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Transducer elements position compensation in a ring array USCT system
超音波 CT における振動子位置補正の検討

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1. Introduction

Breast cancer has a high prevalence among Japanese women[1]. Before it metastasizes outside the breast ducts, it is important to detect and treat it. The standard diagnostic method for breast cancer is X-ray mammography and a combination of ultrasound images[2]. For further investigation, sometimes MRI is used. X-ray mammography has a high spatial resolution, but has the disadvantage that the produced image is a two-dimensional projection of the compressed breast between the detector and the plate. It has excellent calcification detection detectability, but X-ray absorption is large for both breast cancer and breast glandular, and it is difficult to identify a small breast cancer. Therefore, it is not appropriate for younger women with predominant glandular tissue. Furthermore, frequent inspection is not recommended because of the limitation of X-ray exposure. In conventional ultrasound imaging, small calcification detection, biological properties diagnosis, and identification of diseased area are difficult. MRI can three-dimensionally visualize the disease but the specificity is low, both the system price and inspection fees are expensive.

An inexpensive high-spatial-resolution three-dimensional imaging system without X-ray exposure, combined with a therapeutic system is needed. To respond to this need, we are developing a system combining ultrasound computed tomography (USCT) and high intensity focused ultrasound (HIFU).

USCT can reconstruct not only cross sectional images in the reflection mode but also images of the speed of sound and the attenuation in the transmission mode. In breast cancer, the speed of sound increases in disease has been reported[3].

For USCT image reconstruction, the demand for high accuracy of transducer element position is higher than conventional backscattered echo imaging. Incorrect information of the element position can result in line-artifacts and deteriorated resolution. Compensation of transducer element position is described in this study.

2. Method

2.1 USCT experimental system

A newly developed transducer for USCT had a full 360-degree circumference divided into four parts, each of which was composed of a 90-degree block. The transducer had a center frequency of 1.75 MHz, a -6dB transmit (Tx) and receive (Rx) two-way band width of 66%, and a diameter of 104.5 mm. Each transducer block had 256 elements, i. e. the whole ring array transducer had 1024 elements.

It was combined with a V-1 System (256ch Tx, 128ch Rx, Verasonics), used for the ultrasonic research platform. The Tx frequency was 2.5MHz. The received signal was sampled every 100 ns and stored in PC.

A high voltage electronic multiplexer circuit, consisting of 1024ch-to-256ch Tx and 1024ch-to-128ch Rx multiplexers, was newly developed. The transducer and the platform were connected with this circuit. Switching of the Tx/Rx channels was controlled under the instructions from the platform. Experimental setup schematic is shown in Fig. 1.

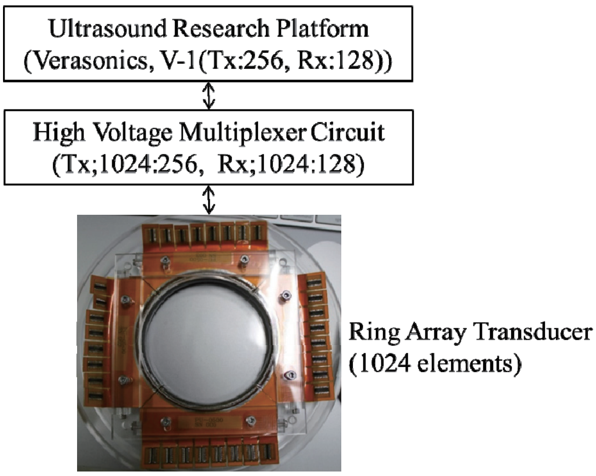

Fig. 1 Schematic of experimental setup

2.2 Compensation of transducer elements position

The possible geometric error, in the order of a wavelength, in joining the four blocks into a whole ring transducer was found to be an obstacle to precise image reconstruction. Fig. 2 shows a joint between transducer blocks. A small geometric error can be seen. Test imaging was performed in order to compensate the error in transducer elements position. A 0.1 mm metal wire, parallel to the axis, was placed approximately at the center of the ring[4] as shown in Fig. 3. Using each one of the all transducer elements, a 2.5 MHz pulse was transmitted and the echo from the wire target was received.

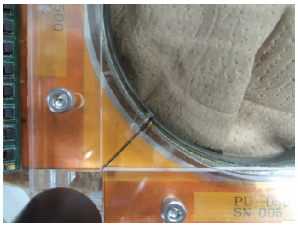

Fig. 2 Joint between transducer blocks.

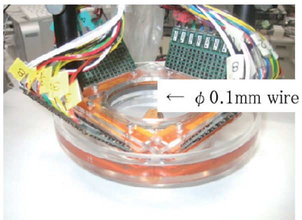

Fig. 3 Ring array transducer with Φ 0.1 mm wire-target

3. Result and discussion

Fitting of the receive time of the wire echo to a sinusoidal curve was performed for every element. Fig. 4 shows the difference between fit and measured data.

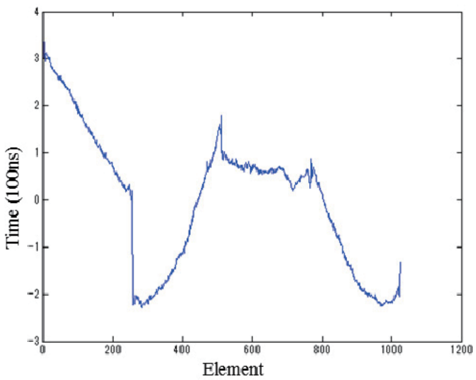

Fig. 4 Time difference between fit and measured data

The result shows that receive time difference among the all transducer elements, 1 to 1024, was up to 500 ns. This corresponds to slightly more than a wavelength at 2.5MHz, which should cause significant image degradation. The time difference was used to compensate the information of each transducer element position.

By applying the transducer elements position compensation to the received data, the -6 dB Tx-and-Rx beam width was reduced from 1.71mm to 0.63mm and the characteristic of the Tx-Rx beam are significantly improved. Fig. 5 shows the wire target cross sectional image before (a) and after compensation (b). The improvements are clearly seen.

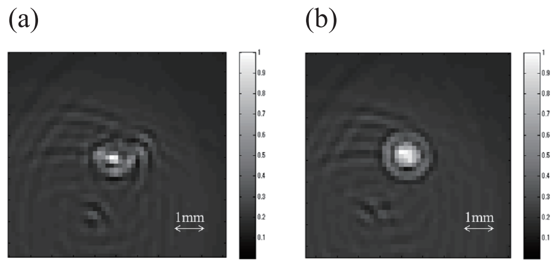

Fig. 5 Wire target cross sectional image before compensation (a), after compensation (b).

4. Conclusion

In this study, we have developed an experimental USCT system and transducer elements position compensation was performed. We believe that early breast cancer diagnosis is possible using precise USCT imaging. Furthermore, it would provide a consistent system from diagnosis to treatment when combined with HIFU.

Acknowledgment

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