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Design and development of Electrical Impedance Tomography (EIT) based System

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ABSTRACT

Electrical Impedance Tomography (EIT) is relatively a new imaging technique with which the images of the internal impedance of the region of interest in human body can be constructed effectively without prolonged exposure to radiations. EIT is fast, inexpensive and portable as compared to other imaging techniques. The presented work focuses on construction of human organ images acquired from impedance graph of the organ under diagnosis. In the presented work, upper arm part has been brought under EIT electrodes system network in order to get the impedance measurement using the proposed circuit. The impedance is measured by using a resistive network and tabulated in an array. The impedance array is then analyzed in MATLAB to construct the image of the particular organ. The main emphasis is given on stability of the impedance of the particular parts under different strain conditions.

General Terms

Medical imaging, Electronics Product Design, Image Reconstruction Algorithm

Keywords

Electrical Impedance Tomography (EIT), medical imaging, direct algorithm, MATLAB

1. INTRODUCTION

Tomography is basically an imaging technique. The word tomography is composed of two words- 'tomo' and 'graphy' which originates from the Greek word 'tomo' which means section or slice and 'graphy' refers to representation. Hence tomography refers to a method in which images are reconstructed based on the internal structural information within an object. This information is obtained by stimulating a physical process involved. There are various types of medical tomography which uses X-ray absorption, positron emission, magnetic resonance, and sound waves (ultrasound) as the emanation.

Electrical Impedance Tomography (EIT) is a recently developed non-invasive medical imaging technique. In EIT, the images of internal electrical conductivity can be reconstructed from voltage measurements on the surface of an object under study. Since impedance is not directly measurable, it is calculated from boundary voltage measurements which are a function of the impedance and a current which is applied or injected. Using different current injection patterns and voltage measurement sequences, an approximation of the spatial distribution of the impedance or changes in impedance within the object are reconstructed.

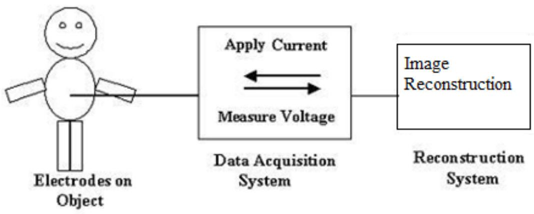

Figure 1: General view of EIT system [8]

It is also possible to inject voltages and measure the resulting currents; but the majority of work done till date uses the former technique.

2. RELATED WORKS

Mohammad Khalighi et.al proposed a practical EIT instrumentation to be used in industrial process monitoring. The system designed is precise and low cost. The image of the conductivity distribution of subject body under test is reconstructed by injecting current into the subject boundary, measuring voltages and transmitting them to computer where processing is done through MATLAB. The designed system contains high output impedance current source which ensures the system accuracy in totality. The ICs used are not expensive, ensuring the low cost of the system. The quality of the reconstructed images is also good. [1]

Z. Zhou et.al proposed a telemedicine system based on EIT which is fast and portable. The proposed system can be used for monitoring the health status of out-of-hospital patients. The system has two working mode-field diagnosis mode and medical record mode. The medical data is recorded using cloud storage technique and field diagnosis is implemented using 3G communication and voice broadcasting. FPGA chip performs the digital signal processing and transfers data via 3G network. A circular salt water grove test was designed to check the performance of the image reconstruction module. To enhance the portability and work efficiency, two lithium batteries were employed. [2]

Alzbeta Elizabeth Hartinger et.al developed EIT based system with handheld probe comprising 16 disposable semiinvasive electrodes for the early diagnosis of skin cancer. The FEM model of skin has been developed and electrical behaviour of skin layer is studied to discriminate the operating frequencies of malignant from benign lesions. FEM model is used to develop algorithms for image reconstruction. The model simulation showed great improvement and resolution and image artifacts were decreased by 70%. The system and algorithm were validated and measurements were in correlation with simulation. [3]

Tushar Kanti Bera et.al designed a multifrequency EIT system for biomedical imaging. Practical phantoms were developed using NaCl solution as bathing medium and vegetable (carrot) tissue cylinders as the inhomogeneity. EIDORS (Electrical Impedance Tomography and Diffuse Optical Tomography Reconstruction Software) has been used to reconstruct resistivity images obtained from the surface boundary potentials. The images were reconstructed efficiently. [4]

3. EIT IN MEDICAL FIELD

Biological tissues have electrical impedance that is complicated because it is expounded to the tissue dimension, the interior structure and also the arrangement of the constituent cells. Therefore, the electrical impedance can be used to obtain useful information based on heterogeneous tissue structures, physiological states and functions [13]. In addition the concepts of time varying distribution of electrical properties inside a human body such as electrical conductivity and permittivity can be used to analyze a variety of medical conditions. Biological tissue exhibits two important passive electrical properties:-

a) It includes free charge carriers and may be considered an electrical conductor. It would be expected that electrical physical phenomenon is a characteristic property of tissues and that images of electrical conductivity may resolve structure and even be indicative of pathology.
b) Tissue also contains bound charges leading to dielectric effects and it might also be possible to form an image of relative electrical permittivity.

Electrical properties such as the electrical conductivity ‘σ’ and the electric permittivity ‘*ε*’ determine the behavior of materials under the influence of electric fields [12]. Different body parts show different electrical properties, based on their composition. Table 1 shows the two main electrical properties of various biological tissues measured at frequency 10 kHz.

Table1. Electrical properties of various biological tissues [10]

Tissue	1/ σ (Ω cm)	*ε (μ Fm-1)*
Lung	**950**	**.22**
Muscle	**760**	**.49**
Liver	**685**	**.49**
Heart	**600**	**.88**
Fat	**>1000**	**.18**

A map of σ and ε can be used to infer the structure of internal electrical impedance.

4. DESIGN OF EIT SYSTEM

Designing of EIT system is broadly divided into two modules:-

a) Data Acquisition Module that forms the hardware unit.
b) Image Reconstruction Module that forms the software unit.

4.1 Data Acquisition Module

This module consists of an electronic circuitry to obtain data signals from body surface. The flow of signal is represented in figure 3. The EIT system consists of an electrode array which is connected to the body part of interest. Input is given from a constant current source. The electrodes are connected to a multiplexer who gives only one signal out of many at one time.

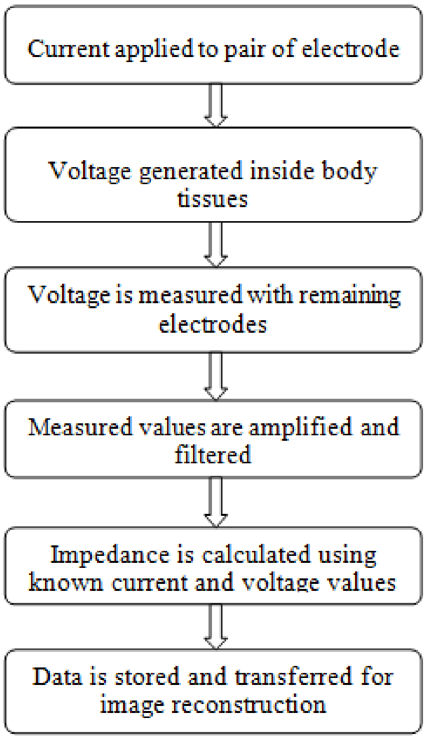

Figure 2: Flow of signal in EIT system

The output of multiplexer is fed to the signal conditioning circuit. This unit basically consists of an amplifier, a filter and a buffer. The signal is amplified because body signals are very weak and of very small magnitude. After amplification, the signal is passed through filter circuit to eliminate higher frequencies and noise signals, if any. Then analog signal is converted into digital form using A/D converter. After digitization, the data is processed using micro controller and saved in memory. The results are displayed using display devices. Figure 4 shows the block diagram of basic hardware implemented in this paper.

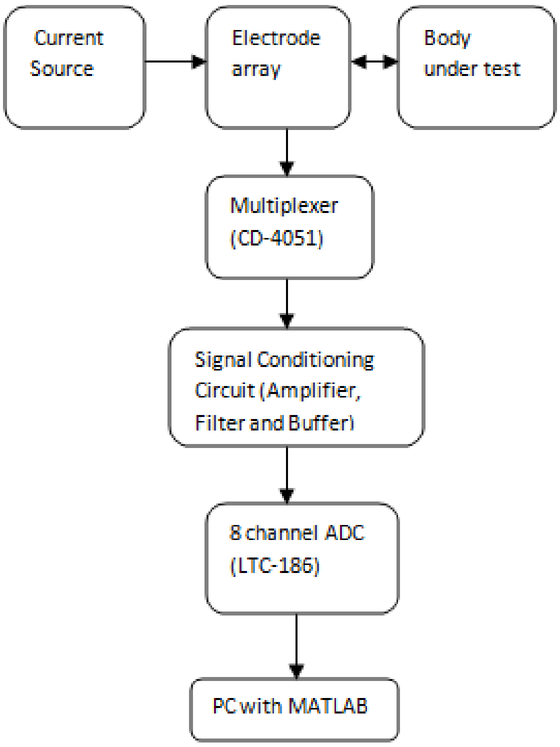

Figure 3: Basic hardware design for EIT system

4.1.1 Electrodes Specification and Position
The quality of EIT data greatly depends on the surface electrodes used and good electrode-skin contact [11]. To obtain good results, silver-silver chloride (Ag-AgCl) electrodes are used. They yield acceptable standards of performance as they give almost noise free characteristics. The electrode application site is cleaned and dried properly. After cleaning the skin, an electrolyte gel is applied between electrodes and skin surface [13].

4.1.2 Multiplexer
In the designed system, 4 pairs of electrodes i.e. 8 electrodes are used. To select output from one pair at a time, multiplexer CD-4051 is used, operated at 5V. It has fast switching and propagation speeds which provides low crosstalk between switches [14].

4.1.3 Signal Conditioning
The signal from the multiplexer is fed to the signal conditioning unit where the quality of the signal is improved. The signal from the body is very weak so it is amplified using CA-3140 instrumentation amplifier. This amplifier is preferred over others because it has high input impedance, high CMRR, high slew rate and consumes less power. The op-amp is configured in amplification mode. Then to attenuate unwanted signal components and noise signals, band pass filter is used. The buffer conditions the selected input signal to a suitable level for application to the A/D converter. 741 IC is used for filtering and buffering purposes.

4.1.4 ADC
The information obtained from signal conditioning unit is in analog form. For further processing the signal is digitized using LTC-186. It is an 8-channel ADC and has sampling rate of 200 kbps [14].

4.1.5 Control Unit
P89V51RD2 microcontroller has been employed for controlling and timing purposes. It transfers the digital signals from ADC to the PC where the signals are processed further using MATLAB and image is reconstructed.

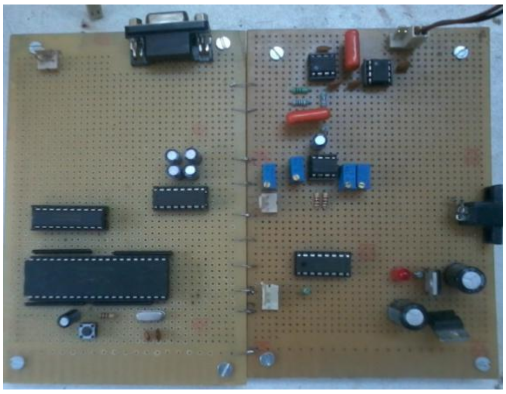

Figure 4: EIT hardware

4.2 Image Reconstruction Module
In this module, the measured values of impedance are used to reconstruct the image of particular body tissues. Different materials have different electrical properties. Due to these differences, the images for unhealthy tissue will be different from a healthy one. The image reconstruction algorithm will be developed using MATLAB environment. There are many different image reconstruction methods for EIT. In general, they can be mainly classified into two categories:

a) Direct methods
b) Iterative methods

For two dimensional (2D) EIT, there aren't any substantial differences between these two kinds of strategies. However, when three dimensional (3D) EIT is applied, direct methods become deficient in computing time and memory consumption since they are based on some kind of matrix factorization. Therefore, iterative methods are far more economical for 3D EIT reconstruction. For iterative algorithms, convergence is extremely vital and preconditioning performs as an effective way to enhance the convergence rate of the algorithm.

5. RESULTS AND CONCLUSIONS
It has been observed that the human body impedance varies in the range from 700 – 1000 Ω. The electrode array is placed around the arm and electrodes are switched in a way to cover the entire arm. The accuracy of the impedance measured depends upon the constant current and reference resistance source used for the same. The proposed methodology provides ease of measurement of body impedance that can further be converted to images using the MATLAB tool. The proposed method is non-invasive method and does not suffer

from any kind of after effects of radiations. The images so obtained are required to be validated from the original shape of the body organ. And that part is yet to be covered up as in the presented work we have focused our attention to accurately extract the impedance and store them in order to convert into the images.

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