International Journal of
Intelligent Systems and
Applications in Engineering
IJISAE
ISSN:2147-6799 www.atscience.org/IJISAE
Advanced Technology and Science
Original Research Paper

Analysis and Validation of medical Application through Electrical Impedance based System

Ramesh Kumar[1], Sharwan Kumar[1], A. Sengupta[2]

Accepted : 06/12/2017 Published: 30/03/2018

Abstract: This paper discussed the Design and implementation of the electrical impedance-based system, which covers both techniques (Impedance Plethysmography (IPG) and Electrical Impedance Tomography (EIT)). The electrical impedance distribution image of the cross-section of a phantom based on current excitation and voltage measurement using electrodes pair is reconstructs image according to the electrical property of the medical phantom. The electrical impedance based image provides the significant morphological information. Image quality depends upon many other iterative process and image processing algorithms in addition to. The hardware designing of the system is a most important part of all impedance-based techniques. In measurement section, the current source of the electrical impedance-based system should supply multi-frequency signal for measurement because it provides more useful information about the phantom. Therefore, a signal source that provides accurate excitation and a reference signal for measurement is more useful. Matlab is used for image reconstruction and processing of the impedance data.

Keywords: *Impedance Tomography, Image Reconstruction, impedance plethysmography, Phantom, morphological Information*

1. Introduction

Recent techniques are based on electrical impedance, like impedance plethysmography [8] (IPG) and electrical impedance tomography (EIT) [1]. The electrical impedance tomography is a technique in which images are reconstructed by the interior structure of an object. In EIT as the expression explains, different impedance and electrical conductivity of objects or phantom help to reconstruct the image [5]. For this electrode are uniformly attached, a current pulse is flow and images are reconstructed based on the measured voltage across the phantom. The current pulse must have a frequency range between 10 to 100 kHz and amplitude of the current wave up to 5 mA [6]. EIT technique is a non-invasive medical imaging in which current is applied to the surface of the object/body through contact electrode and the resulting surface voltages obtained from the subject, are used in the reconstruction of images which provides various information about the human body [6]. In EIT technique can be used monitor and measure of electrical activity of the body parts [2]. It identifies any damage to body muscles, checks the position of the body organs and muscles and investigates the effect of drugs.

Impedance-based system (EIT system) in medical application more used because of the difference in bioelectrical properties between tissues, the conductivity distribution can show the structural and functional properties of the subject [9]. Different organs of human body show a variation in bioimpedance imaging [1]. Bioimpedance is used to calculate many physiological parameters. The bioelectrical property change due to physiological variation, such as increased blood volume in lungs, which can be imaging as a varying conductivity distribution [6] [1].

[1] Dr. B. R. Ambedkar National Institute of Technology, Jalandhar, India
[2] Indian Institute of Technology Delhi, India
* *Corresponding Author: Email: rameshk.ic.14@nitj.ac.in*

In the following sections, the paper is prepared in a precise manner. In section 2 the materials and methodology of the technique, in section 3 proposed system, such as electrodes, current source, multiplexer module, control unit, and serial communication device with the computer have been discussed. In section 4, data acquisition method has been discussed. In section 5, proposed image reconstruction algorithm according to acquiring data of EIT system. In section 6, the validation of the system and result based on the proposed system has been discussed, and the conclusion is drawn in section 7.

2. Materials and Methods

EIT is a medical imaging technique in which an image of the conductivity or permittivity of a part of the body is taken from the surface electrodes measurements [6]. Electrical conductivity depends on free ion content, with a change in biological tissues or different functional states of one & the same tissues or organs electrical conductivity changes. Most of the EIT system apply small alternating currents at single frequency & sometimes used multiple frequencies for better differentiation between normal and abnormal tissue within same organ the body [6]. Human body tissues contain a wide range of conductivities, and hence the potential exists is used EIT to carry out medical imaging using the conductivity as the parameter to be mapped [11]. The goal of the work is to design & develop an EIT-based system which produces an image of the internal conductivity of any subject [6].

This system is wholly based on electrical impedance signals of the different frequency applied to get different electrical impedance as the properties of this us. Healthy cells have impedance variation independent of frequency and abdominal cells having frequency dependent on electrical impedance can be identified using EIT [12]. The various method of EIT is neighboring method, opposite method, cross method, adaptive, etc. A methodological diagram of the system is shown in figure 1. In this eight electrode (also used for four electrodes for IPG technique) are used which are excited by an AC source 10 kHz, and corresponding electrodes responses are taken [15]. The impedance values are known by processing response signal through impedance analyzer integrated circuit. By using these values of impedance image of the object concerning conductivity is constructed [7].

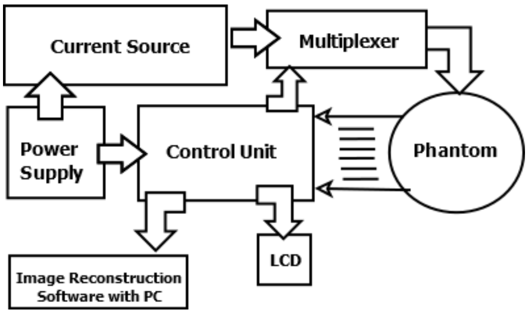

Fig 1: A block diagram of the impedance-based system.

3. Proposed EIT system

EIT system contains some digital & analog circuits, electrodes, and a PC. In our design, the analog section of hardware includes a current source, multiplexer, and control unit [3] [14]. As shown in figure 2. The accuracy of all units acting a very significant role for more resolution of the image of the inner portion of the object [7]. Every part has been practically tested on NI Multisim simulation software produced successful results according to EIT system requirement. Finally, the design of all circuitry parts was assembled on PCB. EIT system architecture block diagram as shown in figure 2.

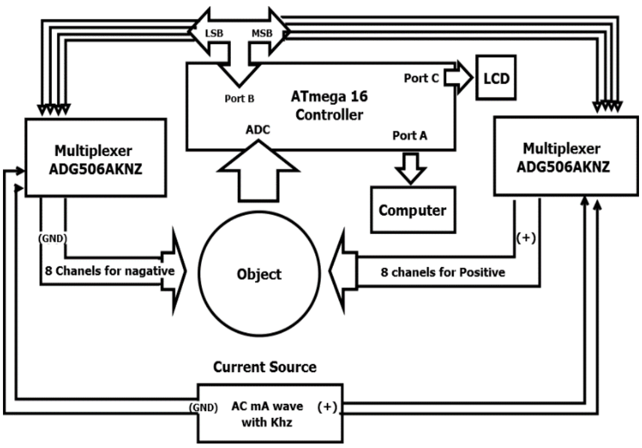

Fig 2 system Architecture of EIT system

The main part of the system architecture includes a current source, control unit, multiplexer module, and LCD [3]. The current source creates a low amplitude sinusoidal signal and converting the voltage signal to current sinusoidal signal, according to application requirement. Control unit, which is controlling the switching of the multiplexer (ADG506) and method of EIT [14]. The acquired data load on MATLAB which is simulated to reconstruct the image based on the acquiring data from the object [9].

3.1 Electrode or sensor

EIT system uses various methods of electrode arrangement like one ring or more than one ring according to the application [7], but in this work, we used one ring of the electrodes with nail type electrodes. The electrodes may be used nail type, and Ag-Agcl electrode is also used for biomonitoring and ECG, EEG and other application of medical monitoring [12]. The placement of these electrodes on the body, we need some leads, these leads are directly attached to the electrode of the body sites and used to examine electrical movement by monitoring change between them [6].

3.2 Current Source

The current source is the combination of signal generator and voltage to the current converter. In the first section of the current source, the signal generator is used for generating a constant sinusoidal alternating Voltage signal through the DAC (digital to analog converter) [13], which creates a low voltage alternative signal and this signal must have mV range with KHz frequency [6]. After that, the created voltage signal is passed into a VCC (voltage to the current source) [13]. The VCC created using LM358, which is two operational amplifier Combination (shown in figure 3). The created current signal is injected into the surface of the phantom. Several combinations of the operational amplifier are available at present, like Holland circuit, two [3] or three operational amplifier Combination [13].

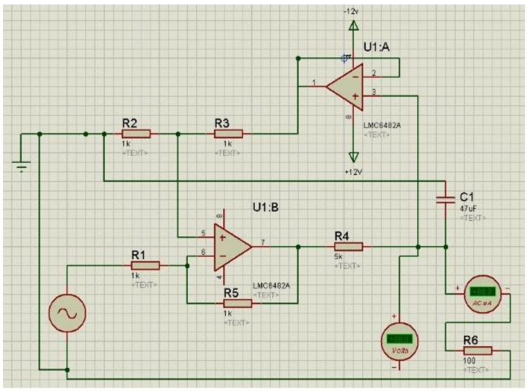

Fig 3 Voltage to Current Converter for Current Source

3.3 Multiplexer section

Multiplexer's panel used is developed for current switching and calculating of voltages of the electrode from the phantom [10]. Here we used a high-speed analog multiplexer (ADG506A) IC, which is developing an automatic switching system for current to inject into the adjacent pair of electrodes [14]. Here two multiplexer will use for current switching, which is directly connected to PORT B of the controller unit through the section line. Four pins of PORT B is connected to MAX 1 and other four pins for MAX 2. The data pin of the multiplexer is used for a current source (+VCC for MAX1 and –VCC for MAX 2).and this max module directly attached to phantom, which used for voltage measurements. Multiplexers to switch the current in the electrodes are created by the microcontroller and are fed into the multiplexers connected to the surface electrodes of the phantom [10], as shown in figure 4.

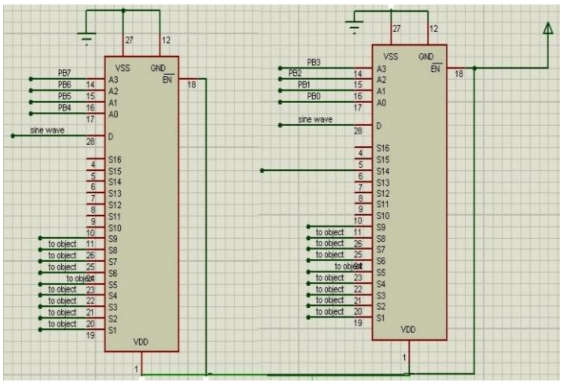

Fig 4 Multiplexer Module for EIT System

3.4 Control Unit

The controller unit is a central part of the EIT system. In this paper, we used an ATMEGA16 controller [2]. This controller has four ports, and these port simultaneously will be used for our requirements. Such as Port A used for voltages measurements from the phantom, Port B used for current switching and Port C for Display of LCD. At last TXD/PD1 pin used for data communicating with PC [3], using the serial communicating device, as shown in figure 5. It is controlling the current switching of the multiplexer (current position and voltage position measurements) to determine the potential measurements of each electrode pairs, also communicating with a PC and matching with a software platform for data transaction through LCD [14].

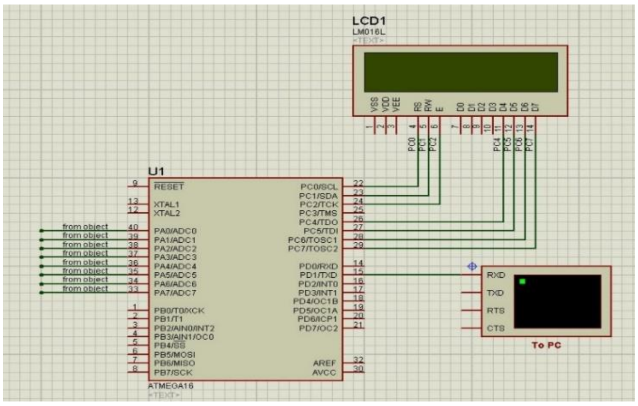

Fig. 5 Control unit

3.5 PC and LCD

Serial communication is one of the procedures that are supported by several types of a computer for connecting the computer to a microcontroller, here we used a USB to TTL device, as shown in figure 5. Presently various serial interface device or cable are available, like RS-232, USB to TTL, through wireless communication [14], etc. and also display on LCD all voltage measurements for whole EIT system [2].

4. Data acquisition

In EIT, There are numerous ways for current inserting Electrodes, the voltage determining electrodes and current patterns. So we are using several methods of the data collection collecting from the phantom [4]. In the Neighbouring method, the current position is applied to electrodes and measures voltages from all other adjacent electrode sets. However, In opposite method, current is injected through two's electrodes. In the cross method, a more uniform current distribution is obtained when the current is injected between a pair of more distant electrodes [15]. Moreover, In the adaptive method, current is injected through all electrodes. Because current applying through all the electrodes of the object. Here we used the neighboring method for data collection from the phantom

In neighboring Method, the current position is applied to Neighbouring electrodes set and measuring voltages from all other electrode pairs [15], which have been used in the proposed system. As Shown in Figure 6, the applied current location is in an electrode pair, like 1 and 2, after that calculating the voltage measurements from the other electrode set, like 3-4,3-5, 3-6, 3-7, 3-8. After that changing the current location on next neighboring electrode set and calculating the voltage measurement [15] and also taking voltages measurement of IPG technique through the designed system from the object [8].

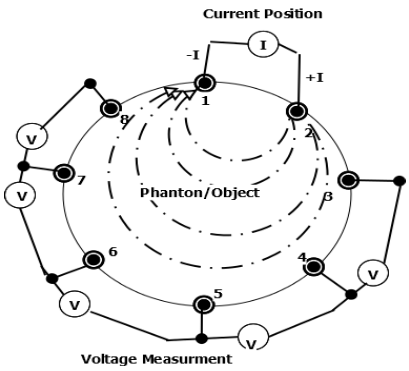

Fig. 6 Neighbouring Method for data acquisition of EIT technique.

5. Image reconstruction toolkit

In this work, EIDORS toolkit is used for image reconstruction from the obtained data from the phantom. EIDORS software stands for electrical impedance tomography and diffuse optical tomography reconstruction software [3]. It is a software suite for diffuse optical data and electrical impedance based data for image reconstruction. Its object is to provide adaptable and distributable software for data reconstruction of electrical signals. This software provides an orientation implementation against which new development can be compared [5]. An identified the impedance is used in the forward problem to calculate the surface voltage measurements from the applied current of the phantom, through the finite element method used from the experimental data is collected from the phantom [9]. The measured potentials and applied currents in the inverse problem are used to solve for unknown conductivity distribution. These reconstructed or simulated conductivity values are expressed by EIDORS image [5].

6. Experimental work and validation

In experimental setup firstly we have to take papaya as a phantom (it is more analogues to the stomach of the human body) and constructing an image for it by putting electrodes over its circumference of the phantom and applying current to electrodes and finding the voltage for another electrode through the neighbouring method of EIT technique[2]. In this experimental used Current is one mA with a Frequency have 30 kHz. The electrodes used are Needle-type or nail type and also use Agcl disposable ECG electrode [4], as shown. Fig. 7.

In this experiment, analysis of obtaining data from the different current pattern/position. In the experimental works shown the impedance distribution according to one position of current And the whole system position of current for the EIT system[4], as shown. Fig. 8.

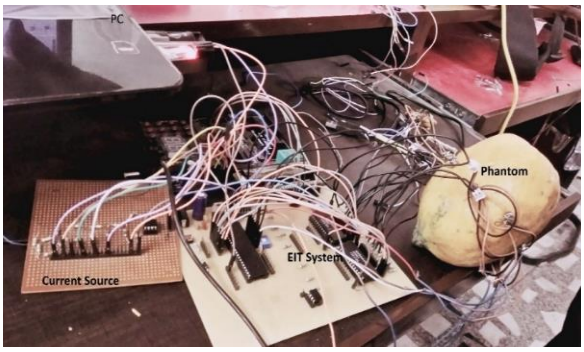

Fig. 7 Experimental setup

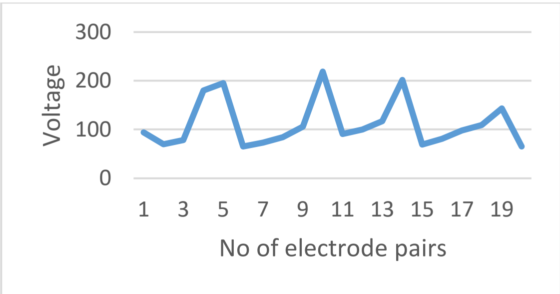

Fig 8 Impedance distribution of the experimental results

7. Result

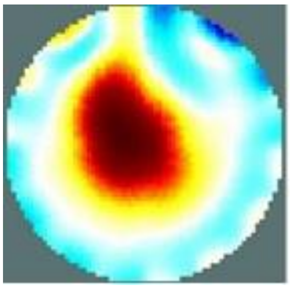

Figure 9. Image of Internal Structure of Papaya (Experimental Works)

The assembled EIT hardware, containing all the parts is shown in Experimental work section. The newness of this hardware designed within its lowest price and simple designing according to 8\4 electrodes, using both impedance plethysmography and electrical impedance tomography technique. Also showing some analysis part of this technique, like impedance distribution, voltage measurements for one current location and Impedance distribution of all position of currents locations of the phantom. This impedance distribution is comparable results to other research papers [3], as shown in fig 8. The reconstructed images of the phantoms as the experimental results which have been gotten from the proposed system are illustrated. The images were reconstructed with MATLAB package of EIDORs Toolkit, Also in Fig. 9.

The final obtained image shows the internal structure of the papaya or phantom. This image has three colors, which shows the internal medium of the papaya. The red color defines the central internal medium and outer medium define in form of the white and blue color combinations. Many phantoms are used for validation of this system. For the example, we used the pineapple, which consists of the internal structure of a uniform medium. So can define the final image in form of white or blue color combination.

8. Conclusion

A miniaturized electrical impedance-based system has been developed for non-invasive and non-contact imaging of cell with high temporal resolution. Our main objective of this experimentation was to accumulate impedance values from the different types of the phantom according to no. of electrodes. The experimental results show that image reconstruction is one of the key components of the electrical impedance tomography system. So we can say that the image reconstruction accuracy and image resolution in EIT extensively depend on some electrodes and electrode materials. In this paper, it is studied to examine the phantom responses for different electrode geometry and number of electrodes. Finally, we say that the electrical impedance tomography technique is used more efficiently for medical applications and our future aim is to improve the resolution of image construction by EIT.

References

[1] Holder, D. S. Electrical Impedance Tomography Methods, History, and Applications. *Institute of Physics Publishing Bristol and Philadelphia*, (*2005)*

[2] Rahim, R. A., Huei, L. Y. I., San, C. K. O. K., Fea, P. J. O. N., & Lean, L. C.. The initial result on electrical impedance tomography. *Engineering*, *39*(D), 105–112. (2003)

[3] Bera, T. K., & Nagaraju, J., A simple instrumentation calibration technique for electrical impedance tomography (EIT) using A 16-electrode phantom. *2009 IEEE International Conference on Automation Science and Engineering, CASE 2009*, 347–352. (2009)

[4] Kumar R, Pahuja SK, Sengupta A. Phantom based Analysis and Validation using Electrical Impedance Tomography. Journal of Instrumentation Technology and Innovation.; 5(3): 17–23p, (2015)

[5] Bera, T. K., & Nagaraju, J. An FEM-based forward solver for studying the forward problem of electrical impedance tomography (EIT) with a practical biological phantom. *2009 IEEE International Advance Computing Conference, IACC 2009*, (March), 1375–1381. (2009)

[6] Kumar, S., Anand, S., & Sengupta, A. Development of a non – invasive point of care diagnostic tool for fetal monitoring using electrical impedance based approach, 2013 IEEE PHT, 2013, 16–18. (2013)

[7] Dong, F., Xu, C., Zhang, Z., Ren, S., & DONG Feng *, XU Cong, Z. Z. and R. S. The design of parallel electrical resistance tomography system for measuring multiphase flow. *Chinese Journal of Chemical Engineering*, *20*(2), 368–379. (2012)

[8] Attenburrow, D. P., Flack, F. C., & Portergill, M. J. Impedance

plethysmography. *Equine Veterinary Journal*, *22*(2), 114–117.(1990)
[9] Bagshaw, A. P., Liston, A. D., Bayford, R. H., Tizzard, A., Gibson, A. P., Tidswell, a. T., … Holder, D. S. Electrical impedance tomography of human brain function using reconstruction algorithms based on the finite element method. *NeuroImage*, *20*, 752–764. (2003)
[10] Hong, S., Lee, J., Bae, J., & Yoo, H. A 10. 4 mW Electrical Impedance Tomography SoC for Portable Real-time Lung Ventilation Monitoring System, 4–7. (2014)
[11] Soleimani, M. Electrical impedance tomography imaging a priori ultrasound data. *BioMedical Engineering Online*, *8*, 1–8. (2006)
[12] Anand, S., Sengupta, A., Mahajan, R., & Pahuja, S. K. Fabrication of microcontroller based multipurpose measuring system with inbuilt data acquisition. ICBBT 2010, 2010, 10–13.
[13] Robert F. Coughlin, Frederick F. Driscoll, Operational Amplifiers and Linear Integrated Circuits, Prentice Hall, (2000).
[14] K Aleksanyan, I Gorbatenko Nikolay, T. Development of the hardware-software complex for electrical impedance tomography of biological objects. *Journal of Applied Sciences 9*, *9*(12), 1030–1033. (2014)
[15] Ramesh Kumar, Sarwan Kumar, Amit Sengupta., a Review: Electrical Impedance Tomography System and Its Application. *Journal of Control & Instrumentation*, 7(2): 14–22p. (2016)