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Blood flow measurement by Counter-Crossed Beam Contrast Echo method
- Prototype system using ultrasound diagnostic equipment -
Counter-Crossed Beam Contrast Echo 法による血流計測
－超音波診断装置を用いたシステムの試作－

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1. Introduction

A contrast-echo imaging method, in which administrated contrast agents can enhance echo intensity, thus permitting effective visualization of the distribution of the microvascular, is the prevailing technology. In the contrast-echo imaging method, all echo signals except those from microbubbles can be eliminated by using secondary signals generated by nonlinear vibration of the microbubbles (contrast agents). Thus, the distribution of the microvascular system is generally determined by a harmonic-imaging method that visualizes the second-harmonic component in the echo signals. However, a second-harmonic component is generated during propagation through biological soft tissues as well as by nonlinear vibration of the microbubbles. In particular, when measuring a slow blood flow velocity such as in the diagnosis of hepatocellular carcinoma, the influence of the propagation through biological soft tissues cannot be ignored. Therefore, separation of the echoes caused by microbubbles in the blood flow from echoes received from biological soft tissues is an important issue.

In order to address this issue, we proposed a novel method for a blood flow measurement using counter-crossed beams of two different ultrasonic frequencies[1]. This method is called Counter-Crossed Beam Contrast Echo method (C-CBCE method).

In order to study the feasibility of C-CBCE method in clinical diagnosis, we prototyped the measurement system which consists of a commercialy available ultrasound diagnostic equipment, another ultrasonic probe, a function generator, and a power amplifier. In this study we measured the flow velocity using the sum frequency conponent generated by microbubbles in a channel in the crossed region of two ultrasonic beams.

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2. Measurement system for C-CBCE method using ultrasound diagnostic equipment

2.1 System configuration

We prototyped the measurement system to study the feasibility of the C-CBCE method in the clinical diagnosis. This system consists of a commercially available ultrasound diagnostic equipment (APLIO SSA-700A, Toshiba), a convex array probe (PVT-375AT, Toshiba), another ultrasonic probe (INS774, Japan Probe) a function generator (33250, Agilent), and a power amplifier (4055, NF). The block diagram of the measurement system is shown in **Fig. 1**. The convex array probe was located at the water surface to receive the echoes from inside a tube. The ultrasonic probe which consists of an annular ring type focusing transducer of 2.8 MHz and a coaxial circular type focusing transducer of 4.8 MHz was located at the bottom of water tank.

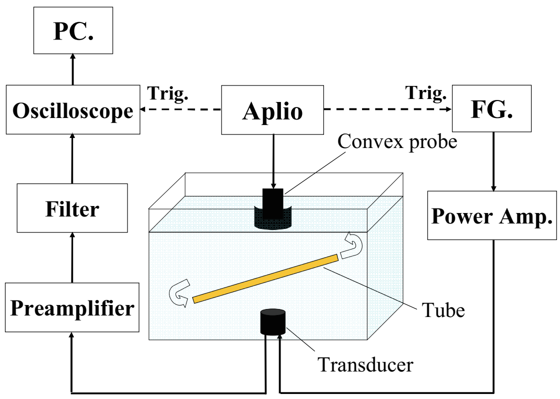

Fig.1 Block diagram of measurement system.

2.2 Measurement of flow velocity in a tube by using contrast agents

A silicon rubber tube of an internal diameter of 4 mm was located at the focal point of the concave transducer. Sonazoid[2] was used as microbubbles. Degassed water with the microbubbles was flowed into the tube. The ultrasonic pulsed waves of 3.0 MHz were transmitted from the convex probe. The pulse repetition frequency is 1.2 kHz. The sinusoidal burst waves of 3 MHz and 40 cycles were transmitted from the annular ring transducer. The circular type transducer was used to receive the echoes from the microbubbles in the focal region.

The scattered waves by the microbubbles in the tube were received by the circular type transducer as well as the convex probe, since the flow velocity was measured by the ultrasound diagnostic equipment while monitoring the frequency components of scattered waves. Since the sum frequency in the focal region was 5.2 MHz, the quadrature detection of measurement of flow velocity for the ultrasound diagnostic equipment was set at 5.2 MHz.

2.3 Results and discussion

The frequency of the ultrasound waves transmitted from the convex probe was 3 MHz (f_1) and the frequency of the ultrasound waves transmitted from the annular ring transducer was 2.2 MHz (f_2). The scattered waves by the microbubbles were received by the circular transducer located at the bottom as well as the convex probe located at the surface. The spectrum of the received wave at the bottom was shown in **Fig. 2.** The amplitude is normalized by the fundamental component (f_2). The sum frequency component (f_1+f_2) is higher than the second harmonic components (2f_1, 2f_2) as shown in Fig. 2 Therefore, these frequency components are generated by the nonlinear vibration of the microbubbles.

B-mode image of the silicon tube which is obtained by the ultrasound diagnostic equipment is shown in **Fig. 3**. It is clearly imaged as a bright linear region enhanced by the microbubbles in the flow. The flow velocity at the region marked as a circle in Fig.3 was computed by Dopplar shift frequency of the sum frequency component in the echo signals. **Figure 4** shows the time variation of flow velocity. The mean flow velocity was set to 23 mm/s. This value agrees with the mean value of the flow velocity measured by the ultrasound diagnosis equipment shown in Fig. 4.

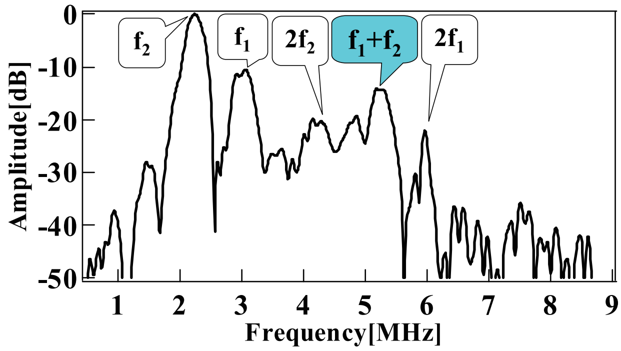

Fig. 2 Frequency spectrum of scattered waves by microbubbles (f_1=3 MHz, f_2=2.2 MHz)

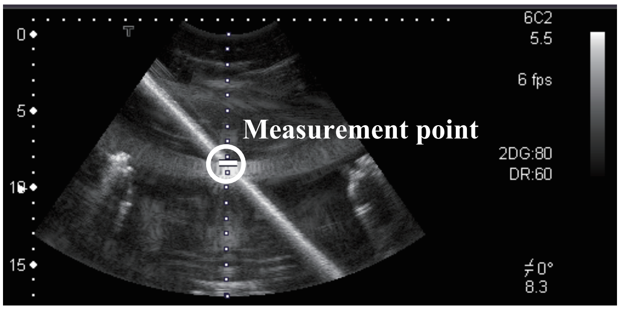

Fig. 3 B-mode ultrasound image of received signals

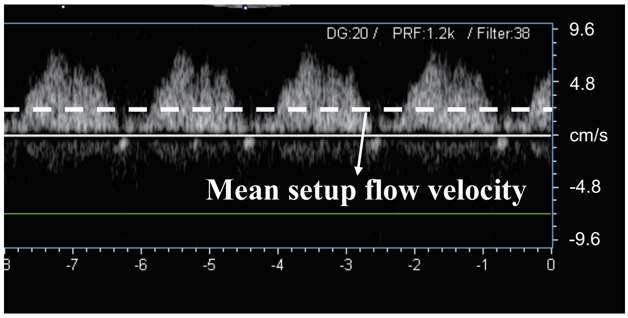

Fig. 4 The flow velocity measured at the marked region in Fig. 3

3. Conclusion

The blood flow measurement system using commercially available ultrasound diagnostic equipment was prototyped to study the feasibility of the C-CBCE method in the clinical diagnosis. The contrast agents of Sonazoid was used as the microbubbles. The sum frequency components generated by the nonlinear vibration of microbubbles in the channel were confirmed by measurement of the scattered waves. Then the flow velocity using the sum frequency component was measured by the commercially available ultrasound diagnosis equipment.

Acknowledgment

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References

1. T. Eura, K. Yoshida, Y. Watanabe, T. Takayasu, K. Nakamura and I. Akiyama, (to be published in *Acoustical Imaging Vol.30*, *Springer*,)

2. R. Watanabe, M. Matsmura, C-J Chen, Y.Kaneda and M.Fujimaki, *Biol. Pharm. Bull.*, **28**(6) 972-977(2005)