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CONTRIBUTION OF LOW FREQUENCY COMPONENTS OF A DIRECT SOUND AND LATERAL REFLECTIONS TO AUDITORY SOURCE WIDTH

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SUMMARY

Four psychological experiments are performed to make clear the contribution of low frequency components of a direct sound and lateral reflections to auditory source width(ASW). The experimental results show that if the lower cut-off frequency of only lateral reflections and those of both of a direct sound and lateral reflections exceed around 300Hz, ASW significantly decreases, but that even if the low frequency components of only a direct sound are eliminated, ASW does not change at all. In conclusion, the low frequency components of lateral reflections play an important role to create ASW, but the presence of low frequency components of a direct sound does not.

INTRODUCTION

It is well known that auditory source width(ASW) increases, as the low frequency components of the incident waves increase. Blauert *et al.*[1], and Morimoto and Maekawa[2] showed that the low frequency components of a source signal contributed to create ASW. Barron and Marshall[3] showed that if the low frequency components of lateral reflections below 400Hz was eliminated, ASW decreased, and that the low frequency components below 400Hz was important for wide ASW. But, the effect of low frequency components of a direct sound, which are often attenuated by seat absorption, is not made clear. In this paper, it is investigated that whether the low frequency components contribute to create ASW in itself, regardless of a direct sound and reflections. The following four cases are investigated. In case A, the low frequency components of only a direct sound are eliminated and in case B, only those of lateral reflections are eliminated. In case C, those of both of a direct sound and lateral reflections are eliminated simultaneously. In case D, the same amount of the low frequency energy which is eliminated from the lateral reflections is added to a direct sound, keeping the power spectrum of the incident waves constant.

PSYCHOLOGICAL EXPERIMENTS

Method

A simple sound field, which consisted of a direct sound and two discrete lateral reflections, was used. The source signal was a pink noise. Its frequency range was from 100Hz to 8000Hz. Three loudspeakers were arranged in an anechoic chamber. The first loudspeaker was in front of a subject at a distance of 1.5m. The other two loudspeakers were placed at the horizontal angles of $\pm 90^\circ$ from the median plane, at 1.5m distance. The frequency characteristics of the three loudspeakers were equalized within ±4dB in the frequency range from 100Hz to 8000Hz by a frequency equalizer. The low frequency components of a direct sound and reflections were eliminated with a filter with a cut-off slope of -48 dB/oct. The lower cut-off frequency(flc) was raised from 100Hz to 510Hz in steps of one critical band width. The sound field of which flcs of both of a direct sound and lateral reflections were 100Hz, was regarded as a reference sound field. Therefore, the total number of the stimuli was seventeen(reference sound field + 4 cases × 4 flcs), as shown in Table 1.

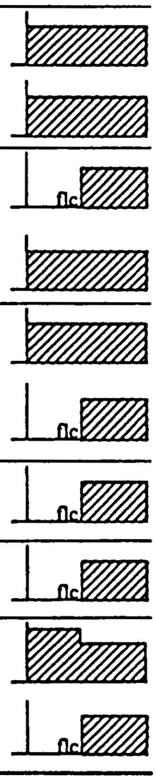
Complete paired comparison tests of ASW were carried out. The test had 272 pairs, including reversals of stimuli. The duration of stimulus was 3s and the interval between two stimuli was 1s. All pairs of stimuli were arranged, followed by an interval of 4s, in random order. Accordingly, the total time of the test for each subject was about 50 min. Each test was divided into four units(68 pairs) to reduce the time for each continuous test. Four units were arranged, in random order. Each subject was tested individually, while seated, with his head fixed in an darkened anechoic chamber. The task of the subject was to judge which stimulus of ASW was wider. Five male students, 22 to 25 years of age with normal hearing sensitivity acted as subjects.

Results and discussion

The psychological scales of ASW were obtained using the Thurstone[4] Case V model. The origin of psychological scale was that of reference sound field. All figures are drawn with the common origin and the unit, because the data was obtained by complete paired comparison test. The psychological distance of 0.68 corresponds to the just noticeable difference.

Table 1 Seventeen kinds of stimuli.

case	frequency range(Hz)		condition of low frequency cut off
	direct	reflection	
reference	100-8k	100-8k	dir. / ref.
A	200-8k	100-8k	dir.
	300-8k	100-8k	
	400-8k	100-8k	ref.
	510-8k	100-8k	
B	100-8k	200-8k	dir.
	100-8k	300-8k	
	100-8k	400-8k	ref.
	100-8k	510-8k	
C	200-8k	200-8k	dir.
	300-8k	300-8k	
	400-8k	400-8k	ref.
	510-8k	510-8k	
D	100-8k	200-8k	dir.
	100-8k	300-8k	
	100-8k	400-8k	ref.
	100-8k	510-8k	



Case A : Low frequency components of a direct sound are eliminated

Figure 1 shows the results of case A. The psychological scales of ASW are constant at 0.03±0.02 regardless of the low cut-off frequency of a direct sound. That is, the lack of the low frequency components of a direct sound does not affect ASW. Therefore, it is reasonable to conclude that ASW does not change at all if the low frequency components of a direct sound is attenuated by the seat absorption.

Case B : Low frequency components of lateral reflections are eliminated

Figure 2 shows the results of case B. As the lower cut-off frequency of the two lateral reflections increases from 100Hz to 510Hz, ASW decreases monotonously. It can be considered that if the lower cut-off frequencies of lateral reflections exceed 300Hz, ASW

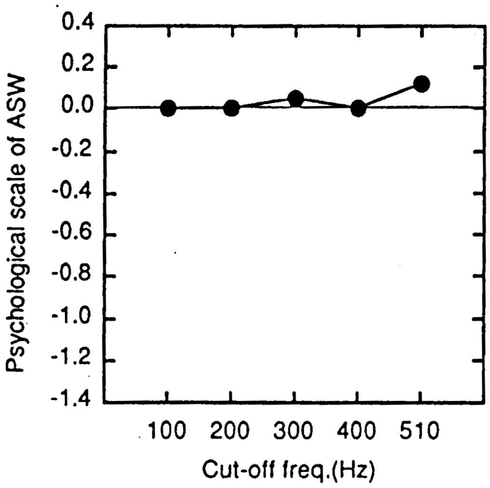


Fig.1 Psychological scales of ASW as a function of the low cut-off frequency of a direct sound.

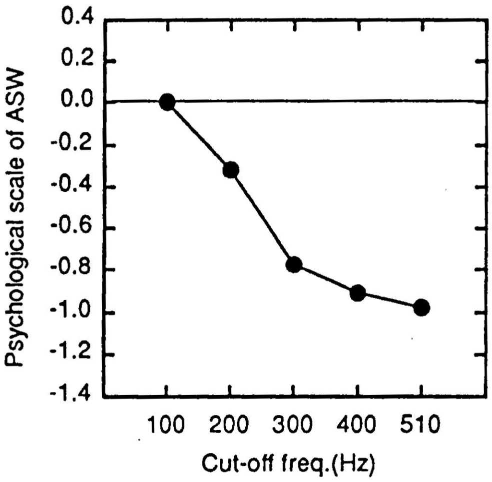


Fig.2 Psychological scales of ASW as a lower cut-off frequencies of lateral reflections.

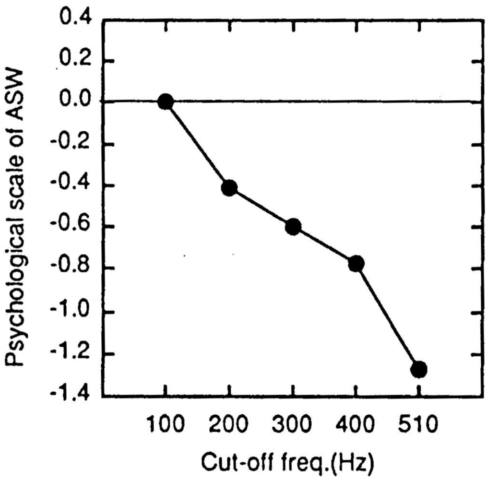


Fig.3 Psychological scales of ASW as a function of the lower cut-off frequencies of a direct sound and tlateral reflections.

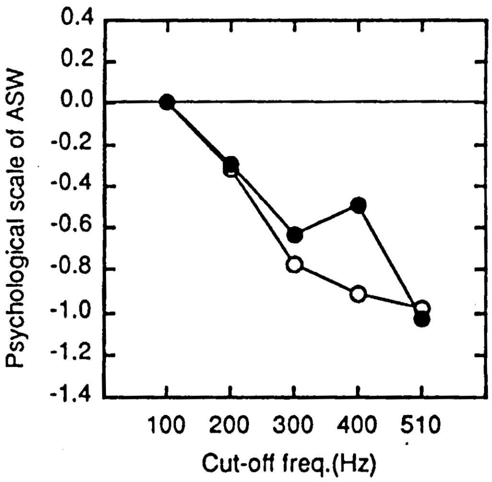


Fig.4 Psychological scales of ASW as a function of the lower cut-off frequencies of tlateral reflections(●), under the condition that the same amount of the low frequency energy which is eliminated from the lateral reflections, is added to a direct sound. That of case B is also indicated for comparison(○).

significantly decreases. Barron and Marshall[3] noted that the spatial impression was reduced under the condition that the lateral reflections were low-pass filtered below 400Hz. It is reasonable to conclude that ASW significantly decreases, if the lower cut-off frequencies of lateral reflections exceed around 300Hz.

Case C : Low frequency components of both of a direct sound and lateral reflections are eliminated simultaneously

Figure 3 shows the results of case C. As the lower cut-off frequency of a direct sound and lateral reflections increase from 100Hz to 510Hz, ASW decreases monotonously. It can be considered that if their lower cut-off frequencies exceed 300Hz, ASW significantly decreases. This result coincides with that of case B and that of Morimoto and Maekawa[2].

Case D : The same amount of the low frequency energy which is eliminated from the lateral reflections is added to a direct sound.

Figure 4 shows the results of case D, and case B for comparison. As the lower cut-off frequencies of the two lateral reflections increases from 100Hz to 510Hz, ASW decreases. Furthermore, difference between case D and case B does not exceed 0.68. Therefore, it is not possible to compensate the reduction of ASW caused by the lack of low frequency components of lateral reflections by adding them to a direct sound. However, this result was obtained under the condition that the low frequency components which were eliminated from the lateral reflections were added to a direct sound to keep the power spectrum of the stimuli constant. Further investigations on the effect of the reinforcement of the low frequency components of a direct sound on ASW will be needed.

CONCLUSIONS

In this paper, the contribution of the low frequency components of a direct sound and the lateral reflections to ASW was investigated. The results show:

(1) ASW is affected by the lack of the low frequency components of lateral reflections, but not by the lack of those of a direct sound.
(2) ASW significantly decreases, if the lower cut-off frequency of only lateral reflections and those of both of a direct sound and lateral reflections exceed around 300Hz.
(3) It is not possible to compensate the reduction of ASW caused by the lack of low frequency components of lateral reflections by adding them to a direct sound.

Consequently, the low frequency components of lateral reflections play an important role to create ASW, but the presence of low frequency components of a direct sound does not.

REFERENCES

[1] J.Blauert, U.Mobis, and W.Lindemann,"Supplementary psychological results on auditory spaciousness," Acustica 59, 292-293 (1968).

[2] M.Morimoto and Z.Maekawa,"Effect of low frequency components on auditory spaciousness," Acustica 66, 190-196 (1988).

[3] M.Barron and A.H.Marshall,"Spatial impression due to the early lateral reflections in concert halls: The derivation of a physical measure," J.S.V. 77, 221-232 (1981).

[4] L.L.Thurstone,"A law of comparative judgement," Psychol. Rev. 34, 273-286 (1927).