A New Method for Simultaneous EIT/ECG Data Acquisition*

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Abstract: A new method for simultaneous EIT/ECG signals acquisition is proposed. In this method, an integrate & dump filter followed by a 2^{nd} order low-pass filter separates the ECG signals from the EIT signals. The preliminary experimental results showed a good reception of a model ECG signal combined with an active EIT signal.

1 Introduction

Collecting ECG waveforms during EIT measurments is useful for providing additional clinical information as well as aligning EIT images with their location in the cardiac cycle. In earlier work on wearable sensors [1], ECG data were obtained by filtering the measured voltage with a 1^{st} order high-pass filter at 0.05 Hz followed by 2^{nd} order low-pass filter at 150 Hz.

In this work, we propose a different approach for simultaneous EIT/ECG data collection when using the adaptive current source described in [2], though the approach has wider applicability. The current source in [2] was designed, implemented, and tested for obtaining high-quality EIT images by compensating for all the current loss through any shunt impedance to the ground, i.e., delivering the desired current to the load. The proposed approach uses an integrate & dump filter designed to pass the low-frequency ECG signal and reject high-frequency EIT. The approach has low processing cost and makes it possible to simultaneously collect ECG data from all electrodes in a multi-source EIT system.

2 ECG Filter

Although the large frequency difference between the EIT and ECG signals should make the separation easy, several factors affect the filter implementation. The high sampling rate of 1.2 MHz used in [2] compared to the desired bandwidth of 150 Hz for the ECG signal requires the use of high precision coefficients for a digital LPF filter in a fixed-point format. Since the target EIT system is multi-frequency, using EIT excitations from 30 kHz to 1 MHz, downsampling is complicated by the associated aliasing of the EIT signals. Another critical factor is the large magnitude difference between the EIT and ECG signals. The system described in [2] designed to allow a maximum swing of $1V_{pp}$ for the measured EIT voltage, which is three orders of magnitude higher than the ECG signal. So high attenuation is needed to allow a high ECG/EIT signal-to-interference ratio.

The approach to recovering the ECG signal takes advantage of the EIT signal design. As in most EIT systems, the approach in [2] samples the electrode voltages at a high rate and implements a matched filter operating over an integral number of cycles of the EIT excitation signal to perform the voltage measurements. In the test system, the matched filters utilize 1024 samples and excitation frequencies are chosen such that 1024 samples represents an integral number of cycles. A consequence of this approach is that integrating (summing) the EIT signal over 1024 samples produces zero, i.e. an integrate and dump filter utilizing 1024 samples completely rejects the EIT signal for all excitation frequencies used in the system.

Following the medical standards for the ECG bandwidth, a 2^{nd} order LPF with a cutoff frequency at 150Hz was used as a final stage of filtering the received ECG signal [3]. The lower cutoff frequency is determined by the analog design of the Howland source and passive components values in [2].

3 Experiments & Results

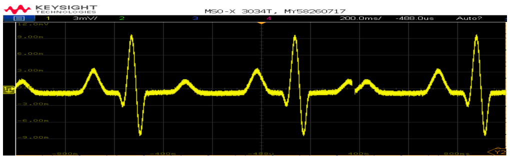

Figure 1: Generated ECG sample

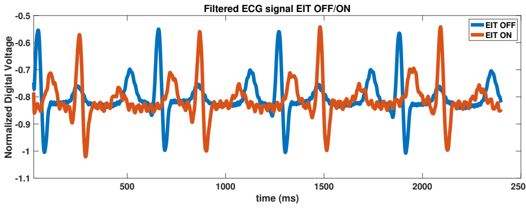

Figure 2: Received ECG Signal

Experimental results were obtained to validate the proposed approach. The lab-generated ECG signal sample is shown in fig.1 and has a repetition rate of 1.5 Hz. A resistor network is used to apply a 1 mV_{p-p} ECG signal to a 1 kΩ resistive load that can also be driven with an EIT current of 0.2mA and 93.75kHz excitation frequency. The results in fig.2 show the reconstructed ECG signal from the first 2400 measurements taken at a roughly 1 kHz rate both with and without the EIT signal present. It is important to clarify that the time delay shown between the two signals is not a result of the addition of the EIT signal. The time offset results from running both experiments independently where the first sample can be any point on the input ECG signal. The results are very promising, showing a good reconstructed ECG signal with a relatively small amount of degradation with the addition of the EIT signal.

References

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[3] International Standard *:Medical Electrical Equipment-part 2-25* IEC 60601-2-25, 2nd ed., 2011

*Research reported in this paper was supported by the National Institute of Biomedical Imaging and Bioengineering of the National Institutes of Health under award number 1R01EB026710-01A1. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.