the power spectrum's alpha, beta, and thetawaves, are among the historically designated frequency bands that are the subject of much of the electroencephalography (EEG) literature. In order to identify patterns across disorders,J. J. Newson and T. C. Thiagarajan [4] has reviewed 184 EEG studies that report differences in frequency bands in the resting state condition (eyes open and closed) for a variety of psychiatric conditions, such as depression, ADHD, autism, addiction, bipolar disorder, anxiety, panic disorder, post-traumatic stress disorder (PTSD), obsessive-compulsive disorder (OCD), and schizophrenia. They demonstrated that the power increases across lower frequencies (delta and theta) and decreases across higher frequencies (alpha, beta, and gamma) are the most prevalent patterns of change across various illness types, including ADHD, schizophrenia, and OCD. Some diseases, like PTSD, addiction, and autism, do nothave a dominant trend for spectral change in either direction. They reported consistency and validation scores across the disorders and conditions that demonstrate that, when summed across all studies reporting this result, the dominant resultacross all disorders is typically only 2.2 times as likely to occur in the literature as alternate results, typically with less than 250 study participants.

III. Materials and Methods

The work aims to generate a control signal for a neurostimulator, which can act as feedback from the physiological domain to make the operation of the neurostimulator adaptive. The relation between unsynchronized beta waves with the intensity of parkinsonism is utilised here, and the beta signals derived from Local Field Potentials(LFP) are processed to derive the feedback factor. The available unsynchronized EEG data from the physio net database is used for the operations [5]. The pre-conditioned EEg signal is shown in Fig 1.

In the block diagram in Fig 2., the LFP recording is the primary source of neural activity data from which the EEG signal is derived. It is pre-processed using a low-pass filter to remove high-frequency noises and artefacts. It is then filtered using a Butterworth band pass filter to extract the beta wave frequency band (13 - 30 Hz). The thresholding process quantises the beta wave obtained, which converts the continuous beta wave signal into a binary on/off signal based on a predetermined threshold. This signal is then used to control the duty cycle of a generated PWM signal. The PWM signal is then used to control an implantable pulse generator (IPG). This IPG contains a Power Control Unit (PCU) and the digital signal is converted to an analog signal to maintain the charge balance.

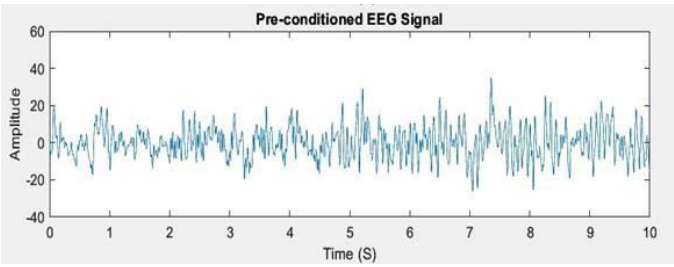

Fig. 1. Enter Caption

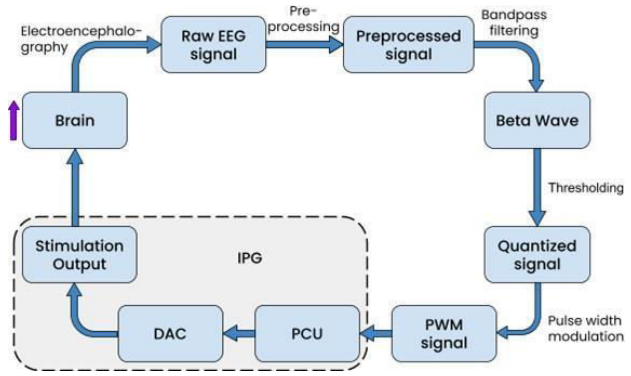

Fig. 2. Block Diagram of the system

A. *Preprocessing*

The raw EEG signal obtained is first preprocessed to remove unwanted noises and artefacts. Preprocessing helps increase the signal's quality by increasing the signal-to-noise ratio (SNR) and makes the signal suitable for further processing. A Butterworth low pass filter at a cutoff frequency of 50Hz is employed to remove high-frequency noises and artefacts. Also, a Butterworth high pass filter at a cutoff frequency of 0.5 Hz is used to eliminate low-frequency drifts and to remove slow variations in the signal and DC offsets. The output signal after the filtering operation is given in Fig. 3

B. *Beta wave extraction*

To extract the beta waves from the preprocessed signal, in the range of 13 - 30 Hz, a Butterworth band pass filter with a cutoff frequency of 13 Hz and 30 Hz is used since it has a more significant response for a low-frequency fast-varying signal. The maximally flat frequency response in the passband ensures that they do not introduce ripples or distortions in the frequencies in the range of interest. Fig 4 shows the response of the used bandpass filter.

Butterworth filters provide a smooth transition between the passband and stopband. This gradual roll-off minimises signal distortion near the cutoff frequency and helps maintain signal integrity in adjacent frequency bands. Butterworth filters exhibit a linear phase response, introducing a constant delay across all frequencies [6].

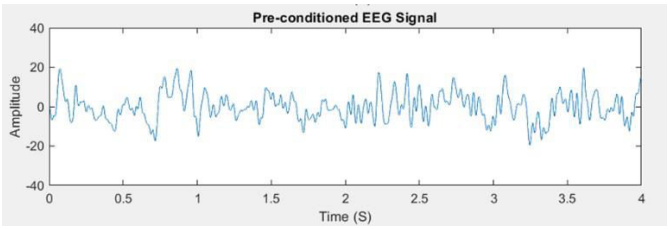

Fig. 3. Preconditioned signal after filtering

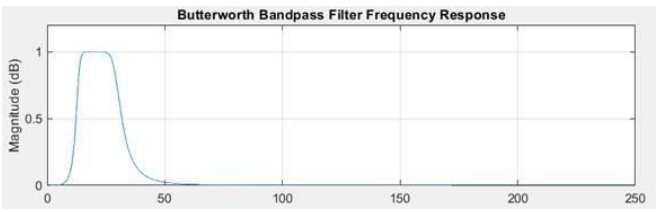

Fig. 4. Block Diagram of the system

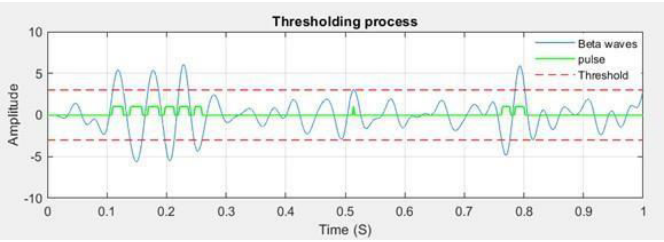

Fig. 5. Thresholding process

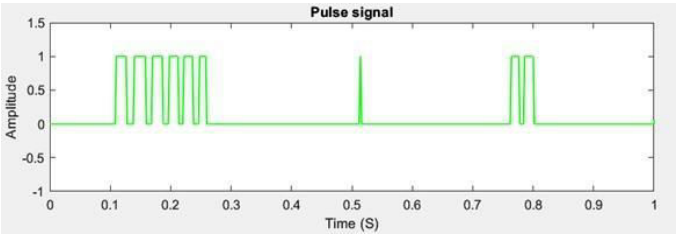

Fig. 6. Derived Pulse signal

C. *Thresholding*

The beta wave obtained is thresholded to form a binary on-off signal. It helps us to identify the beta asynchrony. The beta wave amplitude of an average person is about 3 µV. So, fixing the threshold as 3 µV, the beta waves with an amplitude above 3 µV and below -3 µV are converted to value 1, and the beta waves in between -3 µV and 3 µV are treated as 0. The Fig. 4 shows the thresholding process. The Fig. 5 shows the derived pulse signal.

D. *Generating the Pulse Width Modulation signal*

The thresholded beta waves are then converted to a PWM signal by modulating with a 150Hz sine wave to generate the control signal. Fig. 7 and Fig. 8 show the process of developing the PWM control signal. The obtained PWM signal is then averaged to a DC-level waveform, which can be fed to a Neurostimulator to control the intensity and duration of the pulse train.

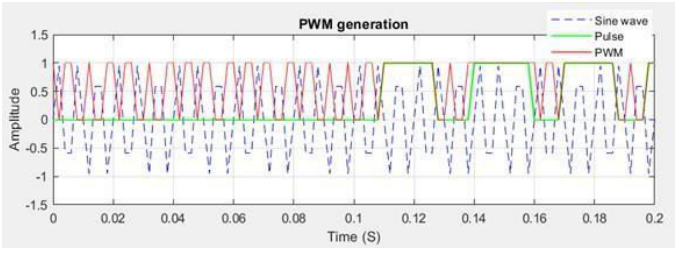

Fig. 7. PWM generation from the beta

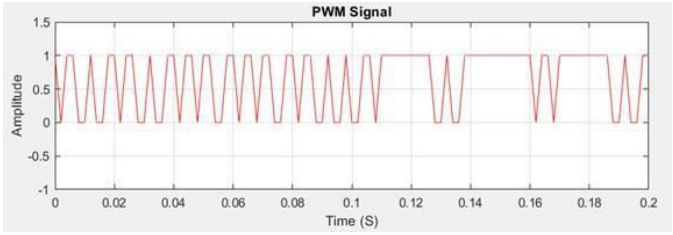

Fig. 8. Generated PWM

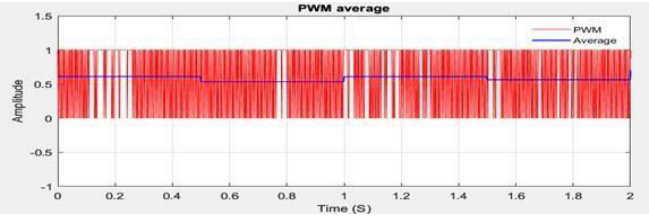

Fig. 9. Averaged PWM Signal

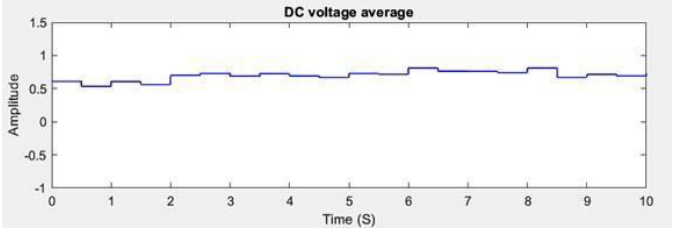

Fig. 10. DC derivative from the PWM

IV. RESULTS

The time-averaged PWM signal is shown in Fig. 9, and the DC extract of the average is shown in Fig 10. The DC waveform obtained by averaging the PWM modulated control signal can be used as a feedback signal, as it carries information about the unsynchronised beta waves and their level of unsynchronisation. The amplitude of the waveform in Fig 10 directly gives a notion about the level of synchronisation of the beta wave, which is a direct marker of disease progression. This particular information is fed to the implantable pulse generator of the neurostimulator to generate adaptive stimulation.

The beta-based approach to unsynchronised EEG waves in LFP localisation for movement disorders has significant potential to advance our understanding of the human brain and neurological disorders. The beta frequency band is closely linked to movement and is a critical component of the neural circuitry involved in motor control. Localising beta oscillations in the LFP may make it possible to develop more precise and effective interventions for Parkinson's disease and other movement disorders.

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