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Horn Loudspeaker with Whole Circumference Aperture for Horizontal Omnidirectional Characteristics
水平無指向性を実現する全周開口ホーンスピーカ

Akihiro Itagaki ‡ , Naoto Wakatsuki, and Koich Mizutani (Univ. Tsukuba)
板垣 彰宏‡，若槻 尚斗，水谷 孝一 (筑波大院・シス情工)

1. Introduction

Sensing grid of spatial temperature distribution using acoustic probes has been studied [1,2]. Spatial temperature distribution measurement requires a number of acoustic probes, which consist of louds-peakers and microphones. It is desirable for the loudspeaker in the sensing grid to be omnidirectional. However, the use of spherically omnidirectional loudspeakers leads to a lot of energy loss. The requirement of the directivity of the loudspeaker is horizontal omnidirectional characteristics, which makes loss of energy low.

Thus, this paper describes horizontal omnidirectional characteristics with the horn loud speaker with whole circumference aperture. The optimal horn performance is that the directivity is sharp in horizontal direction. Although the characteristic desired is similar to exponential horn, the aperture may be different in whole circumference. In this paper, following two types of horn loudspeakers are considered to be desired. Exponential thickness type (ET), which has thickness varying exponentially, and exponential cross-section type (EC), which has cross section area varying exponentially, are selected as shape of horns. Then, the acoustic directivity from the both horn shapes was compared.

2. Principle

If the cross section change rate of the exponential horn stays constant, a sound wave propagates uniformly in horn. Thus, the sound propagates like the plane wave in a free space. This provides sharp directivity, and the sound propagates long distance.

2.1 *Ordinary exponential horn*

Figure 1 shows a shape of ordinary exponential horn. When the cross section, $S(r)$, of the horn at the distance from r=0 to r increases exponentially,

$$S(r) = S_0 \cdot \exp(m r), \tag{1}$$

where S_0 is the cross section at r=0, and m is flare constant. Also $S(r)$ is given by

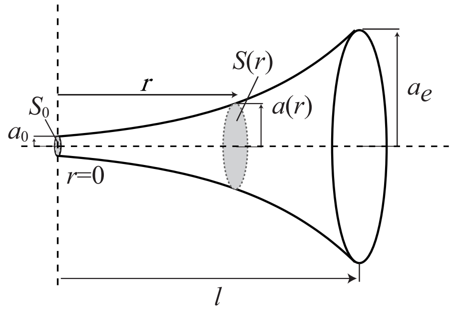

Fig. 1 Shape of ordinary horn

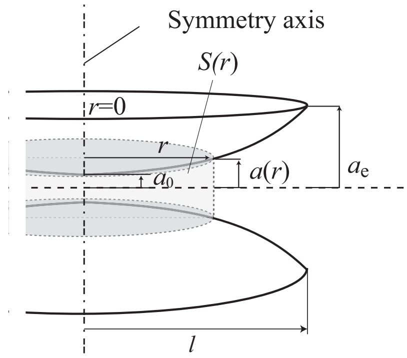

Fig. 2 Horn shape with whole circumference

$$S(r) = a(r)^2, \tag{2}$$

where $a(r)$ is radius of the horn at the distance r. Consequently, $a(r)$ is given by eq (1) and (2),

$$a(r) = a_0 \cdot \exp\left(\frac{m r}{2}\right). \tag{3}$$

Equation (3) represents the curve of the exponential horn. Both the cross-section and the curve are of exponential functions.

2.2 *Whole circumference horn*

Figure 2 shows a shape of whole circumference horn. Horn aperture is whole circumference; therefore, the circumference of the horn at the position of distance r is $2\pi r$. Therefore, $S(r)$ is given by,

$$S(r) = 2\pi r \cdot 2a(r), \tag{4}$$

where $2a(r)$ is distance between the curved surface of horn.

We consider two types of whole circumference horns. One is exponential thickness (ET) type horn, and another is exponential cross-section (EC) type. ET type, which $a(r)$ is increases exponentially,

$$a(r) = \exp(m r), \tag{5}$$

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mizutani@iit.tsukuba.ac.jp

Consequently, $S(r)$ is given by eq. (5),

$$S(r) = 4\pi r \cdot \exp(m r) . \tag{6}$$

Note that the cross-section is not exponentially varies. On the other hand, when $S(r)$ is increased exponentially, $a(r)$ is given by

$$a(r) = \frac{\exp(m r)}{4\pi r} , \tag{7}$$

According to equation (7), curve of the EC horn is represented. When length of the horn, l, meets the following equation [3],

$$l = 2.3\frac{2}{m}\log_{10}\frac{2}{ma_0} , \tag{8}$$

The open end of the horn becomes more than 45 degree for the axis. Consequently, the reflection of an open end becomes small enough [3].

3. Simulation

Figure 3 shows the shapes of ET and EC type horns according to eqs. (3) and (5). The open end of thickness a_e of the horns shared the same distance. Sound field radiated from both horns were calculated in condition that a_e was 54 mm, 80 mm and 120 mm. Sound fields were calculated by finite element method**.** Because the horn with whole circumference aperture is axial symmetric, axial symmetrical three dimensional models are used. Sound field in the simulations is a spherical space of the radius was 1 m. The diaphragm was driven by sine wave whose frequency was from 0 to 20 kHz. Boundary surface of spherical space was set to absorption condition and horn surface was rigid wall. The simulation area was divided by triangular elements whose number is about 590, 000.

4. Results and Discussions

Figure 4 shows typical frequency characteristics in horizontal direction at 1 m. Frequency characteristics of the ET and EC horns are similar. Both have cut-off frequencies at about 2 kHz and 19 kHz.

Figure 5 shows typical directivity by 19 kHz and **Table 1** shows half-value angle of the directivity. Directivities of both horns were sharp in horizontal direction. As the thickness a_e increased, directivity of ET horn became sharper. On the other hand, when the distance a_e increased, directivity of EC horn stays constant. The best half-value angle of the ET horn was 28.0 deg and the best half-value angle of EC horn was 38.5 deg. As a result, the shape of the ET horn was sharply-directed.

5. Conclusion

Horn loudspeaker with whole circumference aperture of the similar characteristics to ordinary horn examined as horizontal omnidirectional loudspeaker. As a result, it was confirmed that ET horn could realize sharply-directed sound radiation in horizontal direction. As further study, the horn loudspeaker with whole circumference aperture is planned to prototyped and be examined.

References

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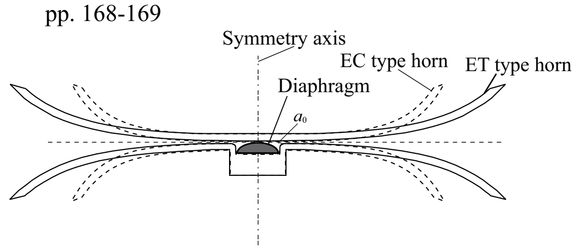

Fig. 3 Shape of ET and EC horn

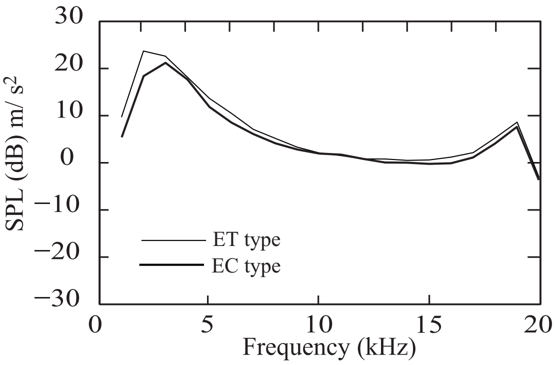

Fig. 4 Frequency characteristics

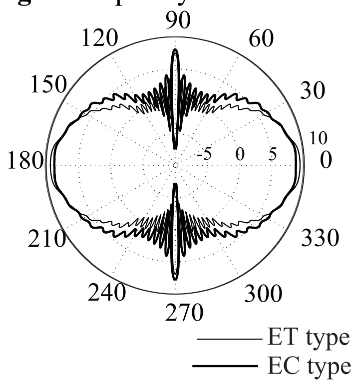

Fig. 5 Directivity characteristics.

Table 1 Half-value angle of the horn

Horn shape	Open end of distance a_e		
	54 mm	80 mm	120 mm
ET type	39.1	29.5	28
EC type	38.5	42.1	39.8