ELECTRICAL IMPEDANCE TOMOGRAPHY USING THE MAGNETIC FIELD GENERATED BY INJECTED CURRENTS

Ö. Birgül, Y. Z. İder
Dept. of Electrical and Electronics Engineering
Middle East Technical University, Ankara TURKEY
e-mail: obirgul@rorqual.cc.metu.edu.tr, ideryz@rorqual.cc.metu.edu.tr

Abstract **In 2D EIT imaging, the internal distribution of the injected currents generate a magnetic field in the imaging region which can be measured by magnetic resonance imaging techniques. This magnetic field is perpendicular to the imaging region on the imaging region and it can be used in reconstructing the conductivity distribution inside the imaging region. For this purpose, internal current distribution is found using the finite element method. The magnetic fields due to this current is found using Biot-Savart law. Sensitivity of magnetic field distribution to inner conductivity perturbations for different current injection profiles is studied. It is found that, to achieve a uniform spatial resolution, a current profile which generates uniform current inside the imaging region is to be applied. The condition number of the sensitivity matrix obtained for this case is found to be very low. Several images are obtained using simulation data.**

I. INTRODUCTION

In standard EIT imaging an internal current distribution is obtained in the imaging region by either induction or injection. For the case of a 2D object, these currents flowing in the object plane generate a 3D magnetic field which is perpendicular to the object on that imaging region. For the imaging region given in Figure 1, 2D currents on x-y plane generate a magnetic field only in the z-direction on that plane. It has been shown that z-component of the magnetic field generated by quasi static bioelectric and RF currents can be measured using Magnetic Resonance Tomography [1] wheree z-direction is the direction of the main magnetic field

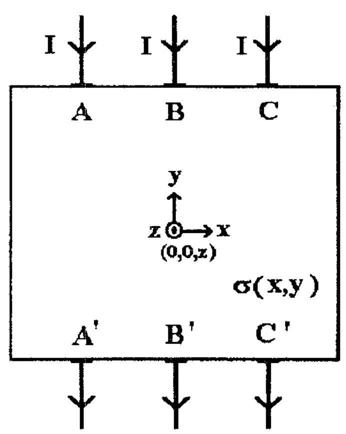

Figure 1. Definitions for space coordinates and current injection patterns. Size of the imaging region is 9 cm x 8.5cm .

and these methods are also extended to AC frequencies used for EIT [2].

When the inner conductivity distribution is perturbed, the current distribution is altered and therefore a perturbation in the generated magnetic field is obtained. Therefore, if this perturbation in the magnetic field can be measured then an inverse problem may be solved to find the conductivity perturbation. Injected and induced EIT has low resolution for inner conductivity regions. The main reason for this is that only peripheral voltage gradient measurements can be made. However, since the magnetic field can be measured everywhere, with same sensitivity, it may be possible to obtain good spatial resolution in inner as well as outer regions using magnetic field. In this study, the relation of the z-component of the magnetic field to inner conductivity perturbations is studied. Sensitivity matrices for different current injection profiles is calculated and the behaviour of these matrices are analysed. Using this sensitivity matrix and simulated data, several images are obtained for objects located at different parts of the imaging region and some representative ones are presented here.

II. METHODS

For a given current injection profile, potential field inside the imaging region is calculated using the finite element method (FEM). For potential field calculations, a mesh with 225 nodes and 392 triangular elements is used and the internal current distribution is obtained using node potentials. Z-component of the magnetic field at any point of the imaging region, generated by these internal currents is calculated using Biot-Savart law given by the summation

$$\vec{B} = \frac{\mu_o}{4\pi}\sum_{i=1}^{n}\frac{Id\vec{l}\,'\times\vec{R}}{R^3}$$

where μ_o is the permeability constant, n is the number of source points, Idl is the differential current element, R is the distance between source point (x',y',z') and field point (x,y,z). In this summation, the terms for which $(x(i),y(i),z(i)) = (x'(i),y'(i),z'(i))$ are excluded.

III. RESULTS

Sensitivity matrices for two different current injection profiles are calculated. In the first case, current is injected using B-B' electrode pair shown in Figure1. Internal current distribution for this injected current profile is calculated.

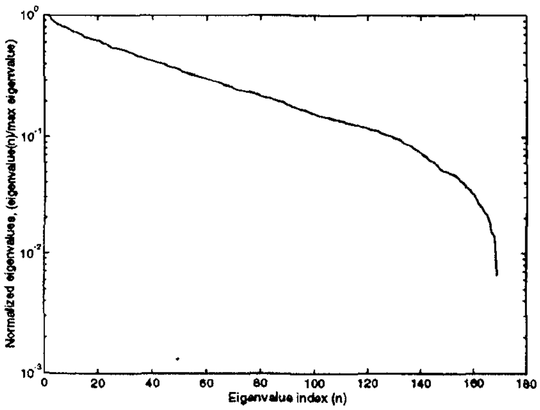

Figure 2. Sensitivity pattern obtained for multiple current injection case.

This current has both x and y components in the imaging region. The magnetic field generated by this current is high near the electrodes and decreases towards the central regions. For the second case current is injected from electrodes A, B, C and driven from A', B', C' and the current distribution inside the image region is approximately uniform in y-direction. To obtain sensitivity matrix, conductivity of each element is perturbed by 1% and corresponding change in the magnetic field at whole imaging region is obtained for both cases.

In order to understand the conditioning of the sensitivity matrix, its singular value pattern is studied. The eigenvalues for multiple injection electrode pairs is given in Figure 2 with values normalized to maximum eigenvalue. The condition number of the sensitivity matrix is found to be of order 2 (approximately 150) whereas, for the case of injected current EIT using gradient measurements from the boundary, this number is of order 5 [3]. Therefore, the ill-conditioning of the EIT reconstruction is significantly reduced. This is due to increase of the sensitivity of measurements to the conductivities of the inner elements.

The relation between conductivity perturbations and change in magnetic field is given by:

$$\Delta m = S\Delta\sigma$$

where Δm is difference between field values for uniform and perturbed conductivity cases, S is the sensitivity matrix and $\Delta\sigma$ is the change in conductivity values. The conductivity values are obtained using:

$$\Delta\sigma = S^{-1}\Delta m$$

where S^{-1} is the generalised inverse of sensitivity matrix found using singular value decomposition (SVD). Reconstructed images, using above formula is given in Figure 3. In these figures, it is seen that, reconstructed images for a circular object with radius 1 cm placed in different parts of the imaging region has similar image quality. No truncation is done during SVD procedure.

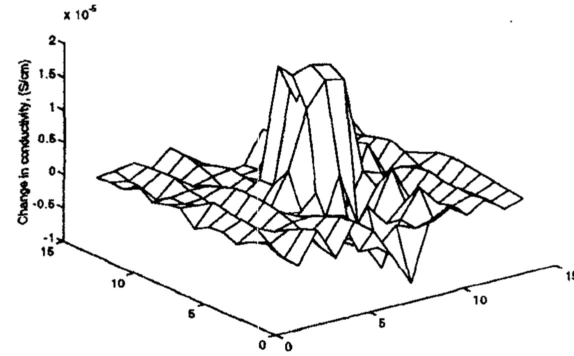

Figure 3a Image obtained for an object with radius 1 cm located at the center of the imaging region. Conductivity of the object is 2.02 mS/cm. Background conductivity is 2 mS/cm

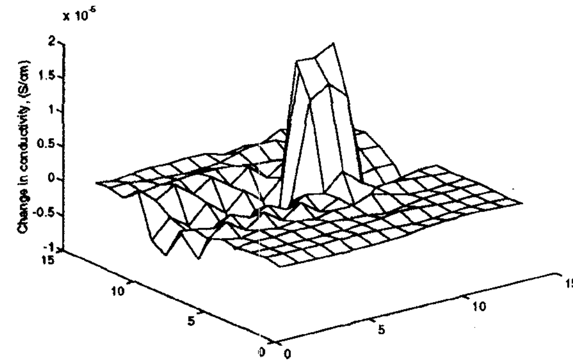

Figure 3b Image obtained for an object with radius 1 cm where its center is located at (1,1). Conductivity of the object is 2.02 mS/cm. Background conductivity is 2 mS/cm.

IV. Conclusions

The images presented above show that using a current injection profile which generates uniform current distribution inside the imaging region, a uniform spatial resolution can be achieved. With this approach, the ill-conditioned behaviour of the sensitivity matrix for standard injected EIT problem can be eliminated.

References

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[2] Ider, L. T. Muftuler, and O. Birgul, "Use of MRI for measuring AC internal currents of EIT: A feasibility study" in *Proc. IX International Conference on Electrical Bio-Impedance in conjunction with European Concerted Action on Impedance Tomography* pp 420-422, September 1995.

[3] N. G. Gençer, M. Kuzuoglu, and Y.Z. İder, "Electrical Impedance Tomography Using Induced Currents", *IEEE Transactions in Medical Imaging* vol.13 pp 338-350 June 1994.