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Development of automatic focus control system for HIFU devices

HIFU デバイスの自動焦点制御システムの開発

Gaku Shinbo[1] Hirotaka Yanagida[1], ([1]Grad.sch. of Sci & Eng,Yamagata Univ.)
新保　岳[1]，柳田　裕隆[1]，　([1]山形大学院理工学研究科)

1. Introduction

A treatment method called HIFU is a technique that kills cells by irradiating it with strong ultrasonic waves locally and is used to treat prostate cancer. In this study, we are developing an ultrasonic probe for HIFU treatment. The ultrasonic probe for HIFU used in the medical field has a concave shape, and the sound wave is focused on a single focal position, so the operation is physically performed by a doctor. We have devised and evaluated a HIFU system that can move the focus by electronic control. The devised system patterns a Fresnel lens with a focal point at an arbitrary point on an ultrasonic transducer to form an ultrasonic sound field. In this study, a linear array with a Fresnel pattern was driven and the sound pressure distribution in water was measured. The array with the Fresnel pattern with the focal position changed was driven, and it was confirmed whether the focusing point had moved to the target position. It was also confirmed whether the reception intensity at the convergence point reached the temperature at which the cells were killed.

2. Method

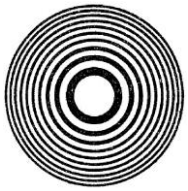

Fig.1 Fresnel zone plate

Fig.2 Fresnel zone plate(1D)

A flat plate with concentric passage (white) and non-passage (black) is called a Fresnel zone plate, which is used for focusing light. This was used because the same effect can be obtained with ultrasonic waves. This was used because the same effect can be obtained with ultrasonic waves.

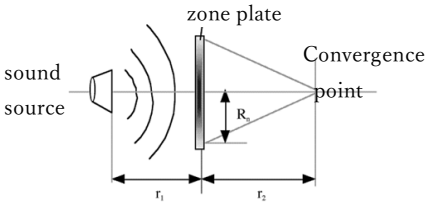

Fig.3 zone plate and focusing point

The radius Rn of the Fresnel zone plate is calculated by Eq. (1).

$$R = \sqrt{\frac{r_1 r_2 n\lambda}{r_1 + r_2}} \quad (1)$$

The sound source is the position of the zone plate. In that case, since r1 → ∞ can be obtained, equation (1) can be converted to equation (2).

$$R = \sqrt{r_2 n\lambda} \quad (2)$$

In this study, the sound wave irradiation pattern is determined using Eq. (2).

3. Control system

Application

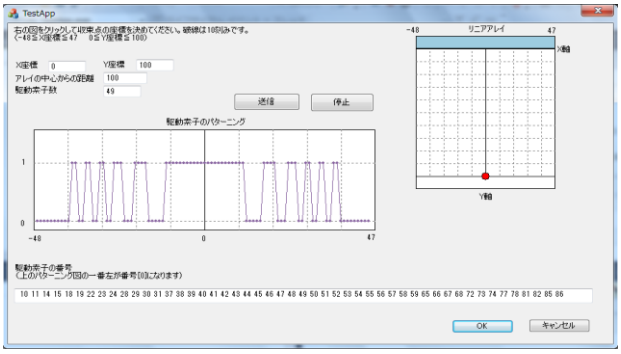

Fig.4 Application focus coordinates, selection

The right side of **Fig. 4** is the ultrasonic irradiation region, and when an arbitrary point in the region is selected with the mouse, the driving element and the non-driving element are determined by the calculation of Eq. (2). The determined Fresnel pattern is displayed in the left window in Fig. 4. This Fresnel pattern is transmitted to the digital output unit of **Fig. 5** to control the electronic relay of **Fig.6** The electric signal for driving the ultrasonic element is single, and the ultrasonic element selected as the driving element is driven in the same phase.

Digital output unit

Fig.5 shows a digital output unit. This is connected to the PC by USB and controls the relay of the element (driving element) and the non-passing (non-driving element) that pass through the Fresnel zone plate calculated on the PC.

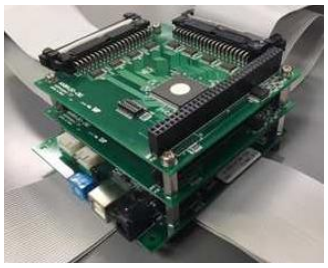

Fig.5 digital output unit

Control board

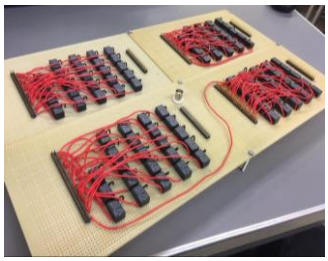

Fig.6 control board

Fig. 6 shows a 96ch mechanical relay board. This board applies a sine wave with a voltage of 23V and a frequency of 1MHz to the driving element, and electrically shuts off the non-driving element.

Linear array

Fig. 7 is a photograph of a linear array transducer, which is fixed so that the downward direction is in contact with the water surface, and ultrasonic waves are radiated into the water tank.

The linear array transducer is composed of 96 ultrasonic elements, and when individually inspected, it was confirmed that ultrasonic waves can be output from all 96 elements.

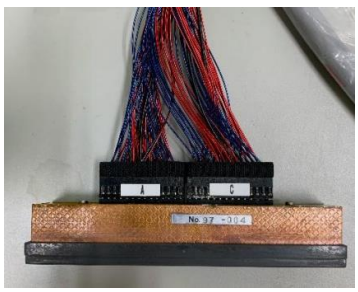

Fig.7 linear array

4. experiment

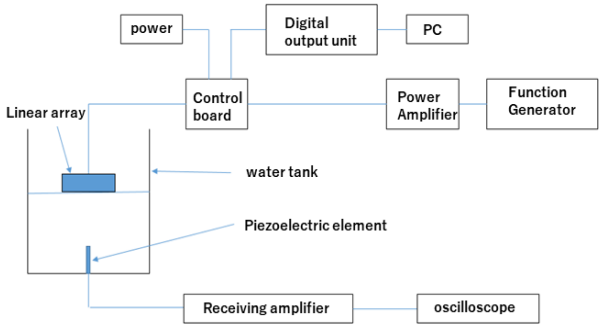

Fig.8 Schematic diagram of experimental

5. result

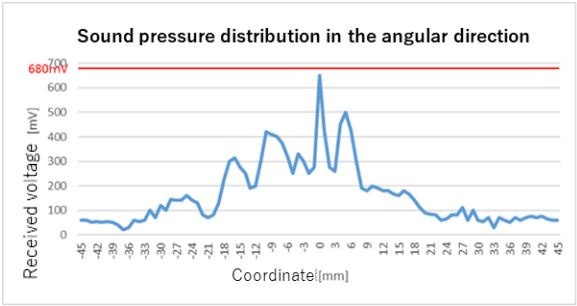

Fig.9 Sound pressure distribution in the angular direction

The voltage that drives the ultrasonic element was 23V, and a sine wave with a frequency of 1MHz was output for 20 cycles. The repeat interval was 1 ms. The focusing position was set to (0,50).

Fig.8 shows the sound pressure distribution at 50 positions from the center of the linear array.

The focus is on the peak at the set coordinates. The voltage value at the focusing point was 650 mV, which did not reach 680 mV, where significant heat generation was observed.

6. Summary

The focus was successfully moved by controlling the drive pattern of the linear array. To generate ultrasonic energy with a therapeutically effective intensity, it is necessary to increase the driving area and improve the sound wave generation efficiency of the ultrasonic element itself.

7. References

[1]Patterning of 30MHz Ultrasonic Fresnel Zone Plate by Laser Poling of PVDF-TrFE Film, **H. Yanagida**, Y. Tamura, T. Takahashi, IEEE International Ultrasonics Symposium Proceedings, pp.2185-2188 (2009)