A NEW LINEAR ARRAY IMAGING SYSTEM OF ELECTRICAL AND ULTRASONIC PROPERTIES IN A LIVING BODY

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Abstract: In this paper, a new linear array imaging system of ultrasonic and electrical properties in the living body is proposed. The proposed imaging system measures not only the ultrasonic property of the living body using the linear arrayed piezoelectric ceramic transducers, but also the electrical property using the surface electrodes of each piezoelectric ceramic transducer. From these data, ultrasonic and electrical properties in the same object space are simultaneously reconstructed. In the experiment, propagation time and electrical voltage of the living body model are measured by the proposed imaging system based on linear arrayed eight piezoelectric ceramic transducers. Ultrasonic and electrical properties are reconstructed from the measurement values. It was found that the ultrasonic and electrical properties in the same space could be reconstructed by the proposed imaging system. Therefore, it is suggested that the proposed imaging system has potential for application although there are some problems that must be solved.

1 INTRODUCTION

Imaging techniques based on the ultrasonic property (Opielinski and Gudra, 2000, Simaeys et al., 2000) or electrical property (Holder et al., 1993, Barber and Brown, 1984) of a living body are especially important in medical field, and have been actively researched. A non-invasive ultrasonic imaging system using ultrasonic properties of the living body has been studied for determining the blood flow velocity distribution and internal organ imaging (Nitta et al., 1996, Lopez et al., 1992). The electrical impedance computed tomography using electrical properties of the living body has also been developed for imaging of the heart and lungs (Fuks et al., 1991), temperature distribution measurements (Conway et al., 1992) and so on.

The aim of our research is to establish a non-invasive simultaneous imaging system of two parameters in the living body such as temperature and a body composition. To achieve it, we propose a new linear array imaging system of ultrasonic and electrical properties in the living body. In the proposed system, the ultrasonic propagation time is measured by the linear arrayed piezoelectric ceramic transducers. In addition, the electrical potential is measured by the surface electrodes of poizoelectric ceramic transducers (Kimoto and Shida, 2001, 2002). Therefore, it is possible to measure the ultrasonic and electrical properties in the same object space using the proposed imaging system. From these data, ultrasonic and electrical properties in the living body are reconstructed. Moreover, two parameters such as temperature and composition are estimated from their reconstructed distributions.

In this paper, the imaging system with the linear arrayed eight piezoelectric ceramic transducers is established. In the experiment, ultrasonic propagation time and electrical voltage in 0.1 % saline solution with acrylic as the living body model are measured by the proposed imaging system, and then, the reconstructions of ultrasonic and electrical properties are demonstrated from their measuremet values.

2 PRINCIPLE

The ultrasonic and electrical properties in the living body are generally measured by different sensors. In the proposed method, they are measured by the same sensor. Figure 1 shows the measurement method of the ultrasonic and electrical properties in the living body. In this method, a linear arrayed piezoelectric ceramics are used. In figure 1(a), an electrical signal with a resonance frequency of the piezoelectric

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ceramic transducer, S_t, is applied to a piezoelectric transducer, and the reflected wave, S_r is measured by the other piezoelectric ceramic transducer. From these signals, the ultrasonic property of the object is obtained. In figure 1(b), the constant current is injected between the surface electrodes of a pair of piezoelectric ceramic transducers and the induced voltage between each surface electrodes are measured. The electrical property is obtained from the induced voltage and injected current. Therefore, the ultrasonic and electrical properties in the same object space are obtained using a pair of piezoelectric ceramic transducers. Moreover, the reconstructed distributions of the ultrasonic and electrical properties are respectively obtained from the measured values by using linear arrayed many piezoelectric ceramic transducers.

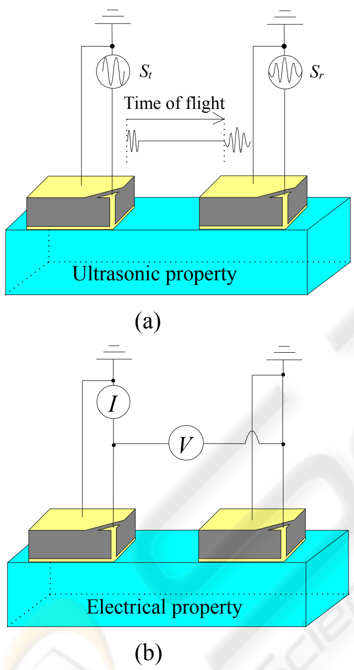


Figure 1: Measurement method. (a) Measurement of ultrasonic property. (b)Measurement of electrical property.

3 MEASUREMENT SYSTEM

Figure. 2 shows the schematic diagram of the measurement equipment. The rectangular equipment (40×40×100 mm^3) was constructed by acrylic plate and the eight piezoelectric ceramic transducers (10×5×1 mm^3) with 2 MHz resonance frequency are linearly arrayed with the gap of 1 mm at an acrylic plate inside the equipment. It is filled with the 0.1% saline solution as the living body model.

Figure 3 shows the outline of the measurement system. In the ultrasonic measurement, the burst wave of the five sinusoidal waves with the amplitude of 10 V and the 2 MHz frequency as the transmitted wave is given to one of the piezoelectric ceramic transducers by the function generator. The reflected wave is measured by each piezoelectric ceramic transducer. Transmitted and reflected waves are passed through the AD converter and stored at the PC. From their waves, propagation time is obtained.

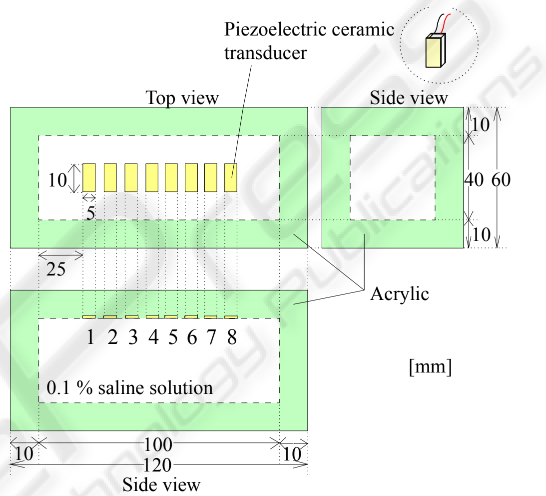


Figure 2: Schematic diagram of experimental equipment with linear arrayed eight piezoelectric ceramic transducers.

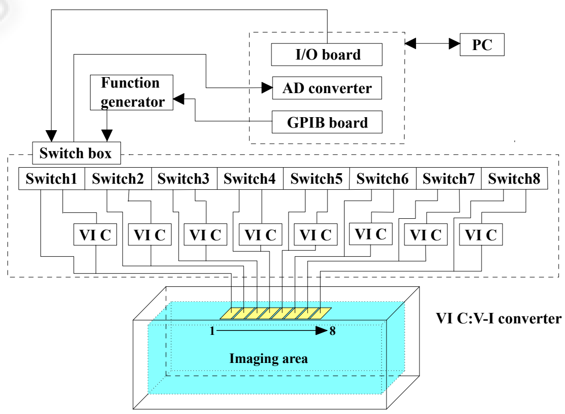


Figure 3: Schematic diagram of measurement system.

In the electrical measurement, the sinusoidal current of 1mA, which sinusoidal voltage with the amplitude of 1 V and 10 kHz frequency is converted by V-I converter, is injected between the surface electrodes of a pair of piezoelectric ceramic transducers. The voltages induced on rest of surface electrodes of piezoelectric ceramic transducers are measured. Each voltage is also digitalized by the AD converter and stored at the PC.

The ultrasonic and electrical measurements and the selection of piezoelectric ceramic transducers are changed using the switching system controlled by the I/O signal.

4 EXPERIMENT

Figure 4 shows the experimental model. 0.1 % saline solution model, which acrylic (10×10 mm^2) is inserted at the position of 15 mm apart from the piezoelectric ceramic transducers, was prepared. The ultrasonic and electrical distributions are respectively reconstructed from the measurement values of ultrasonic propagation time and electrical voltage. In this time, propagation time and voltage for reconstructing the ultrasonic and electrical distributions were measured as follows.

Propagation time as ultrasonic property was obtained from transmitted and reflected waves measured at each piezoelectric ceramic transducer from No.1 to No.8. Therefore, ultrasonic distribution was obtained from eight data. In electrical property, the voltage induced at surface electrode of piezoelectric ceramic transducer between a pair of surface electrodes used as current electrodes was measured. Table 1 shows the combinations of current and voltage electrodes. Therefore, 56 voltage values were used for the imaging of electrical property. In this time, impedance distribution as electrical property was reconstructed by the measured data and the numerical calculation using the finite element method (FEM).

Table 1: Combination of electrical measurement.

Current electrode numbers	Voltage electrode number
(1,3), (2,4), (3,5), (4,6),(5,7),(6,8)	(2), (3), (4), (5), (6), (7)
(1,4), (2,5), (3,6), (4,7), (5,8)	(2,3), (3,4), (4,5), (5,6), (6,7)
(1,5), (2,6), (3,7), (4,8)	(2,3,4), (3,4,5), (4,5,6), (5,6,7)
(1,6), (2,7), (3,8)	(2,3,4,5), (3,4,5,6), (4,5,6,7)
(1,7), (2,8)	(2,3,4,5,6), (3,4,5,6,7)
(1, 8)	(2,3,4,5,6,7)

Figure 5 shows the 26 unknown elements of impedance estimated by FEM. Impedance values in other regions are those of 0.1 % saline solution. Impedance of each element was estimated by the modified Newton-raphson method as the iterative method (Kimoto and Shida, 2000).

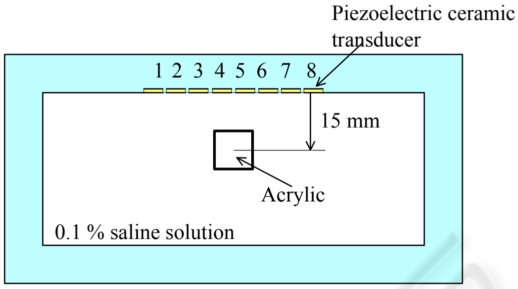


Figure 4: Reconstructed model.

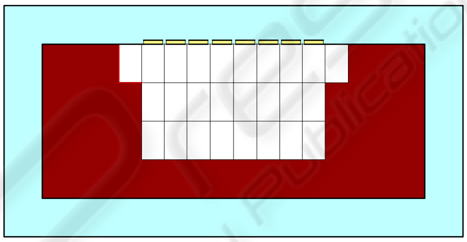
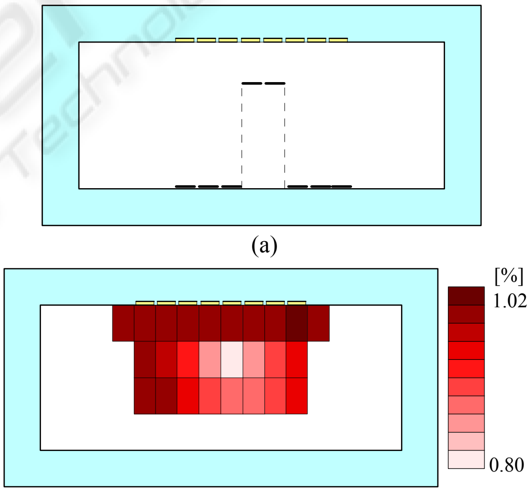


Figure 5: Estimated elements of electrical property.



(a)

(b)

Figure 6: Reconstructed results. (a) The ultrasonic propagation time. (b)The change ratio of electrical impedance.

5 RESULTS

Figure 6 shows the reconstructed results of ultrasonic and electric properties. Figure 6(a) shows the positon of reflected wave obtained by the propagation time and the sound speed. In this time, sound speed was calculated by propagation time measured in 0.1 % saline solution and 40 mm distance of equipment. From figure 6(a), it is found that the boundary of the target in 0.1 % saline solution is obtained although it was difficult to detect the construction of the target. Figure 6(b) shows the impeadace change ratio between 0.1 % saline solution with and without acrylic at three iteration. From figure 6(b), it is found that impedace in the part of acrylic decreased although the estimated resolution is insufficient. In this system, it is possible to reconstruct the ultrasonic and electrical properties by measuremets of propagation time and voltage. In addition, it is suggested that the resolution of the reconstructed image would be improved by combining the ultrasonic and electrical reconstructed images because their reconstructed distributions are different.

6 DISCUSSION

The accuracies of reconstructed distributions of ultrasonic and electrical properties were insufficient. They are mainly caused by measurement error of the system and insufficient measured data number. The measurement system, especially, the switching system must be improved. Data number will be also increased by using several measurement combinations.

In this time, although ultrasonic and electrical measurements are changed by the switching system, simultaneous measurements of the ultrasonic and electrical properties are possible in which one electrical signal is created from the electrical signal with the resonance frequency for ultrasonic measurement and that of the electrical impedance measurement and is applied to the electrode as an alternating current.

7 CONCLUSIONS

A new linear array imaging system of ultrasonic and electrical properties in the living body was proposed. In the proposed imaging system, the ultrasonic propagation time is measured by the linear arrayed piezoelectric ceramic transducers and the electrical potential is also measured by the surface electrodes of poizoelectric ceramic transfuces. Therefore, it is possible to measure the ultrasonic and electrical properties in the same object space using the proposed system. From these data, ultrasonic and electrical properties in the living body are reconstructed. In the experiment, the ultrasonic and electrical properties in 0.1 % saline solution with acrylic as the living body model were reconstructed from propagation time and voltage measured by the proposed imaging system. As a result, it was suggested that the proposed imaging system has potential for application although there are some problems that must be solved.

REFERENCES

Opielinski K. J. and Gudra T., 2000, Ultrasound transmission tomography image distortions caused by the refraction effect, *Ultrasonics*, vol.38, pp.424-429

Simaeys B., Philips W., Lemahieu I. and Govaert P., 2000, Quantitative analysis of the neonatal brain by ultrasound, *Computerized Medical Imaging and Graphics*, vol.24, pp.11-18

Holder D. S., Ed., 1993, Clinical and physiological applications of electrical impedance tomography, UCL Press London

Barber D.C. and Brown B.H., 1984, Applied potential tomography," *J. Phys. E: Sci. Instrum.*, vol.17, No.9, pp.723-733

Nitta N., Hagihara K. and Shiina T., 1996, Experimental Investigation of 3-D Blood Flow Velocity Measurement, *Jpn.J.Appl.Phys.*, vol.35, Pt.1, 5B, pp.3126-3130

Lopez H., Loew M.H. and Goodenough D.J., 1992, Objective Analysis of Ultrasound Images by Use of a Computational Observer, *IEEE Trans. on Med. Img.*, vol.11, No.4, pp.496-506

Fuks L. F., Cheney M., Isaacson D., Gisser D. G. and Newell J. C., 1991, Detection and Imaging of Electric Conductivity and Permittivity at Low Frequency, *IEEE Trans. Biomed Eng.*, vol.38, No.11, pp.1106-1110

Conway J., Hawley M., Hangnall Y., Amasha H. and VanRhoon G. C., 1992, Experimental assessment of electrical impedance imaging for hyperthermia monitoring, *Clin. Phys. Physiol. Meas.*, vol.13, Suppl.A, A185-A189

Kimoto A. and Shida K., 2001, Proposal of a New Multifunctional Measurement Method Using Piezoelectric Vibrator, *Jpn. J. Appl. Phys.* Vol.40, Part1, 6A, pp.4258-4259

Kimoto A. and Shida K., 2002, A proposal of measurements of conductance and propagation time for determination of temperature and ingredient in the living body model, *Trans. IEE of Japan*, vol.122-E, No.6, pp.332-337 (in Japanise)

Kimoto A. and Shida K., 2000, Imaging of temperature-change distribution in the brain phantom by means of capacitance measurement , IEEE Transactions on Instrumentation and Measurement, Vol.49, Issue 3, pp.591-595