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Design of the radiation beam pattern of an ultrasonic transducer by electrode shading technique

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1. Introduction

Ultrasonic transducer is the key element in transmitting and receiving acoustic signals in medical ultrasonic diagnosis or nondestructive testing of industrial equipment. Depending on its application, the transducer is often required to compose various shapes of its sound beam, which are called beam patterns. The most common requirements of a good beam pattern are a low sidelobe level and a small beam width while maintaining the on-axis sound level of a main lobe above a certain value.

Ultrasonic imaging transducers have many channels along its azimuth, which allows easy forming of the sound beam into a desired form. However, the most usual ultrasonic imaging transducer is a one dimensional (1D) array, and thus has no control of the beam pattern along its elevation. In order to overcome this difficulty, many different kinds of acoustic lens have been developed such as Fresnel lens [1] and Hanafy lens [2]. Some of them are quite effective and have been successfully applied to commercial transducers.

In this work, a rather new and simple method is proposed to manipulate the beam pattern along the elevation, i.e. shading the electrode on top of the piezoelectric layer. The proposed technique splits the initial uniform electrode into several segments and combines those segments to compose a desired beam pattern.

2. Electrode shading

Fig. 1 shows the schematic structure of the shaded electrode of an ultrasonic channel along its elevation direction. Initially, a uniform electrode of L_1 long is deposited on top of the piezoelectric layer. Shading the electrode means splitting the L_1 into several segments, i.e. cutting the uniform electrode into the three electrodes of $(L_1\text{-}L_2)/2$, L_2, and $(L_1\text{-}L_2)/2$ as shown in Fig. 1. Since we are looking only the elevation side, the transducer in Fig. 1 can be simplified as a line source.

$$P = i\frac{\rho_0 c}{2}U_0\frac{a}{r}kL\left(\frac{\sin(\frac{1}{2}kL\sin\theta)}{\frac{1}{2}kL\sin\theta}\right) \quad (1)$$

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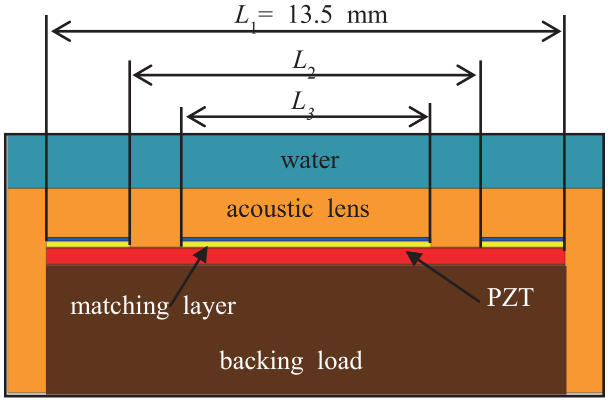

Fig. 1 Schematic structure of the shaded electrode of an ultrasonic channel.

The sound pressure P from a line source is written as Eq. (1), where ρ_0 is the density, c is the sound speed, and U_0 is the volume velocity of the radiation medium, i.e. water. k is the wave number, r is the distance from the source, and a is the radius and L is the length of the line source. θ is the inclination angle from the normal to the line source. **Fig. 2** is the exemplary beam pattern of a line source when the length L is 13.5 mm and the electrode is uniform.

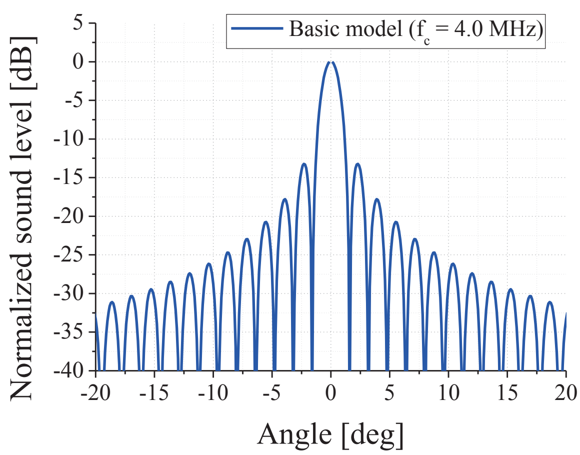

Fig. 2 The beam pattern of a basic non-shaded electrode pattern.

The total sound pressure from the three segments in Fig. 1 can be presented as Eq. (2). The resultant sound pressure is considered as the summation of three pressure fields from the three segments.

$$P_{total} = P(L_1) - P(L_2) + P(L_3) \qquad (2)$$

3. Structural optimization of the transducer

Then, the L_2 and L_3 can be optimized to achieve a desired beam pattern. **Fig. 3** shows the optimization scheme developed in this work. The purpose of the optimizing is to suppress the level of the side lobe below a certain value and to maximize the magnitude of the total sound pressure. **Fig. 4** is the result of the optimization, i.e. the beam pattern of a shaded electrode having the optimal L_2 and L_3. Compared with Fig. 2, the level of the largest sidelobe decreased from -13.2 dB to -17.3 dB. The same technique can be expanded to a larger number of segmented electrodes. **Fig. 5** is the beam pattern optimized for five segments. The level of sidelobe decreased from -13.2 dB to -19.4 dB.

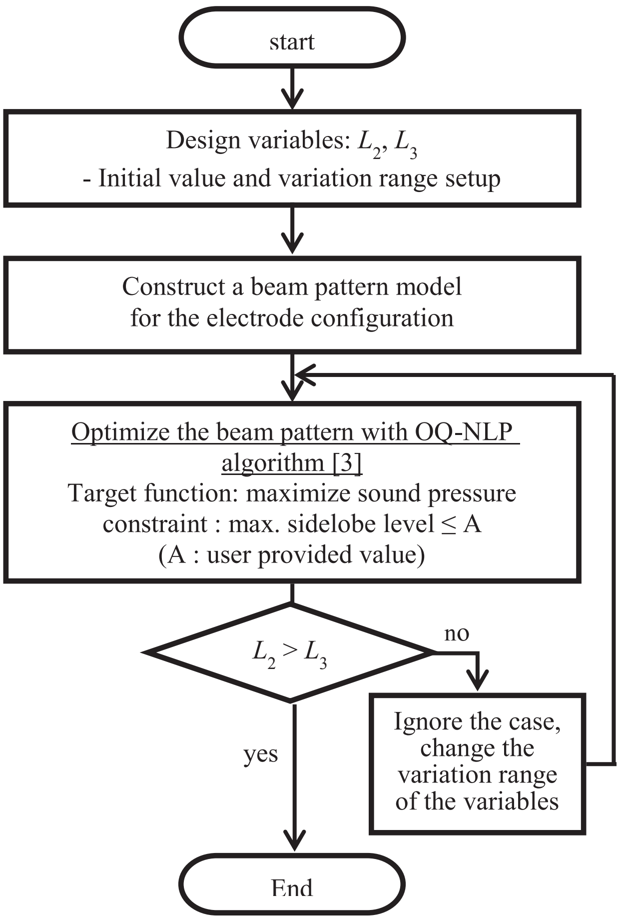

Fig. 3 The algorithm to optimize the electrode pattern to achieve a desired beam pattern.

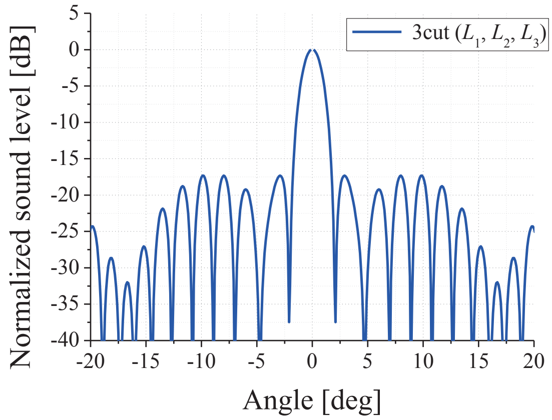

Fig. 4 The beam pattern of a shaded electrode pattern split into three segments.

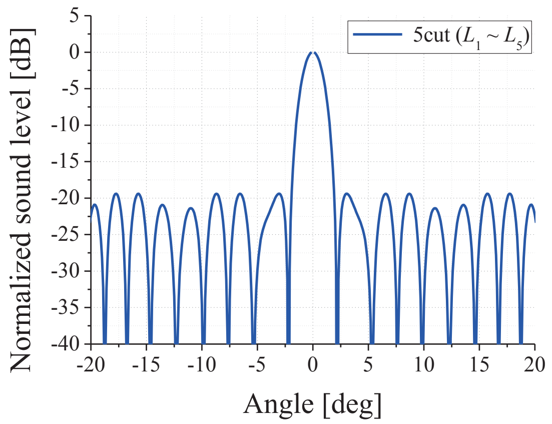

Fig. 5 The beam pattern of a shaded electrode pattern split into five segments.

4. Conclusions

The electrode shading technique has been proposed to manipulate the beam pattern of an ultrasonic transducer along the elevation, and its efficacy has been verified with sample analyses cases.

Acknowledgment

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