A Low Cost Electrical Impedance Tomography Using EIDORS

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Abstract—*Electrical Impedance Tomography (EIT) is a non-invasive medical imaging technique in which an image of the conductivity or permittivity of part of the body is inferred from surface electrode measurements. This paper describes the design, development and implementation of a low cost electrical impedance tomography system. A 16 copper electrode EIT system was designed around a closed phantom tank for detection of abnormality present. A 5 Hz alternating current of known value 20mA is injected in two adjacent electrodes and the voltages are measured in neighboring pattern at every consecutive pair of electrodes. The output data sets are fed and then executed in MATLAB which is interfaced with EIDORS software to reconstruct the image based on the acquired data for detecting inhomogeneities inside the phantom. The EIDORS (Electrical Impedance and Diffused Optical Reconstruction Software) is an open source software tool used in the MATLAB software & this suite is used for the reconstruction of EIT.*

Keywords: *Electrical Impedance Tomography, Medical Imaging, Reconstruction, EIDORS.*

1. INTRODUCTION

Electrical Impedance Tomography is an upcoming medical and industrial imaging technique. It is advantageous to other imaging technology in medical field such as Positron Emission Tomography (PET), X-Ray, Computed Tomography (CT), and Breast Magnetic Resonance Imaging (BMRI) with respect to harmful radiations which may cause side effects to the body. Also these machines are bulky and require special attention by skilled personnel while EIT is portable. EIT makes noninvasive sample analysis for geophysical explorations as well as biomedical diagnosis for breast cancer. The measured voltages are used in reconstruction algorithm to reconstruct the resistivity profile inside the body under test.

Finite Element Method is the basis for all the software used for reconstruction in EIT. EIDORS is used for 2-D and 3-D reconstruction of image based on voltage dataset. EIDORS is an open source suite implemented in MATLAB package. This software is divided in three stages i.e. mesh generation, forward problem and inverse problem. The forward problem calculates the voltage values inside the object when conductivity distribution is given in that object. The inverse problem is to obtain an adequate estimation of the interior conductivity distribution, based on the measured voltage values. To perform the EIT an experiment directly on the patient's body is neither ethical nor permitted hence a phantom can be used instead of human body.

2. EIT SYSTEM WORKING

Fig. 1 shows EIT Experimental set up. It includes signal generator, a voltage to current converter producing a current of 20 mA at 5 KHz, a closed phantom with 16 electrode set up and a multimeter to measure resulting differential voltages. This paper gives description of experiments performed on 16 copper electrodes, plastic container of 14cm diameter and 7cm height filled with saline solution of 0.9% of sodium chloride having electrical conductivity of 300 ms/m. The low magnitude and low frequency sinusoidal current is applied to the pair of electrodes. Current can be applied in neighboring pattern, opposite pattern, cross pattern and adaptive pattern. The neighboring pattern is also known as adjacent pattern. Brown and Segar (1987) suggested a method where current is applied to a pair of electrodes and voltage is measured from other noncurrent pair of electrodes.
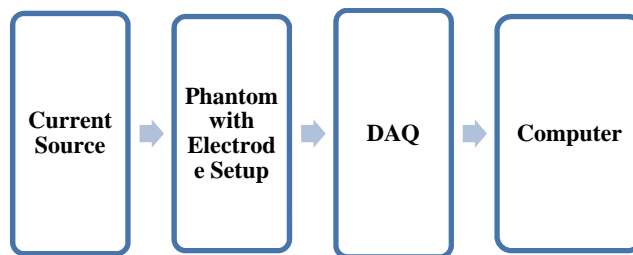

Fig. 1: EIT Block Diagram

The 16 electrodes are arranged inside phantom in clockwise direction from 1 to 16. Here the current is applied in neighboring pattern as shown in Fig. 2. In first projection current is applied to one pair i.e. electrode 1 and electrode 2 and differential voltage is measured between other pair i.e. between electrode 3 and 4 then voltage drive is shifted to next

pair between electrode 4 and 5 and so on up to last pair i.e. electrode 15 and 16. The current density is highest between current electrodes and goes on decreasing rapidly as a function of distance. In second projection current drive is shifted to the next successive pair i.e. electrode 2 and 3 and differential voltage is measured between noncurrent pairs i.e. between electrode 4 and 5 followed by electrode 5 and 6 and so on up to pair electrode 16 and 1. From adjacent method 16 such projections are obtained without keeping any impurity in phantom. After inserting the impurity, again all 16 projections are repeated. One projection includes 13 voltage readings therefore for 16 projections there are 208 (16×13) voltage readings. These two datasets for both without impurity and with impurity are used for reconstruction of resistivity image.

Various conducting and non conducting impurities are used in this experiment Conducting impurities used are a copper spindle of 4.5 cm diameter and copper cents of 1.8 cm diameter which are 17 in number and are arranged in cylindrical fashion to form a single conducting impurity. The non conducting impurities used are wooden balls of different diameters, smaller wooden ball has diameter of 3.5 cm and larger wooden ball has diameter of 5 cm. The other non conducting impurities are clay cylinder of 1.8 cm diameter × 5.8 cm height and an oval shaped marble having diameter of 4 cm and height of 5.8 cm. These conducting and non conducting impurities are inserted one after another inside the solution.
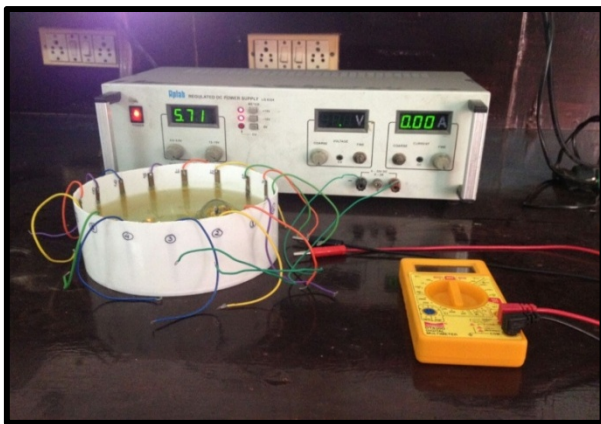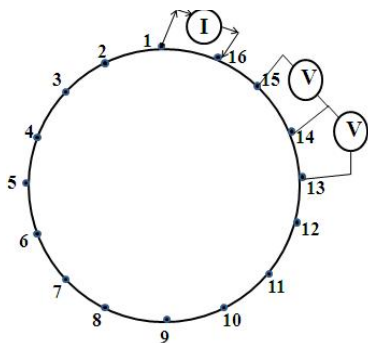

Fig. 2: Experimental setup

Fig. 3: Adjacent Pattern of Measurement

3. RECONSTRUCTION METHODS

This paper focuses on Inverse problem for 2-D reconstruction considering the position of impurity as unknown. Initial stage for estimating the permittivity and conductivity distribution in plastic container is to create finite element model of electrodes and circular container. This finite model is solved by assuming homogenous conductivity and calculating voltage distribution.
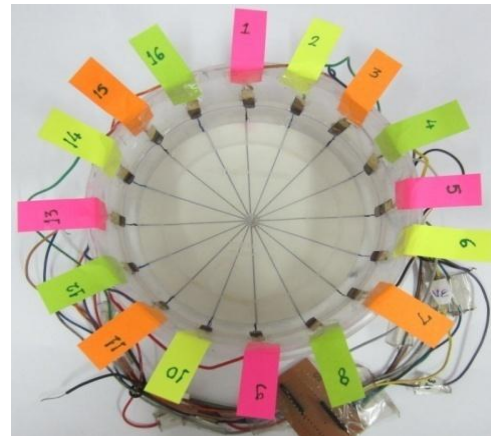

Fig. 4: Electrode arrangement in Saline Solution inside plastic container
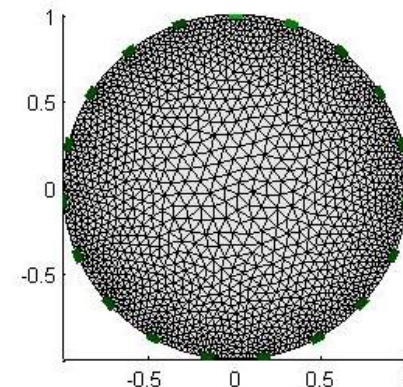

Fig. 5: Reconstruction of saline solution in plastic container using EIDORS at normal state of condition

The voltage dataset is loaded in MATLAB and inverse algorithm is applied. Inverse algorithm uses difference method to obtain reconstruction of image. Fig. 3 shows the circular plastic container with electrodes and saline as a medium and Fig. 4 shows the reconstruction of saline solution in plastic container which gives the homogenous conductivity in solution.

Fig. 6 shows the variation of voltage distribution profile when single non-conducting impurity i.e. large wooden ball is placed near electrode 11, 12 and 13. Presence of non conducting impurity increases the voltage in that region so that voltage rises in respective area indicated by red color. In all above experiments, impurities are kept at the periphery of phantom.
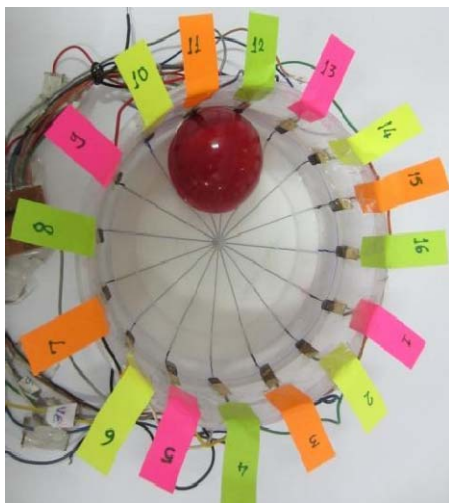
Fig. 6: Electrode arrangement for wooden ball in Saline Solution inside plastic container
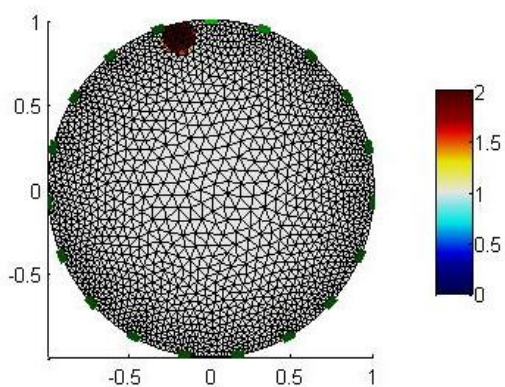

Fig. 7: Reconstruction of wooden ball in saline solution in plastic container using EIDORS

4. RESULT

The reconstructions of the image from the data obtained by different plates by EDIORS. The blue color shows the abrupt declining in conductivity. Thus the presence of conducting impurities is confirmed. Similarly, the red color in reconstructed images detects the presence of non conducting impurity.

5. CONCLUSION AND FUTURE PLANS

Thus Electrical Impedance Tomography is used to tackle challenging problem of detection of abnormalities in human tissue as well as the inhomogeneities in materials. The simulation carried out by EIDORS detects the objects having high electrical conductivity as well as low electrical conductivity. The conductivity distribution depends on the material of electrodes, number of electrodes and the medium used in experiment.

Easy detection of tumor can be made out and this will a cheap method and accurate also. In order to get knowledge about the impurities present inside the body cells it can be used.

6. ACKNOWLEDGMENTS

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