Biomedical abnormality analysis through Internet of Things (IoT)

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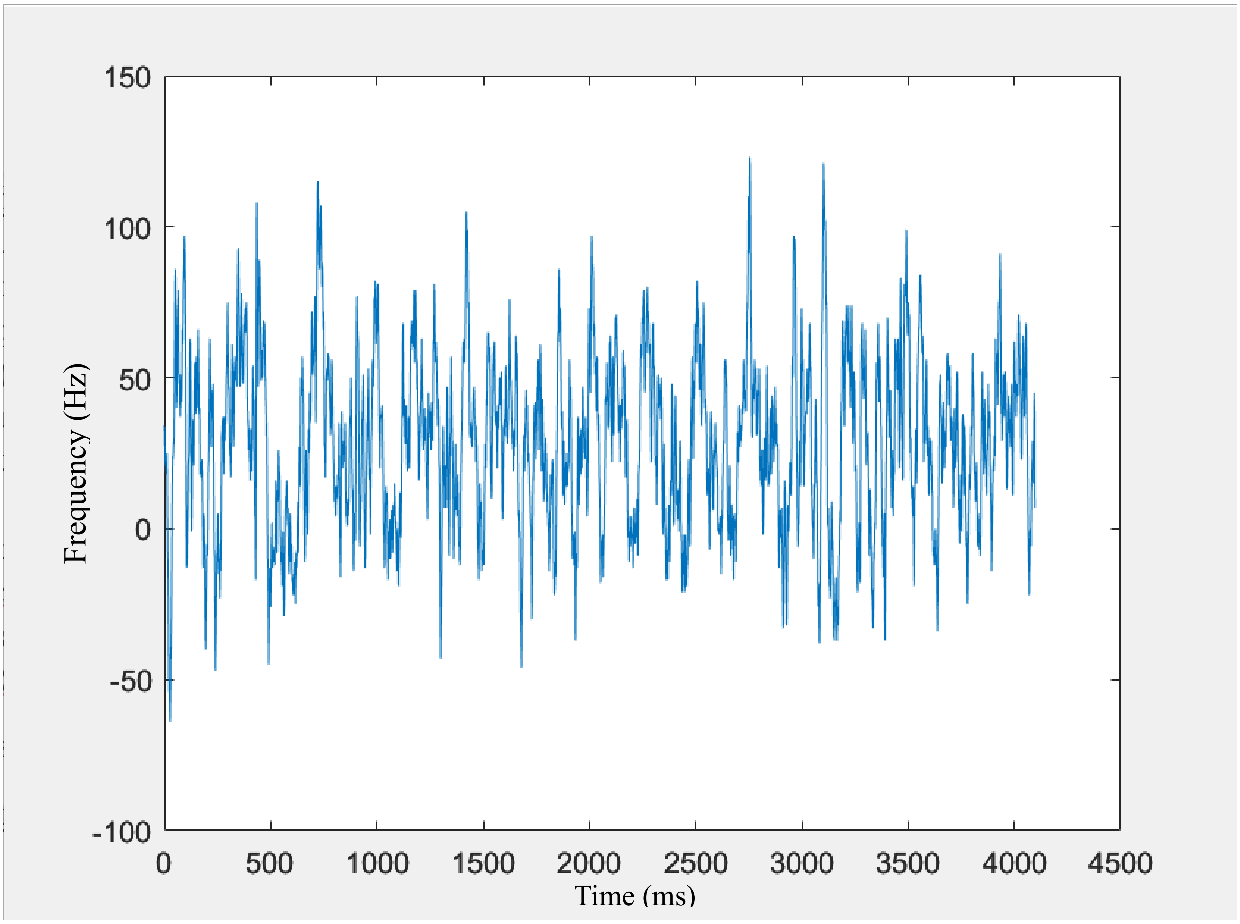
Introduction:

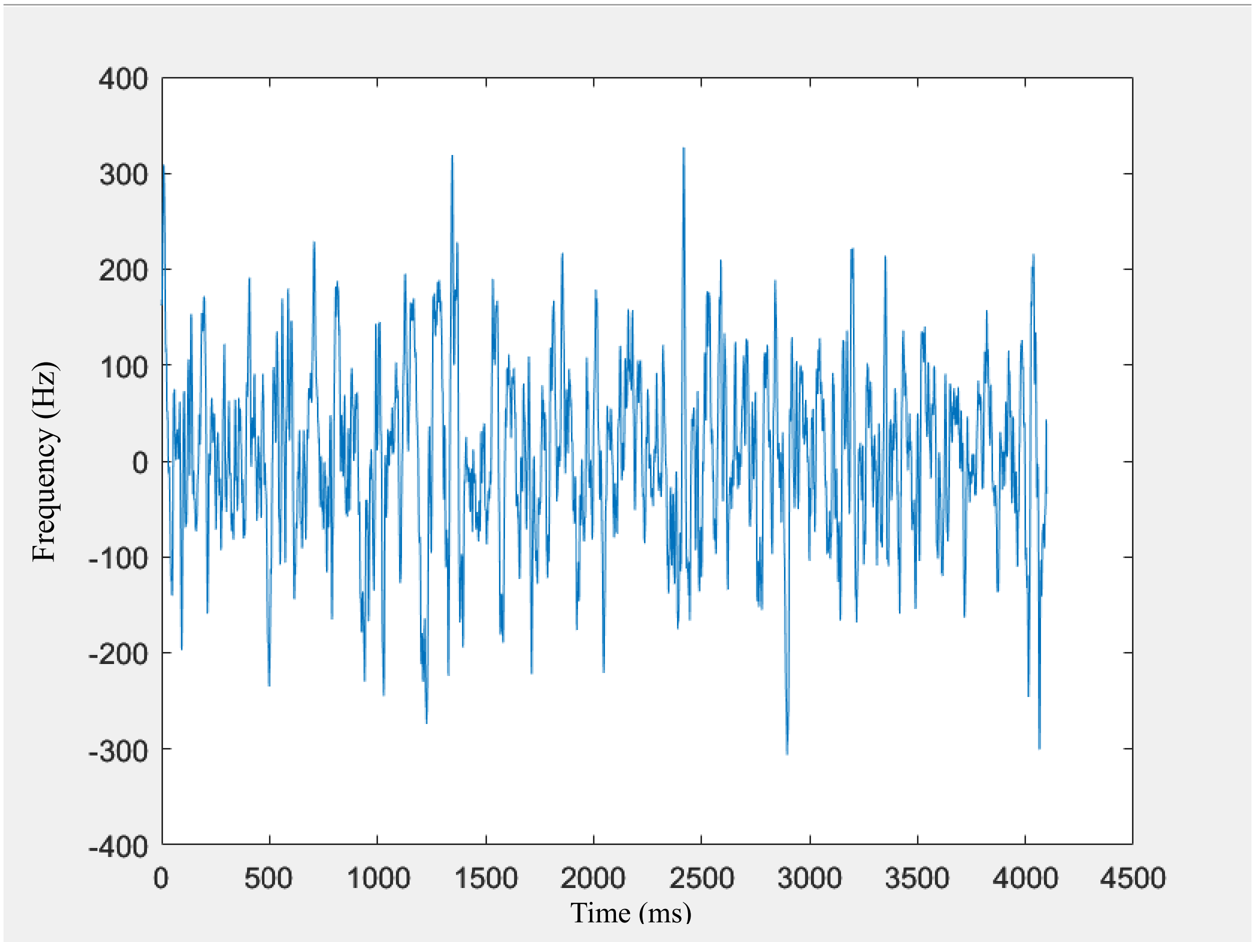
Epilepsy is a disorder involving the onset of unprovoked seizures in an individual. Although there are medicinal and surgical treatments for this disorder, many patients continue to be symptomatic and suffer a deteriorated quality of life (Sirven). One way to measure the neurophysiological function of an individual with epilepsy is through electroencephalography (EEG). When a corresponding electrode cap is placed on a patient's scalp, this device serves to measure the electrical activity of neurons firing within the brain (Light, Williams et al.). A normal EEG consists of relatively uniform amplitudes and frequencies of waveforms. Sharp changes in either of these demonstrate an abnormality in neural activity (Britton, Frey et al.). Such abnormalities that signify the onset of a seizure are called ictals. Epileptiform EEGs also contain interictals, which signify the period between seizures (Fisher, Scharfman, deCurtis). This paper will seek to interpret ictal, interictal, and normal EEG waveforms using MATLAB and ThingSpeak. Datasets F001-F100 document the interictal stage, datasets S001-S100 document the ictal stage, and datasets Z001-Z100 document normal EEG results. Signal mobility and complexity of these waveforms will also be evaluated and documented.

Waveform Plot:

Plot F001



Plot F025



400
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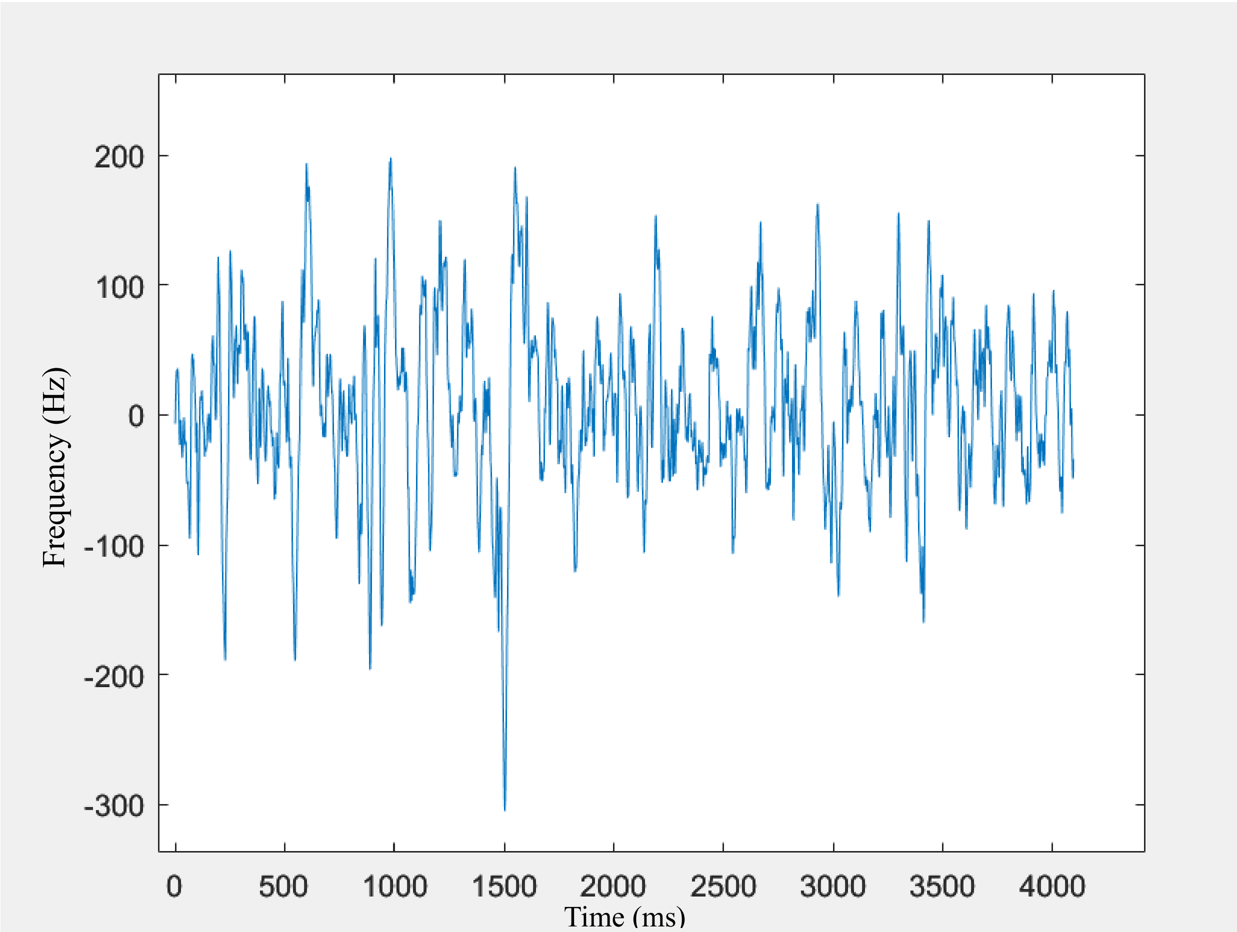
Frequency (Hz)
Time (ms)

Plot F050


Frequency (Hz)
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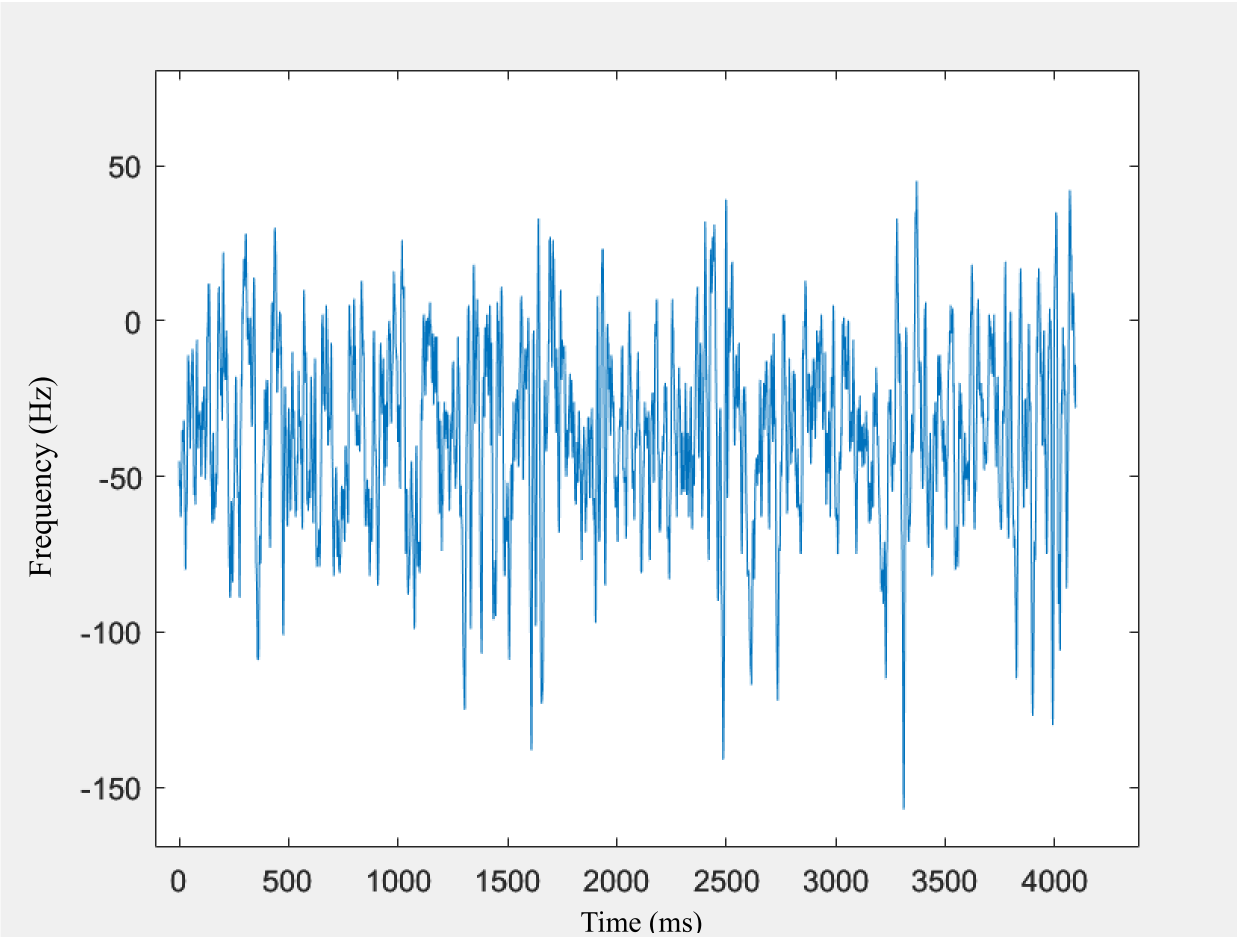
Plot F100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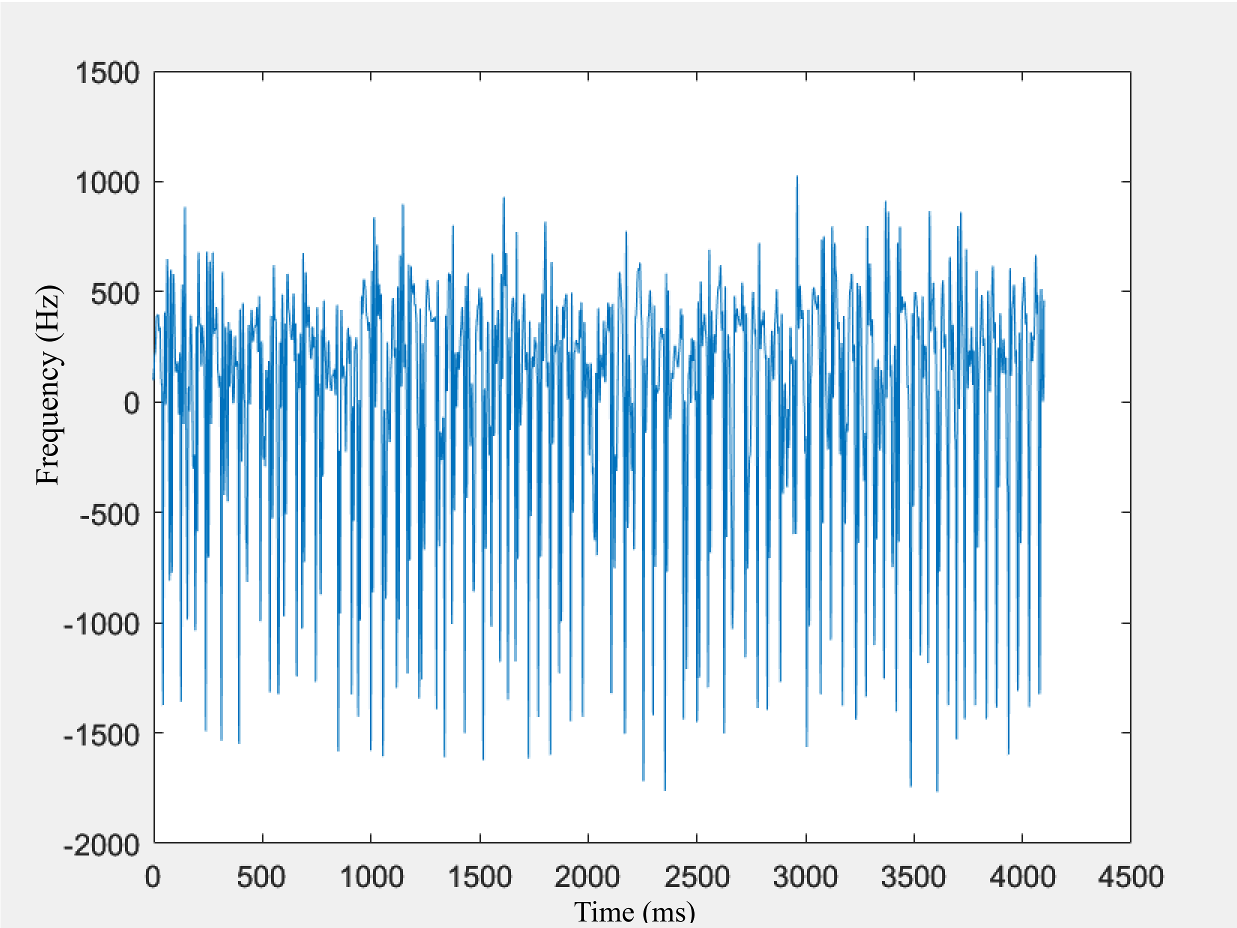
Time (ms)

Plot S001



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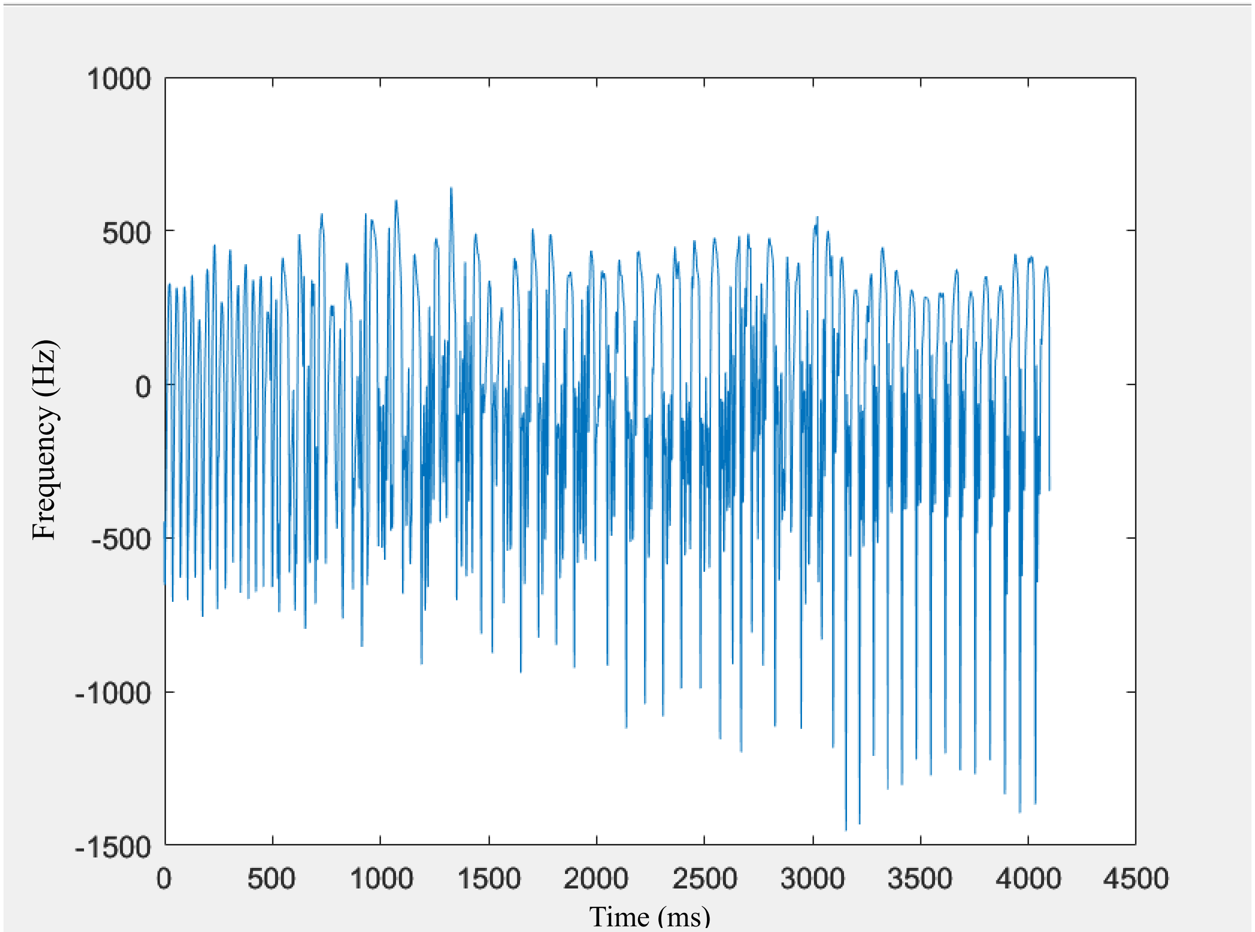
Plot S025



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Frequency (Hz)
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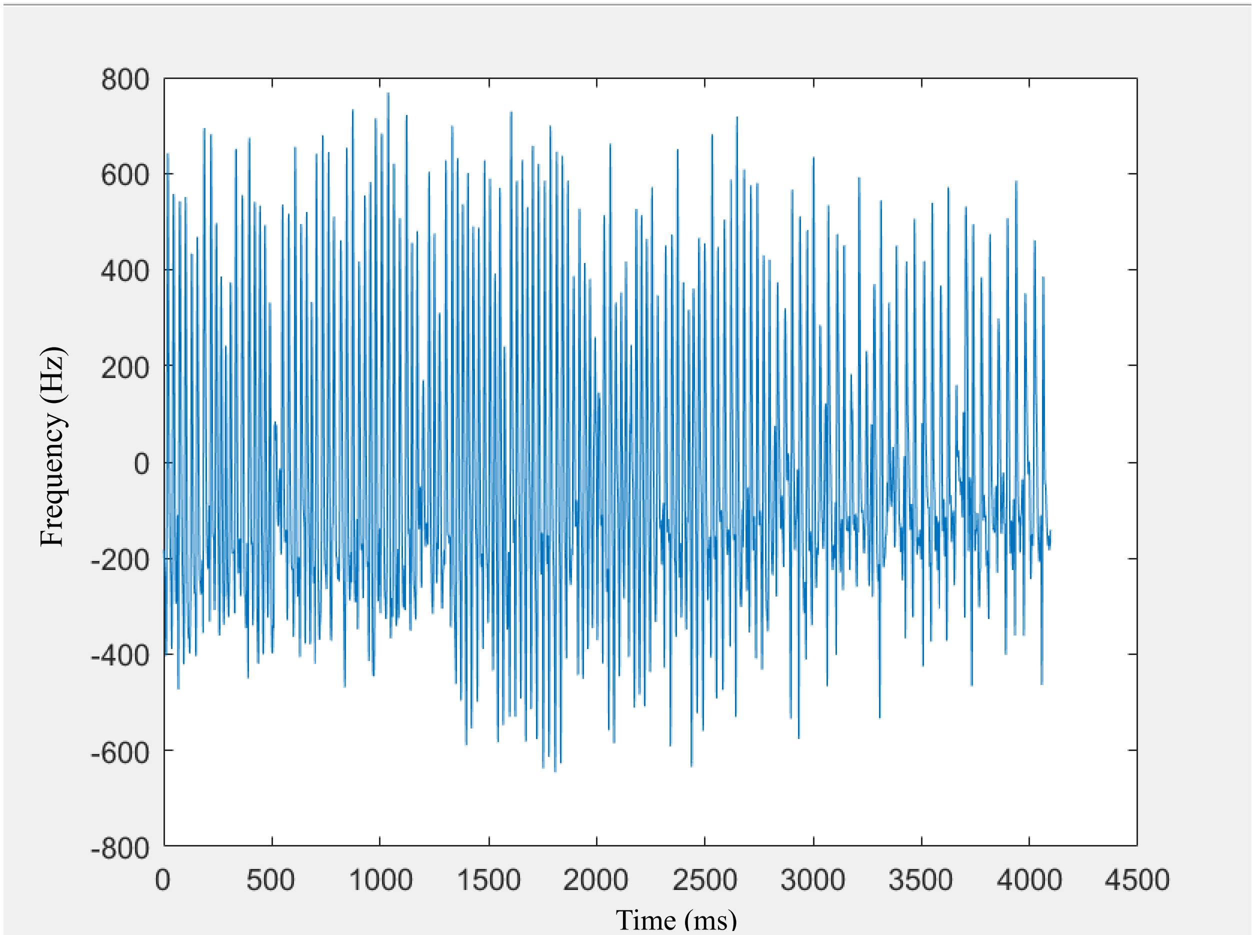
Time (ms)

Plot S050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Frequency (Hz)
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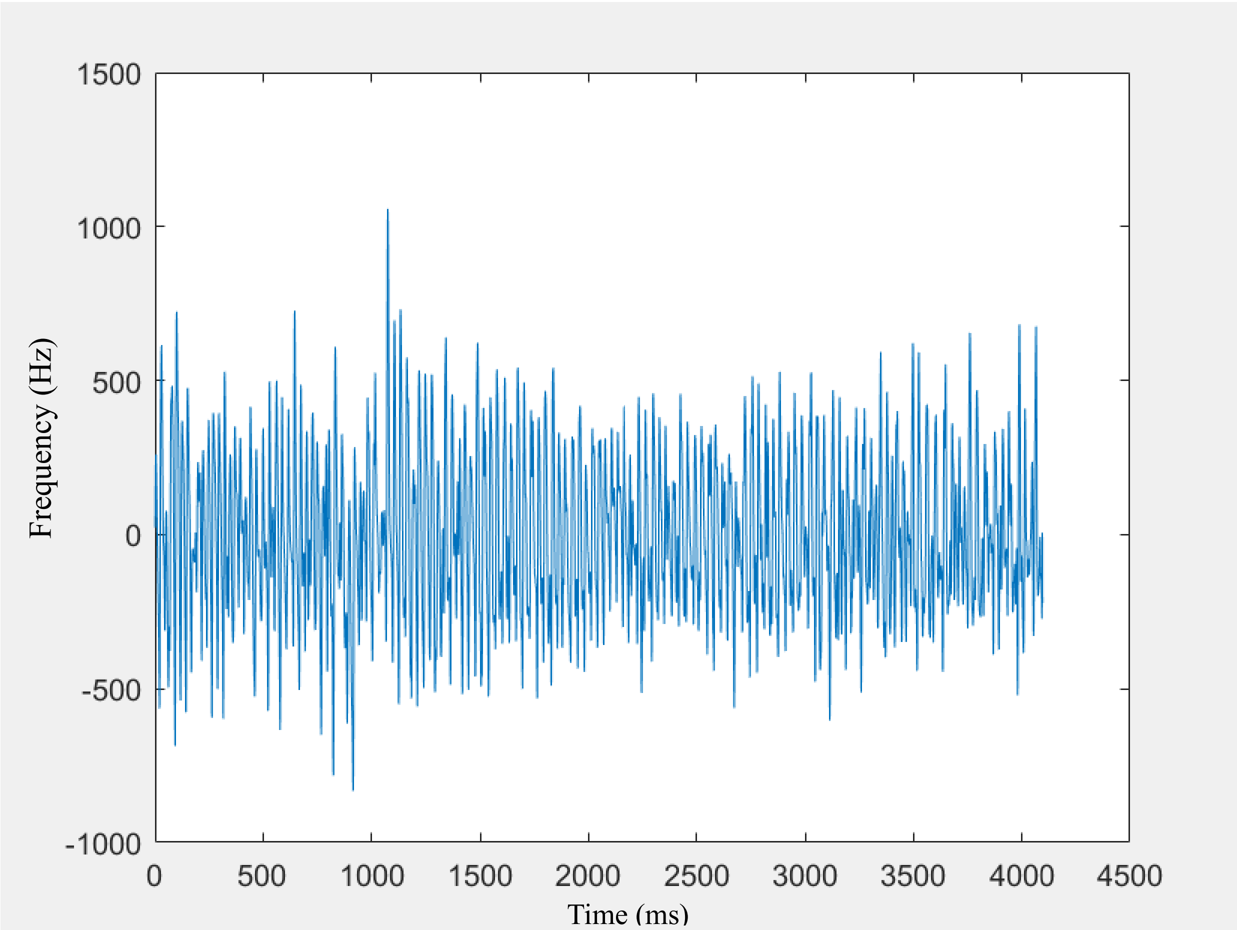
Time (ms)

Plot S100



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Frequency (Hz)
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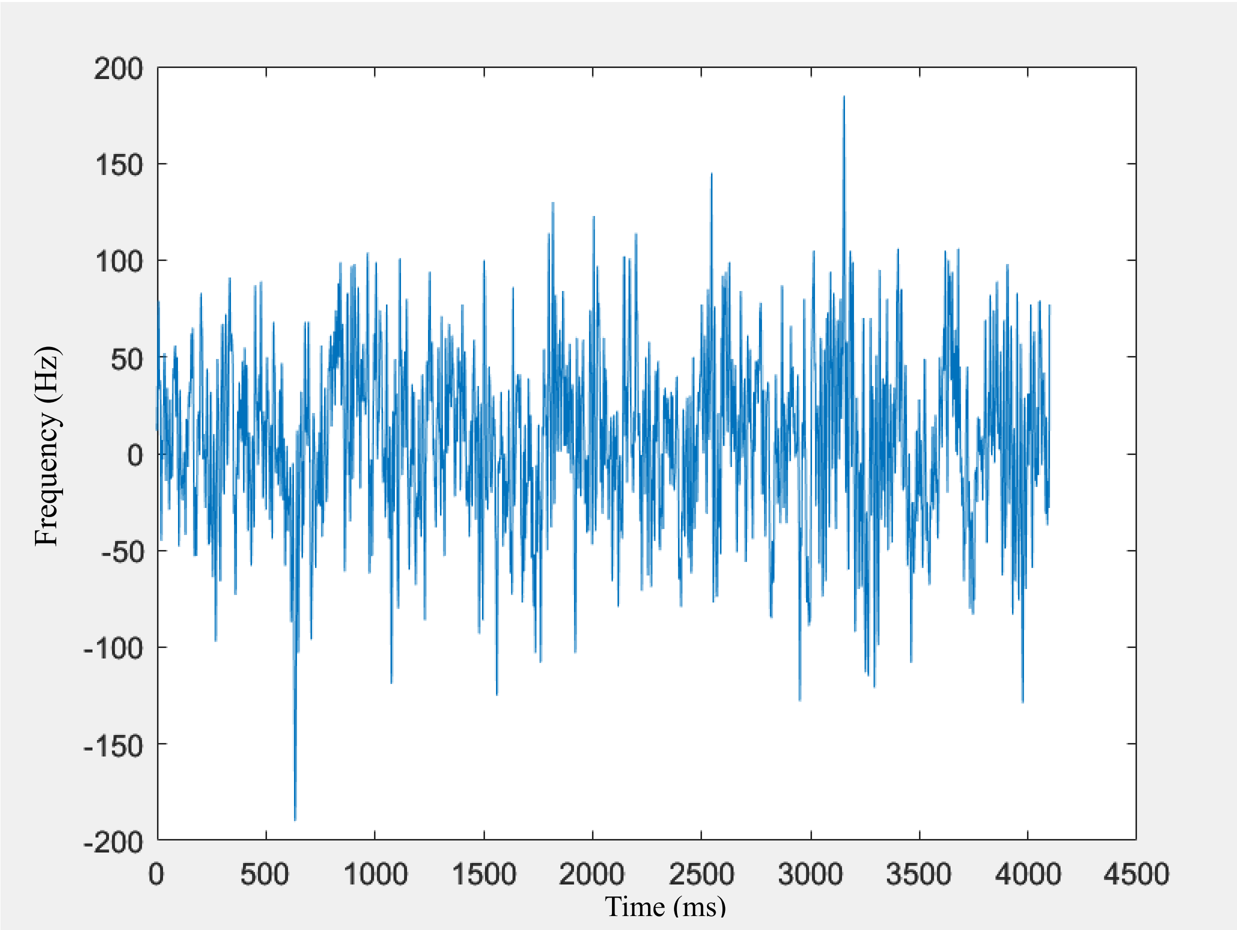
Time (ms)

Plot Z001



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Frequency (Hz)
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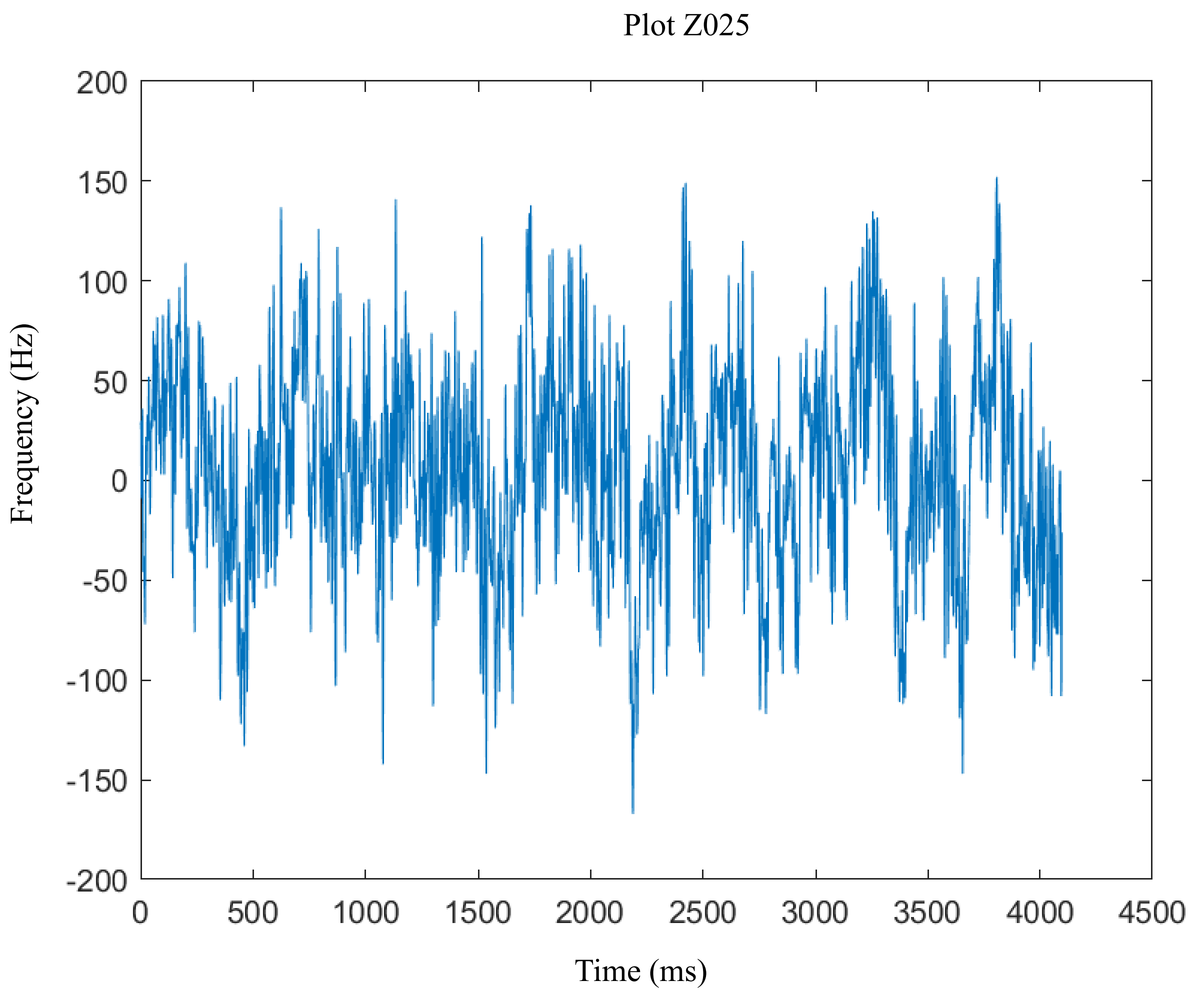
Time (ms)



Plot Z025
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-100
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-200
Frequency (Hz)
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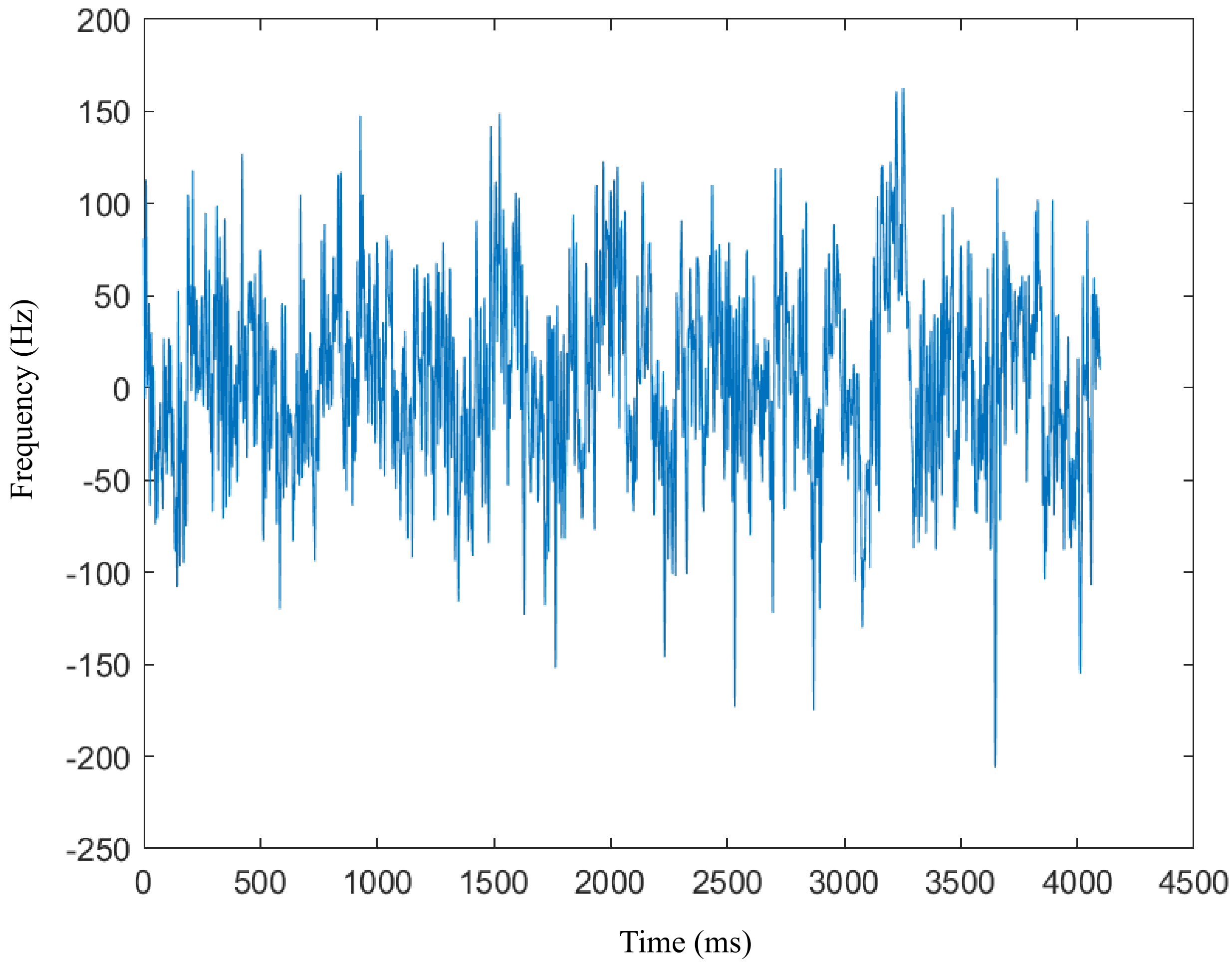
3500
4000
4500
Time (ms)

Plot Z050



200
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Frequency (Hz)
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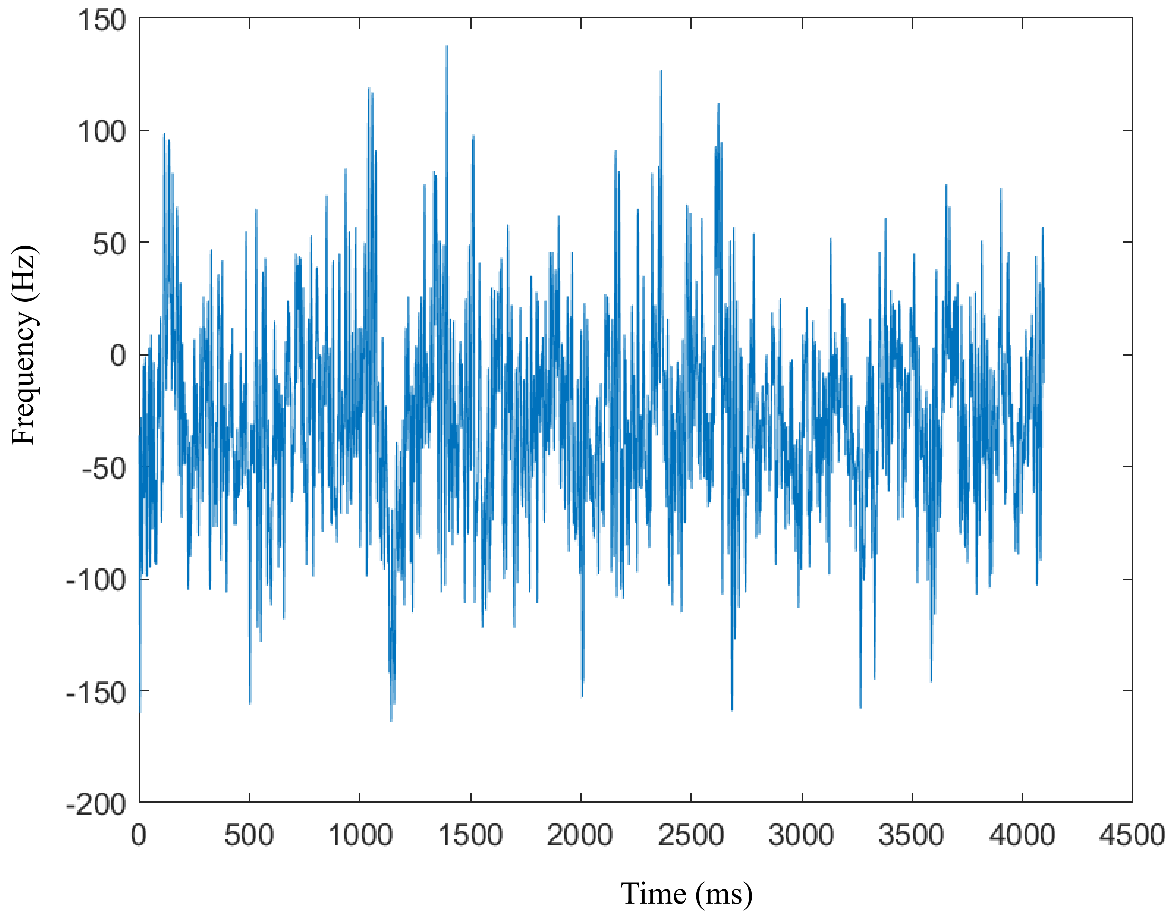
4000
4500
Time (ms)

Plot Z100



Frequency vs. time data was captured from each dataset for the waveform plots through the use of the following MATLAB code.

```
%Analysis of Seizure:  from bonn data
fs = 173.61    ;  % fs
T = 1/fs;         % sampling rate or frequency
load('Z100.mat')
y1=Z100;
N =length(y1); ls = size(y1); % find the length of the data per second
tx =[0:length(y1)-1]/fs;% Make time axis for EEG signal
fx = fs*(0:N/2-1)/N;   %Prepare freq data for plot
```

Feature extraction:

From this data, signal mobility and signal complexity were determined using MATLAB code. The mathematical expressions for each are as follows:

Signal Complexity:

$$\sqrt{}[\left(\frac{s_2{}^2}{s_1{}^2}\right) - \left(\frac{s_1{}^2}{s_0{}^2}\right)]$$

Signal Mobility:

$$\frac{s_1}{s_0}$$

Where

d = diff (y_1) → gepgypexiwxlihmjjivirgi$fix{iir$ehnegirx$ipiqirxw$sj y_1

g = diff (d) → calculates the difference between adjacent elements of d (diff (y_1))

s_0 = rms(y_1) → calculates the root mean square ($\sqrt{\frac{1}{n}}\sum_i {y_i}^2$) for values of y_1

s_1 = rms(d) → calculates the root mean square for values of d

s_2 = rms (g) → calculates the root mean square for values of g

Root Mean Square:

$$(\sqrt{\frac{1}{n}}\sum_i {y_i}^2)$$

Where n is the number of measurements, and y_i is the numerical value of each measurement

The following is the MATLAB code used to determine signal mobility and signal complexity from each dataset:

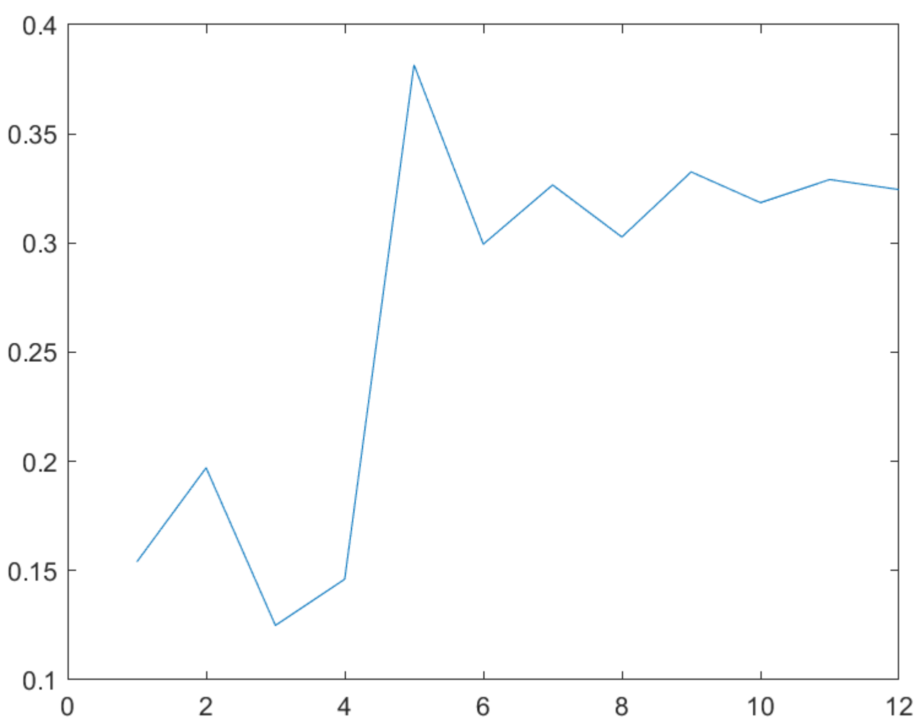
```
%The quadratic mean of the second column is:
%%%%
d = diff (y1);
g = diff (d);
so = rms(y1);
s1 = rms(d);
s2 = rms (g);
%%%%%%%%%%%%%%%%%
signal_complexity = sqrt((s2^2/s1^2) - (s1^2/so^2))
signal_mobility = s1/so
```

Experimental Results:

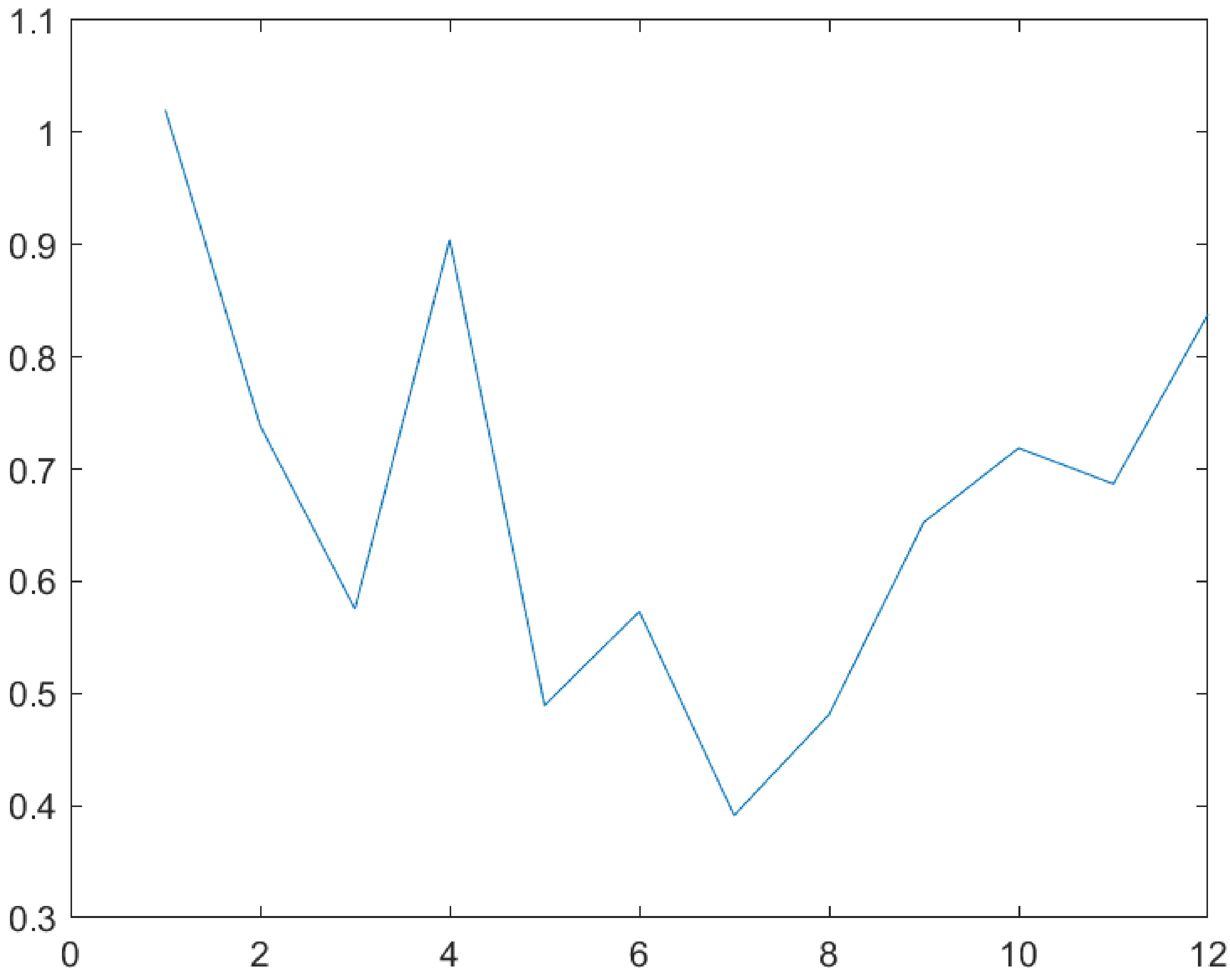
Signal Mobility and Signal Complexity Dataset

Data Set	Signal Mobility	Signal Complexity
F001	0.154	1.0202
F025	0.1971	0.7388
F050	0.1249	0.5754
F100	0.1461	0.9045
S001	0.3816	0.4894
S025	0.2995	0.573
S050	0.3266	0.3913
S100	0.3028	0.481
Z001	0.3326	0.6525
Z025	0.3185	0.7187
Z050	0.3291	0.6868
Z100	0.3245	0.8383

Signal Mobility Plot



Signal Complexity Plot

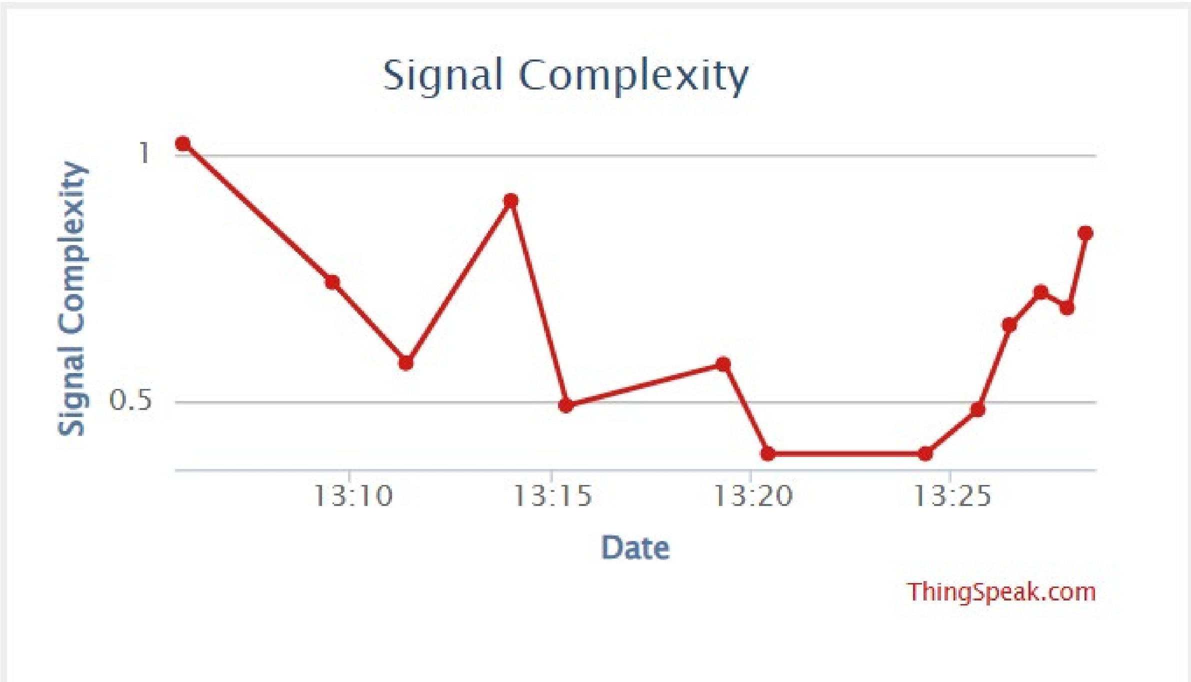


IoT Implementation:

The following MATLAB code was used to upload signal complexity data to the ThingSpeak channel.

```
thingSpeakWrite(2606684,[signal_complexity],'Location',[1,2,3],'WriteKey','N7BNABF0GRPY7T6W')
```

ThingSpeak Plot



Conclusion:

In conclusion, this paper successfully utilized MATLAB and IoT implementation to analyze EEG data. As seen from the results, the ictal stage dataset (S001-S100) had high signal mobility and signal complexity. The ictal stage also presented higher and more varying frequencies than that of the other data sets. In the normal EEG waveforms (Z001-Z100), frequencies tended to stay between the -200-200 interval, while those in the interictal stage (F001-F100) experienced periodic spikes up to 350 Hertz. In summation, this study on ictal, interictal, and normal EEG waveforms in comparison to signal mobility and signal complexity can serve as a great insight into the treatment of epilepsy and prevention of seizures.

Works Cited

Sirven JI. Epilepsy: A Spectrum Disorder. Cold Spring Harb Perspect Med. 2015 Sep 1;5(9):a022848. doi: 10.1101/cshperspect.a022848. PMID: 26328931; PMCID: PMC4561391.

Light GA, Williams LE, Minow F, Sprock J, Rissling A, Sharp R, Swerdlow NR, Braff DL. Electroencephalography (EEG) and event-related potentials (ERPs) with human participants. Curr Protoc Neurosci. 2010 Jul;Chapter 6:Unit 6.25.1-24. doi: 10.1002/0471142301.ns0625s52. PMID: 20578033; PMCID: PMC2909037.

Britton JW, Frey LC, Hopp JLet al., authors; St. Louis EK, Frey LC, editors. Electroencephalography (EEG): An Introductory Text and Atlas of Normal and Abnormal Findings in Adults, Children, and Infants [Internet]. Chicago: American Epilepsy Society; 2016. The Normal EEG. Available from: https://www.ncbi.nlm.nih.gov/books/NBK390343

Fisher RS, Scharfman HE, deCurtis M. How can we identify ictal and interictal abnormal activity? Adv Exp Med Biol. 2014;813:3-23. doi: 10.1007/978-94-017-8914-1_1. PMID: 25012363; PMCID: PMC4375749.