Evaluation of ECoG Band-Energy Features for Epileptogenic Discharge Detection

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***Abstract*—This paper evaluates band-energy features of electrocorticographic (ECoG) signals for detecting short time windows containing epileptogenic discharges in patients with drug-resistant epilepsy. The aim was to identify frequency bands that best distinguish ECoG time windows containing epileptogenic discharges from time windows without epileptogenic discharges. The material included ECoG recordings from six patients undergoing presurgical evaluation. A clinical neurophysiologist manually selected windows containing epileptogenic discharges (EPI) and windows without epileptogenic discharges (NON). For each window, band energy was calculated in classical and high-frequency ranges and then compared between the two groups. The largest and most repeatable energy increase was observed in the beta, gamma, and broad 3–80 Hz frequency ranges. Ripples (80–250 Hz) also showed higher energy in EPI windows, although the effect was weaker than in the beta and gamma bands. Fast ripples above 250 Hz did not provide useful discrimination between the two groups in this dataset. The results indicate that a practical ECoG discharge detector should combine beta, gamma, and 3–80 Hz band-energy features, use ripples as an additional feature, and account for the individual background activity of each patient.**

***Index Terms*—ECoG, epilepsy, epileptogenic discharges, feature extraction, band energy, HFO, classification.**

I. Introduction and Aim

Electrocorticography (ECoG) records electrical activity directly from the cortical surface. Compared with scalp EEG, ECoG usually provides higher signal amplitude, better signal-to-noise ratio, and higher spatial resolution. For this reason, invasive recordings are used in the diagnostic work-up of drug-resistant epilepsy, especially when epileptogenic regions must be assessed before surgical treatment.

Clinical interpretation is still based mainly on visual assessment by an experienced neurophysiologist. This assessment is time-consuming, particularly for multichannel ECoG recordings and long monitoring sessions. Quantitative methods can support this process by indicating time windows in which epileptogenic discharges are more likely to occur [1], [2]. The method should not only return a formal class label, but also provide clinically interpretable information: which frequency bands change in discharge windows and whether the change is repeatable across patients.

High-frequency oscillations (HFOs), especially ripples in the 80–250 Hz range and fast ripples above 250 Hz, have received substantial attention in the epilepsy literature. These phenomena have been described in intracranial recordings and linked to epileptic activity [3]. HFOs have also been proposed as potential biomarkers of epilepsy [4]. At the same time, a practical decision-support method should not assume in advance that the best marker must come only from very high frequencies. Earlier ECoG studies suggest that defined spike parameters and interpretable signal features may also support clinical decisions [1], [2].

The aim of this study was to evaluate the usefulness of ECoG band-energy features for the detection of time windows containing epileptogenic discharges and to determine which frequency bands best discriminate EPI windows from windows without epileptogenic discharges (NON). The study had a technical and application-oriented character. We did not assume a priori that the most informative energy feature would originate from the HFO range. Therefore, energy features derived from conventional EEG frequency bands, broader frequency ranges, ripples (80–250 Hz), and fast ripples (>250 Hz) were evaluated. The results were intended to indicate which features should be included in a future EPI-window detector and whether patient-specific normalization is needed.

The problem was considered at the level of short time windows, not at the level of the whole recording. This is important for future clinical use. A window-based detector can support signal review by marking fragments that are more likely to contain epileptogenic discharges. This mode of operation is consistent with clinical practice, where the neurophysiologist evaluates local signal fragments and their spatial distribution over the electrode grid.

II. Material

The clinical material was collected at the 118th Military Hospital with Outpatient Clinic in Elk, Poland, from patients evaluated before planned brain resection in the course of drug-resistant epilepsy diagnostics. The analyzed ECoG recordings came from six patients, denoted in this paper as P1–P6. Signals were sampled at $f_s = 2000$ Hz. Depending on the patient, 17 to 20 ECoG channels were available. The analysis used one-second windows, corresponding to 2000 samples per channel.

In total, 60 time windows were evaluated: 30 windows with epileptogenic discharges, denoted as EPI, and 30 control windows without discharges, denoted as NON. For each patient, five EPI windows and five NON windows were used. The windows were selected by a clinical neurophysiologist. Because epileptogenic activity is not necessarily visible over the whole ECoG grid, the analysis was restricted to electrodes selected clinically for each patient.