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Visualization of Frequency Dependent Attenuation of Tissue by Phase-Contrast Imaging Based on Ultrasonic Interference Method

超音波干渉法による位相差画像を用いた組織の周波数依存性の検討

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1. Introduction

To order to enable definitive diagnosis of tissue by ultrasonic examination, we have developed a puncture needle-type ultrasonography.[1-6] This imaging method makes it possible to observe cells without staining like optical microscopy. In this imaging method used for pathological diagnosis, it is necessary to display more information in the image to make it possible to distinguish cancer tissue from normal tissue. As is well known, the frequency dependence of attenuation due to viscosity and elasticity depends on the type of elastic body and the amount of oil contained therein. The ability to display difference in frequency dependence as an image may provide useful information for pathological diagnosis. Previously, we have demonstrated that by using multispectral phase-contrast imaging of acoustic impedance we can obtain difference in frequency dependence of samples.[7] In this study, we performed experiments on samples similar to living tissues, assuming clinical application.

2. Principle

2.1 Phase-contrast imaging of complex acoustic impedance[6]

The phase-contrast imaging procedure is illustrated in **Fig. 1**. Complex acoustic impedances are represented as

$$\dot{Z}_{L1} = |Z_{L1}| e^{j\varphi_{L1}} \qquad (1)$$

$$\dot{Z}_{L2} = |Z_{L2}| e^{j\varphi_{L2}} . \qquad (2)$$

When a burst signal is transmitted from the PZT, it is reflected at the end of the rod sensor and the surfaces of the sample. Both reflected signals interfere with each other, and the amplitude of the interference signal indicates the magnitude and phase difference of the complex acoustic impedance of the sample. When the magnitude difference is small ($|Z_{L1}| \approx |Z_{L2}|$), the contrast of the image mainly shows the phase difference ($\varphi_{L1} - \varphi_{L2}$) of the complex acoustic impedance.

2.2 Multispectral phase-contrast imaging of acoustic impedance[7]

Figure 2 illustrates the concept of multispectral phase-contrast imaging. Frequency-dependent scattering and attenuation are displayed in one image by measuring three images of different frequencies and superimposing them in one image by intensity modulation of three colors (red, green, and blue).

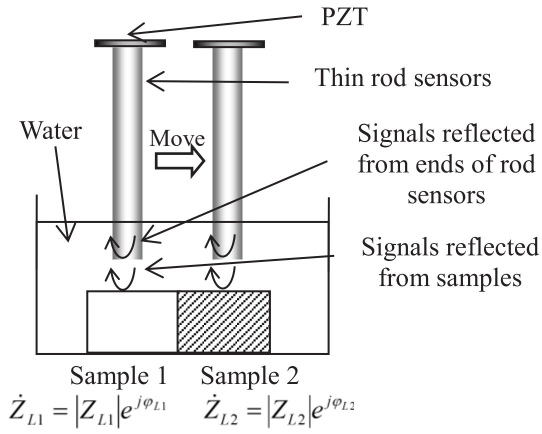

Fig. 1. Phase-contrast imaging procedure.

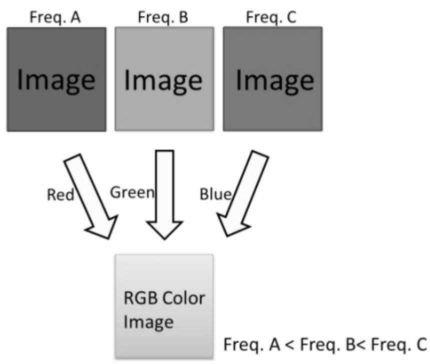

Fig. 2. Concept of multispectral phase-contrast imaging.

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3. Experiment

Figure 3 shows a schematic diagram of the experimental setup. In this experiment, a fused quartz rod having a diameter of 0.83 mm and a length of 62 mm was connected to a transducer having a center frequency of 44.9 MHz. The tip of the rod had a concave spherical surface with a focal length of approximately 0.5 mm from the end of the rod. Three electrical burst waves with amplitude 10 Vp-p, frequencies 40.0 MHz, 44.9 MHz, and 50.0 MHz, and pulse width 20 cycles were applied. Sample (processed meat with scattering and viscoelastic structure) was used as an imaging object.

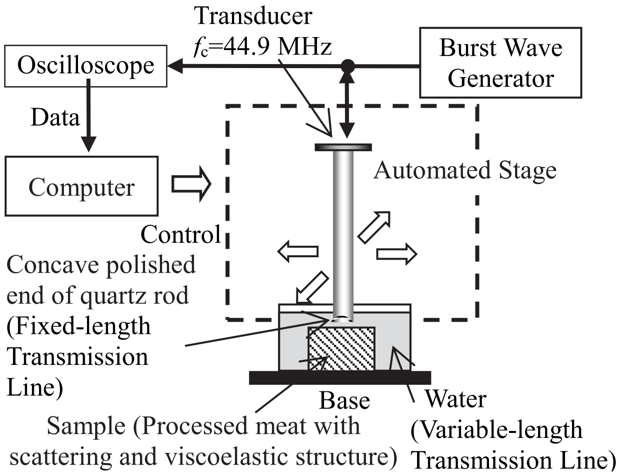


Fig. 3. Schematic diagram of experiment.

4. Results and discussion

Figure 4 shows a photograph of the sample. **Figure 5(a)-(c)** show the phase-contrast images measured at the three burst wave frequencies. **Fig. 5(d)** shows the superimposed image. The left side of the image is the lean meat, the right side is the fat part. Comparing the lean meat parts in Fig. 5(a), (b), and (c), Fig. 5(b) is bright. That is, the lean portion contains many frequency components of 44.9 MHz. In Figs (a) and (b), the fat area is bright. It contains many low frequency components from 40 MHz to 44.9 MHz. FIG. 5(c) is displayed dark as a whole. This was absorbed by the viscosity of the sample. In addition, Fig. 5(d) is difficult to understand with a gray scale image, but expression in the image is different between lean meat and fat. This is because lean meat consists of muscle, fibrous and scatterers, and fat is made up of oil, that is, viscous body.

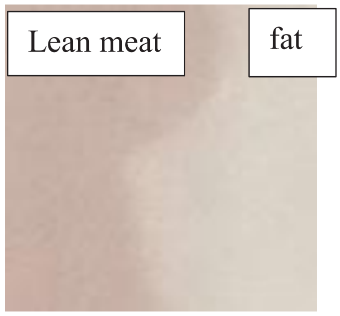
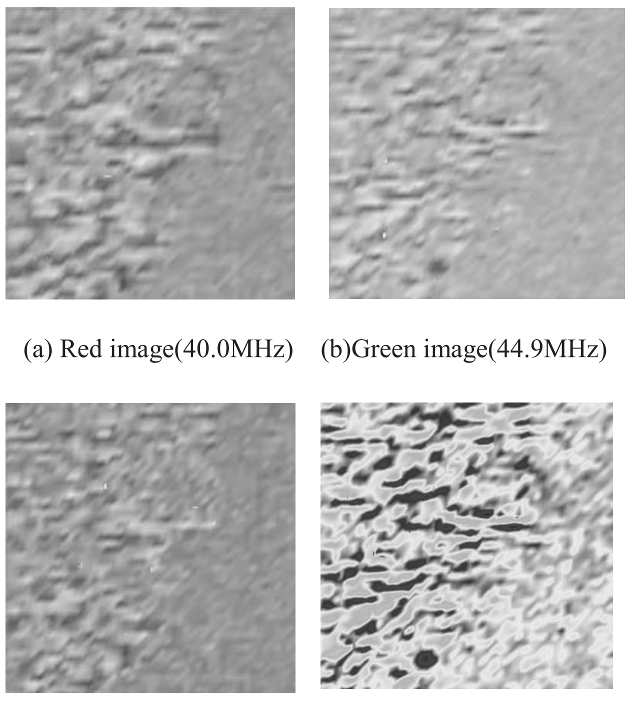


Fig. 4. Photograph of sample.



(a) Red image(40.0MHz) (b)Green image(44.9MHz)

(c) Blue image (50.0 MHz) (d) Superimposed image

Fig. 5. Phase-contrast images of sample.

5. Conclusion

We demonstrated the possibility of expressing the difference in structure of samples using multispectral phase contrast imaging. In the future, it is necessary to analyze the effectiveness quantitatively by simulation.

References

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