A Study for B-mode Imaging using 100-MHz-Range Ultrasound through a Fused Quartz Fiber

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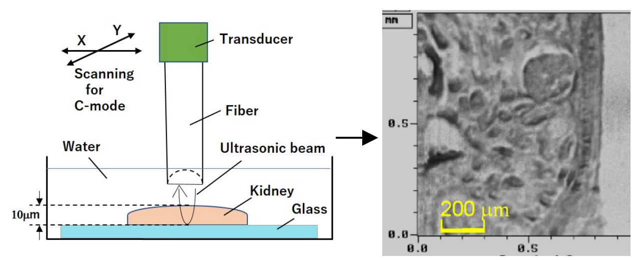
***Abstract*— We have studied the C-mode and B-mode imaging using high-frequency ultrasonic waves through a thin fiber for direct observation of the microscopic image of tissue. In the former experiments, the C-mode images of soft tissues (kidney and stomach) using the penetration method and the B-mode images of a hard tissue (animal bone) using the reflection method were obtained. However, no C-mode image and B-mode image of soft tissue could be obtained using reflection method. In this paper, we report that the B-mode images and a C-mode image of some kinds of soft tissues could be obtained by newly designed High Pass Filter using the reflection method.**

Keywords-component; quartz fiber, high-frequency ultrasonic wave, microscopic image, B-mode, needle-type ultrasonic probe, High Pass Filter

I. INTRODUCTION

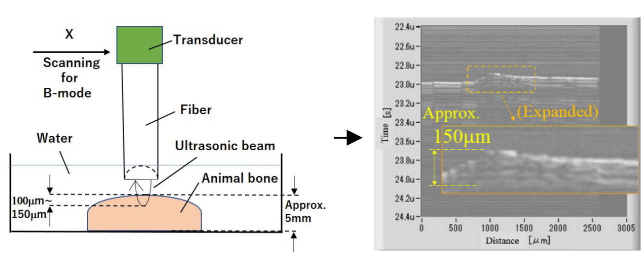
Tissue diagnosis in the current pathological examination takes time because it requires a tissue sample obtained by the biopsy and the observation using an optical microscope, and gives burden on the patient. The main objective of the study is to enable an operator to observe directly microscopic images of the tissue without taking out the tissue sample from the patient. To achieve the objective, we are developing a needle-type ultrasonic prove that uses a thin fiber as an ultrasonic probe [1], [2]. Since the diameter of the probe is so small that it can be inserted into body tissue without giving a severe burden on the patient and still retain non-invasiveness.

We reported that high-frequency ultrasonic waves (70 - 175MHz) were transmitted and propagated approximately 1.6mm in the acoustic coupling medium, and a C-mode image of a coin placed in water was obtained using a tapered fused quartz fiber as the probe [3]. Moreover, the lateral resolution of the image was improved by using the focused ultrasonic-beam, and the fine C-mode image of tissue sample (kidney) was obtained using a penetration method as shown in Fig.1 [4]. And a B-mode image of tissue sample (animal bone) was obtained using a reflection method as shown in Fig. 2 [5]. However, B-mode and C-mode image of soft tissue (like kidney and stomach) could not be obtained using reflection method. In the previous study, we proposed a method to realize the real-time B-mode imaging. In the method, the direction of the focused ultrasonic-beam radiated from the fiber was reflected at right angle by a mirror, and the B-mode image could be obtained. As the results of the experiment, a static (non real-time) B-mode image of a tissue sample (animal bone) was obtained as the first stage of the study. However, the image quality of B-mode image was poor because the sensitivity of the ultrasonic wave radiated from the fiber was insufficient. This paper describes that a new transmitter and receiver (T/R) with three kinds of High Pass Filter was designed and fabricated to improve the sensitivity and signal to noise ratio of the system and B-mode images of some kinds of soft tissues (law ham, bacon, and kidney of pig etc.) could be obtained using the reflection method.



(a) Penetration method (b) C-mode image

Fig. 1. C-mode image of kidney obtained using penetration method



(a) Reflection method (b) B-mode image

Fig. 2. B-mode image of animal bone obtained using reflection method

II. EXPERIMENTS

A. Experimental system

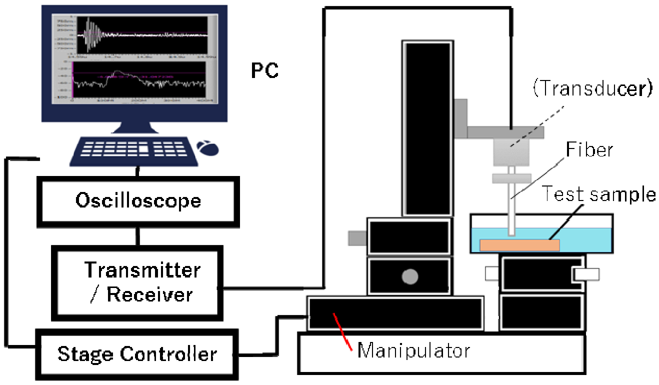


Fig. 3. Schematic of measurement and imaging system

As shown in Fig. 3, the system consists of a transmitter and receiver (T/R) unit, a 220 MHz transducer (Panametrics model V2113) for transmitting and receiving, Personal Computer including a NI LabVIEW, a fused quartz fiber, a test sample (or reflector) and an oscilloscope (LeCroy 64MXs). The T/R unit was newly designed and fabricated for this experiment. In the unit, three kinds of High Pass Filter (HPF; 100, 125, 150 MHz) and an Amplifier (30dB pre-amp., 60dB post-amp. and ATT) are included. The ultrasonic pulse (approximately 50Vp-p amplitude) with a wide frequency-band width (95~278 MHz) is transmitted into the fiber. The transducer and the fiber are assembled together to maximize the amplitude of the reflected wave from the test sample.

B. Measurement for effectiveness of HPF

In order to recognize the effect of High Pass Filter (HPF), we measured the frequency characteristic of the echo from the reflector (stainless steel board) placed in water as shown in Fig. 4. The focal point of the ultrasonic-beam was set on the surface of the reflector. The measurement was performed in each value of the filters (100, 125 and 150 MHz). The results are shown in Fig. 5.

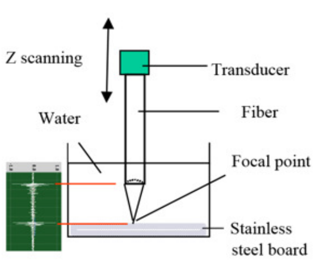
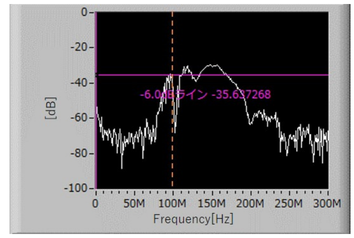
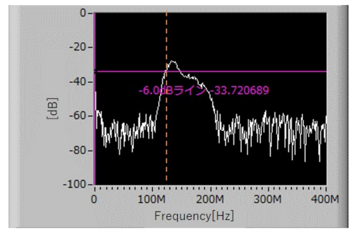


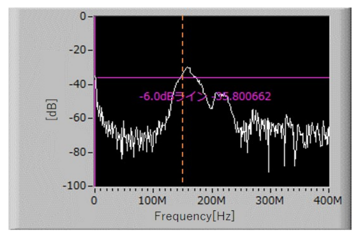
Fig. 4 Schematic for measurement of frequency characteristic



(a) HPRF; 100 MHz



(b) HPRF; 125 MHz

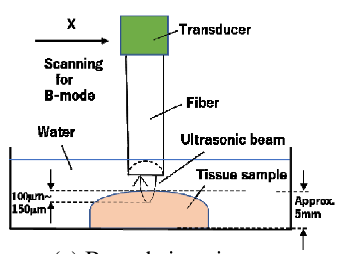


(c) HPRF; 150 MHz

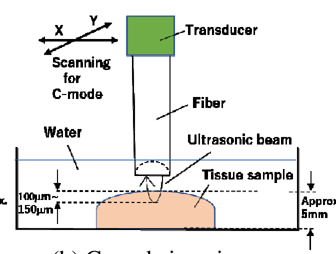
Fig. 5 Frequency characteristic in each HPF

III. IMAGING AND RESULTS

. *A. Imaging method*



(a) B-mode imaging

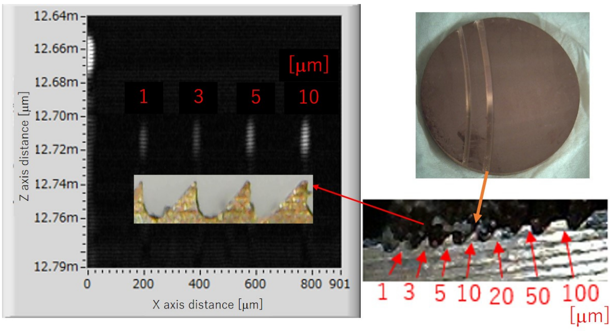


(b) C-mode imaging

Fig. 6. Measurement methods of B-mode and C-mode imaging

Measurement methods for the B-mode and C-mode imaging of tissue samples are shown in Fig. 6. As the sample tissues, some kinds of soft tissues (bacon, beef loin, kidney of pig and law ham) were used. The focal point of ultrasonic-beam was arranged at the surface of the tissue sample.

B. Measurement for detectable size of reflector



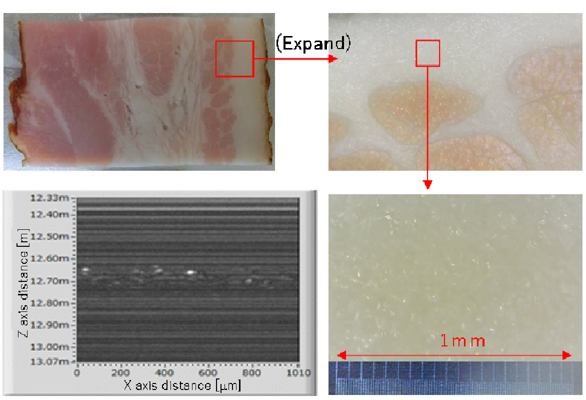
(a) B-mode image of targets (b) Test phantom

Fig. 7. Measurement for detectablity of small size targets

In order to recognize the improvement of the detectability in the B-mode imaging, we measured the echo from the small targets of a test phantom made of copper as shown in Fig. 7.-(b). Measurement was performed using the B-mode imaging method as same as shown in Fig, 6.-(a). The test phantom was used as the reflector instead of the tissue sample. As the test sample, four kinds of soft tissues (bacon, kidney of pig, beef loin and ham) were used. We tested to detect the echoes from the extremely small size (1, 3, 5, 10 μm, and so on) targets of the test phantom moving the transducer to X direction, as shown in Fig. 7.-(a). As the result, the smallest target (1 μm size) could be detected as shown in Fig. 7.-(a)

C. B-mode and C-mode imaging of tissue samples

1) B-mode imaging of bacon

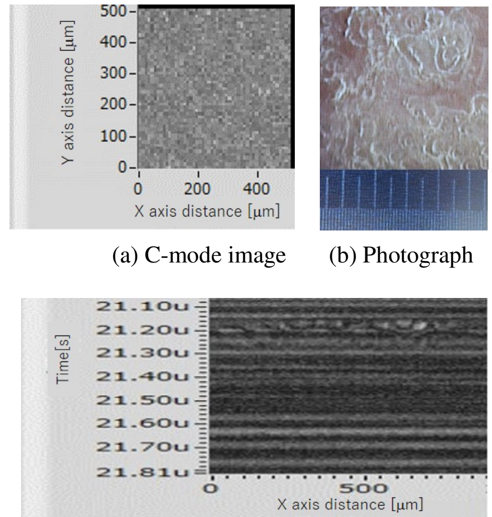


(a) B-mode image (b) Photograph

Fig. 8. B-mode image of bacon

Figure 8-(a) shows the B-mode image of a bacon. In the imaging, 125 MHz filter was used. The displayed distance of the tissue image in depth (Z direction) was approximately 100 micrometer as shown in Figure 8-(a).

2) C-mode and B-mode imaging of beef loin



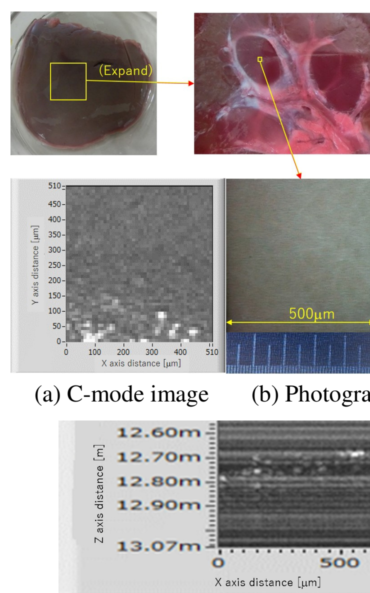
(a) C-mode image (b) Photograph

(c) B-mode image

Fig. 9. C-mode and B-mode image of beef loin

Figure 9-(a) and -(c) show the C-mode and B-mode image of a beef loin, respectively. In both modes, the 150 MHz filter was used and scanning-interval of the ultrasonic-beam was 10 micrometer. The displayed distance of the tissue image in depth was approximately 100 micrometer as shown in Fig. 9-(c).

3) C-mode and B-mode imaging of kidney of Pig



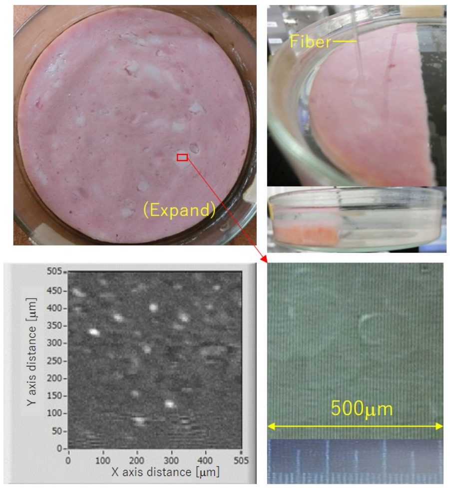
(a) C-mode image (b) Photograph

(c) B-mode image

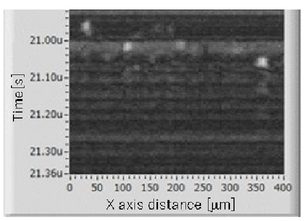
Fig. 10. C-mode and B-mode image of kidney of pig

Figure 10-(a) and -(c) show the C-mode and B-mode image of a kidney of pig, respectively. In both modes, 150 MHz filter was used. The scanning interval of the ultrasonic-beam was 10 micrometer in C-mode imaging and 5 micrometer in B-mode imaging, respectively. The displayed distance of the tissue image in depth was approximately 100 micrometer as shown in Fig. 10 -(c).

4) C-mode and B-mode imaging of ham



(a) C-mode image (b) Photograph



(c) B-mode image

Fig. 11. C-mode and B-mode image of ham

Figure 11-(a) and -(c) show the C-mode and B-mode image of a ham, respectively. In both modes, 150 MHz filter was used and the scanning interval of the ultrasonic-beam was 5 micrometer. The displayed distance of the tissue image in depth was approximately 100 micrometer as shown in Fig. 11-(c).

IV. DISCUSSION

In this study, B-mode images of some kinds of soft tissues could be obtained using the reflection method. In the previous experiments, B-mode image of the animal bone (called hard tissue) could be obtained using the reflection method, but B-mode image of soft tissues could not be obtained. We suppose that the main reason was due to the filtering system. In the previous experimental system, the maximum value of High Pass Filter equipped in the pulser/receiver was 10 MHz. In addition to the deference of the filtering system, it is also considered that the deference of acoustic characteristic impedance between the hard tissue (animal bone) and the soft tissue (kidney) was one of the reasons. The distance of the penetrated ultrasonic wave and the spatial resolution of the B-mode image of the soft tissue were approximately 100 micrometer and 25 micrometer, respectively. They depend on the attenuation of ultrasonic wave in the tissue. On the other hand, the image quality of ham in the C-mode image is fine [fig. 11-(a)] because of less attenuation by the tissue. The spatial resolution of the image is approximately 20 micrometer.

V. IMAGING AND RESULTS

It was successful to obtain the B-mode image of some kinds of soft tissues using the reflection method. The main factor of the improvement depends on the newly designed High Pass Filter (HPF). The distance of the penetrated ultrasonic wave in the B-mode of soft tissue was approximately 100 micrometer. The sensitivity and signal to noise ratio of the system will be improved in the next task. As the results of the experiments, we expect that the microscopic image of tissue can be seen clearly not only in C-mode image but also in B-mode image.

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