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Ultrasonic 2D Array Transducer for Volumetric Imaging

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1. Introduction

3-D ultrasound imaging permits better visualization and allows a more accurate diagnosis to be made, thus the volumetric ultrasound images provide clinicians with more confidence in the diagnosis of disease and add knowledge of complex pathology [1]. The 3-D ultrasound imaging technology has benefitted from the development of the transducers that are in direct contact with patients, which has expanded the possibilities for maximizing patient diagnostic information. In this work, a 2D array transducer has been developed for cardiac imaging in 3D. **Fig. 1** is a schematic structure of the 2D array transducer which consists of an acoustic module at the front end and an electronic module inside the housing to drive the acoustic module. This work focuses on the front acoustic module of the 2D array transducer. The 2D array transducer in this work has 4,096 (64×64) active elements made of the piezoelectric single crystals, PMN-PT, within 1 inch square. The 2D array consists of eight 64×8 element modules to compose the 64×64 channels. In comparison with a single-unit structure, the acoustic module assembly technique had big advantages in terms of the uniformity of the array element performance [2]. However, the module assembly method necessitated more complicated fabrication processes. In this work, the design and fabrication processes of the module type 2D array are descried with characterization results.

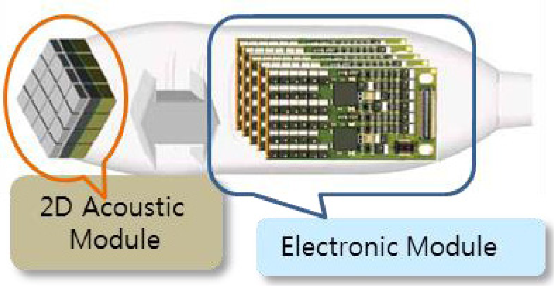

Fig. 1 Schematic structure of the 2D array transducer.

2. Design of the transducer structure

The optimal structure of the 2D array transducer was determined through finite element analysis (FEA) with a commercial software package, PZFlex. Each element of the transducer consisted of an acoustic lens, two matching layers, a PMN-PT element and a backing as shown in **Fig. 2**. In the figure, FPCB means a flexible printed circuit board and GRS means a ground sheet. Each element also incorporates major and minor kerfs to reduce the cross-talk between neighboring elements [3]. Through the FEA, the 2D array transducer was designed to have their center frequency at 3.5 MHz and fractional frequency bandwidth over 60%.

At first, performance variation of the transducer was investigated in relation to the effects of its structural parameters such as thickness of the PMN-PT crystal plate and matching layers, width and depth of the major and minor kerfs, and pitch of the 2D array. Through statistical multiple regression analysis of the FEA results, functional forms of the center frequency and the bandwidth were derived in terms of all the structural parameters. Then, by applying the constrained optimization technique with the genetic algorithm to the derived functions, the optimal combination of the structural parameters, i.e. optimal structure of the transducer, was determined to achieve the widest possible bandwidth while preserving the center frequency of 3.5 MHz [4]. Material properties, thus acoustic impedance, of all the acoustic layers including the backing material were also determined through pulse-echo simulation and harmonic analysis with the same finite element model in PZFlex.

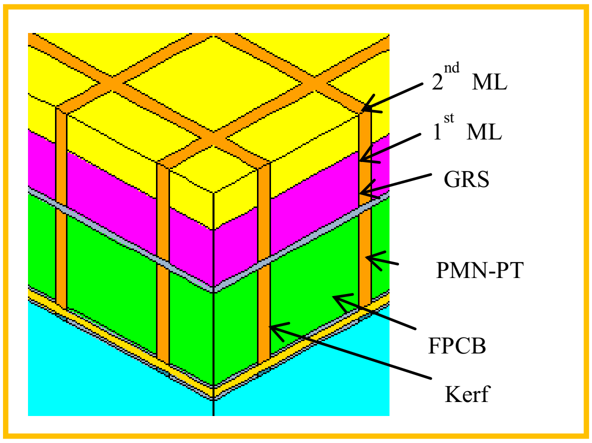

Fig. 2 Internal structure of each ultrasonic channel of the 2D array transducer.

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3. Fabrication of the transducer

The targeted 64×64 channels were composed by assembling eight sub-array modules where each module consisted of 64×8 (512) elements. **Fig. 3** is the schematic structure of the transducer. The signal flexible circuits were attached to the rear surface of the PMN-PT crystal plate, and then a conventional acoustic backing was installed beneath the signal flexible circuits. GRS was bonded into the interface of the matching layers and the PMN-PT crystal plate. Since the whole 2D array comprised eight modules, eight signal and ground flexible circuits were used to wire the whole array to external ASIC chips. The other fabrication processes were similar to those for conventional 1D array transducers.

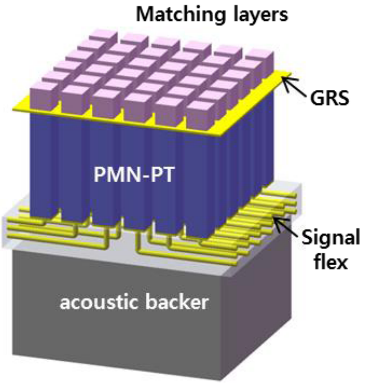

Fig. 3 Schematic structure of the transducer.

Eight modules were assembled by means of very precise mechanical fixtures to maintain the gap between the modules less than one wavelength. Fabricated prototype of the module type transducer is shown in **Fig. 4**. Footprint of the transducer is 1 inch by 1 inch. The transducer prototype was characterized through underwater pulse-echo tests. The characterization results in **Fig. 5** show that the transducer satisfied the design specifications to have its center frequency at 3.5 MHz and fractional bandwidth over 62%. The module had sensitivity uniformity over 99%; 99% of 512 elements had sensitivity deviation less than 2.5 dB from their average. Hence, it could be said that good enough uniformity had been accomplished in the fabrication.

4. Conclusions

A 2D array transducer has been developed in this work for ultrasonic volumetric imaging. The 2D array transducer had 4,096 (64×64) active elements made of the piezoelectric single crystal, PMN-PT, within 1 square inch footprint. The transducer was an assembly of eight 64×8 element modules to compose the 64×64 channels. A prototype was designed and fabricated to have its center frequency at 3.5 MHz and fractional frequency bandwidth over 60%. The transducer prototype turned out to have the sensitivity uniformity over 99%, which confirmed its applicability to practical ultrasound 3D imaging. The 2D array transducer in this work is expected to contribute to advancement and improved understanding of 3-D ultrasound imaging technology.

Fig. 4 Photograph of the fabricated transducer.

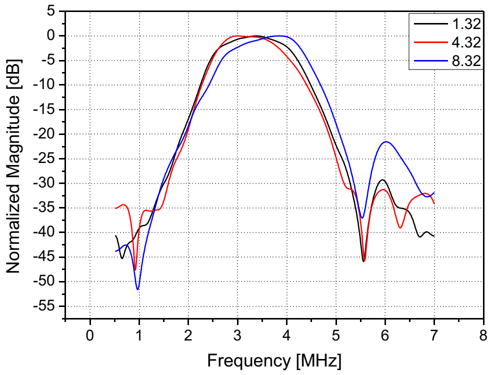

Fig. 5 Frequency spectrum of the transducer.

Acknowledgment

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References

1. K. Baba and D. Jurkovic, *Three-dimensional ultrasound in obstetrics and gynecology, New York* : Parthenon Press, 1997.
2. J. Woo and Y. Roh, Proc. IEEE Ultrason. Symp., pp. 1568-1571, 2012.
3. W. Lee, S. Lee and Y. Roh, Proc. IEEE Ultrason. Symp., pp. 2738- 2741, 2009.
4. Y. Roh and X. Lu, J. Acoust.Soc. Am., vol.119, No.6, pp.3734-3740, 2006
5. D. Pei and Y. Roh, Jap. J. App. Phy., vol.47, No.5, pp.4003- 4006, 2008.