

*electrical impedance tomograph  
forward problem model spice*

Sebastian BIAŁY\*, Zygmunt WRÓBEL\*

## **SIMULATING ELECTRICAL POTENTIAL DISTRIBUTION BY USING „SPICE” FOR ELECTRICAL IMPEDANCE TOMOGRAPHY**

In this paper solution of straight problem was introduced in electrical impedance tomography with help of method of junction's potentials with utilisation of computer program "Spice". Preliminary investigations of model were introduced based on mesh of resistance artificially disturbances of schedule of resistance. Created images of boundary potentials permit onto estimation of errors introduced through model.

### 1. INTRODUCTION

Electrical resistance (or impedance) tomography is an electrical imaging technique from which it is possible to reconstruct an image of the conductivity through a cross section of an object. The conductivity information is obtained from measurements of voltage and/or current on the boundary of the object as a result of externally applied voltages or currents. In typical applications multiple measurements are taken to reconstruct whole object, so both measurements cost and reconstruction algorithm cost is higher[1].

Reconstruction algorithm is (in most cases) very complicated, but can be described as optimising objective function commonly defined as follows:

$$\Phi(\sigma) = \frac{1}{2}(\mathbf{I} - \mathbf{I}_m)^T (\mathbf{I} - \mathbf{I}_m) \quad (1)$$

where:  $\mathbf{I}$  - calculated current vector for n projection  $\mathbf{I}=[\mathbf{I}_1, \mathbf{I}_2, \mathbf{I}_3, \dots, \mathbf{I}_n]$   
 $\mathbf{I}_m$  - measured current vector for n projection  $\mathbf{I}_m=[\mathbf{I}_{m1}, \mathbf{I}_{m2}, \mathbf{I}_{m3}, \dots, \mathbf{I}_{mn}]$

Reconstruction algorithm in Electrical Impedance Tomography is a typical inverse problem. To reconstruct object conductivity, multiple solutions of forward problem must be done, to optimise objective function. In this paper one [3] of forward problem solution method is proposed, based on junctions potentials method. Computer program "Spice" is used to calculate potential distribution.

Junction potential method (Coltri's method) allows directly calculates voltages in circuit. To do this, several steps are required:

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\* Computer Science Department, University of Silesia, 41 – 200 Sosnowiec ul. Będzińska 39

1. Mark one of the nodes as „0” node with potential 0V.
2. Write I Kirchoff’s law for every node except “0”.
3. Eliminate circuit branch currents by using equations describing elements in branch
4. Eliminate branch voltages using II Kirchoffs.

For example, for this node:

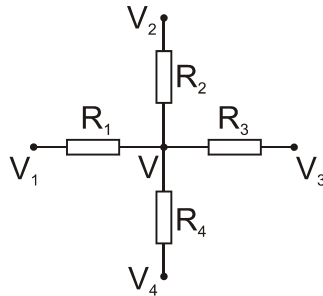


Fig.1. An example model node.

such equation can be written:

$$\left\{ \begin{array}{l} \dots \\ V(R_1 + R_2 + R_3 + R_4) - V_1 R_1 - V_2 R_2 - V_3 R_3 - V_4 R_4 = 0 \\ \dots \end{array} \right. \quad (2)$$

## 2. MODEL

In EIT reconstruction algorithm to solve inverse problem for conductivity involves breaking down the object into a finite number of regions in which the conductivity may be specified simply. In this model every “element” consists of a resistor connected to two nodes. By using this simple model it is possible to simulate different artifacts by changing resistance of some resistors. Picture below shows part of model:

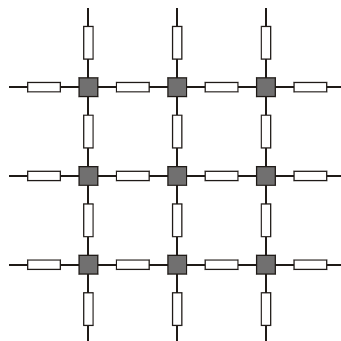


Fig.2. Part of resistors mesh. Gray squares are nodes.

Simulated model consists of total number 900 nodes. Two boundary nodes were selected to inject current inside model.

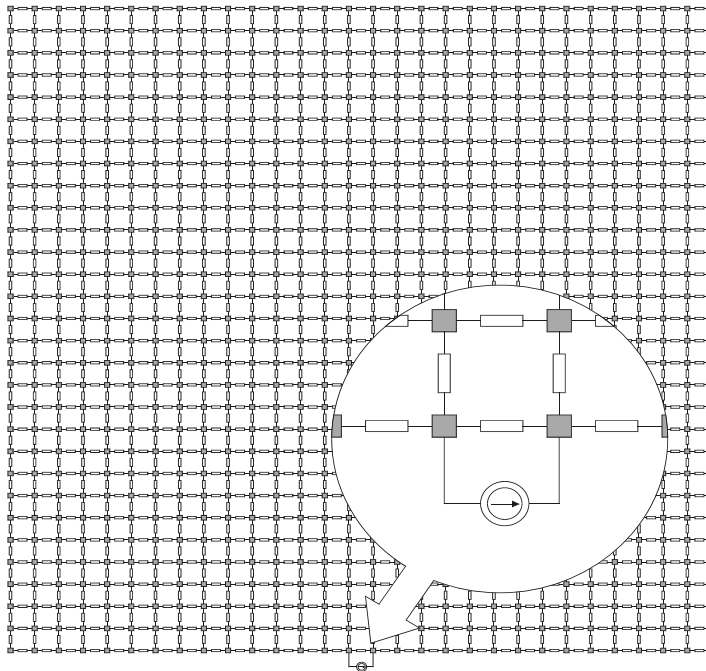


Fig.3. Whole model with attached current source.

### 3. SIMULATION

Operating system Linux Mandrake 8.0 working on P133 class computer was basic platform for simulation.

Process of simulation of potential distribution in model ran in following way:

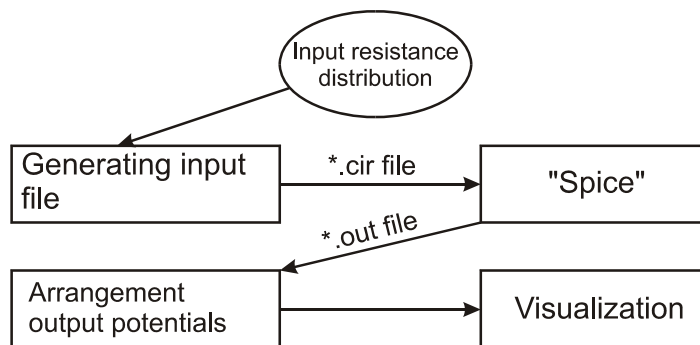


Fig.4. Simulation process.

Because of specific format of input files for simulator, there is specially written program in C language. It converts input resistance distribution file into \*.cir file. Input model can be modified by changing any of 900 resistor values. Output \*.cir file also needs some additional information for

simulator, ex. position (nodes) of current source. After file is created simulation process starts. It takes approximately 10 seconds for 900 nodes model. Spice generates output file \*.out with information about electrical potentials of all nodes. This output file also needs conversion, because potentials are not in proper order. MathCad 7.0 is used for visualisation of created matrix of node potentials.

#### 4. RESULTS

Different simulations were made which estimation was assignment quality of got results and affirming of them of usefulness in impedance tomography.

First simulation was executed on homogeneous model. Resistance of all resistors in model is even ( $1k\Omega$ ) and current source injects current 1A.

Total quantity of nodes of model is 900 (30 onto every side). On picture below distribution of potential was shew inside model as well as distribution of potential on bottom boundary of object (on perpendicular axis value of voltage was marked in individual nodes).

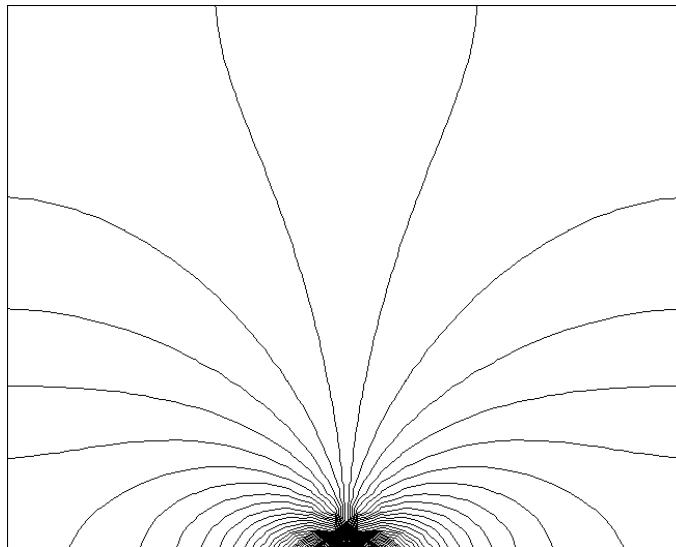


Fig.5. Electric field inside object (homogeneous model).

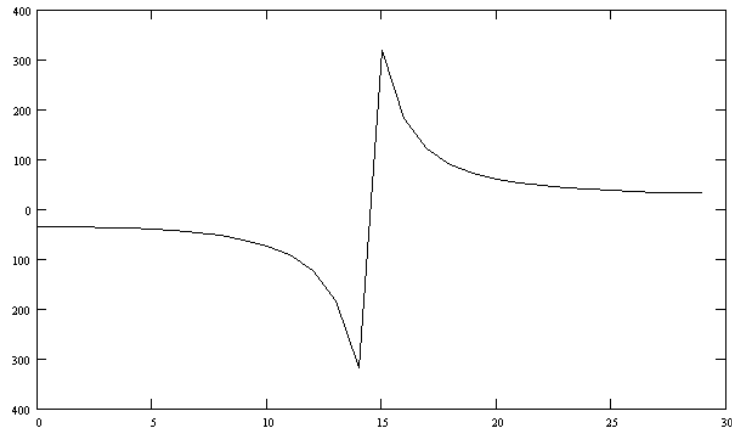


Fig.6. Potential distribution on bottom boundary of object.

Next, modifications were introduced by modifying values of some areas of model. Resistance of grey areas is raised to  $10\text{ k}\Omega$ . On the right side differences of potentials were introduced between homogeneous case and case with modification.

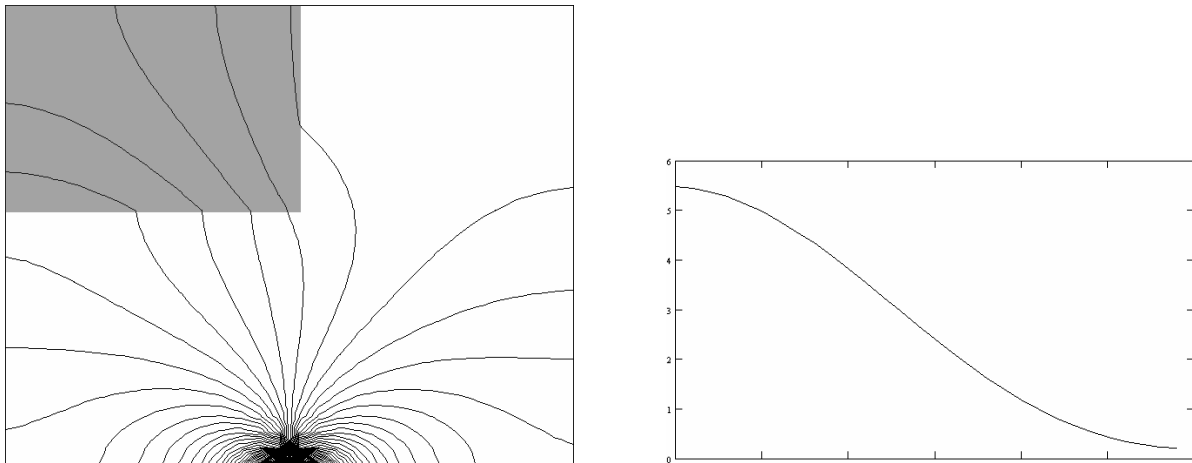


Fig.7. Distribution of electric field inside model after modification in upper left corner.

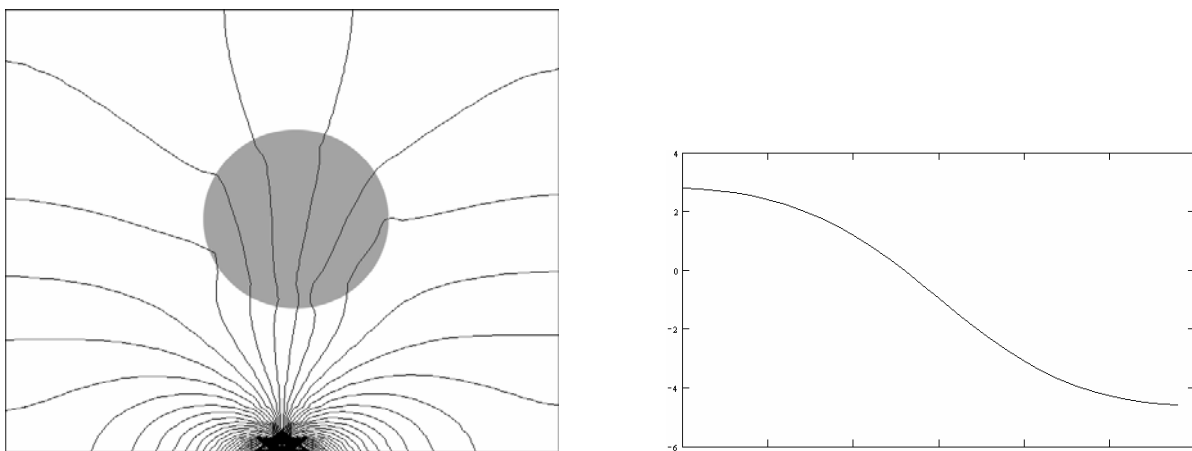


Fig.8. Distribution of electric field inside model after modification in form of circle inside model.

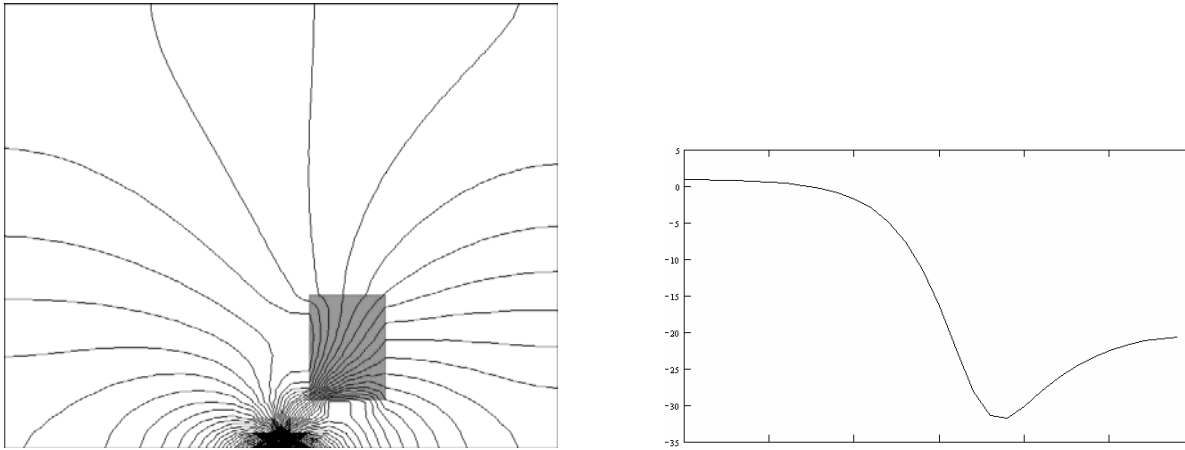


Fig.9. Distribution of electric field inside model after modification near external surface.

## 5. CONCLUSION

Obtained distributions of electric field will give model seem to be sufficient to determine depth of penetration. As we can see on first two simulations deep located artifacts do not produce clear changes of distribution of electric field on boundary of object (changes ca about 1%). It can partly be result of numeric calculation mistakes. Yet artifact near boundary disfigured potential distribution to 5% what seems sufficient result for reconstruction algorithm [2,4].

Introduced model possesses yet many defects, mainly it is flat. In real tissue current flows in whole volume, in that case creation of three-dimensional model of tissue will be next stage. It also seems that adding to model standard elements such as capacitors and coils might make it more accurate. By measuring not only amplitude, but also phase of signals it will be possible to obtain additional data about model.

Estimation of required measure precision (resolution of A/C converters) during measurements of real biological objects will be basic assignment of this model, as well as test of optimisation of dissolving of straight problem by elimination of nodes in model.

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