Factors affecting Sensitivity Maps in Magnetic Induction Tomography

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Abstract: Image reconstruction in Magnetic Induction Tomography (MIT) depends on a sensitivity distribution in a conducting volume, rather than a free-space background. The consideration of factors affecting sensitivity map generation is essential to optimise image reconstruction. The aim of this paper is to investigate such factors and to simulate sensitivity maps while varying conductivity contrast levels and perturbation dimensions.

1 Introduction

In Magnetic Induction Tomography (MIT), a sensitivity matrix maps the changes of conductivity distribution on to the changes of the voltages induced in a receiver coil. Korjenevsky et al [1] used filtered backprojection to reconstruct images (of plastic bottles containing saline solution both in free space and placed inside a larger saline filled tank), arguing that the regions of high sensitivity corresponded to 'flux tubes' linking the excitation and detection coils. Scharfetter et al [2] computed the sensitivity maps for low-contrast perturbations in a conducting background and concluded that the sensitivity was not confined to flux tubes; rather, they found that areas of maximum sensitivity lay on the periphery of the object and were strongly influenced by its conductivity contrast and the geometry. To optimise image reconstruction, it is essential to systematically analyse key factors affecting the sensitivity map. These include coil metrics and object geometry, the number of voxels, conductivity contrast and excitation frequency.

2 Methods

In this study, sensitivity maps were first computed for the coil design and application employed in the Cardiff MIT system [3], termed opposed coils, for a cylindrical sample volume (radius 10 cm, height 20 cm) with homogeneous non-zero conductivity, applying varying conductivity contrast and perturbation dimensions. In the perturbation method, the conductivity of all voxels in the modelled volume was set to 1 Sm^{-1}. A cubic group of voxels (image voxel) were then perturbed from 1 Sm^{-1} by a selected percentage in the range of 1% - 1000000%. The voxels were then reset to 1 Sm^{-1} and a new group of voxels were selected. This was repeated to produce $N \times N \times N$ image voxels covering the modelled volume for each coil combination, with the sensitivity matrix in this case having the dimensions of 240 (coil combinations) × 8000 (image voxels). The perturbation method allows sensitivity matrices to be derived for both the low contrast case with low percentage perturbations, and the high contrast case using high percentage perturbations. The modelled volume was discretised into $80 \times 80 \times 80$ cubic voxels, each of side 0.25 cm.

3 Results

Figure 1 shows the sensitivity maps of various conductivity and perturbation dimensions for an opposed coil arrangement. The columns show the sensitivity maps produced by applying perturbations of 1%, 10000%, 50000%, 100000% and 1000000%, corresponding to conductivities of 1.01 Sm^{-1}, 100 S m^{-1}, 500 Sm^{-1}, 1000 Sm^{-1} and 10000 Sm^{-1} respectively with a 1 Sm^{-1} background. The 2nd to 4th rows show sensitivity maps derived using perturbations of $4\times4\times4$, $8\times8\times8$, $16\times16\times16$ voxels. The last row shows a freespace sensitivity map derived for a $4\times4\times4$ perturbation of 1 Sm^{-1} in a 0 Sm^{-1} background. In each case, the map shows the sensitivity distribution at a cross-section of the mid-point of the volume, which corresponds to layer 40.

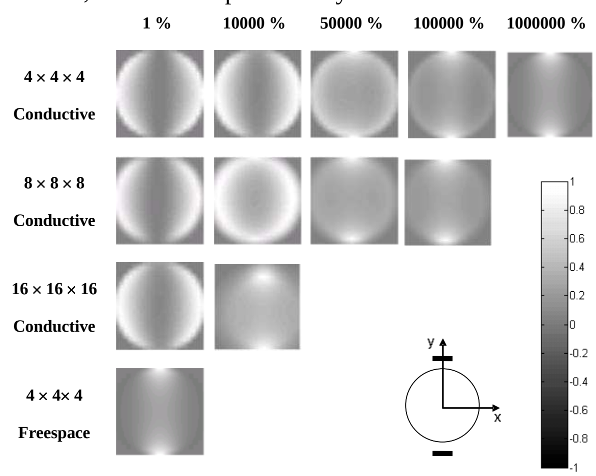

Figure 1: Sensitivity maps produced by applying perturbations of different percentage contrast levels and dimensions.

4 Conclusions

Several publications report MIT image reconstructions implemented when using metal objects. Such high contrast conductivity distributions may have localised zones of sensitivity, with eddy currents, and hence sensitivity localised within these zones. They appear to produce sensitivity distributions equivalent to the freespace condition. By comparison, lower contrast distributions produce a greater spatial range, appearing primarily at the periphery of the object. In conclusion, conductivity values and contrast greatly influence the sensitivity distribution of MIT systems, and these should be carefully selected as relevant to the application when developing algorithms and phantoms. Results obtained using metals objects, for instance, would not be expected to be relevant to most biomedical applications, and could be misleading.

References

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