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Improvement in Spatial Resolution of a Two-Dimensional Sparse Array Probe by Mechanical Scanning

メカニカル・スキャニングによる 2 次元スパース・アレイ・プローブの空間分解能の向上

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1. Introduction

Medical ultrasound systems have become widespread and are being used in many medical fields. In particular, inexpensive portable systems have recently been released such as Vscan (GE Healthcare Ltd.), iViz Air (FUJIFILM Medical Co., Ltd.), and viewphii US (Socionext Inc.), and the number of users is expanding rapidly.

One of the most expensive components in an ultrasound system is the probe. The probe consists of a micro-machines piezoelectric element, a matching layer, and a backing material. In order to manufacture probes inexpensively, it is effective to reduce the number of channels used [1-3]. However, reducing the number of channels has a direct negative impact on the resolution of B-mode images. Alternatively, there are devices that consist of multiple elements, such as four or eight, but transmit and receive with a single element, and observe the object in A-mode or M-mode instead of B-mode.

The ultimate goal of this study is to perform C-mode or 3D volume imaging using a sparse 2D array probe composed of an extremely small number of elements. Recently, technologies that enable low-cost creation of these types of shaped sensors have been studied [4-6]. In this paper, an attempt is made to improve the spatial resolution by transmitting and receiving ultrasound pulses while mechanically scanning the 2D array probe consisting of 8 elements. As a preliminary step to the experiment, a simple numerical analysis was performed to generate pseudo-echoes when the probe was mechanically scanned, and C-mode images were acquired using this analysis.

2. Method

The probe designed in this paper consists of eight circular elements arranged in a two-dimensional configuration with wide spacing. The design of the circular elements is shown in **Fig. 1**, where the radius of each element is 5 mm, and the center frequency of the irradiated signal is 3 MHz.

The procedure to acquire the echo signal is shown below. First, ultrasonic waves are transmitted from one transducer and received by all the elements including the transmitting element. once the echoes of the first transmitted wave are received, the next wave is transmitted by another element and received by all the elements in the same way. When the echoes of the first transmission wave are received, the next transmission is made by another element and received by all elements in the same way. The same procedure is repeated below to receive a total of 64 echoes at one location. After that, the probe is physically moved a certain distance in the y direction and the same process is repeated. In this paper, the amount of shift in the y-direction is changed to 2, 7.5, and 15 mm, and the results are compared with the case without shift. In all moving cases, the total shift was set to 30 mm.

The mesh size of the 3D volume data is a cube with a side of 2 mm. In the numerical analysis, it is assumed that the sound waves radiate from the center of the cube. When moving the probe, the position of the probe is assumed to be measured by an external device. A point target is placed in the tank at a distance of 20 mm from the probe and echoes are acquired. The speed of sound of water is set to 1500 m/s.

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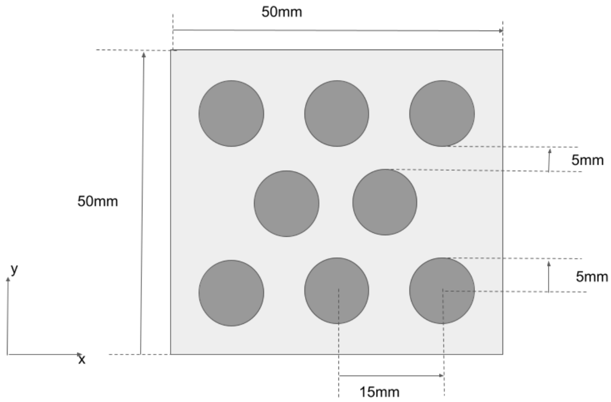

Fig. 1. Design of 8ch transducer.

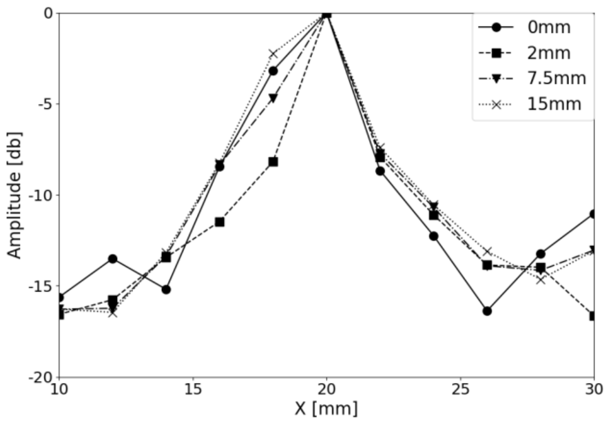

Fig. 3. X-directional resolution.

3. Results

The C-mode images obtained from the echoes are shown in **Fig. 2**. The x-direction profile of the C-mode image is shown in **Fig. 3**. It can be seen that the main lobe becomes steeper as the scanning interval becomes smaller.

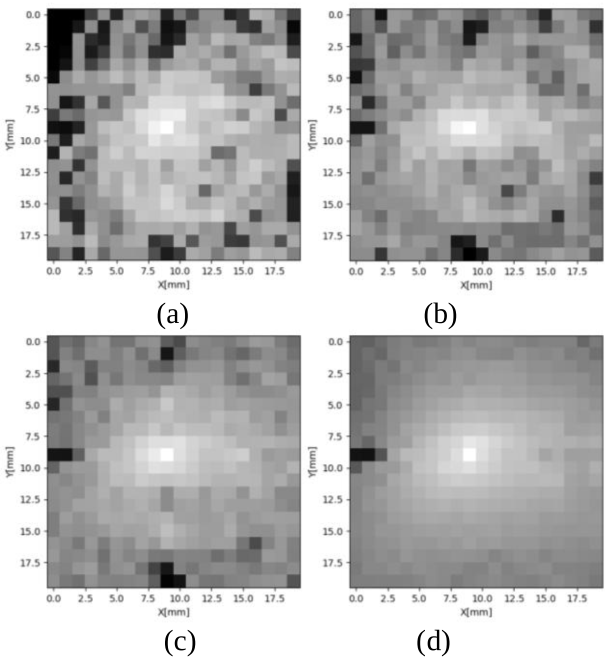

Fig. 2. C-mode images (a) without moving, and with mechanical scanning pitches of (b) 15 mm, (c) 7.5 mm, and (d) 2 mm.

4. Conclusion

In this paper, the 2D sparse array probe was modeled, and the echo waveform acquired while moving the probe mechanically was used to reconstruct the C-mode image. It was confirmed that acquiring echoes while moving the probe improves the spatial resolution which results in a high-definition image.

In the future, simulations that take into account the piezoelectricity of the ultrasound and the materials of the probe will be carried out.

References

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