3P5-18

Real-time Imaging Using a Flexible Array Based on Geometric Phase Correction

Shinryu Matsuoka[1‡], Masayuki Tanabe[2*], Kosuke Sato[3], Toru Uda[3], and Makiko Kobayashi[2]
([1]Grad. School Sci. And Technol., Kumamoto Univ.; [2]Fac. Adv. Sci. Technol., Kumamoto Univ.; [3]NOK Corporation)

1. Introduction

Medical ultrasound arrays, which are widely used in hospitals and disaster sites, have limitations due to their rigid contact surface with the body and their considerable size. Especially when measuring soft areas such as the abdomen or breast, the pressure from the probe can alter the shape of the body tissue. This deformation can subsequently distort the appearance of the internal structures in ultrasound images. Additionally, the size of the probe makes it difficult to attach it to the body.

In response to these limitations, there's a growing interest in the development of flexible ultrasound probes. In our preliminary research, we have successfully developed a thin and flexible ultrasound array[1)]. This innovative probe can be envisioned as a wearable ultrasound sensor that seamlessly conforms to the contours of the body, enabling long-term monitoring feasible.

For accurate imaging of biological structures using the flexible probe, it's crucial to precisely understand its shape. We previously proposed a method to geometrically estimate the shape of the probe by calculating the time of flight (TOF) between elements using direct waves[2)]. Until now, our investigations on this method have been limited to preliminary simulations. However, in this study, we will comprehensively evaluate the performance of the proposed shape estimation algorithm through experiments using our newly developed flexible probe.

2. Method

2.1 Geometric phase correction algorithm

Using the geometric phase correction algorithm previously proposed[2)], we estimated the shape of the probe. **Figure 1** illustrates the proposed algorithm. Pulses are transmitted from the first and N-th elements, and direct waves are received by the other elements to calculate the TOF. The distance between the elements is estimated, assuming that the speed of sound is constant. Finally, the relative coordinates of each element can be obtained from the distance between the elements using the following formula:

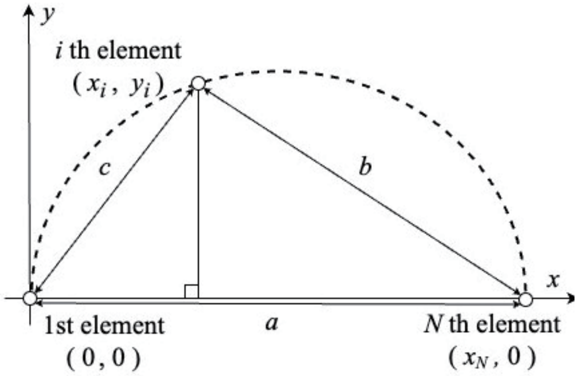

Fig. 1. Diagram of proposed algorithm.

$$s = (a + b + c) / 2 \quad (1)$$

$$x_i = \sqrt{c^2 - {y_i}^2} \quad (2)$$

$$y_i = 2\sqrt{s(s-a)(s-b)(s-c)}/a \quad (3)$$

2.2 Experimental setup

For the underwater experiment, we deformed the probe using a fixture and fixed it in a state with a curvature radius of 20 mm. The structure of the probe is shown in **Fig. 2**, and its various parameters are listed in **Table I**. The experimental circumstance is shown in **Fig. 3**. The flexible probe was connected to a Verasonics Vantage 64 research ultrasound system for transmission and reception control. During the experiment, the probe was submerged in water and no reflector was set up to ensure that only the direct waves and reflections from the tank were received. A pulse wave with an amplitude of ±50 V was separately transmitted from several elements and received by all elements.

E-mail: †matsuoka_s@st.cs.kumamoto-u.ac.jp,
*mtanabe@cs.kumamoto-u.ac.jp

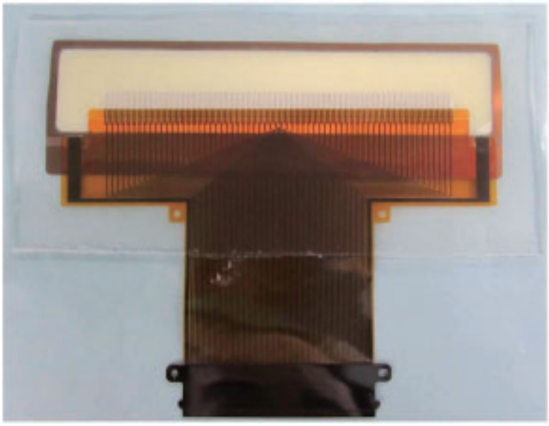

Fig. 2. Photo of flexible probe.

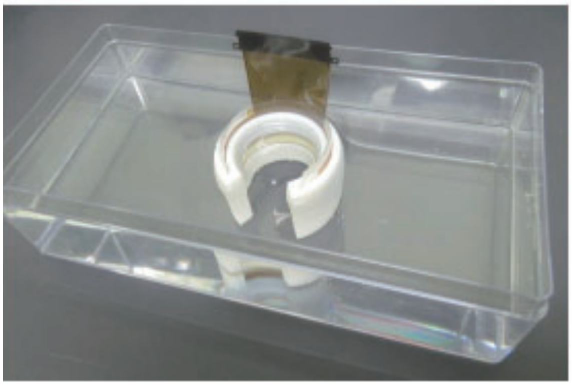

Fig. 3. Photo of experimental circumstance.

Table I. Characteristics of flexible probe.

Element number	64
Pitch	1.0 mm
Height	3.0 mm
Width	0.9 mm
Center frequency	4 MHz

3. Result

A B-mode image produced based on the RF waveforms received in response to the transmission from ch. 32 is shown in **Fig. 4**. Meanwhile, **Fig. 5** shows the RF signals received by elements 1, 2, 3, and 4. The red line in the figures represents the true TOF. The TOF obtained by the experiment were in close agreement with the theoretical values, indicating the feasibility of geometric phase correction.

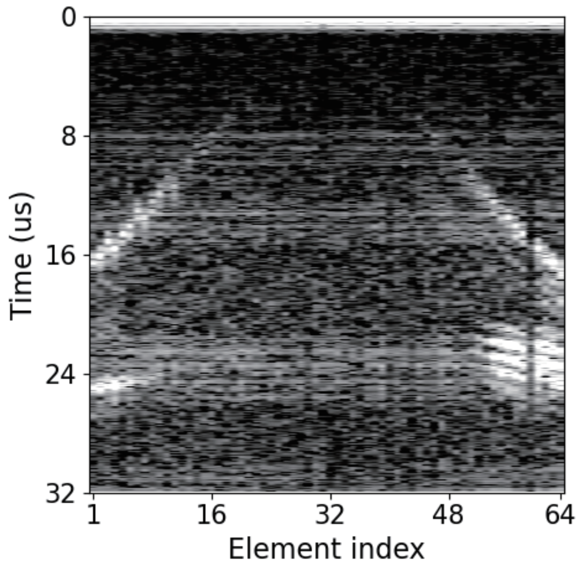

Fig. 4. B-mode image constructed using RF signals from ch. 32 transmission.

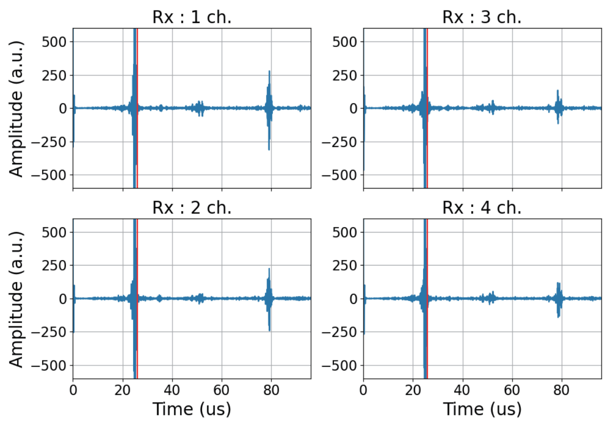

Fig. 5. Examples of obtained direct waves.

4. Conclusion

In this study, we presented the feasibility of the geometric phase correction algorithm based on the TOF of direct waves. In future work, we plan to implement the shape estimation based on these results, aiming to form the desired beam and attempt imaging through ultrasonic transmission and reception.

References

1) M. Tanabe, K. Sato, T. Uda and M. Makiko, Jpn. J. Appl. Phys. **62**, SJ1034 (2023).
2) M. Sada and M. Tanabe, Jpn. J. Appl. Phys. **59**, SKKE25 (2020).