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Loudspeaker systems for low frequency radiation by piezoelectric ultrasonic actuator

圧電超音波モータを用いた低音再生用スピーカシステム

Hiroya Saito[1†], Juro Ohga[2], Hirokazu Negishi[3], Ikuo Oohira[4], Kazuaki Maeda[5] and Kunio Oishi[1]
([1] Tokyo Univ. of Tech.; [2] Shibaura Inst. of Tech./MIX Acous. Lab; [3] MIX Acous. Lab; [4] Self-Employee; [5] TOA.)
齋藤大矢 [1†], 大賀寿郎 [2], 根岸廣和 [3], 大平郁夫 [4], 前田和昭 [5], 大石邦夫 [1]
([1] 東京工科大; [2] 芝浦工大/MIX 音研; [3] MIX 音研; [4] 自営; [5] TOA)

1. Introduction

The authors present two sorts of new loudspeaker constructions by piezoelectric ultrasonic actuators.

The conventional electrodynamic loudspeakers have been actuated by a permanent magnet and a coil. They seem almighty, now. However, they include fundamental limitations in its performance, especially in its characteristics at very low frequency region. Ordinary direct-radiator loudspeaker diaphragms show a remarkable resonance whose frequency is called as f_0. This phenomenon results signal distortion.

To avoid this defect, use of an electromechanical transducer with large mechanical impedance for a driver is necessary. However, the electrodynamic transducers for the conventional loudspeakers do not have satisfactorily high driving impedance because its driving force is induced indirectly, via an air gap.

The authors are developing a completely new direct-radiator loudspeaker by using. It uses piezoelectric ultrasonic motors as the driver. The ultrasonic motor (USM) is characterized by very high driving mechanical impedance because its rotor contacts its stator tightly.

2. Loudspeaker by rotational type piezoelectric ultrasonic actuator

Fig.1 shows a cut model of a commercially available traveling wave type piezoelectric ultrasonic actuator. It is consisted by a circular metal ring rotor and a nicked metal ring stator. The stator is laminated by a thin piezoelectric ceramic ring.

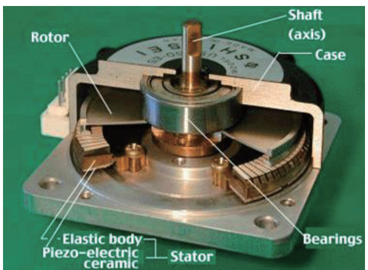


Fig.1 Structure of an ultrasonic actuator.

E-mail address: hirosaito12@gmail.com

Rotational speed of the piezoelectric ultrasonic actuator is controlled by the signal frequency applied to each piezoelectric ceramic, parts of the stator. **Fig.2** shows a relationship between measured rotational velocity and driving signal frequency of three samples. The velocity is controlled from 30 to 100 revolution per minute by varying the input signal frequency from 43.6 kHz to 42 kHz.

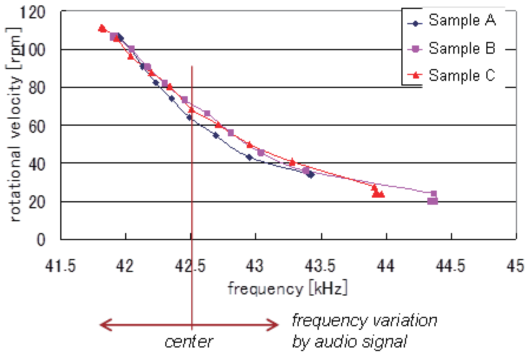


Fig.2 Input-output characteristics of three samples.

After examinations of a few experimental models, the authors invented a construction, not too heavy nor too fragile to perform as a practical loudspeaker system, including four co-axial piezoelectric ultrasonic actuator shown in **Fig.3**. It is called as QMDS (quad-motor, de-spin) model. The experimental model with a cone radiator of 46 centimeter in diameter and an enclosure of 268 liter produces satisfactorily rich output sound pressure, up to 100 dB, with low distortion.

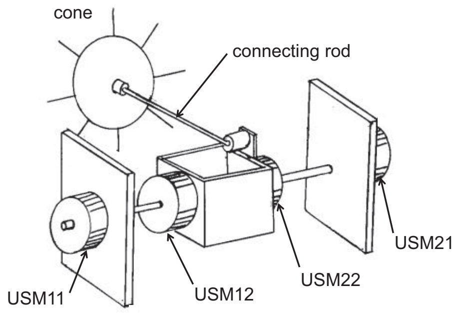
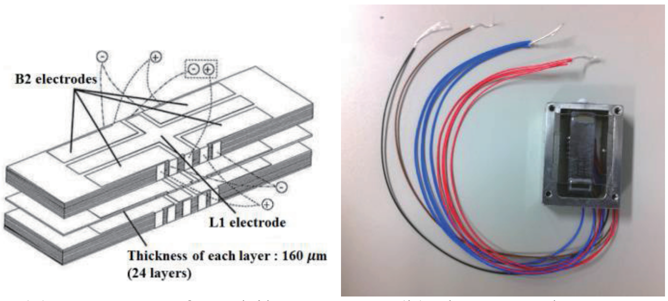


Fig.3 QMDS construction by four ultrasonic actuators.

3. Loudspeaker by linear motion type piezoelectric ultrasonic actuator

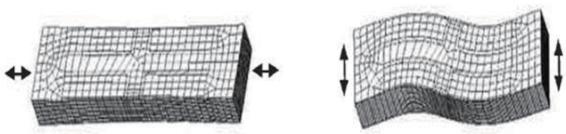
Then, the authors developed the other new loudspeaker with no conversion mechanism from rotational to linear motion. It has a rectangular piezoelectric ceramic block with four divided electrodes on each surface and also a finger tip on its end. The ceramic block is generated a composite of longitudinal 1st vibration (L1) and bending 2nd vibration (B2) at the same resonant frequency, shown in **Fig.4** to induce a small rotational motion of the finger tip. (a) describes structure of multilayer piezoelectric ceramic driver, and (b) shows its photograph.



(a)Structure of Multilayer (b)Photograph

Fig.4 Linear motion type piezoelectric ultrasonic actuator.

In **Fig.5**, the resonant frequencies of longitudinal extension vibration and transverse bending vibration of the ceramic are designed to be close frequency proximity.



(a) L1 mode **(b) B2 mode**

Fig.5 Two sorts of vibration modes.

This linear motion type piezoelectric ultrasonic actuator is driven by an electronic circuit described in **Fig.6**.

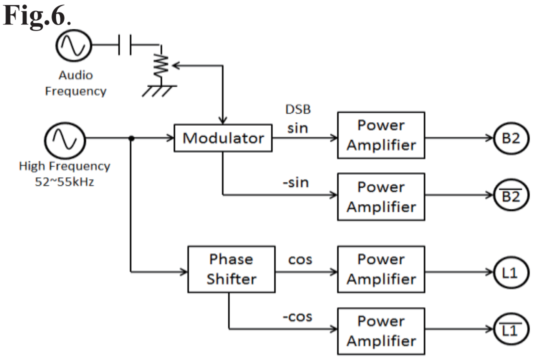


Fig.6 Driving circuit block diagram.

The multilayer piezoelectric actuator used here requires two sorts of ac voltage. One of them shall be modulated by audio signal and audio source as DSB(Double Side Band) wave form. **Fig.6** describes a block diagram of the driving circuit developed by the authors.

Four power amplifiers drive B2 and L1 electrodes by BTL connections. Signal for B2 is modulated by a multiplexer. Phase of signal for L1 is shifted by 90 degrees.

Loudspeaker construction of this model is simple because a cone radiator is driven by linear motion of a driving plate induced by the actuators directly. An example of constructions under examination by authors is shown in **Fig.7**. It includes a micrometer head for driving point adjustment.

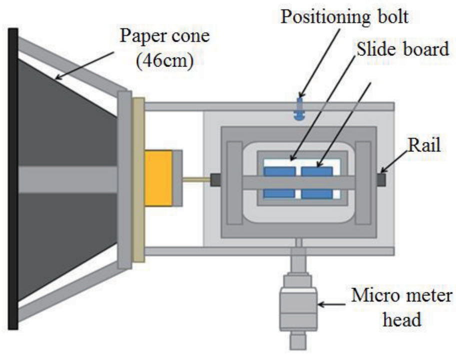


Fig.7 Linear drive model construction.

4. Conclusion

This paper has described two sorts of constructions for direct radiator loudspeakers driven by piezoelectric ultrasonic actuators. They radiate practically rich output sound in low frequency.

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