Lorentz Force Electrical Impedance Tomography using Magnetic Measurements

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INTRODUCTION

In this study, a magnetic field measurement technique of Magneto-Acousto Electrical Tomography (MAET) is investigated to image the electrical conductivity properties of biological tissues. This technique is based on electrical current induction using ultrasound together with an applied static magnetic field. The magnetic field intensity generated due to induced currents is measured using a nearby coil configuration. A time-varying voltage is picked-up and recorded while the acoustic wave propagates along its path. A linear phased array piezoelectric transducer is used to form pressure distribution in human body/tissue. In the existence of a static magnetic field, the resultant (velocity) current density is sensed by a receiver coil encircling the tissue and used for reconstructing the conductivity distribution. Truncated Singular Value Decomposition (tSVD) Method is used as a reconstruction algorithm. Results show the potential of this approach as a practical and high resolution imaging modality for electrical conductivity imaging.

FORWARD PROBLEM

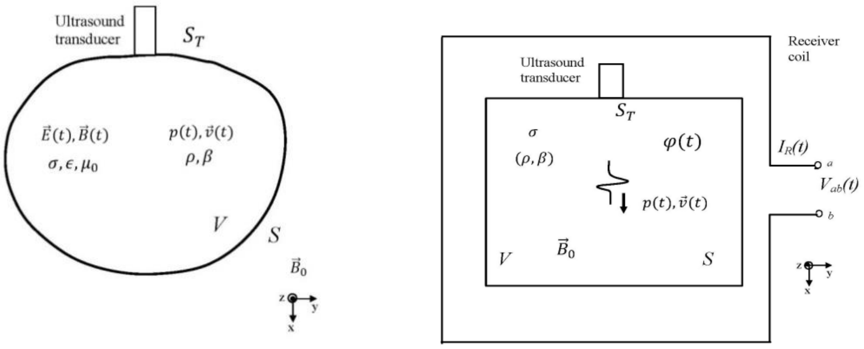
The forward problem of the proposed imaging modality is a *multiphysics* problem, i.e., the electromagnetic and acoustics fields must be solved simultaneously (Figure 1 (a)). In [1] the general formulation of the partial differential equations for the scalar and magnetic vector potentials were presented, and the partial differential equation for the acoustic pressure distribution was given. Thereafter, the relationship of the magnetic measurements to the existing (coupling) electromagnetic and acoustic waves was described. This relationship is given as a final formulation:

$$V_{ab}(t) = \int_{V_{body}} \frac{\partial}{\partial t}(\sigma \vec{v}(t) \times \vec{B}) \cdot \vec{E}_R^0(\sigma) dV \qquad (1)$$

where $\vec{E}_R^0(\sigma)$ is the reciprocal electric field normalized with reciprocal current in the receiver coil, $\vec{v}(t)$ is the particle velocity, $\vec{B}$ is the magnetic flux density, σ is the conductivity of the tissues, and $V_{ab}(t)$ is the pick-up voltage form the receiver coil (Figure 1 (b)).

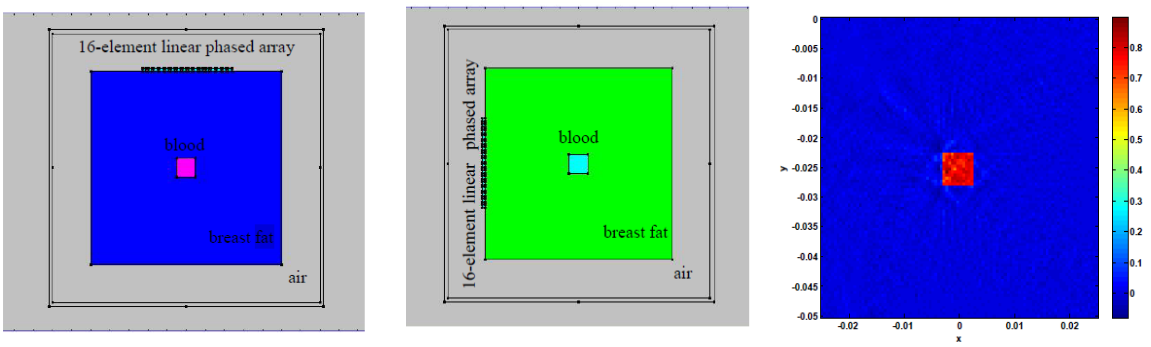
RESULTS

Numerical studies are conducted to show the feasibility of this imaging modality. COMSOL Multiphysics software is used to solve the corresponding multiphysics problem, namely, acoustic, piezoelectric and electromagnetic problems. For this purpose, a single inhomogeneity (square domain of 0.8221 S/m) is located at the center of the body with conductivity of 0.0257 S/m at a distance of 2.5 cm from the transducers (Figure 2 (a) and (b)). A single transducer (16-element linear phased array) is used for excitation. The excitation signal is assumed to be of the form $V_{exc} = \sin(2\pi f t)$ where the excitation is less than a period of the resonance frequency f=1 MHz. This transducer is steered for seven steering angles (-22.5°, -15°, -7.5°, 0°, 7.5°, 15°, 22.5°). The Truncated SVD method is used to reconstruct the image of the conductivity distribution.



(a) (b)

Figure.1: (a) Forward problem geometry. A body with electrical properties (σ, ε, μ_0) and bounded by surface S is under uniform static field $\vec{B}_0$ in the direction of z-axis. To introduce currents inside the body, an acoustic field is applied using an ultrasound transducer. The transducer surface which is in contact with the body surface is denoted by S_T . The acoustic material properties are the mass density ρ and compressibility β. Propagating ultrasound results in a time-varying pressure distribution *p(t)* and particle velocity *v(t).* The interaction of particle velocity *v(t)* with the magnetic flux density $\vec{B}(t)$ generates electric field $\vec{E}(t)$ in the body volume *V*. (b) Problem geometry of the magnetic field measurement approach. The changes in the magnetic field are measured using a coil encircling the body or placed nearby the body.



(a) (b) (c)

Figure.2: (a) The transducer is placed on the top edge of the body. (b) The transducer is placed on the left edge of the body. (c) The reconstructed image when SNR is 80 dB.

CONCLUSIONS

In this study, magnetic field measurement technique for MAET was investigated to image electrical conductivity of body tissues. This technique is based on the measurements generated by ultrasonically induced Lorentz fields. Coils encircling the body were assumed to be used for magnetic measurements. The relation between the measurements and conductivity distribution is given. The performance of the imaging system is investigated using simulation studies. The results show the potential value of this imaging modality.

REFERENCES

[1] R. Zengin, "Electrical impedance tomography using Lorentz fields," Ph.D. dissertation, Dept. Electrical and Electronics Eng., METU, Ankara, Turkey, 2012.