ISSN No:-2456-2165

A Review Paper on the Sensitivity Analysis in Bioimpedance Measurement Technique

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Abstract:- Bioimpedance is one of the most modern measurements of human body which is very essential in analyzing different biological system. Sensitivity analysis is very important in measuring the bioimpedance. Comsol Multi physics software simulations that use finite element method plays a very important role in analyzing the sensitivity. Also Matlab was used in some cases with Comsol to show the 3D representation of sensitivity. Proper sensitivity analysis helps us predict contribution of any the change of conductivity within active. This paper is mainly focused on simulation that has been done so far in analyzing the sensitivity of the region of interest. This review paper shows the sensitivity for different configuration of electrodes- TPIM, 4 electrodes FIM, 6 electrode FIM, 8 electrode FIM. It also shows the sensitivity of the most recent configuration of electrodes where electrodes are placed on back and forth which enhance the sensitivity at the central region that is very important to measure the change of impedance for deep organ inside the body.

Keywords:- *Sensitivity, Comsol Multiphysics, Focused Impedance Method (FIM).*

I. INTRODUCTION

Every components of the human body have an electric features, the properties related with the opposition against an alternating current flow, are called bioimpedance. From the Ohm's law the proportion of the deliberate voltage to the applied current gives the transfer impedance [1], named as ohms. All the tissues in the body have diverse dielectric properties [2-4]; and for an individual tissue it is distinctive in wellbeing and illness. For instance, electrical impedance of harmful tissue is altogether lower than that of ordinary tissue [5, 6]. Bioimpedance can reflect distinctive physiological conditions and occasions; eg. transthorasic impedance changes during breathing in light of the fact that the electrical impedance of lung tissue changes as an element of air content [7]. The bioimpedance estimation measure is noninvasive, nonionizing and furthermore the instrumentation is very basic. Consequently the researchers everywhere on the world are pulled in towards the seeing of anatomical structures and physiological methodology and examination of the human tissues by electrical bioimpedance estimation strategies.

The commitment of the deliberate exchange impedance because of progress in conductivity of a point inside the volume conductor is characterized as sensitivity. To recognize the point sensitivity in the volume conductor correspondence hypothesis is applied which expresses that if the current and the potential electrodes sets are exchanged in the framework, the noticed qualities continue as before. Consequently the sensitivity can be gotten by considering just current passed through both the sets of electrodes. Thusly, on the off chance that we consider J1 and J2 as the current thickness vectors at a point inside the volume conductor because of presentation of current I over the convincing and detecting anode combines separately, at that point the sensitivity of the fact of the matter is expressed as [8,9],

$$Sensitivity = \frac{J1.J2}{I^2} \quad \text{.....(1)}$$

Thus if Jec, Jec2, Jec3 and Jec4 are the current density vectors at a point within the volume conductor due to the injection of current I then the FIM sensitivity at the point is defined by the following equation,

$$FIM\ Sensitivity = \frac{J_{ec}J_{ec2}+J_{ec3}J_{ec4}}{I^2} \quad \text{...(2)}$$

COMSOL Multiphysics expression applied for the 3D sensitivity distribution of FIM was then calculated from the [10]:

((ec.Jx*ec2.Jx+ec.Jy*ec2.Jy+ec.Jz*ec2.Jz)+(ec3.Jx*ec4.Jx+ec3.Jy*ec4.Jy+ec3.Jz*ec4.Jz))/((1[A])^2) … (3)

COMSOL Multiphysics is implemented in simulation analysis of bioimpedance specially measuring the sensitivity of the different region for different placement and configurations of electrodes.

II. DIFFERENT TYPES OF FIM (FOCUSED IMPEDANCE METHOD)

FIM is a combination of two orthogonally placed Tetrapolar (Four) Impedance Method (TPIM) where one pair of electrodes is used as current electrodes and other pair is used to measure the voltages. A group of researcher at BMPT Lab, Dhaka University innovated this method where the contribution of central part of the bulk conductor is much higher than the conventional TPIM also the negative sensitivity is much less than the TPIM. Three types of FIM have been analyzed so far.

A. 8- ELECTRODE FIM

Here Teterapolar electrodes are placed orthogonally which enhance the sensitivity at the central zone. Two pairs of electrodes are used as current electrodes and two pairs of electrodes are used as potential electrodes. The average of the two measurements gives the focused impedance. Figure 1 shows the arrangement of 8 electrodes FIM.

ISSN No:-2456-2165

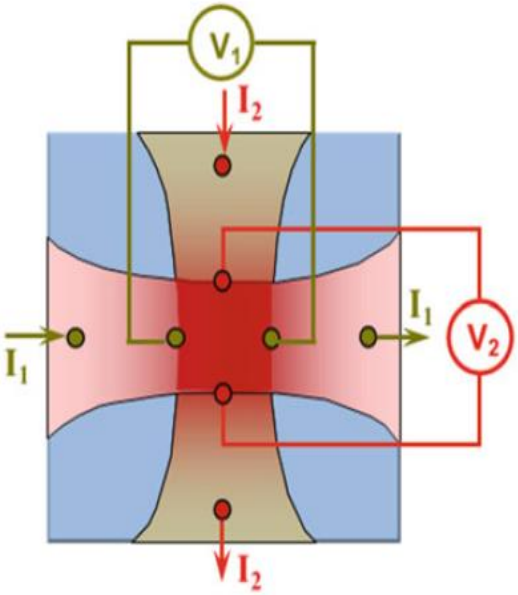

Fig. 1: Eight electrode FIM, consisting of two orthogonal TPIM systems. [11]

B. 6 -ELECTRODE FIM

For this situation supplanting the four inward likely electrodes in Fig. 1 is supplanted by two electrodes put at the two purposes of convergence of the four equipotential lines on the terminal plane as appeared in Fig. 2.This plan will decrease the quantity of electrodes from eight to six. This course of action is relied upon to give basically a comparative outcome as given by FIM-8 however with less complex instrumentation.

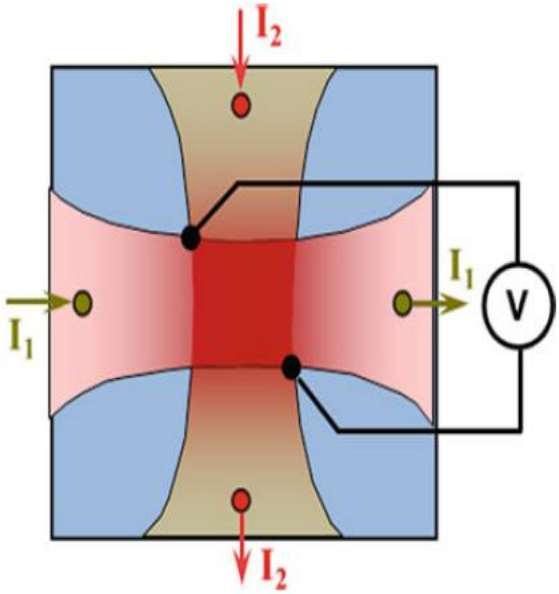

Fig. 2 : 6 electrode FIM [11]

C. 4 -ELECTRODE FIM

Here two contiguous terminals are utilized to drive the current, while the contrary pair of electrodes is utilized to gauge the possible contrast. To get a symmetrical estimation the entire plan is then exchanged. Once more, as before for FIM-8 and FIM-6, the normal of the two estimations has an upgraded sensitivity at the focal locale giving the ideal centered impedance. This arrangement utilizes the least number of electrodes and has a balanced math which makes it appealing in numerous applications.

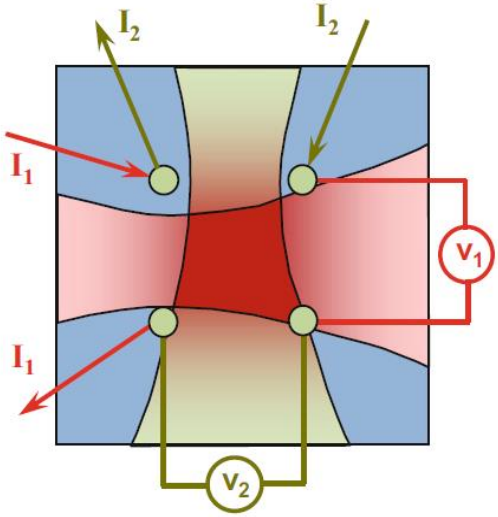

Fig 3: 4 electrode FIM [12]

III. SENSITIVITY OF DIFFERENT FIM

In this section we have shown the sensitivity analysis of different arrangement of FIM simulated so far. Figure shows the 3D sensitivity distribution of FIM-8, FIM-6 and FIM-4 at a depth of 2 mm from the electrode plane in a 200 mm cube done by Islam et al [13]. For this situation the sensitivity disseminations were estimated utilizing Matlab for each of the three FIM anode arrangements for a 200 mm sided 3D shape. For FIM-8 the current electrode separation was 48 mm, and the potential anode placement was 12 mm apart. For FIM-6 the current electrode partition was 48 mm and the potential electrode detachment was 25.5 mm estimated over the inclining, that respond to sides of 18 mm. For FIM-4 the electrode separating was 18 mm. Here the focusing effect can be detected, specially for FIM-8 and FIM-4. High sensitivities can be estimated at the electrodes and some negative sensitivity zone is additionally noticed. The centering isn't so clear for FIM-6 aside from high qualities under the two possible terminals. This is a direct result of the moderately enormous size of the focal square centering district (18 mm side) while that shown for FIM-8 has 12 mm sides. Lessening the size of the zone would decrease the plunge at the middle giving a superior visual translation of the centering. In the figure 4 each of the three figures show high sensitivities at the terminals other than some negative sensitivity as well. Nonetheless, it was seen that at expanded profundities the qualities decline and the centering impact is improved.

ISSN No:-2456-2165

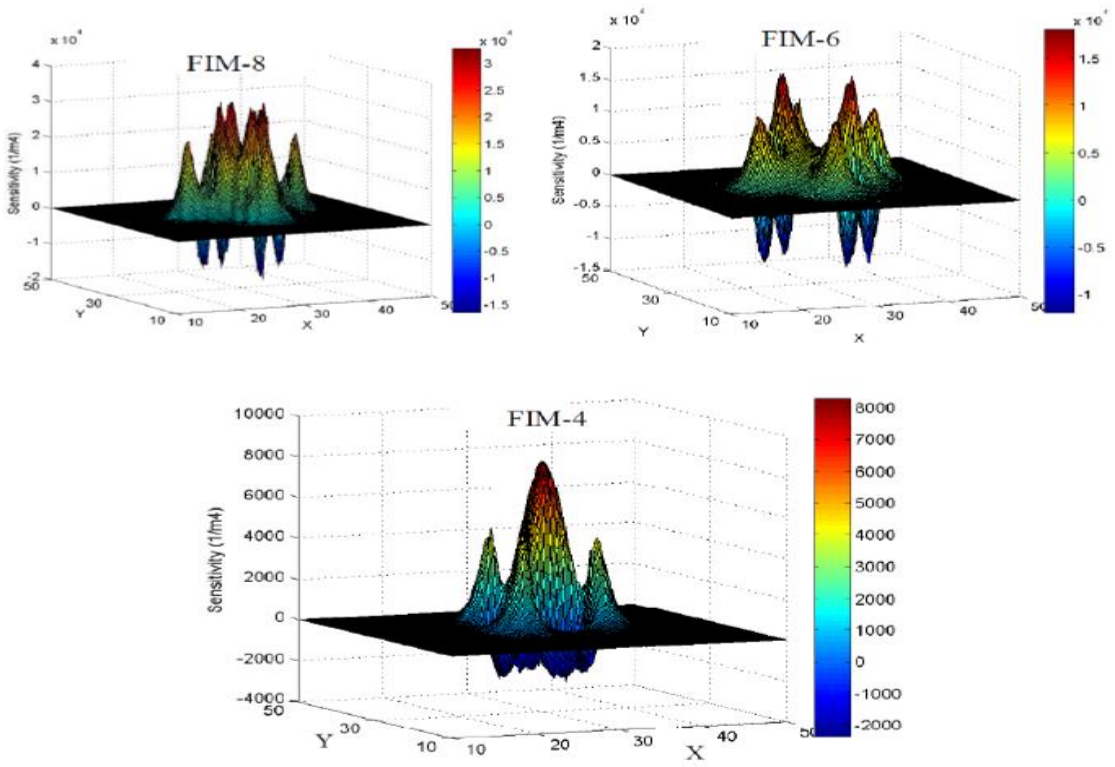

Fig. 4: 3D sensitivity distribution of FIM-8, FIM-6 and FIM-4 at a depth of 2 mm from the electrode plane in a 200 mm cube. [13]

IV. SENSITIVITY OF FIM 4

Kadir at el. (2013) have done this measurement of FIM 4 [14]. In their work they use a cubic tank of edge 30cm which is filled with saline water. The cylindrical electrodes of diameter 1cm and thickness 0.2cm placed on one of the sides, centrally. Separation of electrodes is 7cm. The studies were performed in the frequency domain at 5 kHz. In their work the incorporate a spherical object at the center and measure how sensitivity changes with the radius of the object.

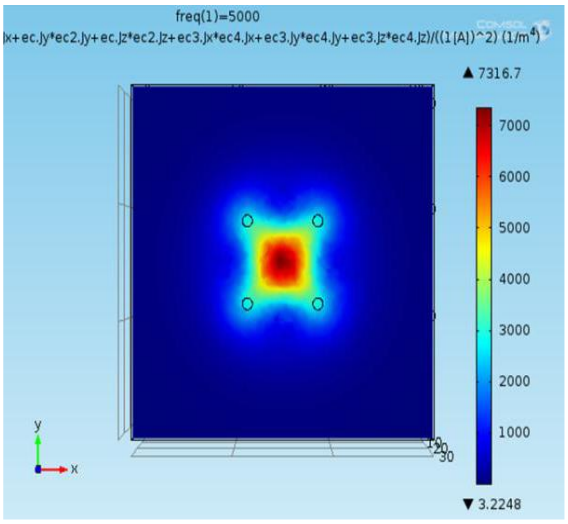

Fig. 5: Sensitivity distribution of FIM at a plane at 3cm depth from the electrode plane showing enhanced sensitivity at the central zone [14]

Figure 5 shows the COMSOL recreation of FIM sensitivity conveyance for the 4-anode setup at a profundity 3cm from the terminal plane. From the figure it is seen that the sensitivity of the focal zone underneath the electrode is incredibly higher contrasted with its environmental factors. This upgraded sensitivity zone is named as Focused zone. True to form it was likewise seen that the engaged zone sensitivity diminishes as the profundity is expanding.

V. USING ELECTRODES ON FRONT AND BACK OF THE VOLUME CONDUCTOR

In this section electrodes are used on front and back of the volume conductor suggested by Rabbani [15]. Karal et al. have done the simulation on 6 electrode impedance measurement technique and 4 electrode TPIM on cylindrical model which eventually enhances the sensitivity at the central region [16].Figure 6(a) depicts the planer sensitivity for cylindrical object for 6 electrode configuration and Figure 6(b) shows the same for TPIM . 10 cm electrode separation is implemented between potential electrodes.

ISSN No:-2456-2165

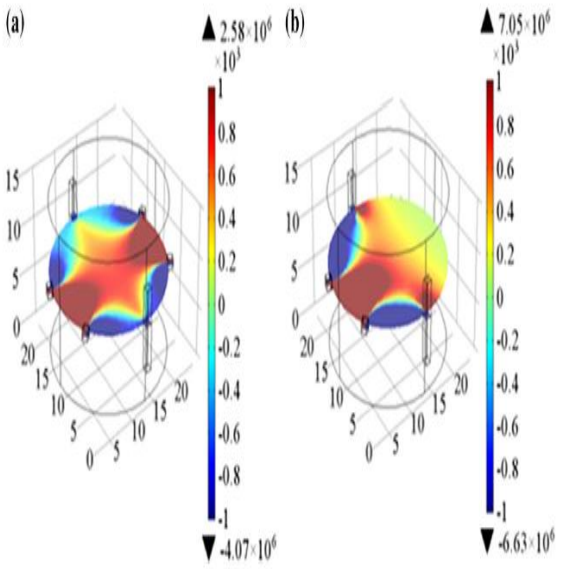

Fig 6: Sensitivity of (a) 6 electrode technique and (b) 4 electrode TPIM (Sensitivity range shown in the figure) [16]

Mobarak at el. (2019) have done the simulation of 4 electrodes FIM which essentially enhance the sensitivity at the center compare to other configuration where electrode separation is 15 cm. The box is filled with tap water with conductivity of 0.51 mS though the sensitivity of the water does not have any impact on the sensitivity in this case where no external object in incorporated. The placement of electrode plays a very significant role in probing deep organ of the body. This measurement has some negative sensitivity zone shown by the blue area in figure 8. electrodes are placed on one side of the body [17]. Size of the volume conductor used is 33 cm length, 26 cm width and 12 cm height as shown in figure. Sizes of the electrodes are 3 cm long and 0.3 cm diameter (shown in figure 6).

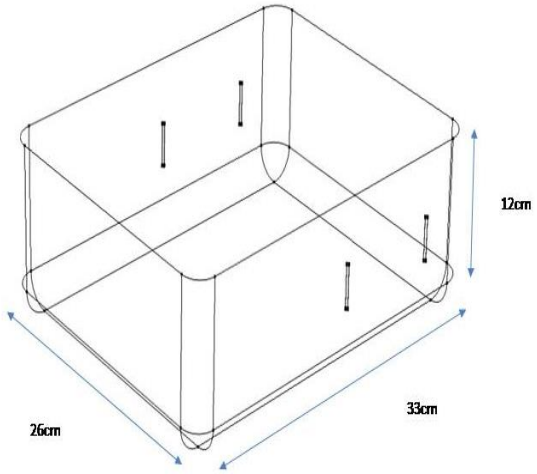

Fig. 6: FIM 4 with long electrodes where electrodes are placed front and back [17]

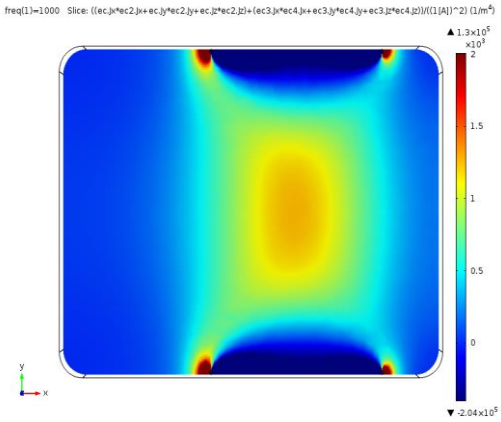

Fig. 8: Sensitivity of 4 electrode FIM of XY plane (Sensitivity range shown in the figure from -400 to 2000) [17].

VI. DISCUSSION AND CONCLUSION

This review paper on the application of Comsol Multiphysics and Matlab shows the simulation work done so far on measuring the sensitivity for various electrode arrangement of FIM. Sensitivity is very essential in measuring any changes of impedance specially in the electrode covering region. If sensitivity is positive and high any changes in the impedance has positive effect i.e. if the conductivity increases impedance decreases and if the conductivity decreases impedances increases. For negative sensitivity the effect is exactly opposite. So we have to be very careful in placement and arrangement of electrodes to identify the active and focus region; otherwise the measurement can give false result. So the proper selection of FIM measurement plays an essential role in measuring the bioimpedance correctly. In this paper sensitivity analysis of different FIM- 4 electrode, 6 electrode and 8 electrode have shown by using Matlab. Here the FIM 4 configuration with placing electrodes in one side of the volume conductor and the recently proposed technique where electrodes are placed on forth and back are also shown .This new arrangement of electrodes appear to be very effective in measuring impedance of deep organs of the body.

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