IBEHS 3A03

Assignment 3 – Fourier Analysis of Biomedical Signals

November 23rd, 2021

Cai, Sharon

Motsenyat, Ariel

Introduction

Signal modulation is the process by which some properties of a carrier signal are varied based on the signal that is being transmitted. A common form of carrier is a sinusoid such as $A\cos(\omega_c t)$ where A is the carrier amplitude and ω_c is the carrier frequency in rad/sec.

Fourier analysis is effective in using sinusoids to represent periodic signals. The frequency content of blood-flow velocity (BFV) signals and electroencephalography (EEG) signals can be evaluated using Fourier analysis.

BFV Plots

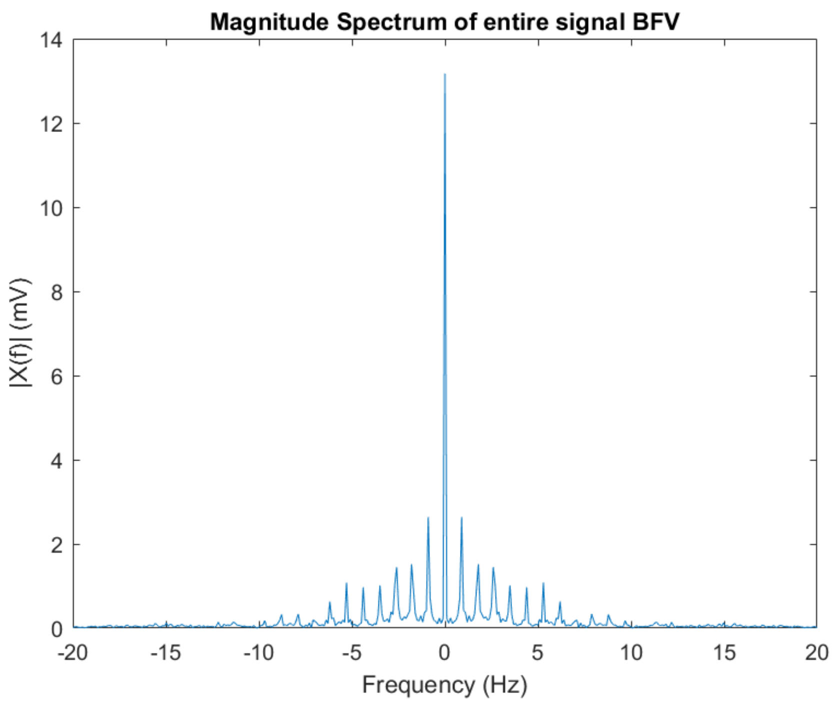

Figure 1: Magnitude spectrum of the full Blood-Flow Velocity Signal

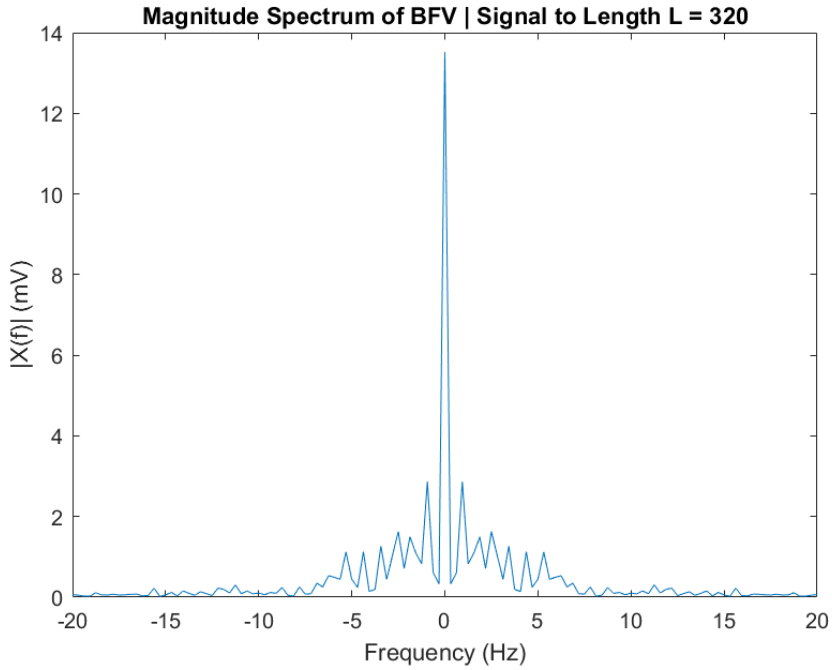

Figure 2: Magnitude spectrum of the Blood-Flow Velocity Signal of length L = 320

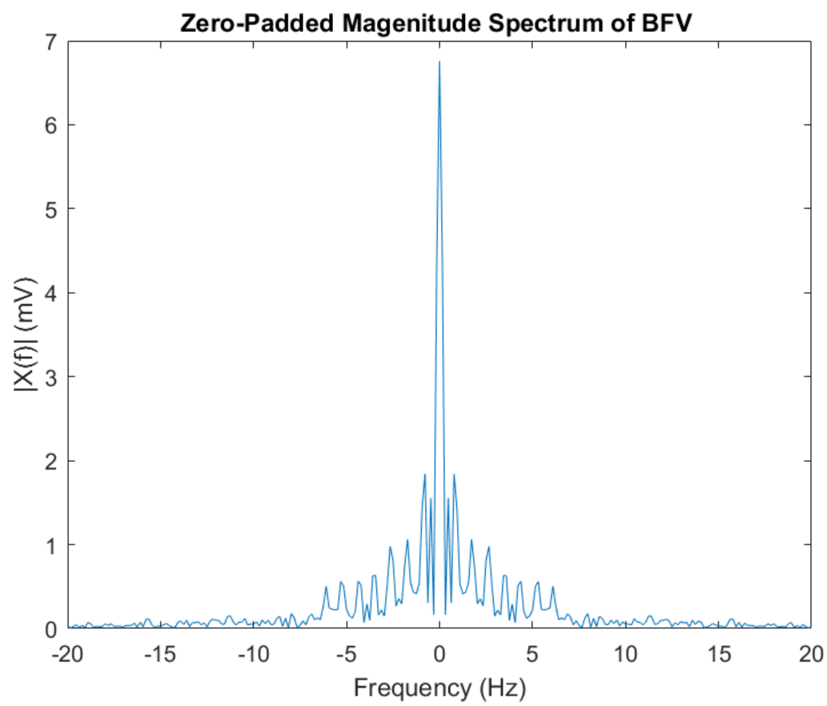

Figure 3: Magnitude spectrum of the zero-padded Blood-Flow Velocity Signal of length L = 320

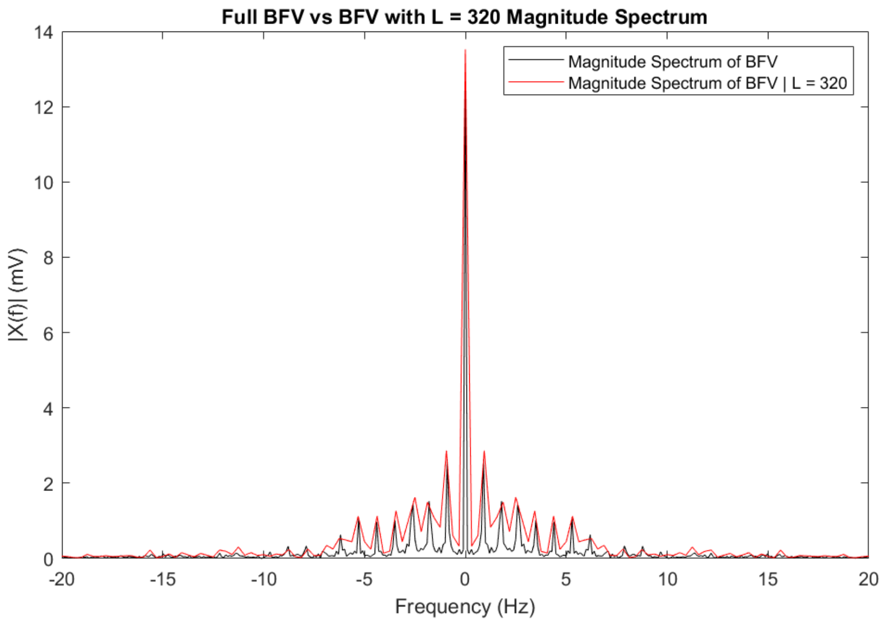

Figure 4: Comparison of the magnitude spectrum of the full Blood-Flow Velocity Signal and magnitude spectrum of the Blood-Flow Velocity Signal with length L = 320

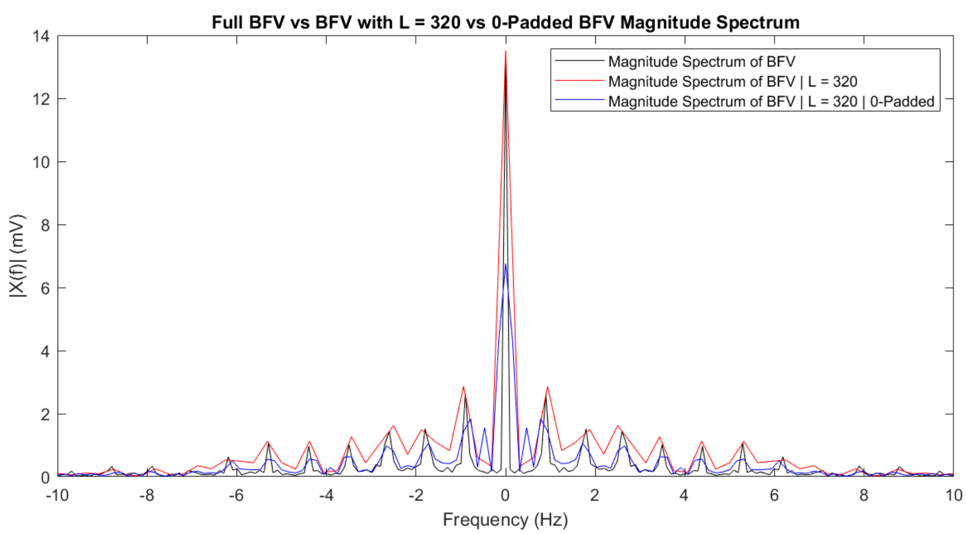

Figure 5: Comparison of the magnitude spectrum of the full Blood-Flow Velocity Signal, the magnitude spectrum of the Blood-Flow Velocity Signal with length L = 320, and the zero-padded magnitude spectrum of the Blood-Flow Velocity Signal with length L = 320

<u>BFV Analysis</u>

L is defined as an integer that is less than N, the length of the entire array. The smallest length of L for which the harmonic structure observed in the spectrum of the BFV signal is a length of

~320. This was determined by computing and plotting the magnitude spectra from Figures 1 – 4. When L is decreased, the harmonic structure becomes less identifiable. Trial and error is used to increase the lengths until the point at which the key features of the frequency structure are once again visible.

Figure 2 demonstrates that at a length L = ~320, the frequency has been resolved into smoother lines, but the key features of the harmonic structure remain clearly visible. A comparison between the spectrum of the sample signal and full signal is shown in Figure 4. The magnitude spectrum at L = 320 provides smoother lines and accurately envelopes a significant portion of the peaks reflected in the full signal spectrum. As such, the spectrum of the entire BFV signal is well represented in the signal segment with a length of ~ 320. However, as the frequency increases, this sample magnitude spectrum becomes less accurate to the original signal. This can be combatted directly using zero-padding.

In Figure 3, the zero-padded magnitude spectrum of the BFV signal with a length of 320 is demonstrated. This graph is produced as a result of the addition of zeros at the end of a segment of the signal. This is done with the purpose of evaluating the signal at a greater number of frequency points in order to clarify the resolution of the frequency. As seen in Figure 3 and proven in Figure 5, zero-padding increases the accuracy of Fourier analysis for shorted signals. In Figure 5, the zero-padded spectrum is directly compared to the full BFV signal spectrum and the L = 320 BFV signal spectrum. This figure demonstrates that the magnitude spectrum plotted with zero-padded provides a closer estimate of the full signal spectrum. Thus, zero-padding aids greatly in obtaining a better estimate of the entire signal's spectrum when using the signal segment of length L.

EEG Plots

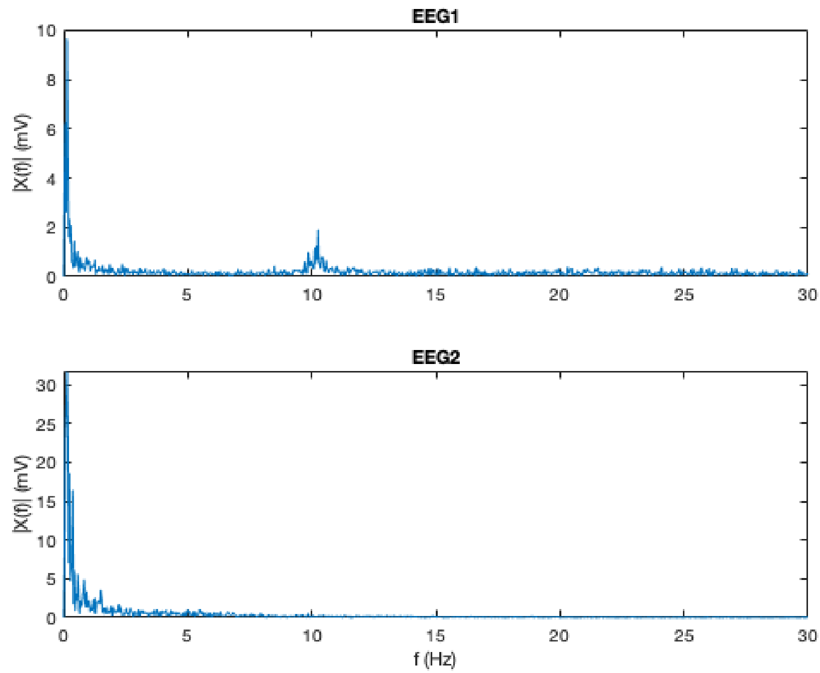

Figure 6: EEG1 and EEG2 magnitude spectra

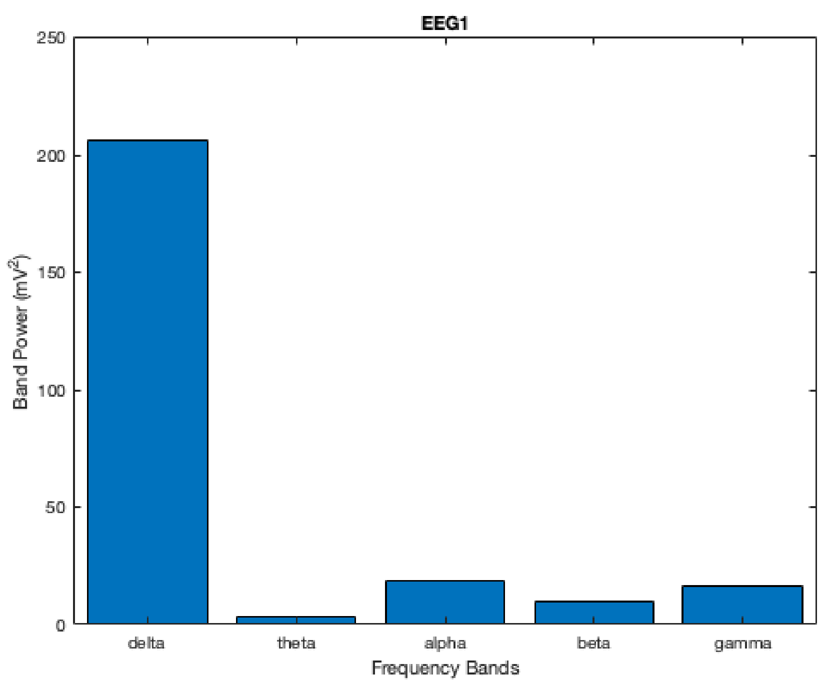

Figure 7: EEG1 Band Power graph

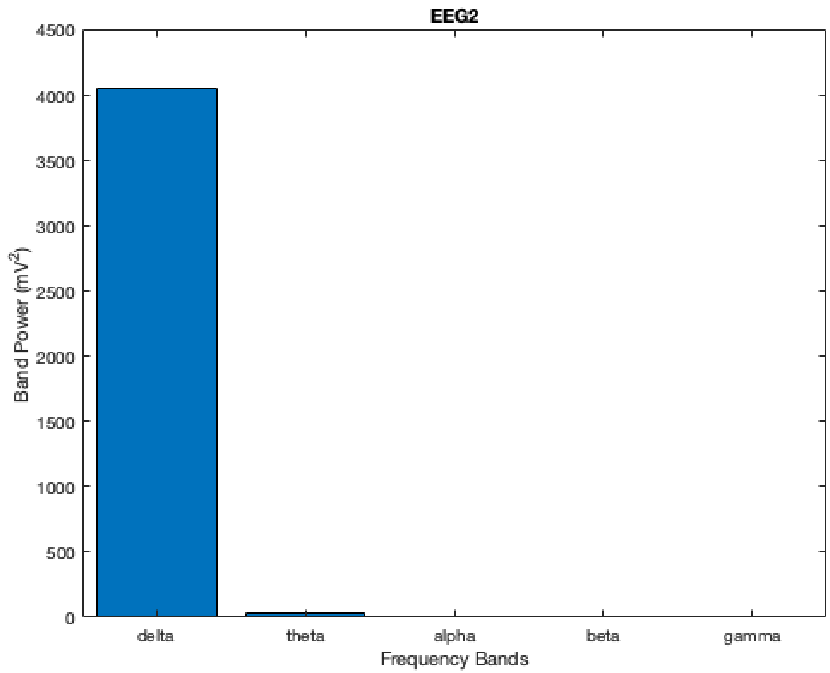

Figure 8: EEG2 Band Power graph

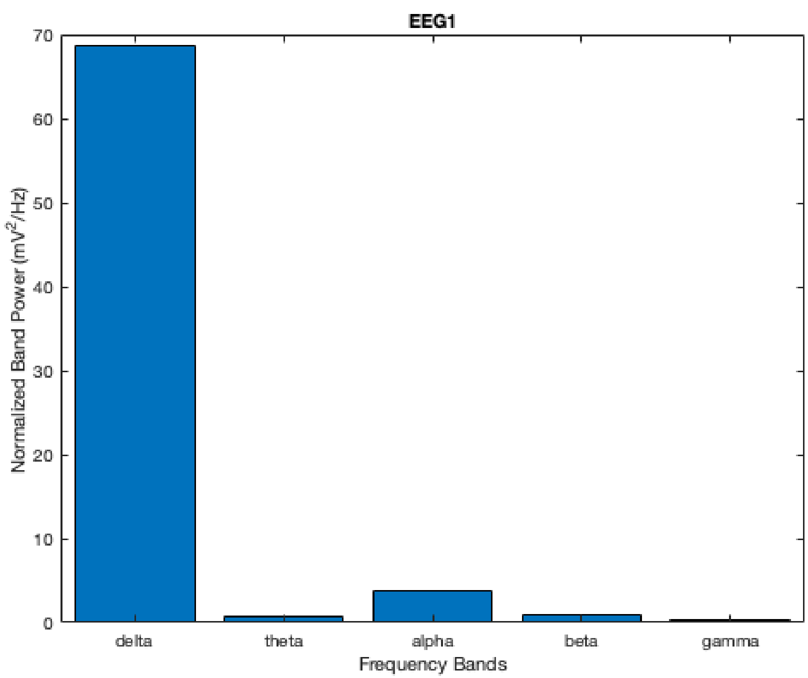

Figure 9: EEG1 Normalized Band Power graph

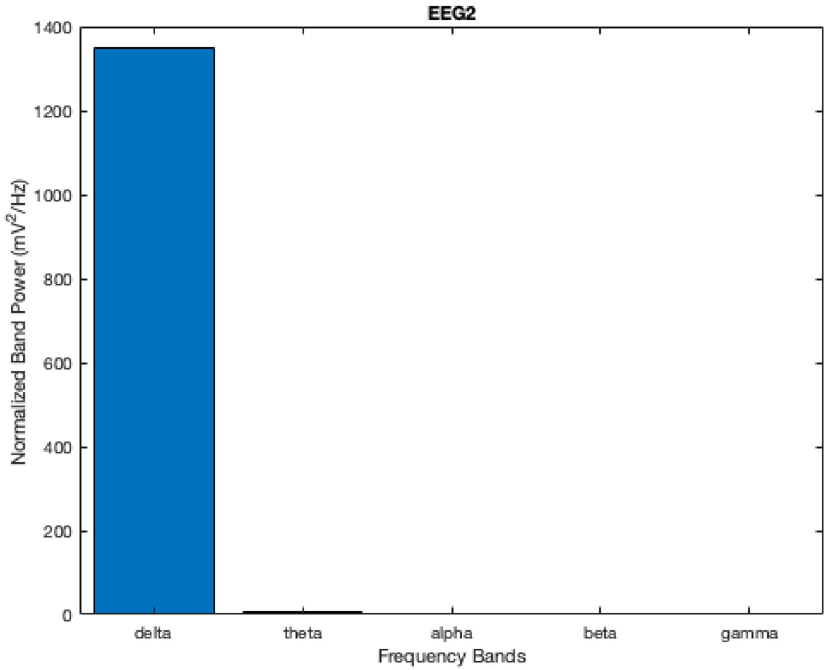

Figure 10: EEG2 Normalized Band Power graph

EEG Analysis

Through analyzing the power band spectrums for both the EEG1 and EEG2 signals, we can determine that the most significant frequency for EEG1 is alpha, while for EEG2 it is delta. The high band power of the delta waves frequency range can be attributed to low frequency noise smaller than 3 Hz. Alpha waves are among the strongest neural signals observed when a patient is awake and resting with their eyes closed. As a patient falls asleep, they enter deep non-rapid eye movement (NREM) sleep, at this state, delta waves are among the strongest neural waves observed. As a result, the subject for EEG1 was awake and resting with their eyes closed, while for EEG2, the subject was in deep NREM sleep.

Bonus

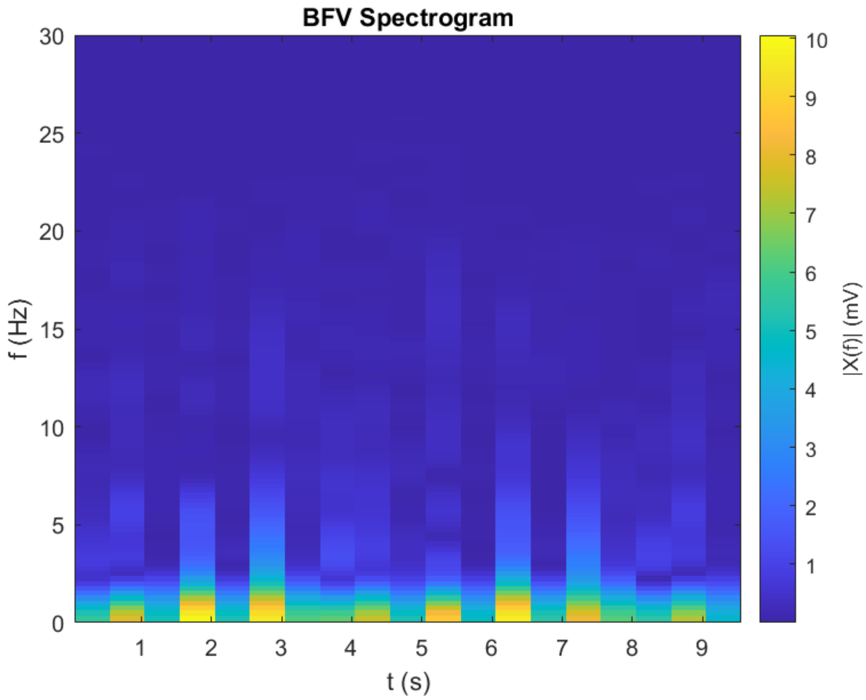

Figure 11: EBFV spectrogram analysis

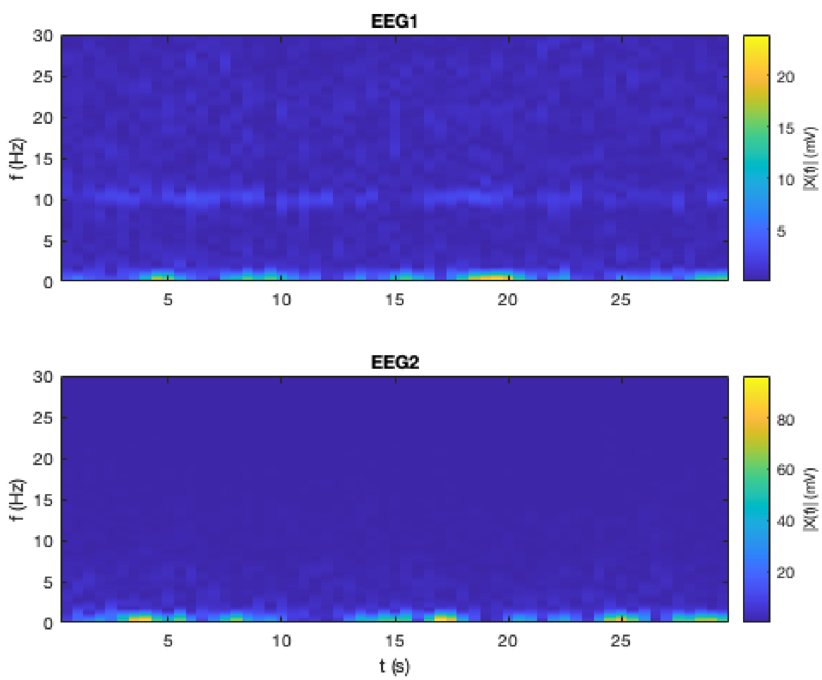

Figure 12: EEG1 and EEG2 spectrogram analysis

A spectrogram analysis visualizes how the amplitudes of various frequency components change over time.

As seen in Figure 11, the BFV spectrogram demonstrates relatively consistent amplitudes over time. The peak in amplitude occurs at approximately 2-3 Hz and below. At these lower frequencies, the amplitude is much higher than at higher frequencies. This spectrogram demonstrates that the waves will change states near 3 Hz and will otherwise remain in a steady state throughout the period measured.

In our EEG samples we see consistent amplitudes along our frequency levels. In EEG1 there is some modulation among the lower delta waves and the medium alpha waves. While EEG2 again sees some modulation among the lower delta wave frequencies. Across the x-axis, the limited amount of signal strength fluctuation indicates that the signals will remain in their state throughout the measured time.