Tissue Imaging Using the Transmission of 100-MHz-range Ultrasound through a Fused Quartz Fiber

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***Abstract*— We have studied transmission methods of high-frequency ultrasonic waves through a thin fiber for direct observation of the microscopic image of the tissue. We reported previously that C-mode images of an artificial bone and an animal bone placed in water were obtained by reflection method using a fused quartz fiber as the probe. In this paper, we describe that the C-mode images of the tissue on the glass in water were obtained by penetration method.**

Keywords-component; high-frequency ultrasonic wave, microscopic image, quartz fiber, C-mode image, penetration method

I. INTRODUCTION

The 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 a 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 [1], [2] as an ultrasonic probe [3]. 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 previously reported that high-frequency ultrasonic waves (70 - 175MHz) transmitted 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 [4]. In the previous study, improving the lateral resolution of ultrasound beam, clear C-mode images of an artificial bone and an animal bone placed in water was obtained by reflection method. In this paper, we describe that C-mode images of tissue on the glass in water were obtained by penetration method.

II. EXPERIMENTS

A. *Experimental system*

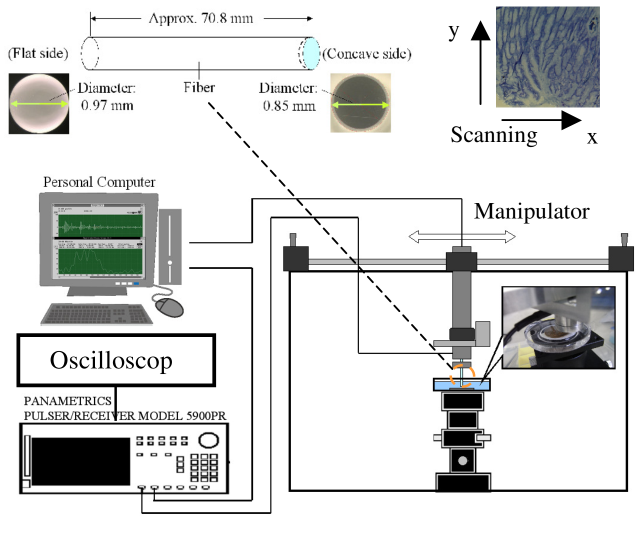


Fig. 1 Schematic of measurements and C-mode imaging system

As shown in Fig. 1, the system consists of a pulser/receiver (Panametrics model 5900PR), a 220 MHz transducer (Panametrics model V2113) for transmitting and receiving, an imaging unit (SONIX JD5520DT-ATX), a fused quartz fiber, tissue samples (mucosal layer of stomach and kidney with 10 μm thickness, respectively) and an oscilloscope (Tektronix TDS5104B). The transducer and the fiber were assembled together to maximize the amplitude of the reflected wave from the concave side of the fiber. The tissue sample was placed at the focal point of the fiber that has a concave surface. The ultrasonic pulse (approximately 50 Vp-p amplitude) with the wide frequency-band width (95~278 MHz) was transmitted into the fiber.

B. *Measurement of lateral resolution for C-mode image*

We measured the lateral resolution of the C-mode image using a “20 µm (diameter) stainless steel mesh” as shown in Fig. 2.

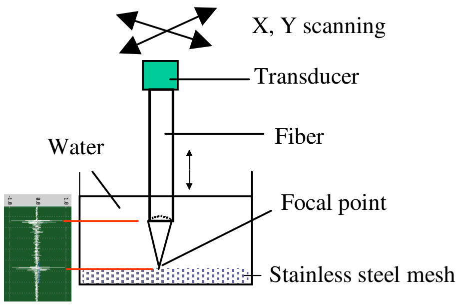


Fig. 2 Measurement of lateral resolution for C-mode image

C. *C-mode imaging of tissue samples*

C-mode imaging of the tissue sample was performed using the experimental system as shown in Fig. 1. The focal point of ultrasonic beam was arranged at the surface of the glass plate in water. In the C-mode imaging, the minimum scanning-interval of the ultrasonic beam was 5 micrometer, and the minimum scanning widths in X and Y directions were 1 mm and 1 mm, respectively. As the sample tissues, mucosal layer of stomach and kidney were used.

III. RESULTS

A. *Lateral resolution for C-mode image*

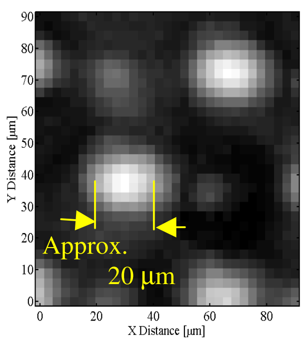


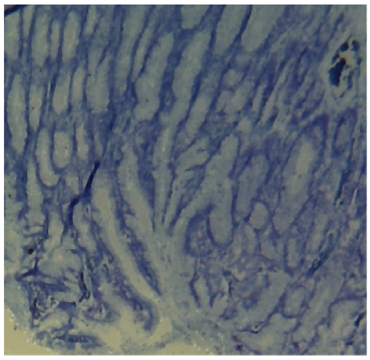
Fig. 3 C-mode image of stainless steel mesh

As shown in Fig. 3, a stainless steel wire with 20µm diameter was detected clearly on the C-mode image.

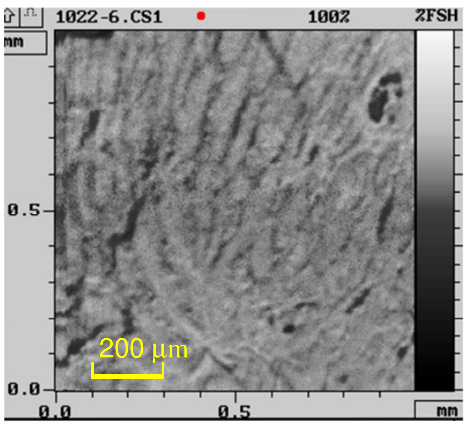
B. *C-mode imaging of tissue samples*

1) Mucosal layer of stomach

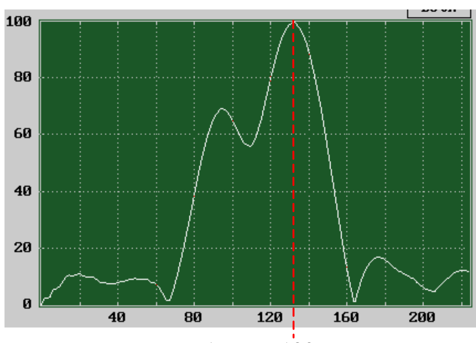
Fig. 4 shows the C-mode image of mucosal layer of stomach. Fig. 4-(a) and (b) are the photograph and the C-mode image, respectively. Fig. 4-(c) shows the frequency characteristic of a reflected wave from the tissue.



(a)



(b)



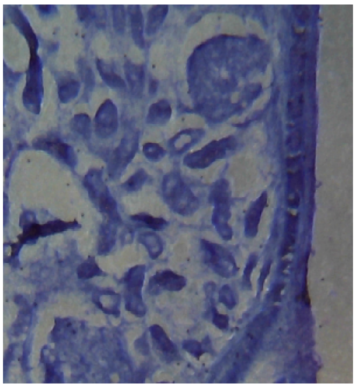
Approx.130 MHz

(c)

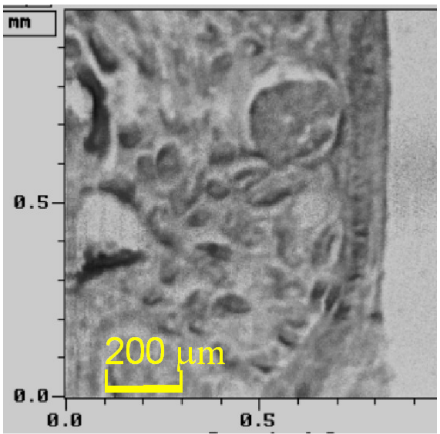
Fig. 4 C-mode image of mucosal layer of stomach and the frequency characteristic of a reflected wave

2) Kidney

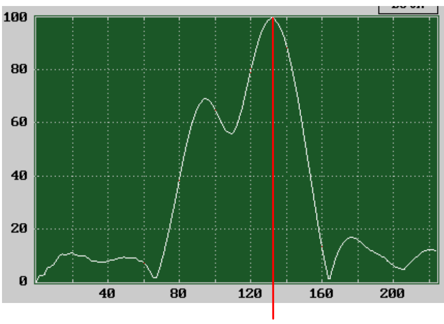
Fig. 5 shows the C-mode image of kidney. Fig. 5-(a) and (b) are the photograph and the C-mode image, respectively. Fig. 5-(c) is the frequency characteristic of a reflected wave from the tissue.



(a)



(b)



Approx.130 MHz

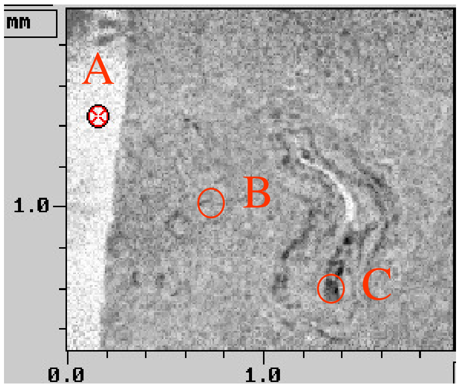
(c)

Fig. 5 C-mode image of kidney and the frequency characteristic of a reflected wave

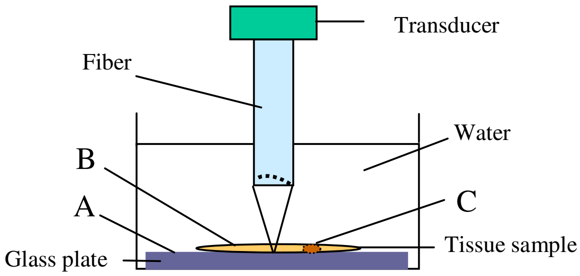
IV. DISCUSSION

A. *Attenuation of ultrasonic wave in a tissue sample*

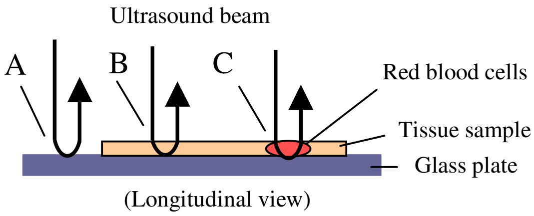
We measured the attenuation of a tissue sample (kidney).



(a)



(b)



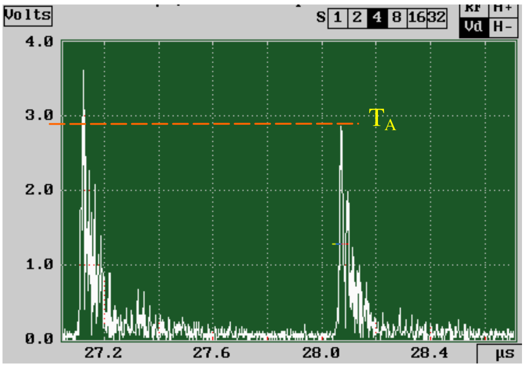
(c)

Fig. 6 Attenuation measurement of tissue sample (kidney)

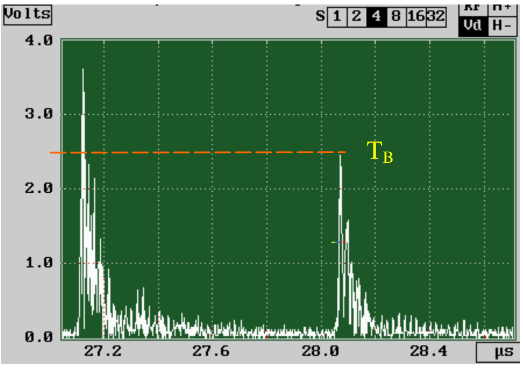
The tissue sample was placed on the glass plate as shown in Fig. 6-(b). The ultrasonic beam generated by the transducer was transmitted through the fiber, and radiated to the sample. When the ultrasonic beams are transmitted as shown in A, B, and C of Fig. 6-(c), bright points A, B, and C in C-mode image are obtained as shown in Fig. 6-(a).

The amplitude of the ultrasonic wave reflected from the surface of the glass plate depends on the characterization of the tissue.

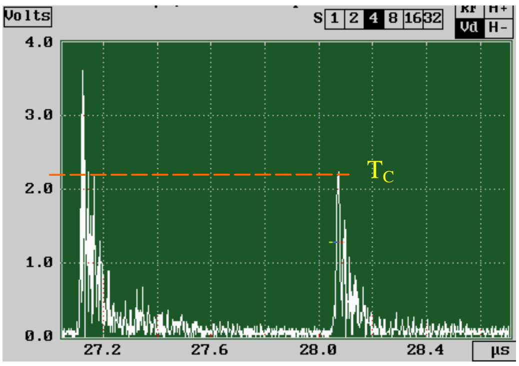
Reflected waves from the tissue sample are shown in Fig. 7. When the no tissue is placed on the glass plate (A), the amplitude of the reflected wave (T_A) is the largest as shown in Fig. 7-(a).



(a)



(b)



(c)

Fig. 7 Reflected waves from the tissue sample

Fig. 7-(b) and (c) show the reflected waves (T_B and T_C) from part B and C, respectively.

Each attenuation (ATT) of part B and C was calculated as follows

ATT of B : $20 \log (T_B / T_A) = - 0.98$ dB

ATT of C : $20 \log (T_C / T_A) = - 2.09$ dB

V. Conclusion

C-mode images of the tissue samples (mucosal layer of the stomach and kidney with approximately 10 µm thickness, respectively) were obtained in the penetration method. As an image of the stainless steel mesh was also obtained, it was shown that the lateral resolution of the image was approximately up to 20 µm. The frequency characteristic of echoes from tissue samples have high frequency spectrum, approximately 130 MHz (approximately 13 µm wave length).

As the results of the experiments, we expect that the microscopic image of the human tissue can be seen directly.

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