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Sensitivity of Four-electrode Focused Impedance Measurement (FIM) System for Objects with Different Conductivity

M A S Karal[1] and K S Rabbani [2]

Department of Physics, Dhaka University, Dhaka 1000, Bangladesh

email: asayem221@phy.buet.ac.bd; rabbani@univdhaka.edu

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Abstract

This work presents the results of an empirical study of the sensitivity of a four-electrode FIM technique developed by us earlier, for objects of different conductivity. FIM has potential for the characterization of biological tissue in physiological study and diagnosis. Experimental measurements were performed on a 2D phantom made up of saline with a focused square zone at the centre. Three cylindrical objects of different conductivities (an insulator, a conductor, and a piece of potato offering an intermediate conductivity) were used for the sensitivity measurements. Adjacent square zones had sensitivities of about 22% of that at the center for the insulator, about 13% for the conductor and about 10% for potato, showing a better focusing in the last case. The outer locations had negligible sensitivities. Inverse (negative) sensitivity, which is unavoidable in tetrapolar impedance measurements, was small and negligible in all the cases. Degree of perturbation of equipotential lines has been suggested to be the cause of the above differences in focusing, less perturbation giving rise to better focusing, which would apply for most biological objects to be studied using FIM.

Keywords: Focused Impedance Measurement, FIM, Electrical Impedance, Bioimpedance, Impedance sensitivity

Short title: Conductivity dependent sensitivity in 4-electode FIM

I. Introduction

There is a potential for the use of electrical impedance techniques for physiological investigation and diagnosis since electrical properties of body-tissues vary widely between different organs, and also between health and disorder[1,2,3]. The Biomedical physics Laboratory of the University of Dhaka conceived of and developed a new methodology, termed as focused Impedance measurement (FIM), which can localize a zone of interest in a volume conductor with simple electronic instrumentation. Two variations of FIM were developed. In one, six electrodes are needed to obtain impedances in two orthogonal directions, the sum of which has a predominant contribution from the central region, and hence is said to be focused[4,5]. The other method uses four electrodes to obtain the sum of impedances in two orthogonal directions [6,7] and has slightly reduced focusing compared to the former, but has the advantage of reduced number of electrodes. It can also be used in the transverse plane, while the former can be used from one side only, typically in the frontal plane.

In the four electrode technique, electrodes are placed on the corners of a square shaped focused region as described later. This is essentially a 2D technique, but since electrical current spreads in all possible directions, 3D sensitivity into the body may be utilized to get information on large organs like stomach, lungs, bladder or heart, or on tissues close to the skin using surface electrodes. Of course placing the electrodes in the transverse plane, deeper structures may be studied. The electrode configuration is the same as used by Brown et al[8] for tetrapolar measurement, but the use in getting a focused effect is novel.

The basic measurement method for this new four-electrode FIM technique is explained with the help of Fig.1, where p, q, r, & s are placed at the corners of a square region 'O', which is the focused zone of interest. Firstly a sinusoidal alternating current of constant amplitude, I, (at tens of kHz, typically) is driven through electrodes p & q while the potential amplitude V_{rs} is measured across electrodes r & s. Next, the same current is driven through electrodes q & r while the potential amplitude V_{sp} is measured across electrodes s and p. Equipotential lines a_1b_1 and c_1d_1 passing through the measuring electrodes r & s respectively for the first measurement enclose the region whose impedance is reflected in the measured value. Similarly equipotential lines a_2b_2 and c_2d_2 passing through the measuring electrodes s & p respectively for the second measurement enclose the region whose impedance is reflected in the measured value. The respective impedances are, $Z_1 = V_{rs}/I$ and $Z_2 = V_{ps}/I$. Now the sum $Z_T = Z_1+Z_2$ of these two impedances will have a dominant contribution from the central common zone, thereby producing the desired focusing effect. Sensitivity mapping using a 2D phantom containing saline in which an insulating cylindrical object was immersed at various 2D points, supported the expectation and established this technique. Fig 2 shows a block diagram of the instrumentation employed for such measurements where alternating current is passed through two adjacent electrodes and potential is measured across the rest two as described above, and the process is then rotated through 90^0.

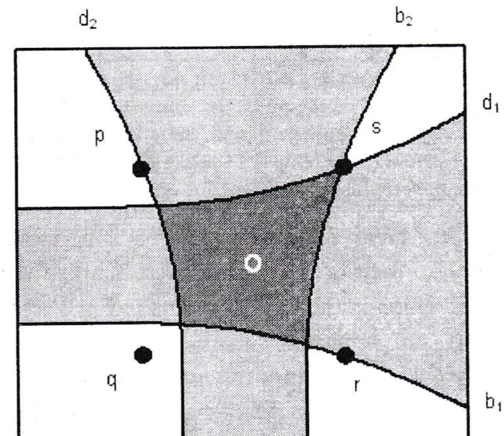

Fig.1. Electrodes and equipotential lines defining a focused zone in a 2D four-electrode FIM system.

[1] Presently at: Department of Physics, Bangladesh University of Engineering and Technology
[2] Presently at: Department of Biomedical Physics & Technology, University of Dhaka