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● *Original Contribution*

# MULTIMODE ULTRASOUND BREAST IMAGING USING A NEW ARRAY TRANSDUCER CONFIGURATION*

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**Abstract—This article presents a diagnostic ultrasound imaging technique that can be used in imaging protruding objects such as a human breast using two opposing array transducers. Because two B-mode images obtained from each of the two linear array transducers facing each other represent the same imaging area viewed in different directions, the image quality can be improved using a compounding technique. Using one array as a transmitter and the other as a receiver, the speed of sound distribution in a medium interposed between them is also reconstructed. In addition, because the spacing between the two arrays can be finely controlled, strain image can also be obtained. This new method can be used to produce a compound B-mode image, a speed of sound image, and a strain image of the same region-of-interest, making it possible to obtain more information leading to better diagnosis. Experimental results on a phantom containing a cylinder of different speed of sound and elasticity confirm that the proposed method is useful in obtaining compound and speed of sound images as well as strain images. (E-mail: sjkwon@daejin.ac.kr) © 2010 World Federation for Ultrasound in Medicine & Biology.**

*Key Words:* **Attenuation, Backprojection, Breast, Compounding, Reconstruction, Speckle, Speed of sound, Strain imaging.**

## INTRODUCTION

Although mammography is widely used in the diagnosis of breast cancer, it may be subject to potential radiation hazard. Breast cancer has different ultrasound characteristics from normal healthy tissue in terms of speed of sound (SOS) and attenuation (Goss et al. 1978). For the case of diagnosing breasts in medical ultrasound imaging, tissue parameter imaging can be used together with B-mode imaging in a complementary manner.

Since the breast protrudes from a human body, it is possible to obtain attenuation and SOS images by using circular transducers or by rotating linear arrays over 360° in transmission or reflection mode using tomographic reconstruction principles (Glover et al. 1977; Greenleaf et al. 1975, 1981). Although this approach enables us to obtain more information about lesion, the use of circular transducers or linear arrays entails the immersion of objects to be imaged in water. Due to relatively long data acquisition time and discomfort to patients, it has not yet been put to practical use.

To overcome these limitations, several researchers proposed data acquisition methods based on linear array transducers (Huang et al. 2004; Krueger et al. 1996). As with mammography, using a linear array transducer and a plane reflector, the SOS image of a human tissue positioned between them was obtained. Compared with tomographic reconstruction methods that collect data over an angle of 360°, the linear array method acquires data over a limited range of angles, making it difficult to produce a complete artifact-free image (Krueger et al. 1996). Huang et al. (2004) compensated for distortion in SOS image using structural information extracted from B-mode image. To superpose images obtained from multiple viewing angles in full angle spatial compounding, Hansen et al. (2007) reconstructed the SOS distribution by placing a reflector behind an object of interest and using the filtered backprojection of the echo data from the reflector. Jeong et al. (2008) obtained SOS images in transmission mode using two transducers that face each other.

Compound imaging techniques acquire data using spatial or frequency diversity and average images of the same region to achieve less speckle noise and better contrast

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(Robinson 1984; Wilhjelm et al. 2000). Carson et al. (1981) introduced a method of obtaining compound image together with SOS image using circular array transducers.

Recently, there has been much research into elasticity imaging of the breast. Since tumor or cancer in soft tissue such as the breast and prostate tends to be stiffer than the surrounding tissue, elasticity imaging that visualizes the degree of stiffness is of great help in diagnosing it (Hall 2004; Ophir et al. 1991; Sarvazyan et al. 1998). Human tissues tend to exhibit a higher contrast in elasticity than other tissue parameters. Therefore, the elasticity parameter is amenable to imaging.

In this article, we obtain spatial compound, SOS, and strain images using two opposing linear array transducers. B-mode or strain images are obtained independently in reflection mode from each of the two array transducers, and are compounded to improve the image quality. In transmission mode, however, we use an imaging configuration where one array transducer is used as a transmitter and the other is used as a receiver. The time of flight (TOF) is measured and an SOS image is reconstructed. A combination of the B-mode, strain, and SOS imaging can increase the accuracy of lesion diagnosis. This article presents each imaging method and experimental results.

## SPATIAL COMPOUND IMAGING

Compound imaging is used to reduce speckle noise as well as artifacts such as shadowing and reverberation by averaging a certain number of images whose correlations are small. However, the degradation of resolution and signal-to-noise ratio (SNR) with increasing depth cannot be compensated for. Conventional spatial compound B-mode images are produced by averaging individual images of the same imaging region obtained by steering scan lines at different angles. However, the number of useful images obtainable with a single transducer array is limited by its characteristics or the performance of an ultrasound imaging system employing it.

If two linear array transducers are arranged such that they face each other, compound images can be reconstructed separately using each of them and those compound images can be averaged again. As a result, the images can be compensated for their depth-dependent characteristics. Figure 1 shows the imaging configuration used in this article where the two linear array transducers face each other. A slanted imaging area that makes an angle of $\theta$ to the upper transducer array normal by steering ultrasound beams is also indicated in dashed lines in the figure.

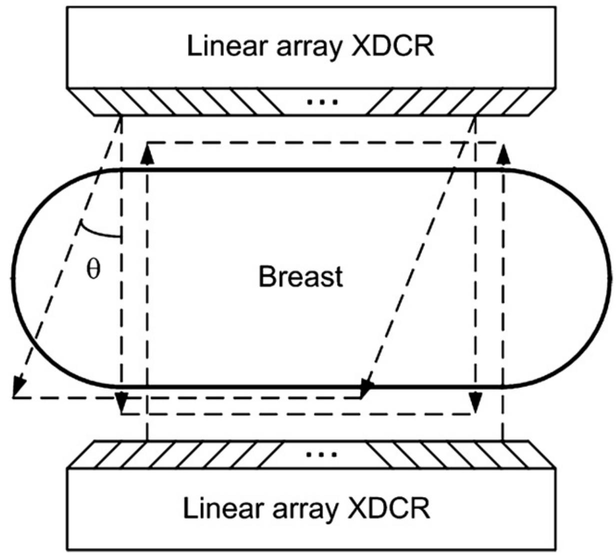


Fig. 1. Compounding of independently obtained images using each of two opposing array transducers.

## SOS IMAGING

The measurement of ultrasound speed has been a topic of interest since it can aid in tissue characterization, beamforming, scan conversion, and image registration (Duric et al. 2008; Glover et al. 1977; Goss et al. 1978; Greenleaf et al. 1975, 1981; Hansen et al. 2007; Huang et al. 2004; Krueger et al. 1996; Krücker et al. 2004; Li 2008, 2009; Robinson et al. 1991). Recently, the work of Duric et al. has been quite noteworthy. They employ a powerful, sophisticated approach to imaging SOS distribution within the framework of ultrasound computed tomography as well as diffraction tomography. Their experimental and clinical imaging results are promising. By surrounding a breast with 256 transducers positioned on a ring in a clinical prototype system called computed ultrasound risk evaluation (CURE), they imaged three parameters of the breast, *i.e.*, SOS, attenuation, and reflectivity, and fused them together to present as a single pseudocolor image. The resolution was approximately 3 mm corresponding to three wavelengths at a central transducer frequency of 1.5 MHz.

If we use two array transducers in transmission mode, SOS and attenuation images can be reconstructed by measuring the arrival time and amplitude of the received signal on one array transducer with insonification from the other array transducer. Figure 2 shows an imaging configuration for two opposing linear array transducers. By exchanging the transmitting and receiving roles of the two array transducers, the range of angles over which data can be acquired is doubled compared with the case of using a single array transducer and a plane reflector (Huang et al. 2004; Krueger et al. 1996).

To reconstruct SOS images from the arrival time of received signals, the backprojection algorithm is employed (Glover et al. 1977; Mizutani et al. 1997). We will briefly explain the procedure used here. The time it takes for the transmit ultrasound signal from the *n*th