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Improvement of Beam Profile by Quasi-array along Elevation Direction of Ultrasound Transducer

探触子エレベーション方向の準アレイ化によるビームプロファイルの改善

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1. Introduction

For accurate diagnosis using ultrasound, imaging quality is important, and various studies have been carried out to improve it [1], [2]. Therefore, we are developing a new imaging system in which an transducer array consisting of a small number of PZT elements called a ``quasi-array” are constructed in an elevation direction of an ultrasound transducer, in addition to an azimuth direction. By this system, we expect that a beam profile can be improved and various signal processings, for example speckle rediction and detection of target motion out of an B-mode cross-section, can be done. In order to design the system and estimate its performance, a simulator is required so as to compute the imaging property quickly but accurately. In this study, we propose a technique to reduce the computational cost of usual FEM simulations.

2. Quasi-array in elevation direction

We suppose that, in this study, a large number of PZT elements constitute an array in an azimuth direction, and hence, transmission is assumed to be ideally focused and is scanned electrically. By this assumption, we focus on a cross-sectional imaging perpendicular to an azimuth direction with no consideration of the beam width along an azimuth direction. Such the imaging cross-section is shown in **Fig. 1**, in which ROI is also indicated. Focusing for transmission along an elevation direction is performed by an acoustic lens to simplify an electric circuit, therefore the direction is fixed. A focusing point is the center of the ROI in Fig. 1. Beam forming for receiving are performed by a quasi-arrayed PZT elements. The number of the elements should be small for a cost-effective system. In this study, we use 8 elements.

3. Simulation method

The proposed simulation technique consists of preprocessing and imaging as follows:

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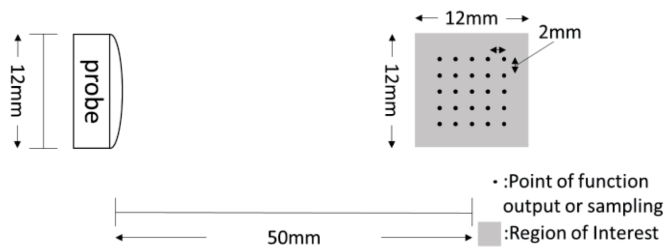


Fig. 1 Imaging cross-section spanned by range and elevation directions.

A. Preprocessing

(i) Transmission and propagation:

At first, transmission and propagation of an ultrasound beam are simulated using PZFlex, the standard code for FEM. Acoustic pulses are generated at all PZT elements simultaneously by applying a common voltage pulse. The pulses are focused through an acoustic lens, and the focused beam is propagated in a medium. **Figure 2** shows an example of the simulated transmission. The reference points, at which point spread functions used for imaging as a reference are computed at the following Step (iii), are defined in the ROI shown in Fig. 1, and the index is defined in **Fig. 3**. Propagated pulse forms distorted through propagation process at the reference points are stored. In this study, water having no attenuation is used as a propagation medium and 25 reference points are adopted.

(ii) Delay-time map:

Next, for delay-and-sum (DAS) beam forming, delay-time of echo receiving at each transducer is computed. Our system uses an acoustic lens and hence, analytical computing of the exact refraction caused by the lens is complicated. Instead of it, we simulate the pulse propagation from each reference point to each PZT element to compute the delay-time. By interpolating those delay times through 2-D polynomial function fitting, we generate a delay-time map for each PZT element. The delay maps for the central element and the upper end element are shown in **Fig. 4**.

(iii) Point spread function:

Finally, point spread functions at the reference points are computed. From each reference point, the distorted pulse computed by Step (i) is assumed to be transmitted. Using the distorted pulse shape and the delay-time map obtained by Step (ii), the point spread function is computed by DAS. As a result, 25 images are generated, and those are used as a reference RF image set. Examples are shown in **Fig. 5**, which still include a carrier wave.

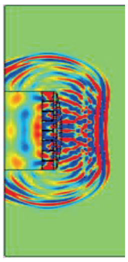


Fig.2 Transmission.

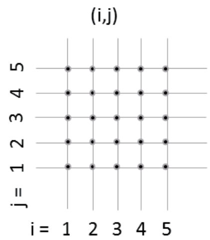
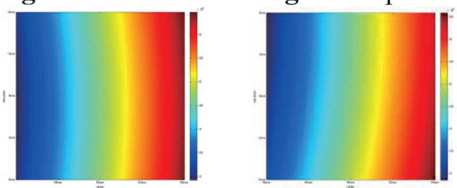
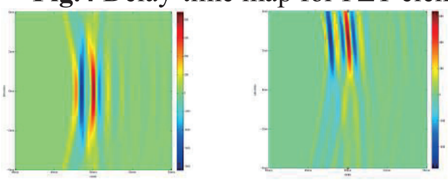


Fig.3 Ref. point index.



(a) Central element (b) Upper end element

Fig.4 Delay-time map for PZT element.



(a) (3,3) point (b) (3,5) point

Fig.5 Point spread functions used as reference.

B. Imaging

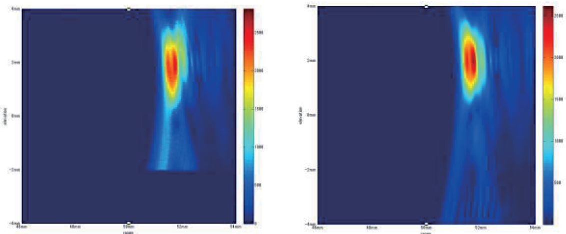
Using the point spread functions computed and defined in Step (iii) described above, the RF image of a scatterer placed at an arbitrary position in a medium is generated. Although there are many methods to do it, in this study, we simply adopt the linear interpolation using 4. For the general case that there are a lot of scatterers, based on a principle of superposition, we can superimpose the RF images generated by the same way at each scatterer's position respectively, and then, convert the integrated image to the base-band image using, for example quadrature detection.

3. Simulation results

The examples of the computed image using the parameters shown in **Table I** are shown in **Fig. 6(a)**. F-number is constant and all PZT elements are used for imaging. For comparison with our interpolation method, the result by more accurate method is also shown in Fig. 6(b). In the method, the distorted pulse computed at the scatterer position is computed by the same way as Step (i) and is used with the delay-map in Step (ii) for DAS imaging. This method took 1,400 sec. but our method needed only 23.5 sec. using core i5 4570 CPU. This difference is valuable for 3-D imaging with a lot of scatterers. In **Fig. 7**, the images at the reference point (3,3) with ignoring the refraction of the lens. By comparing those and Fig. 5(a), we can confirm that the delay-map computing is important.

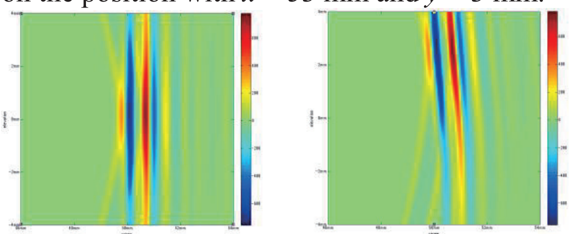
Table I Simulation parameters

Frequency	2MHz
Wave pattern	Sinusoidal wave one cycle
Aperture	12mm
Focal point	50mm
A number of transducer	8
Gap of transducer	0.1mm
Element size of FEM	0.15μ m
Time increment of FEM	2.34ns
Density of water	1000 g/cm^3
Longitudinal wave velocity of water	1500 m/s



(a) Proposed interpolation (b) DAS instead of interpolation

Fig. 6 Example of imaging for one scatterer placed on the position with $x = 53$ mm and $y = 3$ mm.



(a) point (3,3) (b) point (3,5)

Fig. 7 Lens refraction effect at reference.

4. Conclusions

We proposed a simple method for imaging simulation for the quasi-array system based on the interpolation. The actual imaging property for a lot of scatterers should be evaluated. Additionally, by applying the method, the useful application of the quasi-array system for an elevation direction should be studied in future.

Acknowledgment

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References

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