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BE 260 Signal Project – Written Report

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I. Signal Description

The signal chosen for analysis is a respiratory signal that represents the inhalation and exhalation patterns of a subject's breath over a select period of time. This particular signal was collected using a method known as ECG-Derived Respiration, which will be described later. As can be seen in a plot of the signal (Figure 1), the patient's breathing occurred in a consistent and periodic pattern, which would be expected of a healthy person. The x-axis shows the progression of time during data collection, while the y-axis indicates the magnitude of the signal. The sampling interval for this signal is 0.008 seconds, the sampling frequency is 125 samples per second, and the sampling period is 160 seconds.

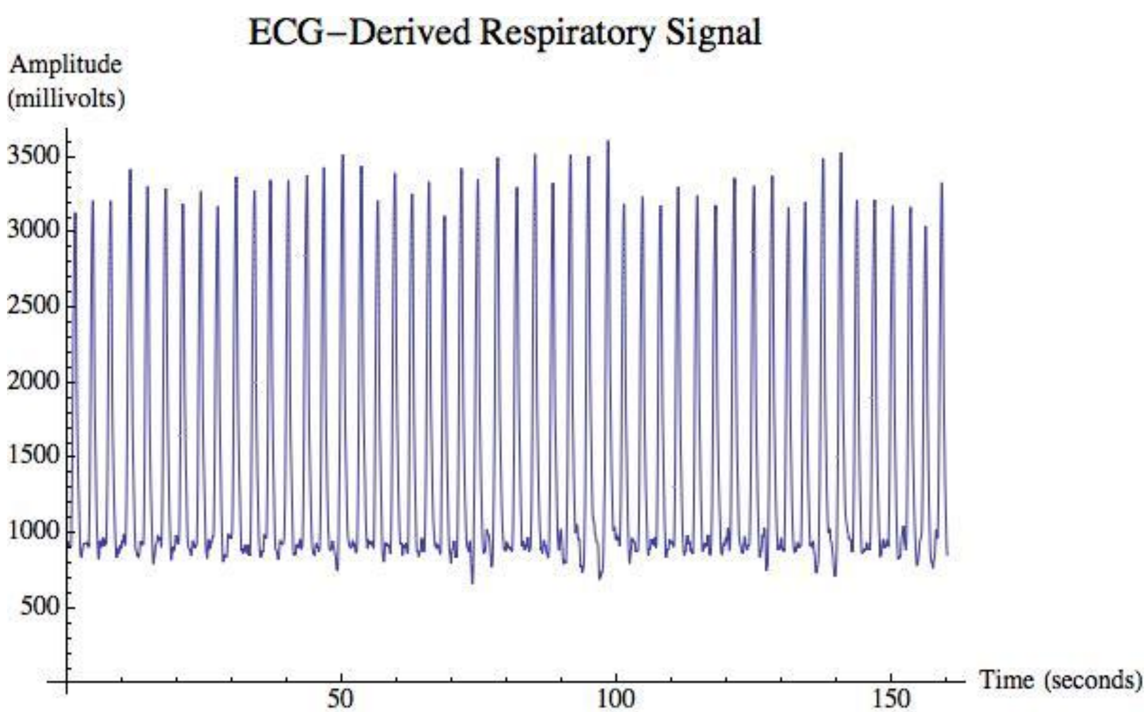

Figure 1. A plot of the respiratory signal

II. Data Collection

Respiratory signals can be collected with a variety of techniques. There are two broad categories of measuring respiration: direct methods and indirect methods. The direct measurements of breathing commonly involve the usage of a spirometer or thermocouple. These tools physically measure the volume of air inhaled and exhaled by a patient, with data collection relying on the expansion and contraction of the lungs. Usually, the focus of these direct techniques is to detect irregularities in the amount of air that enters the lungs and apply this information when diagnosing a patient with a breathing disorder.

Indirect methods, on the other hand, tend to focus more on identifying the rate of a subject's breathing, rather than the magnitude of their breathing. This is usually done by attaching electrodes to a patient and measuring differences in electrical activity while the person is breathing. One specific technique for collecting this data is ECG-Derived Respiration (also known as EDR), which was used for the collection of the signal in Figure 1. As indicated by the name, this method is similar to the standard ECG. Electrodes are attached to the chest near the heart, but instead of measuring the electrical activity of the heart, the goal is to measure changes in voltage across the chest cavity. This process relies on the characteristic known as thoracic impedance; as the chest expands and contracts during a regular breathing cycle, the change in the volume of the chest cavity results in a change in impedance. This impedance affects the voltage reading of the ECG while a person is breathing, and will provide an EDR signal that reflects the subject's breathing rate.

The information collected from an EDR can be used to diagnose a patient with an array of breathing disorders. A common application of the EDR is the monitoring of sleep apnea. A patient with sleep apnea will experience short periods of time where they do not breathe while they are asleep. This means that the impedance across the chest cavity will remain relatively constant during that time span, and the EDR signal will show an unchanging voltage. Using techniques similar to this, doctors are able to identify many other irregularities in a person's breathing. However, there is a significant drawback to the collection of an EDR signal. Although not as invasive as direct collection methods, the EDR requires the subject to be restrained due to the electrodes' sensitivity to movement. An accurate reading can only be obtained when the subject remains immobile.

III. Fourier Analysis

The magnitude spectrum in the frequency domain for the respiratory signal reveals a large peak at 0.3 Hz (Figure 2). The successive peaks correspond to harmonics of the first peak, and are mostly unimportant in the analysis of this signal. However, the spike at 0.3 Hz can be used to determine the patient's breathing rate. In the time domain, this frequency corresponds to a 3.3 second interval between breaths. In terms of breaths per minute, dividing 60 seconds by the breathing interval of 3.3 seconds per breath yields a breathing rate of approximately 18 breaths per minute. This is in the normal range for breathing rate, so this patient can be considered to have healthy breathing.

If one was to analyze the harmonic peaks in the frequency spectrum, they would reveal the pattern of breathing in successive one-minute windows. During the test the patient was breathing at a constant rate of 18 breaths per minute, and the second harmonic frequency at roughly 0.6 Hz corresponds to 36 breaths per minute. This indicates that after 1 minute the patient breathed 18 times and at 2 minutes the patient had breathed 36 times. However, this information could have just been extrapolated from the original 1 minute window.

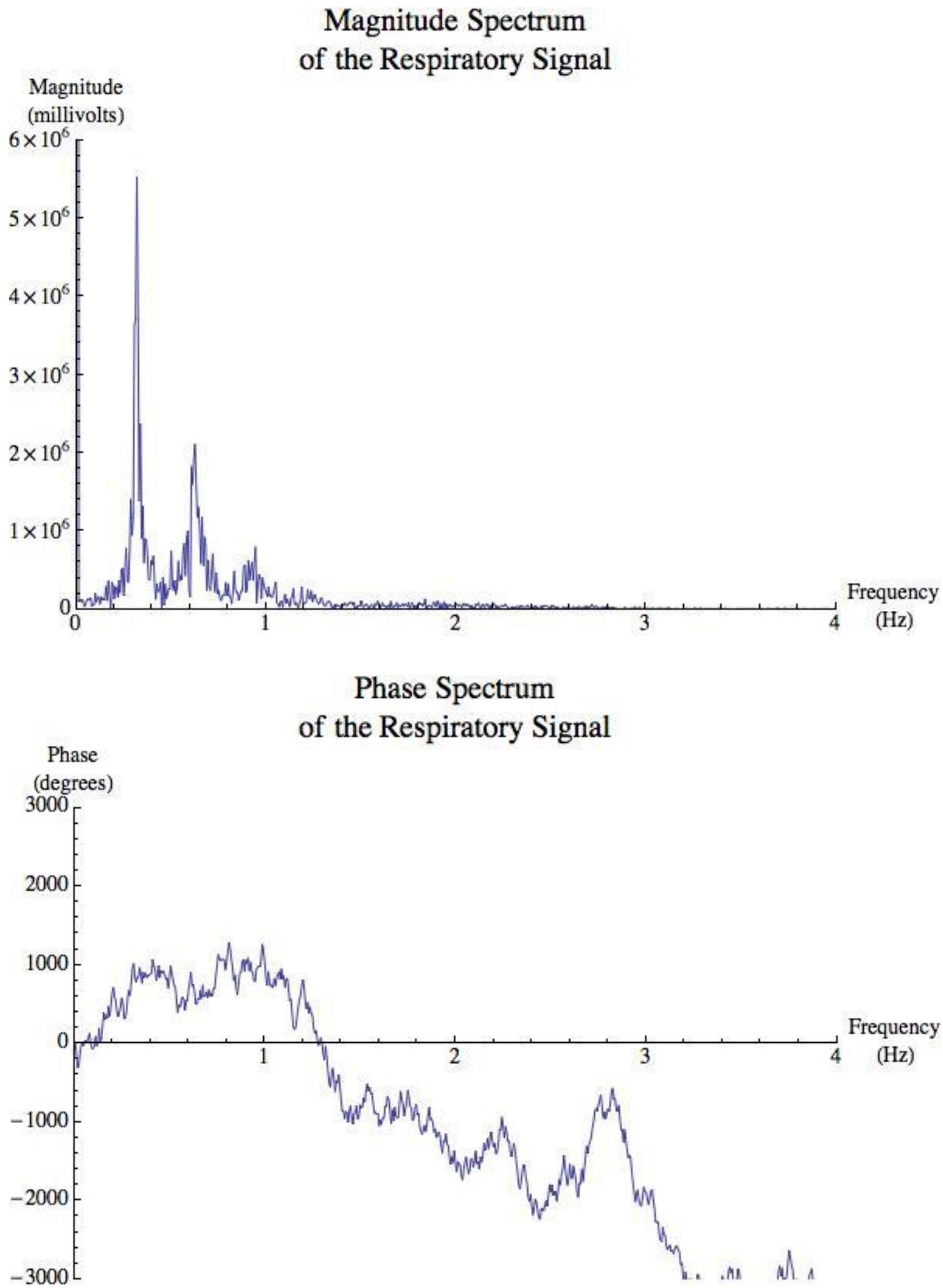

Figure 2. Magnitude and phase spectrums from Fourier analysis of the respiratory signal

IV. Signal Processing

A band-pass filter was applied to the respiratory signal for additional signal processing. The lower cutoff frequency was at 1 Hz and the upper cutoff was at 2 Hz. The chosen range of frequencies for the filter did not include the fundamental frequency of the signal. The result of applying this filter is shown in Figure 3. After applying the filter, the signal was reflected over the x-axis and the amplitude was greatly reduced. This result was completely unexpected and does not appear to have any practical use. However, the exclusion of the fundamental frequency and the inclusion of only the harmonics may partially explain the resulting signal. The original respiratory signal was already highly processed and contained almost no noise at all, so it is believed that the use of a band-pass filter revealed some artifact from the original signal. This processed signal was very interesting, but does not have much analytical use.

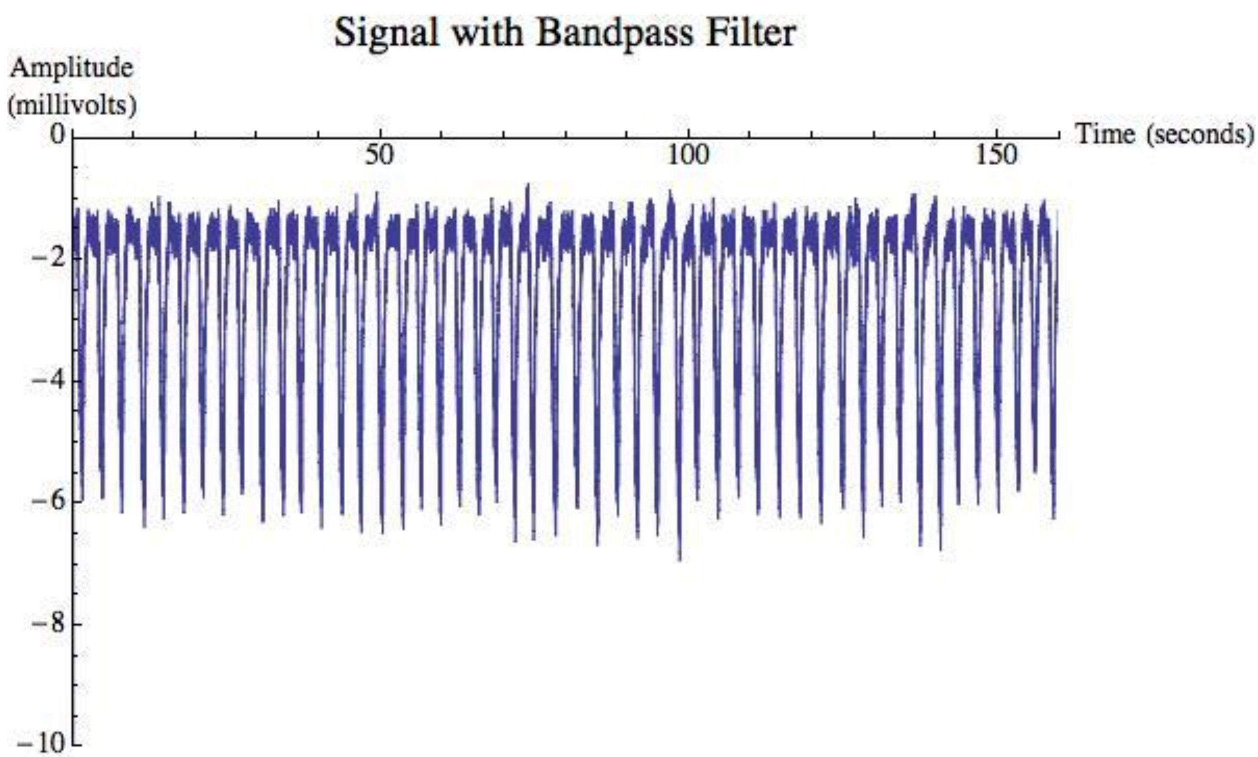

Figure 3. Application of a band-pass filter to the respiratory signal

V. Conclusion

Researching this signal introduced us to a new method of collecting information from the human body, specifically respiratory information. It was interesting to see how a well-known signal collection technique, the ECG, could be applied to collecting a completely different signal. We also learned a very practical use of the Fourier spectrum. Previously, we had never really seen the frequency spectrum applied to a specific situation, but here we were able to analyze the peak and use it to determine a patient's breathing rate. Finally, we learned that signal processing does not always produce the expected results, and can reveal hidden artifacts in a signal.

VI. References

Source of data:

Golberger et al., 2000. *PhysioNet.* National Institute of Biomedical Imaging and Bioengineering. Web. 4 April 2013 < http://www.physionet.org/>.

Credit for code for phase unwrapping:

"Re: Want a Smooth Function from Arg[ ]." *MathGroup Archive: May 1998*. Web. 8 April 2013 < http://forums.wolfram.com/mathgroup/archive/1998/May/msg00105.html>.

Source of signal information:

George Moody et al. "Derivation of Respiratory Signals from Multi-lead ECGs." *Derivation of Respiratory Signals from Multi-lead ECGs*. Web. 28 April 2013 < http://www.physionet.org/physiotools/edr/cic85/edr85.html>.