IMPLEMENTATION OF A DATA ACQUISITION SYSTEM FOR CONTACTLESS CONDUCTIVITY IMAGING

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Abstract-**A data acquisition system is realized to image electrical conductivity of biological tissues via contactless measurements. This system uses magnetic excitation to induce currents inside the body and measures the magnetic fields of the induced currents. A magnetically coupled differential coil system is scanned on the conductive object by a computer controlled scanning system. A data acquisition system is constructed using a PC controlled lock-in amplifier. 1.64V secondary voltage difference can be measured for 0.6 S/m solution. The average data acquisition time is 4.67 sec/mm². 8 mm diameter objects with conductivity 0.2 S/m can be detected with this system.**

***Keywords* - Electrical conductivity, magnetic induction, medical imaging**

I. INTRODUCTION

There are number of techniques to obtain conductivity images of human body [1]. In Applied Current Electrical Impedance Tomography (ACEIT) current injection and voltage measurements are both performed by the surface electrodes. In Induced Current EIT (ICEIT) currents are induced by magnetic induction and voltage measurements are performed by the surface electrodes. Both of these techniques employ electrodes attached on the body, and there are a number of limitations related to electrodes and associated cabling [2].

In this study a new medical imaging system is implemented to image the conductivity distribution by magnetic coupling [3]. The basic principle of the system is shown in Fig. 1. The instrument is a three coil differential transformer. Sinusoidal current excites the center coil (primary) and the two receiver coils (secondary) are connected in series to cancel out the voltage induced by direct coupling. The time varying magnetic field in the transmitter coil induces current in the receiver coils and conductive body. Receiver coil senses the magnetic fields induced by transmitter coil and the conductive body.

II. THEORETICAL BACKGROUND

The theoretical formulation relating conductivity to magnetic measurements is given in [3], however, it will be presented here briefly. Using the magnetic reciprocity theorem, it is possible to obtain the flux ϕ in the detector coil as follows (Fig.2):

$$\phi = \frac{1}{I_R}\int \vec{A}_R \cdot \vec{J} dV \tag{1}$$

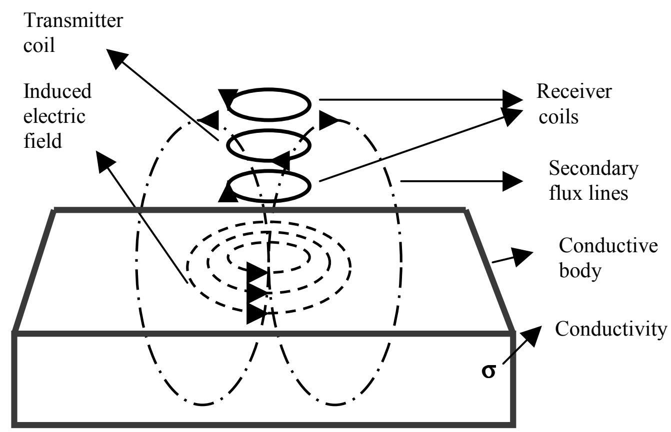

Fig.1. General principle of contactless conductivity imaging system.

where $\vec{A}_R$ is the magnetic vector potential crated by the reciprocal current I_R in the detector coil. Here $\vec{J}$ is equal to $\vec{J}_T$ in the excitation coil and $\vec{J}_I$ in the conductive body. Then flux in the detector coil can be obtained by taking the integrals in the corresponding volumes.

$$\phi = \frac{1}{I_R}\oint \vec{A}_R \cdot \vec{J}_T dV_{coil} + \frac{1}{I_R}\int \vec{A}_R \cdot \vec{J}_I dV_{body} \tag{2}$$

The first term on the right is the primary flux, directly coupled from the transmitter coil. The second term represents the flux caused by the induced currents. The electromotive force in the receiver coil can be expressed as:

$$v = -jw\phi$$

$$v = -j(I_T \oint (\frac{w\vec{A}_R}{I_R}) \cdot d\vec{l}\,) - \int (\frac{w\vec{A}_R}{I_R}) \cdot \sigma (w\vec{A}_T + \nabla\phi) dV' \tag{3}$$

The two terms in the right hand side represents the primary (v_p) and secondary (v_s) voltages respectively.

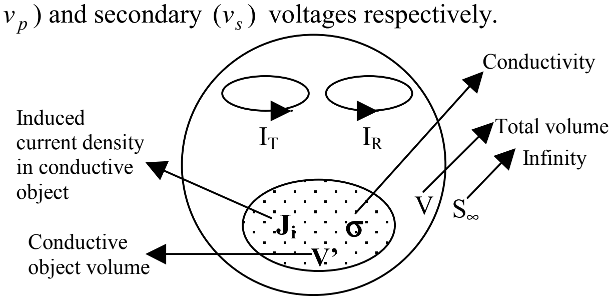

Fig.2. The relation between magnetic flux densities between transmitter coil current I_T and receiver coil I_R.

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III. METHODOLOGY

A. Data Collection System:

The block diagram of the data collection system is shown in Fig.3. The coils are coaxial and 15 mm in radius. Receiver coils are 10000 turns wound on a 3 cm in diameter delrin rod using 0.06 mm copper wire. Transmitter coil is 100 turns and at the same size.

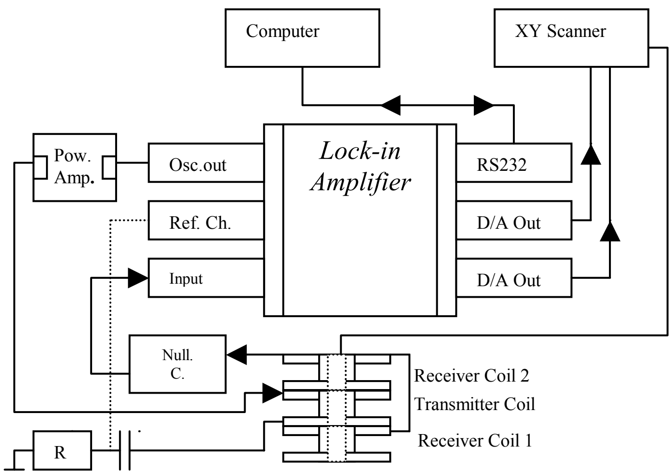


Fig.3. The structure of the data collection system.

Oscillator output of the lock-in amplifier feeds the power amplifier, which excites the transmitter coil. The induced primary voltage is cancelled out by the nulling circuitry so the residue signal becomes 30 mV when there is no conducting object. The output of the nulling circuitry is connected to the input of the lock-in amplifier for phase sensitive detection (The lock-in amplifier's reference signal is fed with the transmitter coil current). The instrument is controlled by a PC and the data is directly collected to the computer. D/A outputs of the lock-in amplifier is also controlled by PC, which feeds the XY scanner. The probe is connected to the XY scanner. Therefore it is possible to collect fully computer controlled data.

B. Choice of excitation frequency:

The operating frequency should be lower than 100 kHz for a number of reasons. High frequency is desirable since the secondary voltage increases with the square of the frequency. But low frequency is desirable to decrease the capacitive coupling between the coils. In most of the electrical impedance tomography studies the operation frequency of 50 kHz is usually used to avoid the effects of stray capacitances [4]. At higher frequencies the wavelength becomes smaller and received signals from the various part of the body do not arrive in phase [5]

The frequency response of the system is found by using computer controlled lock-in amplifier system in which the residue voltage is recorded with changing oscillator frequency (from 2 kHz to 100 kHz) (Fig.4).

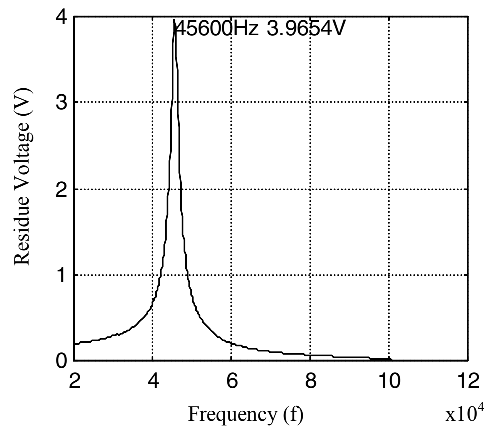


Fig.4. The frequency response of the system when the primary coil is not tuned. It is seen that the resonant frequency of the over all probe system is 45.6 kHz.

It is observed that the residue signal gets its maximum value at 45.6 kHz with 3.9V. The operating frequency from Fig.4 is chosen as 60 kHz where residue signal is 0.20V. The transmitter coil is tuned to 60 kHz. With this tuning the current in the transmitter coil and the residue voltage increases to 363 mA(p-p) and 27 V, respectively.

C. Nulling Circuitry:

The problem in measuring the voltage due to the existence of conductive body is that, the signal to be measured is usually too small compared to the residue voltage (for example, 30 mV compared to 27 V). Consequently, there should be a nulling circuit to cancel the effects of the residue voltage (Fig.5). The signal on the monitor resistor is amplified and phase shifted to obtain a signal, which is equal in magnitude and phase with the residue signal. The amplification and shifting operations is performed with manually controlled potentiometer. The residue signal becomes 30 mV when the nulling circuit is employed.

D. XY Scanning System:

To scan the probe over the phantom a computer controlled XY scanning system is used (Fig.6). The motion is controlled by two step motors, which are controlled by a step motor driving circuit that is fed by computer. The scanning system has a minimum step size of 0.4 mm.

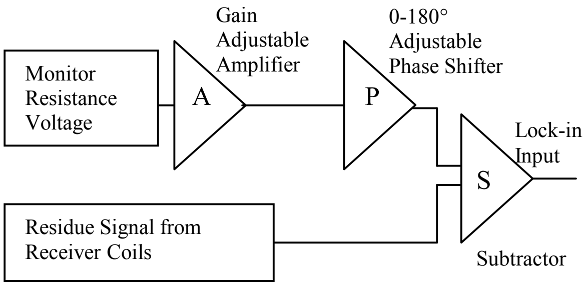


Fig.5. The block diagram of the manually adjusted nulling circuitry.

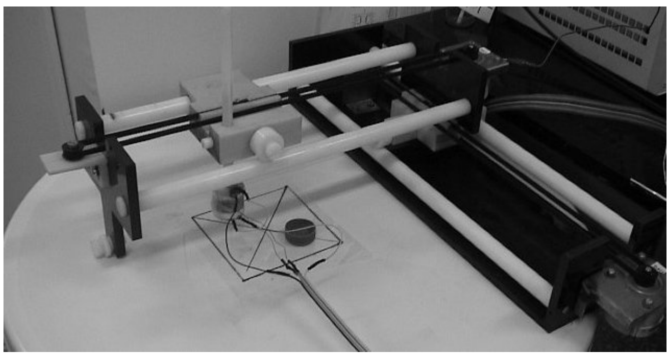


Fig.6. The picture of the XY scanning system with the probe attached. The system is made up of all plastic materials to avoid artifacts.

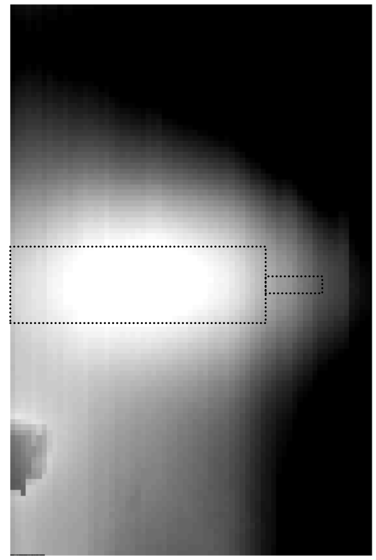
IV. MEASUREMENTS

Three different experiments are performed using different objects and/or experiment parameters. The result of each experiment is presented with gray scale image and contour plots. The actual object geometry is drawn on the gray scale images.

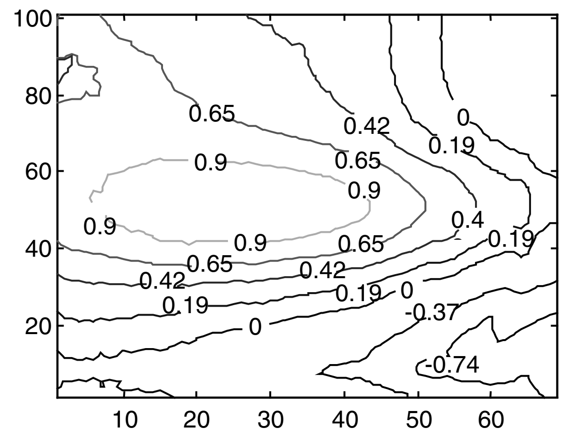
The first experiment is performed with 0.6 S/m saline solution filled syringe prepared with NaCl. The 6.9 cm x 10.1 cm pattern is scanned with 1 mm accuracy. The data acquisition time is 572 min. The voltage profile is shown in Fig.7a and Fig.7b.

The second experiment is performed with 0.6 S/m saline solution filled syringe. The 10.1 cm x 10.1 cm pattern is scanned with 4 mm accuracy. To increase SNR, 50 data is collected for each point. The total data acquisition time is 270 min. The voltage profile is shown in Fig.8a and Fig.8b.

The third experiment is performed with 0.2 S/m solution filled 8 mm diameter circular phantom. The 10.1 cm x 10.1 cm pattern is scanned with 6 mm accuracy. To increase SNR, 100 data is collected for each point. The total data acquisition time is 240 min. The voltage profile is shown in Fig.9a and Fig.9b.



(a)



(b)

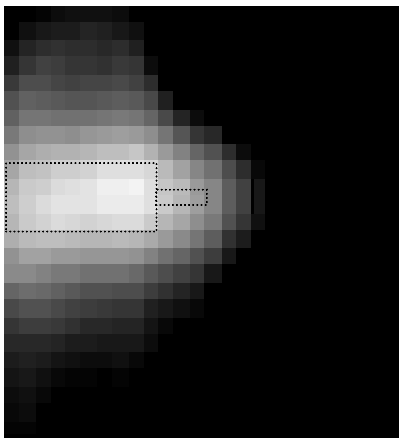
Fig.7. Experiment result of 0.6 S/m solution filled syringe scanned with 1mm accuracy. There is an artifact due to external effects at the left corner. (a) Gray scale Image (b) Contour plot

V. CONCLUSION & DISCUSSIONS

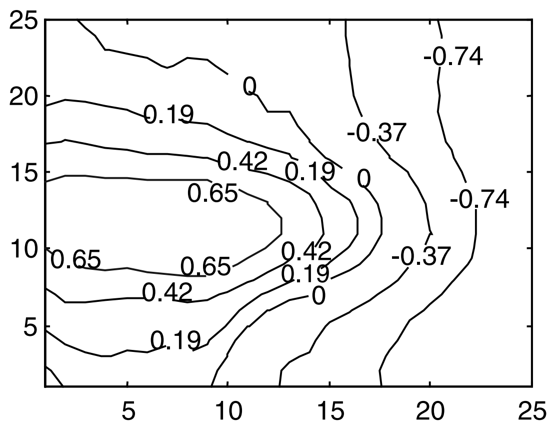
In this study a data acquisition system is realized for conductivity imaging via contactless measurements. It is observed that field profiles are good representatives of the conductive objects scanned by the measurement system. Note that in these study only the field profiles are presented. The three dimensional conductivity distributions can be obtained using the methods discussed in [3].

Three different data is taken with different scanning resolutions. Note that although the resolution decreased by 25 times it is still possible to observe the conductive object. As it might be expected the field profiles spread.

In conclusion, the first results of a promising new medical imaging modality were presented. This system can provide necessary conductivity information for electromagnetic source imaging of brain. Moreover this system can be applicable to brain, breast and lung imaging [1]. Other application areas should further be explored.

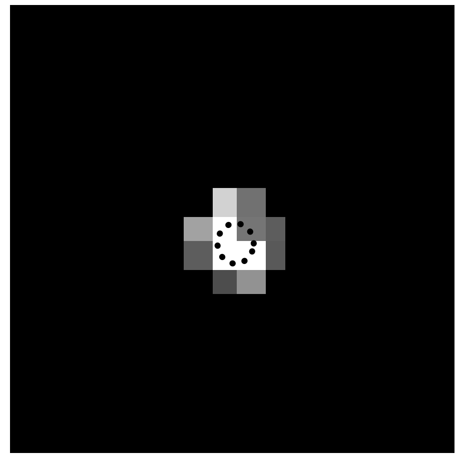


(a)

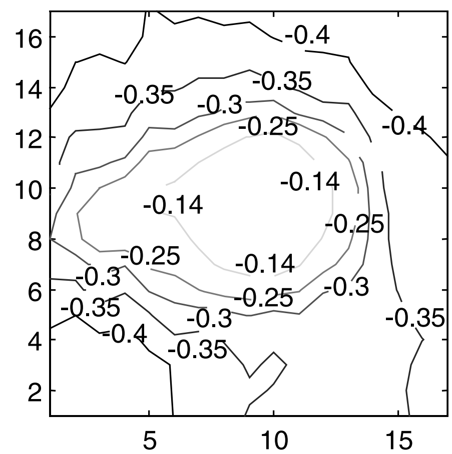


(b)

Fig.8. Experiment result of 0.6 S/m solution filled syringe scanned with 4mm accuracy. (a)Gray scale Image (b) Contour plot



(a)



(b)

Fig.9. Experiment result of 0.2 S/m s solution filled 8 mm diameter phantom scanned with 4mm accuracy. (a)Gray scale Image (b) Contour plot

REFERENCES

[1] J.P. Morucci and B. Rigaud, "Bioelectrical impedance techniques in medicine," *Crit. Rev. Biomed. Eng*. Vol 24, nos.4-6,pp. 655-677,1996.

[2] N.G. Gençer, Y.Z. Ider, S.J. Williamson "Electrical impedance tomography: induced current imaging achieved with a multiple coil system" *IEEE Trans. Biomed. Eng.* Vol 43,pp. 139-149,1996.

[3] N.G. Gençer, M.N. Tek "Electrical conductivity imaging via contactless measurements" *IEEE Trans. Med. Imag.* Vol 18, no 7, pp. 617-627,1999.

[4] J.P. Morucci and B. Rigaud, "Bioelectrical impedance techniques in medicine," *Crit. Rev. Biomed. Eng*. Vol 24, nos.4-6,pp. 467-597,1996.

[5] P.P. Tarjan " Electrodeless Measurements of Resistivity Fluctuations in the Human Torso and Head ", *PhD. Thesis*, Syracuse University,1968.