2P5-7

3D Ultrasound Imaging Using A Single Sensor with Distributed Electrodes and Coding Mask

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1. Introduction

In medicine, ultrasound imaging is widely used as a less invasive examination method. Generally, an array probe with an array of ultrasound transducers is used in ultrasound imaging. In systems using array probes, transducers are arranged in a grid pattern. In addition, it requires the same number of transmitting and receiving circuits as there are transducers, resulting in a high-cost system.

In alternative to array probes, compressed imaging with a single transducer and an encoding mask has been proposed[1,2)] as a method of 3D imaging. In these studies, a mask with locally random thickness is attached to a single transducer. This mask spatially encodes the ultrasonic waves generated from the transducer, and transmits different waveforms depending on the location. Reflections at different locations are received as a single signal, but can be separated by signal processing, thus enabling 3D imaging. This method requires only a single transmitter/receiver circuit, making it a low-cost system. However, to improve image quality, it is necessary to transmit and receive multiple times while changing the sound source distribution, so a mechanism for rotating the transducer is required.

In this research, we propose a method using distributed electrodes and a coded mask. This method makes it possible to change the sound source distribution by switching the electrodes distributed on the transducer at each measurement, and does not require a mechanism to rotate the transducer.

2. Method

As the received echo signal is a combination of the reflected waves at each location, the image can be solved for by the following equation.

$$\boldsymbol{y} = \boldsymbol{D}\boldsymbol{x} \tag{1}$$

where $\boldsymbol{y}$ is the echo signal, $\boldsymbol{D} = \{\boldsymbol{d_1}\ \boldsymbol{d_2} \dots \boldsymbol{d_N}\}$ is a matrix consisting of vectors $\boldsymbol{d_n}$ with echoes when reflected at each measurement point, and $\boldsymbol{x}$ is image.

The images generated from each measured echo can be compounded to improve image quality. In this research, we aim to improve the image quality by compounding images with weights using coherence factor (CF). The CF weights are defined as following equation.

$$\boldsymbol{w_{CF}} = \frac{\left|\frac{1}{M}\sum_{m=1}^{M}\boldsymbol{x_m}\right|^2}{\frac{1}{M}\sum_{m=1}^{M}|\boldsymbol{x_m}|^2} = \frac{\left|\sum_{m=1}^{M}\boldsymbol{x_m}\right|^2}{M\sum_{m=1}^{M}|\boldsymbol{x_m}|^2} \tag{2}$$

Where $\boldsymbol{x_m}$ is the image obtained for each measurement.

3. Simulation

To evaluate the proposed method, we used OnScale, a finite element method simulator. The simulation model is shown in **Fig. 1**. 64 electrodes are distributed on the surface of the transducer and connected to a single transmitter/receiver circuit via a switching circuit. In the simulation, 16 electrodes were randomly selected and 20 measurements were taken to image 5 targets within the region of interest (ROI). The parameters of the transducer and coding mask are shown in **Table 1** (λ indicates wavelength). A Gaussian window-adapted 2.5-cycle sin wave was used for the transmission.

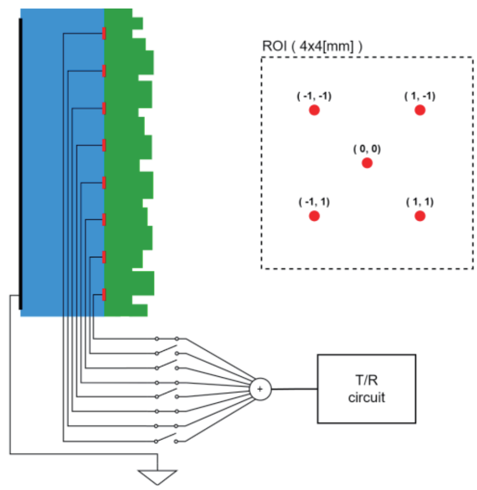

Fig. 1 Configuration of proposed system and ROI setting.

Table 1 Parameters of the transducer and coding mask.

Parameters	
center frequency	8[MHz]
mask thickness	$\lambda/2 \sim \lambda/4$
mask width	$\lambda/2 \sim 3\lambda/2$
diameter	5[mm]

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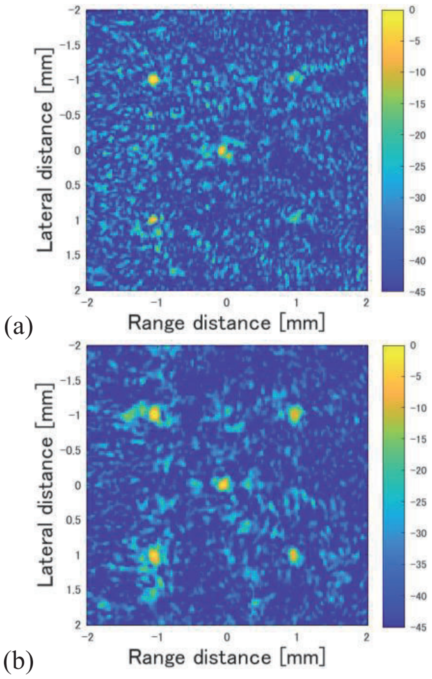

Fig. 2 B-mode images by (a) switching electrodes without rotating coding mask and (b) rotating coding mask without distributed electrodes.

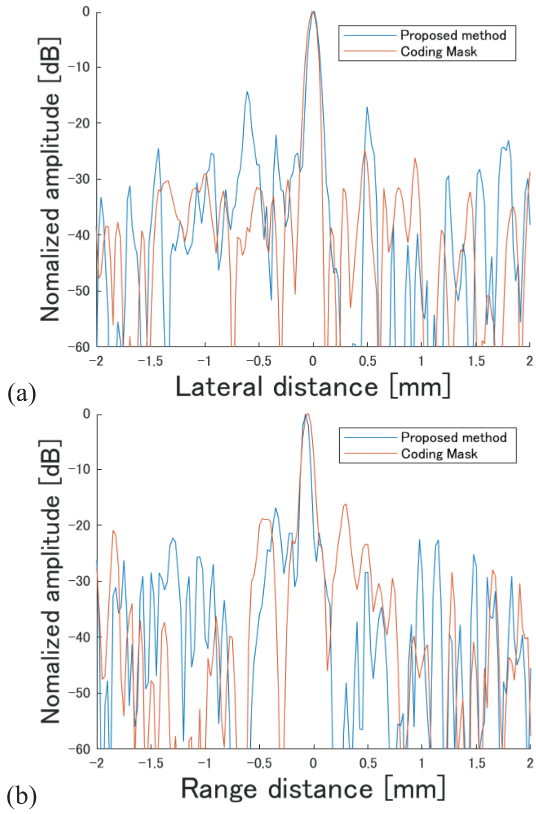

Fig. 3 Amplitude profiles of the images in Figure 2 along (a) lateral and (b) range directions.

4. Results and Discussion

Figure 2(a) shows the image measured by switching electrodes without rotating coding mask. **Fig. 2(b)** shows the image measured by rotating coding mask without distributed electrodes. The profiles of both methods are shown in **Fig. 3**.

Figures 3 and 4 show that the proposed method can construct images with the same level of resolution and background as the conventional method, without the need for mask rotation. It can also be seen from Fig. 2 that the signal level is lower for targets further away from the transducer in the proposed method. This is thought to be due to the use of distributed electrodes, which reduces the transmission power and weakens the reflections.

5. Conclusion and Future Work

We proposed a method of switching the electrode pattern using a distributed electrode and a coding mask, which does not require rotation, and which could construct images with resolution and background levels at the same level as the conventional coding mask. However, the signal level was found to be lower for targets located further away from the transducer.

In future, we aim to develop methods to improve resolution and to solve the problem of weak signal levels in targets that are far away from the transducers.

References

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