3D IMAGING OF BIOELECTRICAL SOURCES FROM SURFACE POTENTIAL MEASUREMENTS

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Source localization has been researched extensively by recording bioelectrical potentials on the body surface and attempting to localize their sources, which is termed the inverse problem. However the success has been limited only to resolving the sources in two dimensions (2D) uniquely, but a three-dimensional (3D) solution is yet exigent. The bioelectrical activity inside the body mostly consists of lumped or distributed charges in the form of dipoles. Many attempts to solve the inverse problem have been suggested. It was shown by Plonsey that there is no unique solution for the quasi-static inverse problem from the body surface potentials. Here we suggest a novel technique for measuring the depth of the source and hence localizing the sources in 3D.

Computer modeling and tank experiments have been conducted to verify the concept. Fig. 1 shows the computer model variation of potential difference along a line on the surface of the medium normal to the dipole orientation. It is seen from the dotted line in fig.1 that the dipole sustains a maximum potential difference (MPD) M1 between the disc and electrode when it is directly beneath the center of the electrode. If the dipole is deeper and yet beneath the center it will have lesser MPD M2 as seen from the solid line in fig. 1. This MPD will tend to fall exponentially with the order R^{-4}, with R as effective distance from the center of the electrode to the dipole. This effective distance is dependent on dimensions of the electrode and depth of the dipole. That is dashed line in fig.1 is the variation of potential difference along the same line but with a larger electrode and the MPD M3 is different from M2 even though the dipole was at the same position for both these plots. Since the dimensions of the electrode are fixed, having the knowledge of the MPD should, allow us to approximate the depth of the dipole.

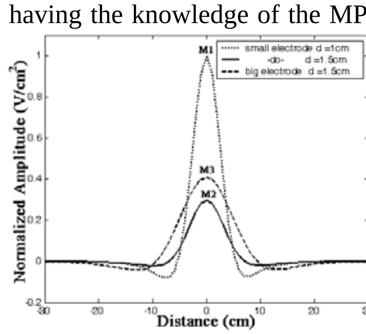

Fig. 1. Lines of Potential difference due an axial dipole at two different depths.

Fig.2 helps explains why M3 is different from M2. Fig.2 is a computer model plot of MPD vs. depth of the dipole for two different sized bipolar electrodes. The MPD varies differently as the depth increases for different size electrodes, this is clear as the dashed and the solid lines intersect at a particular depth (depth of intersection). This means that for a dipole at a certain depth the MPD will not be equal for different size electrodes. When the dipole depth is less than the depth of intersection the MPD of the smaller electrode is greater than that of the larger electrode and visa versa. By comparing the MPD of two different sized electrodes, it can be determined whether the dipole is at a depth less than or greater than the depth of intersection.

By adding another annulus with a radius greater than the outer annulus of a bipolar electrode a tripolar electrode is formed. Shorting the inner electrodes, and taking the difference of the outer electrode a pseudo-bipolar electrode (PBE) is formed. This idea can be expanded to add more annuli to make a multi-element electrode, which will have multiple PBEs of incremental sizes. If any annulus is considered as one pole then shorting all the elements of lesser radii forms the other pole of the PBE.

Two different sized bipolar electrodes divide the depth below into two zones (less than and greater than the depth of intersection). Similarly *n* different sized bipolar electrodes divide the depth below into at least *n* zones, for *n*>1.

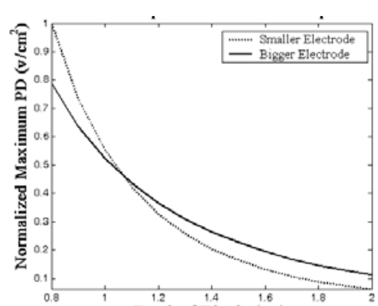

Fig. 2. MPD Vs Depth of dipole, plotted for two bipolar electrodes of different sizes.

The computer model results and the experimental verification clearly confirmed that direct measurements can be performed to differentiate the depth of dipoles using multiple sized concentric annuli electrodes. The use of multiple sized concentric annuli for measuring the source depth inside the volume of a body conductor is a novel technique. The principle of these multiple-annuli electrodes is similar to that of bipolar electrodes. This concept if studied further can provide a new direction in 3D source localization.