Application And Investigation on Reconstructed Cross-Sectional Images By A Electrical Impedance Tomography Prototype In Simulate Biological Tissue With Ground Pork

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Abstract

Electrical Impedance Tomography (EIT) is a technology that uses recorded voltage data to reconstruct the distribution of electrical conductivity in a turbid medium and to illustrate the structures and abnormalities within that medium. The advantages of this imaging technology include non-ionization, non-invasive, impact and continuous monitoring, optimum design, and lower production costs as compared to current techniques such as Magnetic Resonance Imaging (MRI), Computed Tomography Scan (CT- Scan), and Ultrasonic... EIT has shown useful in a variety of medical domains, including identifying pneumothorax, assessing pulmonary edema, and evaluating ventilation distribution between different breathing modes. The EIT is also being studied for application for imaging reconstruction used to obtain images for medical imaging, geological exploration, industrial application and environmental sciences. In this research, a system of 16 electrodes is manufactured for simulate biological tissue using ground pork to simulate the internal environment of the human body. The confirmed experiments are carried out using a phantom while the frequencies between 10kHz to 100 kHz are changed. An Arduino and a PC are used to collect and process the measured data. Electrical Impedance Tomography and Diffusion-based Optical Tomography (EIDORS) software is used to recreate the cross-sectional image. The image reproduced at 100 kHz gives high accuracy to the reconstructed subject.

1. Introduction.

The imaging method known as Electrical Impedance Tomography (EIT) is very recent. With this technique,an array of external electrodes may be used to create reconstructed pictures of the inside of a conductive subject. It is compact, quick, affordable, and patient-friendly. With this imaging technique, the interior portion of a typical conductive subject's electrical conductivity (or electrical impedance) distribution may be seen. The technique of reconstructing an image involves injecting a precise current through two electrodes into the subject's border, monitoring the boundary voltages with the help of other electrodes nearby, sending the data to a computer, and processing the results using reconstruction software.

This paper offers a preliminary study with a self-developed prototype of 16 electrodes with an analysis of the influence on the cross-sectional reconstructed picture by using a biological tissue simulator through ground pork that simulates a part of the human body. While adjusting the frequency with the aim of producing a low-cost electrical impedance tomography device for future research. The identical current pattern is used in experiments with a real phantom while the frequency is varied between 10.0 kHz, 50kHzand 100.0 kHz. Electrical Impedance Tomography and Diffuse Optical Tomography Reconstruction Software (EIDORS) is used to rebuild cross-sectional images. The program is MATLAB-based and incorporates forward and inverse modeling methods for EIT.[1]

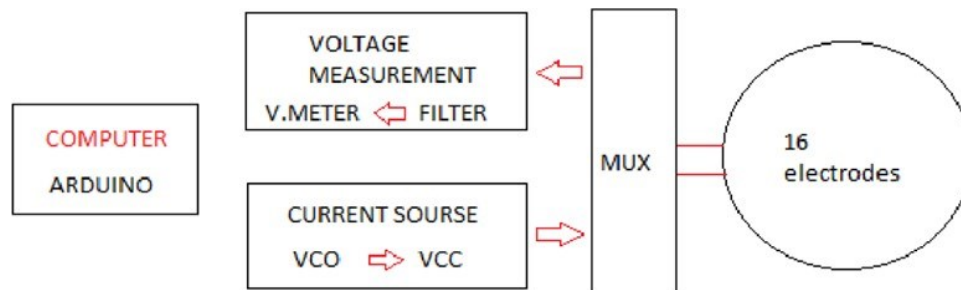# 2. Methods and Implementation

2.1. Block diagram

Fig. 1. Block diagram of a standard EIT system

A typical schematic of a 16-electrode EIT system with its constituent parts is shown in Figure 1. The array of electrodes is fastened to the basin. To biological tissue simulation, a solution that includes ground pork placed in the basin to simulate the environment in the body. With the neighboring electrode method, a current source creates a steady sinusoidal alternating current to inject the phantom surface. Through nearby electrodes, the current is applied. Without include the pairings containing both the current electrodes, the voltage is measured successively from all other nearby electrode pairs. The voltmeter and current injector electrodes are switched between the various electrodes using a multiplexer circuit. Voltage is measured with a demodulator and voltmeter. Filters are employed, and the computer is interfaced with using the Analog to Digital Converter (ADC) module which transforms analog signals to digital signals. [2]

2.2. Current injection and data processing

An Arduino Mega-2560 is used in this research to detect voltage and control the multiplexer module. The modified Howland-based voltage control current source is made using the Voltage-Controlled Oscillator (VCO) and the Voltage-Current Converter (VCC) with two high-speed Op-Amp AD811. The exact sinusoidal waveform produced by the VCO is common for most applications. In this work we use a variety of frequencies, between 10.0 kHz to 100.0 kHz and the generated current ranges from 0 to 100 mA to investigate the voltage distribution in biological tissue simulation.

The Voltage-Controlled Oscillator (VCO) circuit functions as a signal generator to generate an alternating voltage in system. The alternating voltage can be produced by any commercially available function generators or by using a voltage-controlled oscillator (VCO) circuit. [2] In this study, we used Tektronik AFG3252C for create frequencies

The Voltage-to-Current Converter (VCC) and a waveform generator make up a common current source seen in EIT systems. Having a high output impedance is necessary for the VCC in an EIT system since it needs to be stable and very precise. Thus, it is crucial to consider how this component is designed. In most cases, the sinusoidal waveform produced by the waveform generating portion, whether in digital or analog form, is the waveform that is employed in EIT systems. The following are the key characteristics of a typical waveform generator: an accurate output waveform, a low output impedance, a broad bandwidth, and a constant amplitude over the frequency range. A high output impedance, linearity in converting voltage to current, precision of output waveform, support for a wide variety of loads, and correct operation in a wide range of frequencies are other key characteristics of an outstanding Voltage-to-Current Converter (VCC) component. [2]

2.3. Filter

To have an exact waveform without any jitter, noise and distortion, and also to create low output impedance for the next stage a Butterworth band-pass filter has been designed and put between the VCO and VCC parts. There are three filters which the signal must pass: 50.0 Hz notch filter, low pass filter, and high pass filter to get rid of the noise. When the multiplexer receives the boundary potentials, it measures the voltage and sends the information immediately to Arduino, where it is transformed into Excel data for image reconstruction. [1]

2.4. Multiplexer module

In EIT, a boundary potential is measured after a specific current injection technique injects a sinusoidal current signal with a constant amplitude to the boundary of the item being tested. Consequently, switching the surface electrodes is the main task, which calls for a programmed electrode switching system. The practical phantom with a module made up of four analog multiplexers the data gathering apparatus. The electrode switching module is created by shorting all of the comparable pins on four 16:1 MUXs and connecting the common point to the relevant electrodes. The system must measure the voltage potential at all electrodes while also applying a specific current to a selection of those electrodes. Many measurements must be made in such a case, and a high-speed switching mechanism is required.[3]

Fig. 2. CD74HC4067 16-Channel Analog Digital Multiplexer Breakout Board Module
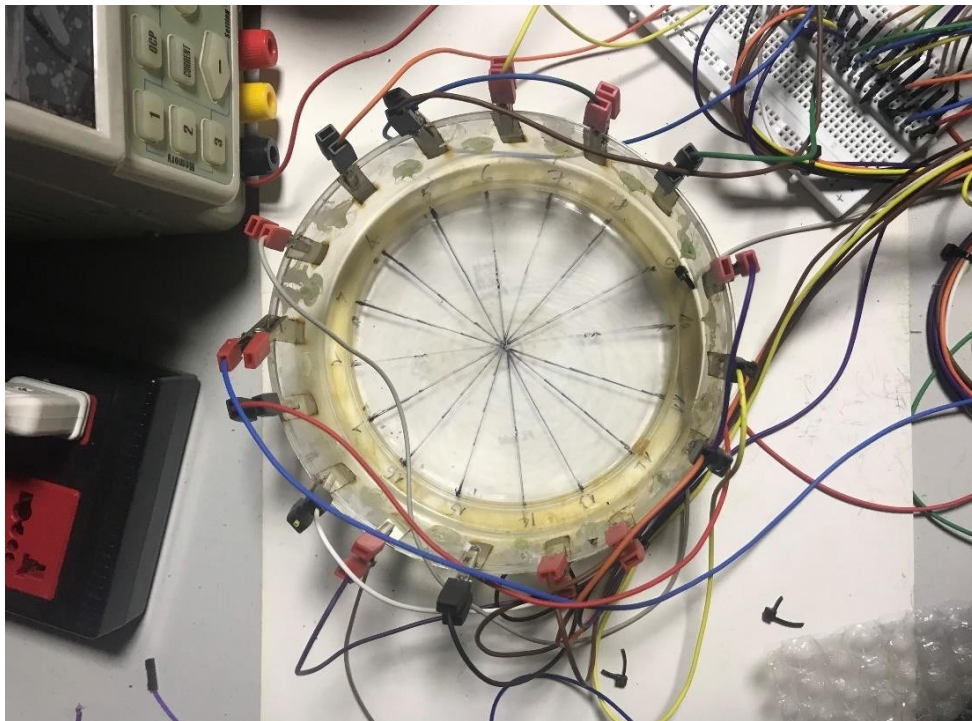
2.5. Phantom

Fig. 3. Illustration of the phantom

As seen in Fig. 3, the practical phantom is a shallow basin (150.0 mm in diameter) with sixteen stain steel electrodes equally spaced throughout the inside wall. Electrodes are composed of a rectangular sheet of high-quality stain steel that is 1.0 mm thick. The EIT electrodes are connected to the system via conventional ECG cables and steel crocodile clips. 500 grams of ground pork is filled inside the tank, the meat composition includes a mixture of lean and fat that can simulate the environment inside the human body, shown in Fig. 4.
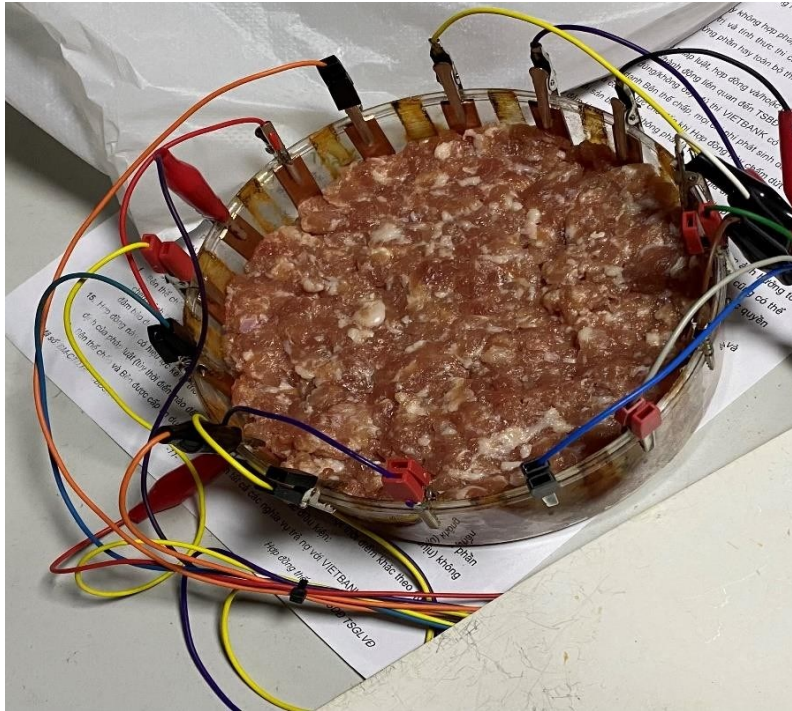

Fig. 4. Experimental phantom includes a shallow basin with sixteens stain steel electrodes

3. Results

The resistivity distribution is reconstructed using EIDORS toolkit. Electrical Impedance Tomography and Diffuse Optical Tomography Reconstruction Software (EIDORS) used for EIT reconstruction and modeling for medical and industrial applications. This is the platform with many reproducible algorithms and is run on Matlab.

In this study, we tested the measurement on ground pork and placed inside non-conductive and non- conductive objects, reproducing images at 3 frequencies: 10 kHz, 50kHz and 100 kHz.

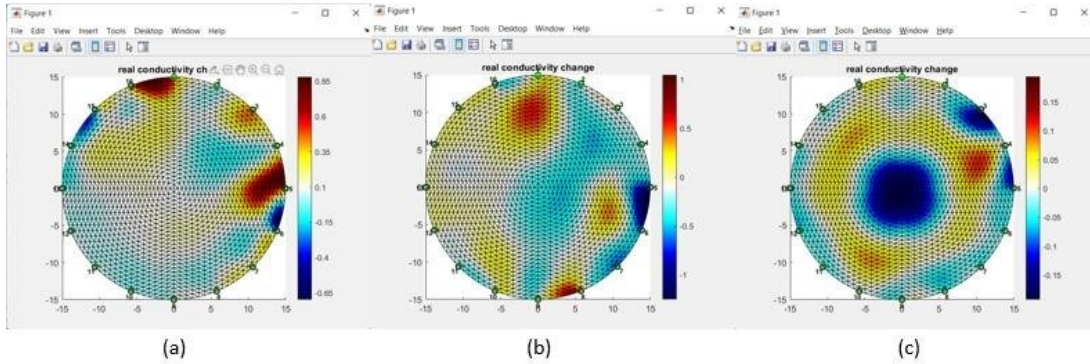## 3.1. Non – conductive object

Fig. 5. Reconstructed image by EIDORS using 1 non-conductive object placed center of phantom; (a) 10.0kHz, (b) 50.0 kHz, (c) 100.0kHz
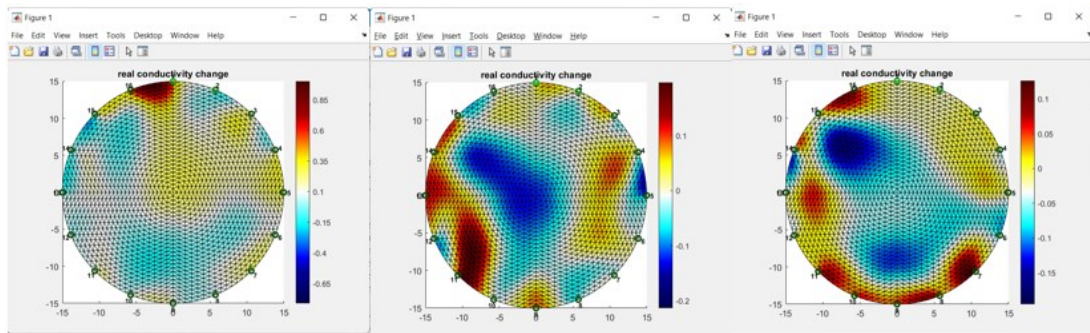

Fig. 6. Images reconstructed with two non – conductive object near 10th and 14th electrodes; from left to right: 10.0 kHz, 50 kHz and 100.0 kHz.

The first experiment, we put a non – conductive item in the center of the ground pork meat tank (Fig. 4). In the second phantom, two non – conductive objects put near the 10th and 14th electrodes (Fig. 5). Experiments are conducted for measuring the voltage and reconstructing the cross-sectional image at 10.0 kHz, 50.0 kHz and 100.0 kHz. The blue area represents the location of the objects.
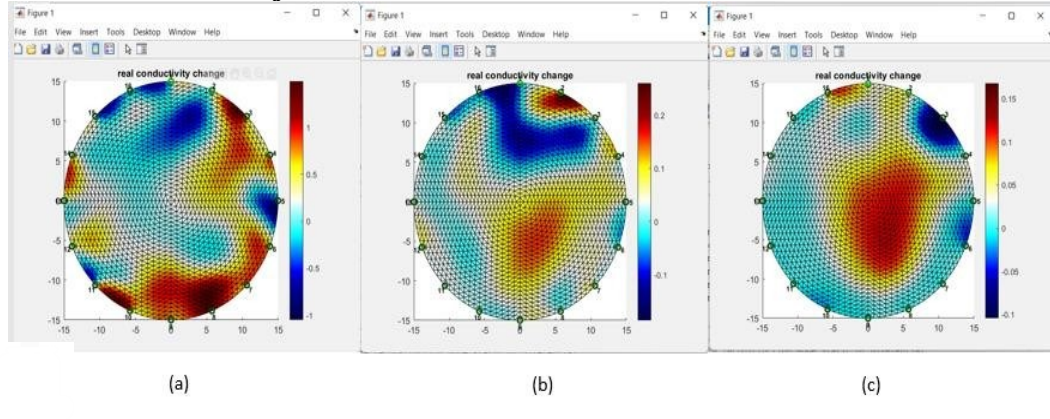
3.2. Conductive Object

Fig. 7. Images reconstructed with conductive object near the center of the basin; (a) 10.0 kHz, (b) 50 kHz, (c)100.0 kHz.

Figure 6 illustrates the cross-sectional images reconstruction during measure at 3 different frequencies which are 10.0 kHz (left), 50 kHz (center) and 100.0 kHz (right) with conductive item near the middle of the basin.

4. Discussion

The self-developed EIT system is capable of performing the measurement, as shown in figures 4, 5, and 6. The images created via cross-sectional reconstruction are quite clear. Simulating biological tissue with ground pork and the objects placed inside can reproduce the image and position of those objects well. The image reproduced with 10.0 kHz is quite good for non-conductive objects, but when placing a conductive object, the reconstructed image cannot clearly see the object's position. For frequencies of 50 kHz, both

conductive and non-conductive, the image is quite well reproduced of the object in terms of size and position, but the noise is still relatively high. At 100 kHz, the image reproduces objects close to their true size as well as the position of the common in the tank, the conductivity distribution is also more accurate than at 50kHz.

5. Conclusions

The studies are carried out in ground pork to imitate the bodily environment with various frequencies in an effort to create a low-cost electrical impedance tomography device. The cross-sectional reconstructed resistivity distribution picture may be created by employing a 16-electrode

self-developed prototype and EIDORS software. The outcome supported and validated the viability of self-developed EIT system-based cross-sectional image reconstruction. The preliminary findings indicate that 100.0 kHz is a good frequency for future investigations.

Conflicts of Interest

The authors declare no conflicts of interest.

Acknowledgement

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