2P4-2
Proceedings of Symposium on Ultrasonic Electronics, Vol. 35 (2014) pp. 289-290
3-5 December, 2014

Linear array transducer for high power airborne ultrasound applications

高出力空中超音波１次元アレイトランスデューサ

Jun Yamamoto†, Yosuke Mizuno, Marie Tabaru, and Kentaro Nakamura
(P&I Lab., Tokyo Institute of Technology)
山本潤†，水野洋輔，田原麻梨江，中村健太郎（東工大　精研）

1. Introduction

In the field of high power airborne ultrasonic applications, high-intensity aieborne ultrasound is generated by using flexural vibrating plate excited by Langevin transducer with a horn [1]. In order to change the direction of ultrasound illumination without moving the transducer, phased array system is required. We have been investigating structure of element suitable for high-intensity ultrasound array [2]. In this study, we fabricated a four-element transducer array and tested the fundamental characteristics.

2. Structure of the linear array

Figure 1 shows a four-element linear array transducer. The upper surfaces having steps emit ultrasound waves. The width of the element transducer is 5 mm and each interval between the elements is 2 mm. Total size of radiation surface is 70 × 26 mm^2. **Figure 2** shows the structure of the element and the result of the free vibration analysis by using the finite element method (FEM) [2]. A multilayered PZT element of 5×5×18 mm^3 (PI) vibrates duralumin frame (A7075P) in a high order flexural mode at 30 kHz. The steps in 5.34 mm are designed to have uniform wave front in air. The hole at center part of the upper surface increases the vibration amplitude.

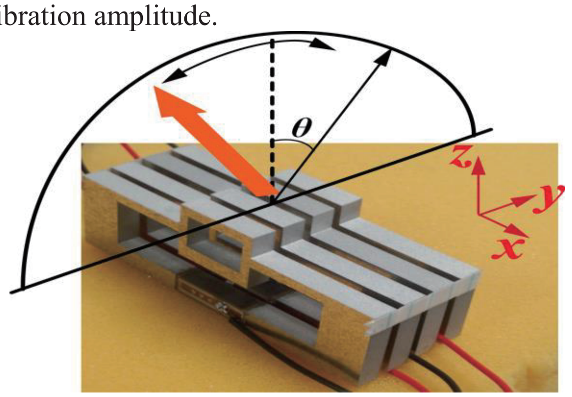

Fig.1. Photogragh of linear array transducer.

Figure 3 shows the velocity distribution of the vibration on the radiation surface along x-axis measured with a laser Doppler velocimeter. **Figure 4** shows the directivity in xz-plane 1.0 m away

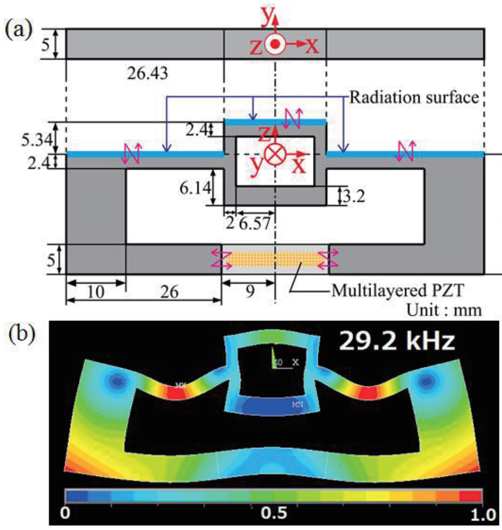

Fig.2. (a) Structure of the element transducer and (b) displacement mode calculated using FEM.

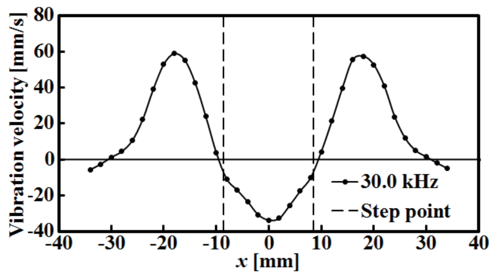

Fig.3.Vibration velocity distribution in z-axis.

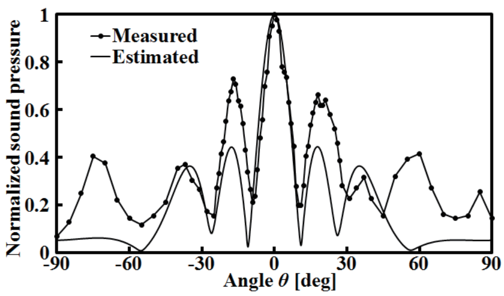

Fig.4. Directivity of an element transducer.

measured with a 1/8-inch condenser microphone (ACO, TYPE7118). Sound pressure calculated from [3]

$$P(r,\theta) = j\rho f \iint_s u(x,y) \frac{\exp(-jkr)}{r} dS, \quad (1)$$

is also presented in the figure, where $u(x, y)$ is the

† jyamamoto@sonic.pi.titech.ac.jp

measured vibration distribution, ρ, the density of air (= 1.225 kg/m^3), f, the driven frequency (= 30.0 kHz), k, wave-number, and c, the sound speed. When the applied voltage is 1.0 V, the maximum sound pressure, full width at half maximum and sidelobe level were 1.5 Pa, 13 degrees, and 0.70, respectively. The maximum sound pressure was 1.4 times higher than that of a commercial ultrasound sensor measured under the same condition.

3. Phased array experiment

Figure 5 illustrates driving electronics. A D/A converter (NI, PCI-7831R) controlled by a PC generated 4-phase sinusoidal signal, and each element was driven at 30.25 kHz after amplified by a linear amplifier (National Semiconductor, LM380N). The variations in the vibration velocities and phases for the elements CH1-CH4 were compensated, where the velocity and phase of CH1 were fixed at 1 m/s and 0 degrees, respectively. **Table 1** shows the resultant values. Phase differences could not be completely corrected because the minimum pitch controlled by the D/A converter was 12.5 degrees.

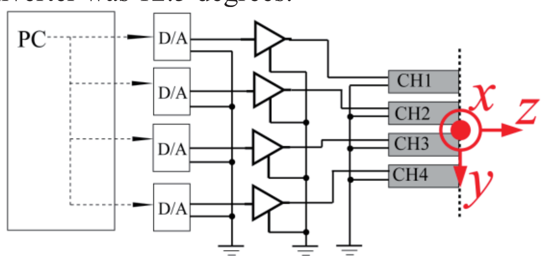

Fig.5. Driving electronics

Table 1. Errors in vibration velocity and phase.

	CH1	CH2	CH3	CH4
Vibration velocity	1	0.96	0.97	0.97
Phase [deg.]	0	+6	-2	+8

Radiation angle is controlled by changing the phase differences according to the following equation [4]

$$\theta\,[\text{deg.}] = \frac{180}{\pi}\sin^{-1}\left(\frac{\Delta\varphi}{360}\frac{c}{d\cdot f}\right), \qquad (2)$$

where d is 7 mm. sound pressure in yz-plane 1.0 m away from the center axis was measured by the 1/8 inch condenser microphone. The dots in **Fig. 6** show the normalized sound pressures versus the radiation angles for the phase differences of -97.5, -72.5, 0, 37.5 and 62.5 degrees. A solid and dotted lines show the calculated values using Eq. (1) with and without compensation of the variations shown in **Table 1**. The results in **Figure 6** show that the effect of the variation in the phases on the beam pattern was small. **Figure 7** shows the angles on the main lobe for the phase differences. When the voltage was 1.4 V, the maximum of sound pressure were 21 Pa for 0 deg., and 15 Pa for the other phases.

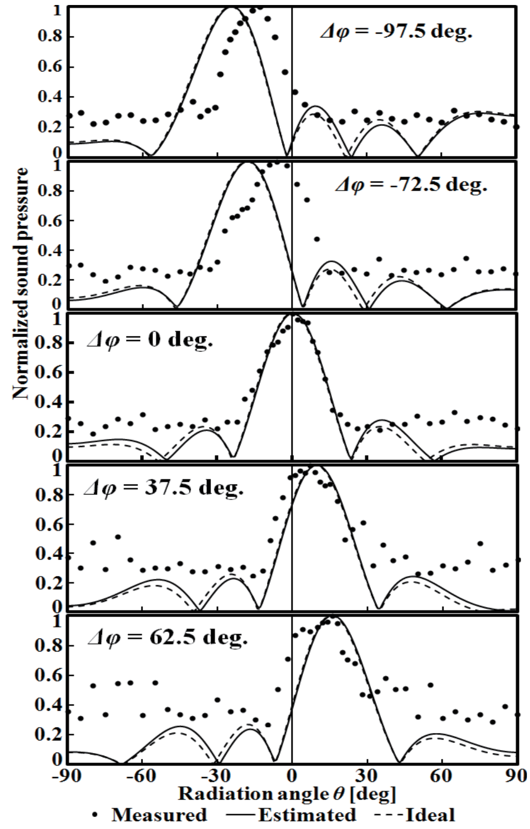

Fig.6. Directivity of the phased array.

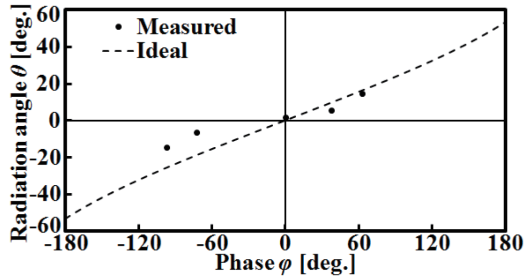

Fig.7. Beam steering characteristics.

5. Conclusion

We made a high-intensity airborne ultrasonic linear array transmitter, and confirmed that the irradiation direction was successfully changed as estimated.

References

1. K. Nakamura, *Ultrasonic Transducers* (Woodhead Publishing) 478 (2012).
2. J. Yamamoto, et al., Proc. Spring Meet. (Acoust. Soc. Jpn.), 1279, 2014.
3. K. B. Ocheltree, et al., IEEE Trans. UFFC **36**, 242 (1989).
4. S. W. Smith, et al., IEEE Trans. UFFC **38**, 100 (1991).