1P4-2

A Study on Element Characteristics Compensation of Parametric Loudspeaker

パラメトリックスピーカの素子特性の補正に関する検討

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1. Introduction

Parametric loudspeakers have attracted attention recently, with applied research such as that of sound image construction systems [1] and compensation of nonlinearity [2]. We intend to develop a space sensing system using a steering beam to obtain spatial information. To obtain large output with few channels and to reduce the side lobe, we developed a parametric loudspeaker with random element arrangement and a speaker drive system [3]. However, it is difficult to control the output beam pattern with high precision because ultrasonic transducer characteristics vary greatly. We investigate the compensation of elemental variation to improve beamformer directivity.

2. Characteristic compensation of ultrasonic transducers

The parametric loudspeaker used for this study is presented in **Fig. 1**. The 17-mm-diameter transducer (UT1612MPR), with center frequency of 40 ± 1 kHz, has 64 elements. The speaker prevents the grating lobe caused by a speaker with a regular element arrangement.

Fig. 2 shows the output power in each channel before and after compensation of the amplitude at 40 kHz. In this figure, the horizontal axis is the channel number, ● denotes the amplitude power before compensation, and □ represents the amplitude power after compensation. As shown by● in Fig. 2, these transducers have different output power. For highly precise output beam control, the elemental variation was compensated. The secondary wave directivity is ascertained as the product of the carrier directivity and sideband. Amplitude compensation is therefore achieved only for the carrier amplitude.

For a phased array to drive the same amplitude in all channels, a reference channel is chosen, the drive amplitude of the channel is made constant, and that of the other channel is found for the same amplitude. The compensated drive amplitude at the carrier frequency is almost flat for all channels compared with that before compensation, as shown by □ in Fig. 2. However,

Fig. 1 Parametric loudspeaker with random element arrangement.

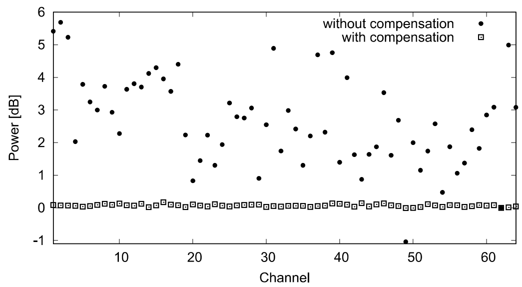

Fig. 2 Power of each channel at 40 kHz.

for a beamformer process to drive the predetermined weight for each channel, the amplitude drives each channel according to the weight.

3. Directivity measurement

To confirm element amplitude compensation effects, we measured the speaker directivity for beamformer using the coefficient calculated for a strong output beam in the target direction and weakened otherwise and a phased array.

3.1. Measurement environment

Speaker directivity was measured in an anechoic room. The distance from the speaker to microphone was 1.5 m. The carrier frequency was 40 kHz. The signal used for modulation was a sine wave of 1 kHz. The elevation angle was fixed to 0° for measurements. Furthermore, the speaker azimuth was changed by 3° with respect to left and right 90°. A microphone, a preamplifier, and a microphone amplifier were used (MI-1531, MI-3140, and AU-2200; Ono Sokki Co. Ltd.).

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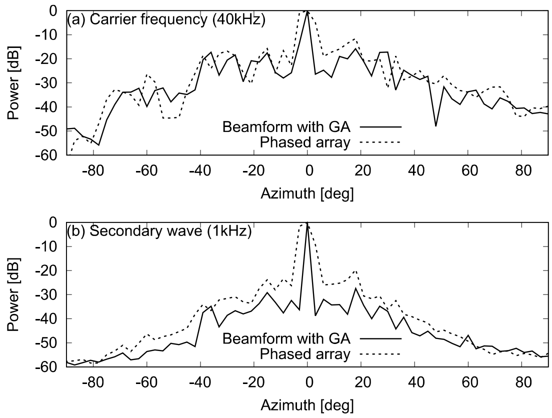

Fig. 3 Measurement results of directivity in case of target angle 0°.

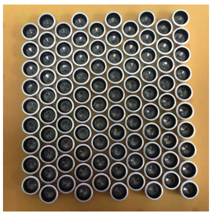

Fig. 4 Parametric loudspeaker with honeycomb lattice element arrangement.

3.2. Measurement result

Carrier directivity at the beam direction in azimuth angle 0° is depicted in **Fig. 3**. Whereas Fig. 3(a) presents the result of the carrier, Fig. 3(b) shows that of the secondary wave. The solid line shows the result with the beamformer. The dashed line shows that with the phased array. For both cases, Fig. 3 shows that a strong beam is formed correctly in the target direction. Moreover, compared with using the beamformer coefficient and phased array, the main beam width was sharper using the beamformer coefficient. The power level difference between the main lobe and maximum side lobe was 4.24 dB for carrier and 7.73 dB for a secondary wave larger than the phased array.

3.3. Comparison with a parametric loudspeaker with regular element arrangement

Measurement results on the speaker were compared with those obtained for a regular arrangement. The speaker used for comparison is portrayed in **Fig. 4**. This speaker is a 95 channel regular array loudspeaker. Its elements are the same as the random arrangement. Among the 95 channels, the number of channels used was 64.

The carrier directivity when the focal direction was set at azimuth angle -20° is shown in **Fig. 5**. In Fig. 5(a) is the carrier result, whereas Fig. 5(b) shows those of the secondary wave. The solid line shows results of the speaker with a random element arrangement. The dashed line is that of regular arrangement. In a regular arrangement, along with the main lobe in the target direction azimuth angle -20°, the same level large side lobe as the main lobe appeared at 15°. In the random arrangement, a large side lobe equal to main lobe did not appear, except for the target direction. The power level difference between the main lobe and the maximum side lobe was 10.01 dB for the carrier and 12.94 dB for the secondary wave larger than the regular arrangement. Therefore, results confirmed that a speaker with a random element arrangement suppressed the grating lobe caused by that with a regular arrangement.

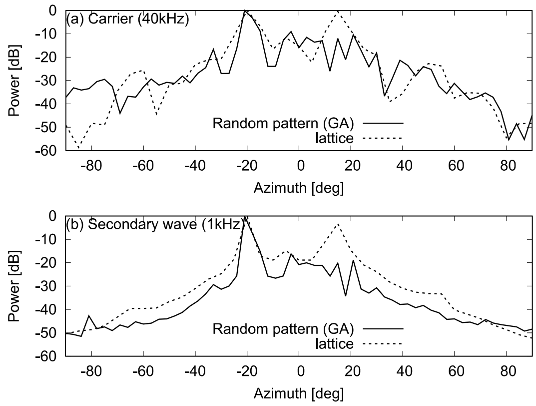

Fig. 5 Measurement results of directivity in case of target angle -20°.

4. Conclusion

To control the output beam pattern of a parametric loudspeaker with random element arrangemet with high precision, we examined characteristic compensation of the ultrasonic transducer and measured its directivity. In element characteristic compensation, the output of other channels can be made equivalent to that of a reference channel. Comparison of the phased array directivity and using the beamformer coefficient showed that the grating lobe was suppressed when using the beamformer coefficient. Results confirmed that the grating lobe caused by a parametric loudspeaker with regular arrangement was suppressed by that with random element arrangement. We also examine the two-dimensional directivity of the azimuth and elevation and spatial sensing.

References

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