Intravascular Ultrasonic Imaging with a Micromotor

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1 Intoroduction

Ultrasonic diagnostic devices allow to observe internal organs, fetus, blood vessels and so on noninvasively, and the observation do less harm to men comparing with X-ray CT and PET. Furthermore, the devices give the anatomical information of the inside structure which can not be obtained with optical devices such as a gastrocamera. However, detailed inside structures of a human body can not be observed with touching an ultrasonic probe on a human body surface due to a strong effect of a bone on echo signals. Therefore, the observation inserting the probe in a human body is needed.

Ultrasonic transducers have been downsizing for the last decade and can be set on the top of a catheter. As the results, an intravascular ultrasonic imaging system, which is used to observe the inside of a blood vessel, have been developed. In most commercial intravascular ultrasonic endoscopes, a cross section of a blood vessels is obtained with the scanning an ultrasonic beam radially. Rotation for the scanning is transferred from a motor located at the other end of the endoscope through a wire.

The scanning wire vibrates and causes friction and strain, which results in dangerous troubles, for example, injury of blood vessels. Furthermore, unstable rotation makes different images from real structure.

We propose a new intravascular imaging system with a micromotor instead of the scanning wire to avoid the above troubles. This paper describes the intravascular imaging system with a micromotor, a revolutionary characteristic of the micromotor and results of fundamental experiments.

2 Micromotor

As shown in Fig.1, the proposed sysytem is simpler than a commercial intravascular system because the scanning wire is not needed.

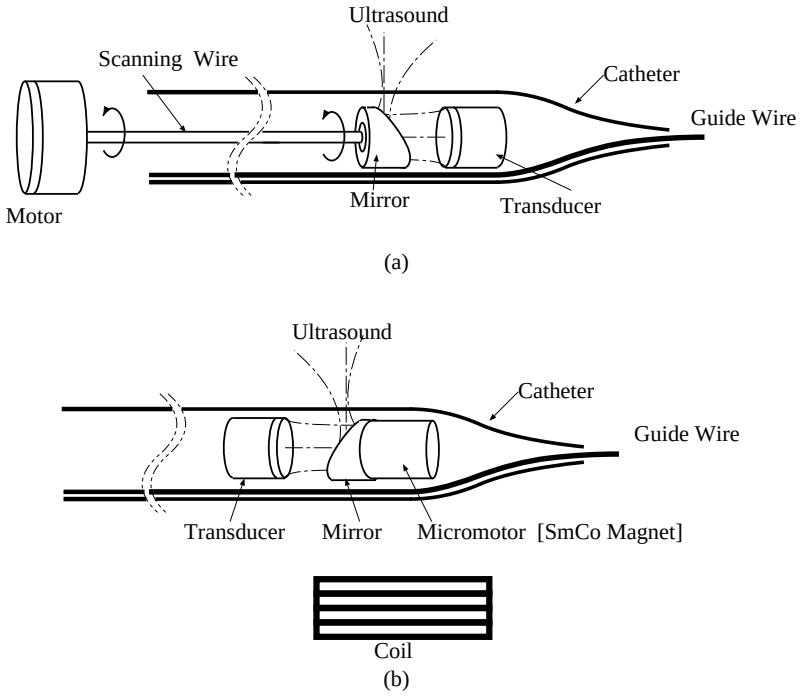

Figure 1: Intravascular ultrasonic system (a)with a scanning wire and (b)with a micromotor.

A SmCo permanent magnet connected to an ultrasonic transducer directly scans an ultrasonic beam radially. We call the magnet a micromotor. The cylindar shaped micromotor with two magnetic poles has a diameter of 1mm and a length of 3mm as shown in Fig.2. The micromotor is rotated by external magnetic fields which is generated by a coil located outside of a human body.

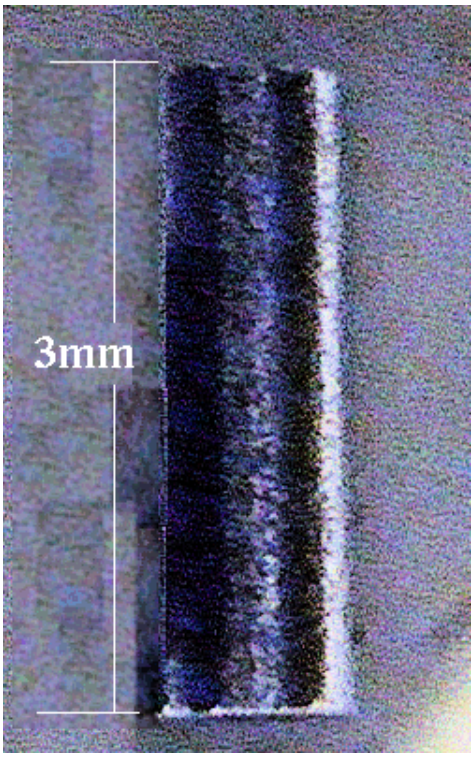

Figure 2: A SmCo permanent magnet with a diameter of 1mm and a length of 3mm.

3 Characteristics of Micromotor

Revolutionary characteristics of the micromotor in water were evaluated. Figure 3 shows the experimental arrangement.

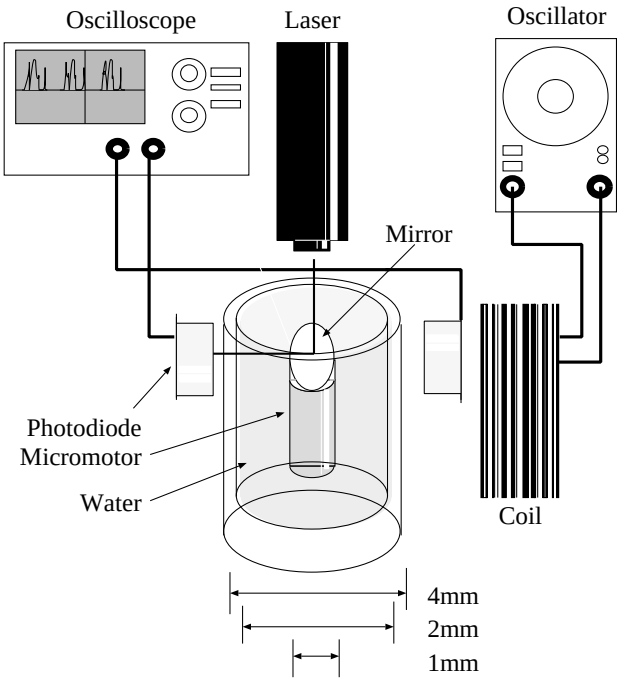

Figure 3: Rovolition detecting system. The He-Ne laser was detected with two photodiodes connected to an oscilloscope(LeCroy 9314L). A coil was connected to an oscillator(KENWOOD AG-204).

The micromotor mounting an Al slant cutting cylinder shaped mirror was located in a tube whose internal diameter was 2mm. The magnetic fields generated by a coil connected to an oscillator(KENWOOD AG-204) was varied the magnitude and frequency. It excited the micromotor placed in the tube filled with water. The mirror was used to reflect a He-Ne laser to two photodiodes. Signals of the two photodiodes were observed with an oscilloscope. The revoluationary characteristics were examined with observing a waveform of the signal. The results were shown in Fig.4.

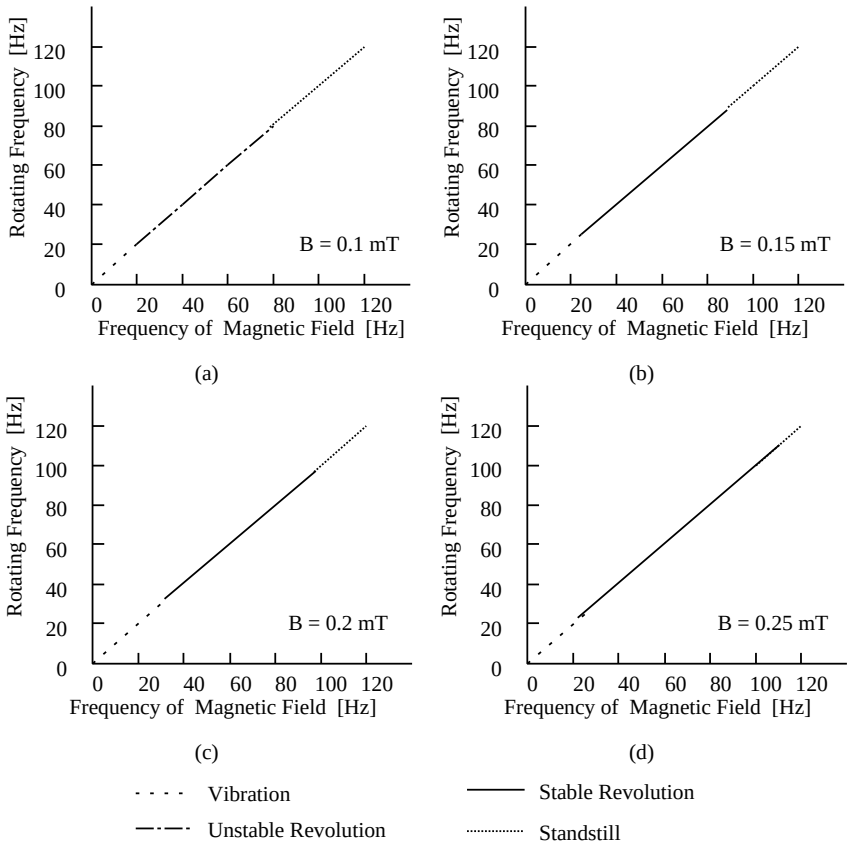

Figure 4: Dependiog on the frequency and magnitude of the magnetif field. Each magnitude of the magnetif field was (a)0.1mT, (b)0.15mT, (c)0.2mT and (d)0.25mT.

This figure shows that a revolutionaly frequency corresponds to that of the magnetic field, and that the revolutional characteristics depends on both the magnitude B and the frequency of the magnetic field. In the magnitude range over 0.15mT and the frequency range from 25-110Hz, the micromotor rotates stably and the frequency range becomes larger as the magnitude of the magnetic fields increases. In the other range, the micromotor does not rotate.

4 Intravasuluar Imaging System

4.1 Signal Acquisition

A fundamental experiment for cross sectional imaging was carried out using a plastic tube with an internal diameter of 13.5mm. In this experiment, the rotating speed was set to

6000rpm and the number of scan lines set to 200 on the condition that the magnitude and frequency of magnetic field was 0.25 mT and 100Hz, respectively.

Figure 5 shows an arrangement of the micromotor and an ultrasonic transducer whose diamater is 1.2mm and a resonant frequency is 20MHz.

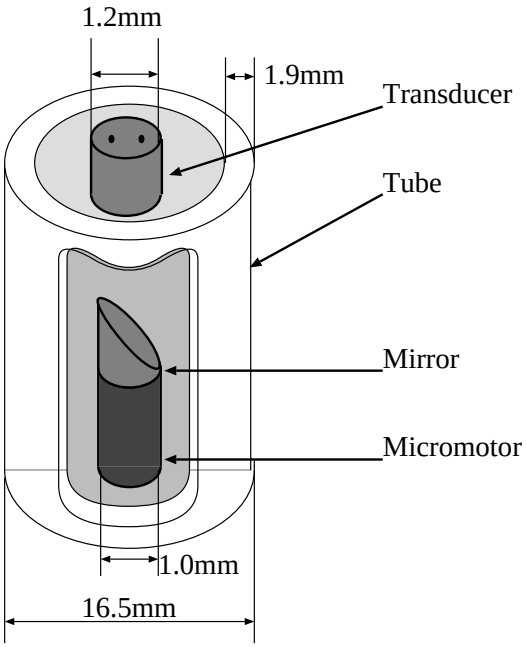

Figure 5: Arrangement of devices. The micromotor was located inside of the tube. The inside of the tube was pasted up a metal sheet. The tube was 16.5mm in diameter and 12.7mm in internal diameter. The transducer was 1.2mm in diameter and fixed a brass cylinder. The mirroor was 1.0mm in length and 1.0 mm in diameter. The miocrotor was 3.0mm in length and 1.0mm in diameter.

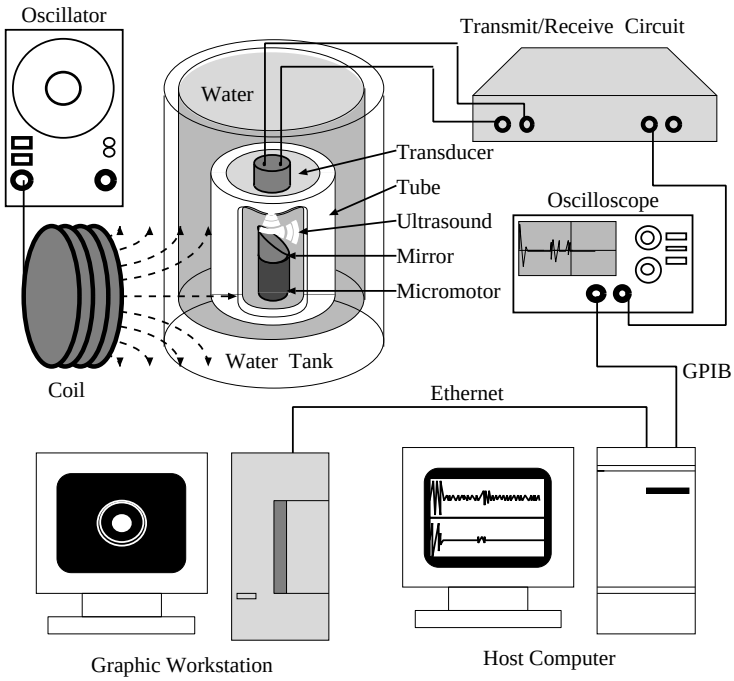

Figure 6: A diagram of an intravascular ultrasonic imaging sysytem with a micromotor.

Figure 6 shows a block diagram of the imaging system. The transducer,the micromotor and the tube were placed in the water. Firstly, 20MHz burst waves with a peak-to-peak of 20V was transmitted from the transducer toward the object through the mirror. Secondly echo signals reflected from the object was received with the same transducer, and stored in a digital storage oscilloscope(LeCroy 9314L) after the signal was amplified 30 times and on-line filtered between 18-22MHz. Figure 7 are the waveform of the received echo signals(a) and that of the amplified and filterd signals(b).

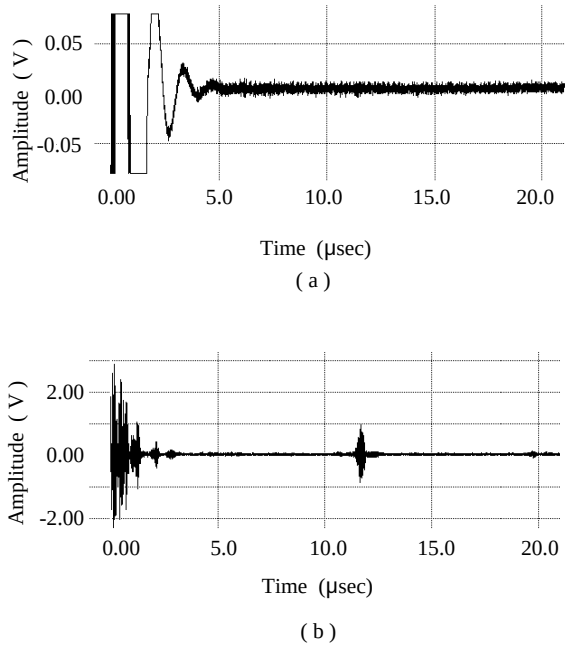

Figure 7: Waveforms of echo signals. (a)received echo signal, (b)amplified and filterd signal.

The first peaks at 0-2μsec are the transmitted wave and the second peaks at 12μsec are the wave reflected from the inside of the tube. Figure 7 also shows that the signal-noise ratio was enhanced by the filter. Finally, the stored data were transffered to a host computer(Apple Macintosh Quadra700) through GPIB and to a graphic workstation(Silicon Graphic Inc. Indigo) through Ethernet.

4.2 Image Reconstruction

From the echo signals of 200scan-lines, a cross sectional image was reconstructed on the graphic workstation. Firstly, the signals were quantized to 256levels. The gap between scan lines was filled with a linear interpolation. Figure 8 shows the reconstructed image.

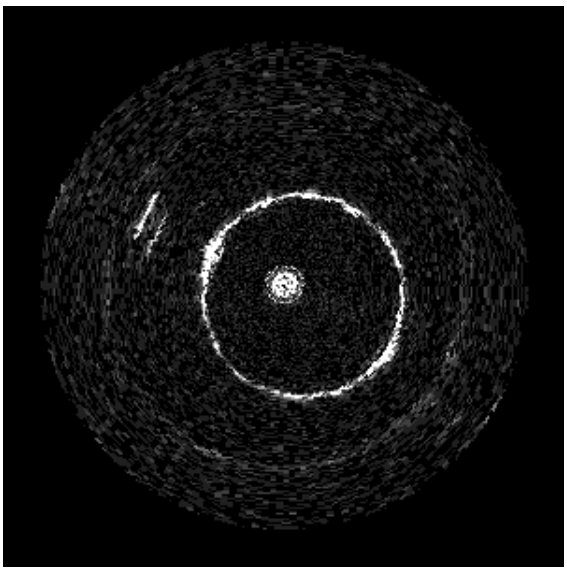

Figure 8: Grayscale image of tube. The circle was the outline of the tube.

A white area in the center is generated by transmitted waves and a circle shows an inside surface of the tube. The reconstructed image is in good agreement with the object, the internal surface of the plastic tube.

5 Discussion

We aim to observe the inside of a femoral artery with an internal diameter of 5-6mm and external of 10mm. Therefore, a catheter size of this intravascular imaging system is small enough to image a cross sectional view of the vessel. Furthermore, the catheter can be smaller for an observation of coronary vessels, because the intravascular imaging system is simple. The simpleness, in addition, enables to implement the other function with the cather.

6 Conclusion

We proposed a new method of an intravascular ultrasonic imaging with the micromotor and reported revolutional characteristics of the micromotor and experimental results. The characteristics show that the micromotor revolves stably in the frequency range of 25-110Hz. Using this method, the cross sectional image of a plastic tube was reconstructed. Since this system is very simple, it has the advantage of the observation in the vessel.

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