Study on methods for localization of low frequency sounds

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ABSTRACT

We examined how to locate the low frequency sound sources. It is difficult to determine these low frequency sound source locations easily because low frequency sound is hard for human beings to hear. Therefore, we examined a method to locate the sound source by using microphone placed on the ground. First, we conducted field experiments on the idling sounds of cars. Eight microphones were arranged on the ground surface so as to surround the car. From these results, it was found that the position of the sound source such as the exhaust and the engine below 100 Hz could be estimated. Next, we conducted experiments on sounds from an outdoor unit of a household water heater and an outdoor unit of an air conditioner. Four microphones were arranged on the ground surface near the units. From the results, outdoor units containing a compressor and/or fan were estimated to be the sound source. From these results, it was thought that the use of a microphone array placed in the vicinity of the cars and machines could identify the low frequency sound source position with an accuracy of about 1 to 2 m.

1 INTRODUCTION

Sounds generating from water discharge of dams, helicopter operations, and elephant calls contain low frequency sound (LFS) components. It is difficult to determine these LFS source locations easily because LFS is hard for human beings to hear. Some techniques using microphones such as “beamforming”, “correlation method”, and so on are well known for identifying the position of the LFS source. Arai et al. [1] installed pressure gauges at intervals of about 2 km and measured the infrasound generated by volcanic eruptions, etc. The authors [2] identified the flight path of a helicopter, such as the CH-47 (Chinook), using three LFS meters installed at intervals of 8 m. Dissanayake et al. [3] detected the approach of elephants to residential villages in Sri Lanka using microphone arrays. In the case of LFS, the microphone placement intervals become longer because the wavelength of LFS is longer. However, there are only a few applications of those techniques for measuring LFS because distance between microphones is needed. We proposed a new method in which the sound source area is surrounded by microphones [4]. Microphone array observation was conducted on elephant's low frequency speech to verify the practicality of this method (Fig. 1). We confirmed that this method can reduce the number of the microphones which is needed for identifying LFS sources.

Recently, low frequency idling sounds of automobiles and low frequency sounds generated from machines such as air conditioners installed outside buildings may be problematic in Japan. In this study, we examined whether it is possible to estimate the position of these LFS sources by using multiple microphone arrays placed on the ground surface by outdoor experiments.

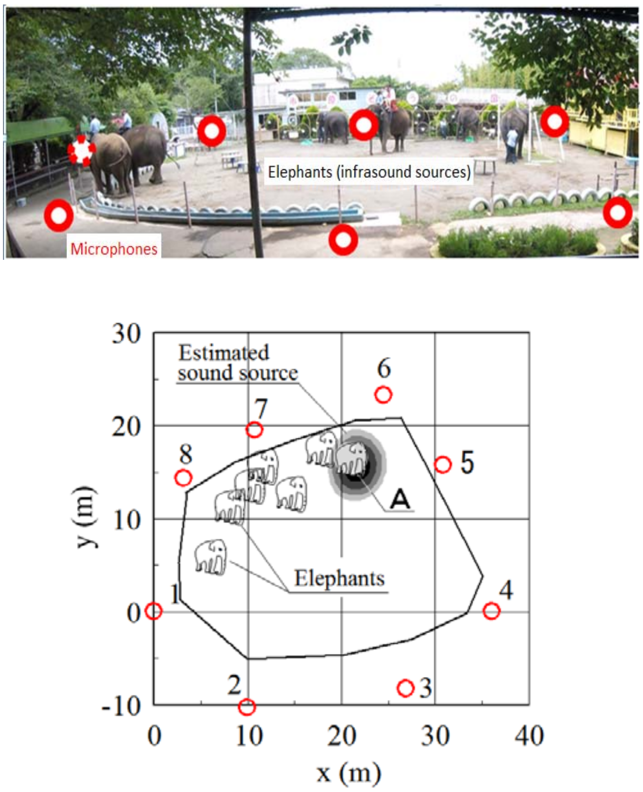

Figure 1: Microphone array observation and the example of results for elephant's low frequency speech [4]

2 FIELD MEASUREMENTS FOR CAR IDLING SOUNDS

First, we conducted field experiments on the idling sounds of two types of car. Fig. 2 shows an outline of the measurement. Car A is a van. Car B is a sports car. As shown in Fig. 2, eight microphones (RION NL-15) were arranged on the ground surface so as to surround the car. The sound was recorded at a sampling frequency of 12 kHz using an 8-channel data logger (RION DA-40). Unlike an ordinary line array, the microphone interval in the case of the surrounding method only needs to be equal to or less than the wavelength [4]. In the case of this arrangement, the analysis target frequency is 100 Hz or less, which corresponds to the maximum microphone interval of 3 m.

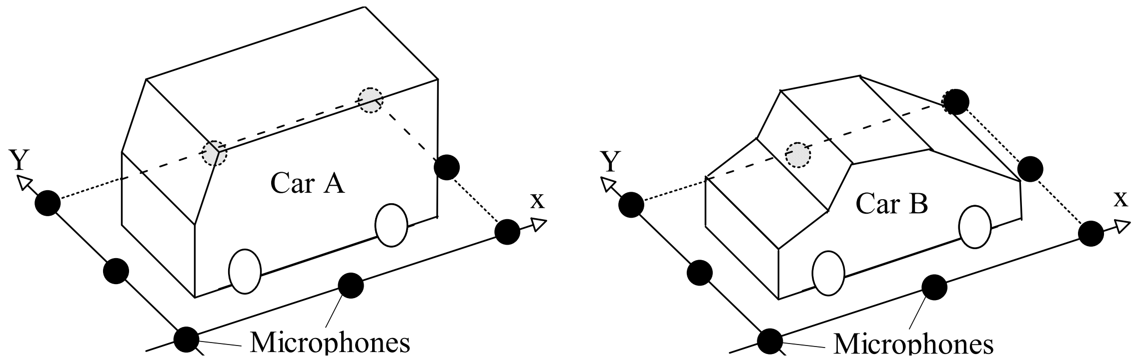

Figure 2: Microphone arrangement on measurement of car idling sounds

Fig.3 shows the frequency characteristics of the idling sounds. The eight lines in the figure show the results for the eight microphones. For car A, predominant frequencies are observed at 50 Hz and 100 Hz. In the case of car B, the dominant frequency is observed at 40 Hz. In Japan, a 1/3 octave band below 80 Hz is called "low frequency sound". Therefore, the 100 Hz band is not a "low-frequency sound" in Japan, but we described these data because some countries call the 100 Hz band a "low-frequency sound."

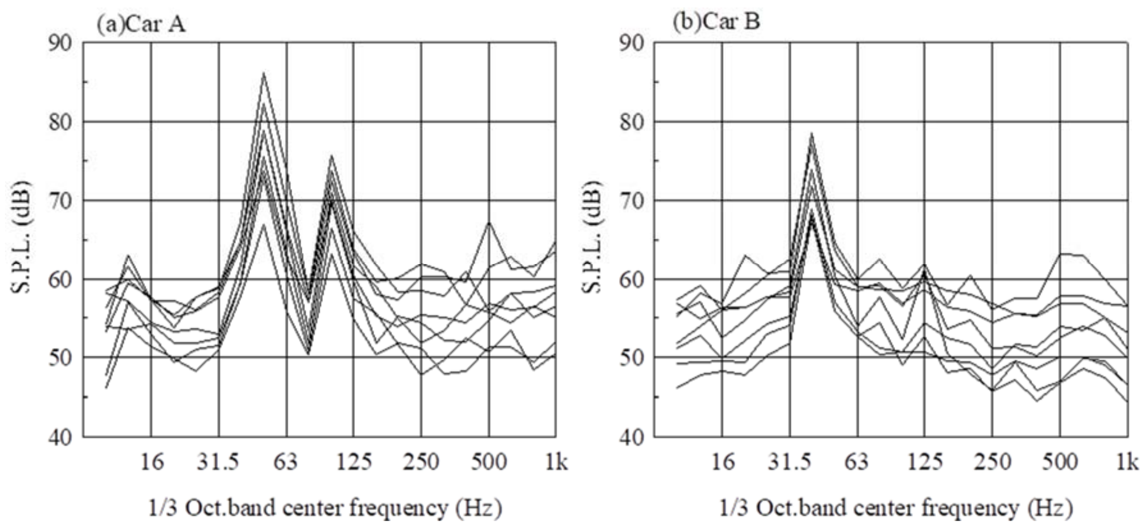

Figure 3: Frequency characteristics of the idling sound

Fig.4 shows the estimated results of the sound source position obtained by the DS (delay and sum) method. The result of Car A at 100 Hz shown in Fig. 4 (b) means that the center of the contour line is located near the exhaust port at the rear of the car. From the results, it is considered that the sound source at 100 Hz is near the exhaust port. On the other hand, in the case of 50 Hz of Car A, the sound source position is estimated to the right side and front of the car because the engine of this car is located in the front part of the car. In the case of Car

B shown in Fig. 4 (c), a sound source of 40 Hz is estimated near the exhaust port. Car B has two exhausts. It is considered that sound is generated from both. From these results, it was found that the position of the sound source below 100 Hz can be estimated with an accuracy of about 1 to 2 m using the microphone arranged so as to surround the car.

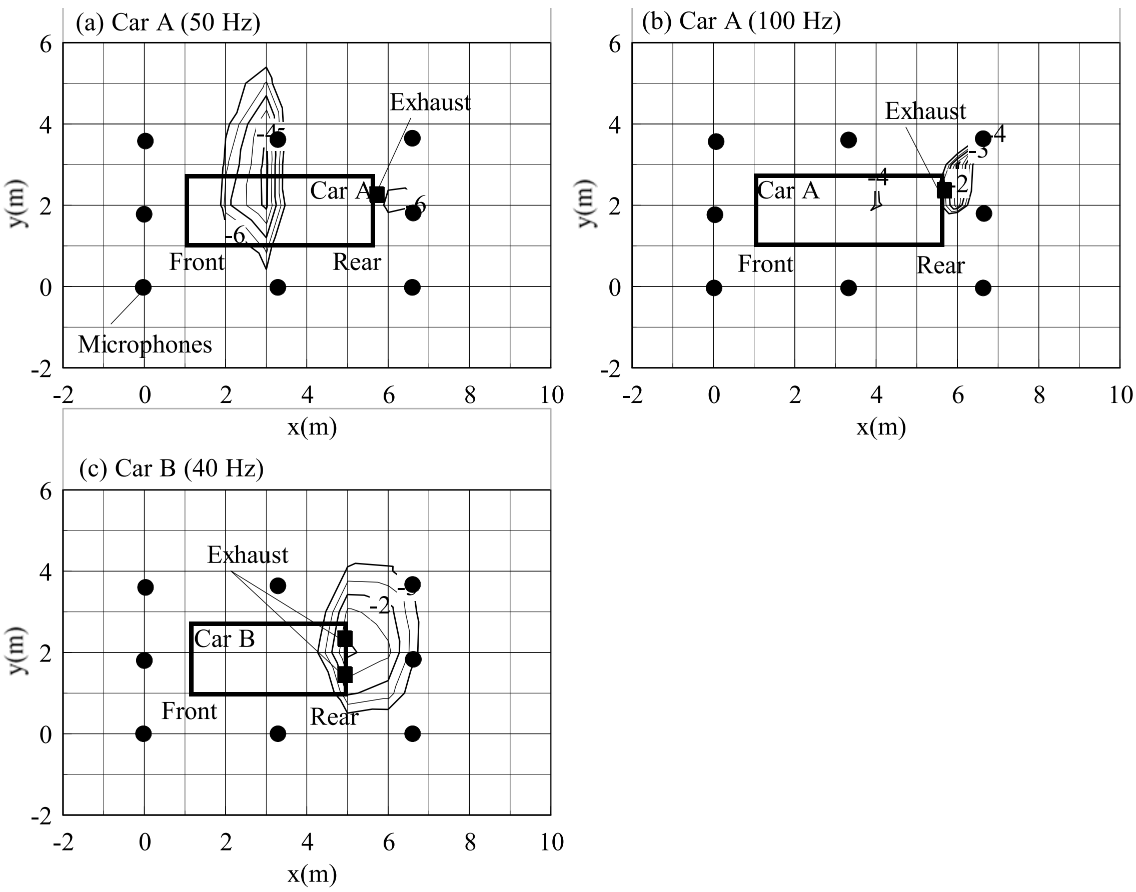

Figure 4: Estimated results of the sound source position on idling sounds

3 FIELD MEASUREMENTS FOR MACHINE SOUNDS

Next, we conducted experiments on sounds from two different machines. Fig.5 shows an outline of the measurements. Machine A is an outdoor unit of a household water heater and includes units A1 and A2. Machine B is an outdoor unit of an air conditioner. Both machines are located outside the building. As shown in Fig. 5, four microphones (RION NL-15) were arranged on the ground surface. The microphones do not surround the subject in this arrangement. Therefore, the microphone interval needs to be less than half of the target wavelength. In this arrangement, the microphone interval between measurement points is 1.7 m, and then the target frequency is below 100 Hz.

Fig.6 shows the frequency characteristics of the sound generated from the machine. The four lines in the figure show the results for four microphones. For Machine A, a dominant frequency is observed at 100 Hz. In the case of machine B, the sound of 40, 80 and 160 Hz is dominant.

Fig.7 shows the estimation results of the sound source position obtained by DS method. The result of machine A shown in Fig.7 (a), (b) show that the sound source of 63, 100 Hz is unit A1. Unit A1 contains a compressor and a fan. Unit A2 contains a tank for storing hot water. From the experiment, the sound source contribution of the compressor and the fan could not be clarified. Fig. 7 (c) shows the sound source position of machine B, and it can be seen that the sound source position is near unit B.

From these results, it was suggested that the use of a microphone array placed in the vicinity of the machine could identify the LFS source position with an accuracy of about 1 to 2 m. These methods using multiple microphones are considered to be useful because they can suppress the influence of wind noise and background noise as compared with the case where one microphone is used. In these measurements, the sound source position of the frequency component below 50 Hz cannot be estimated, and this is a future subject for investigation.

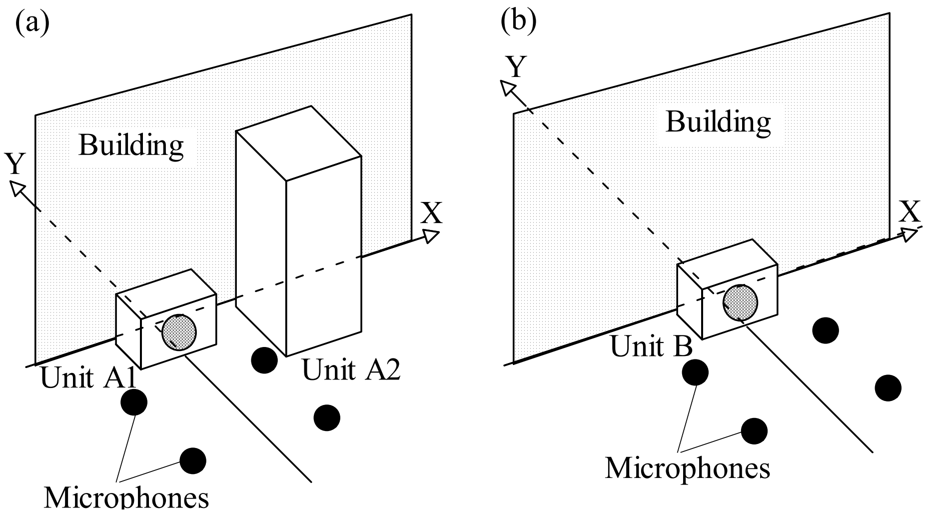

Figure 5: Microphone arrangement on measurement of machine sounds

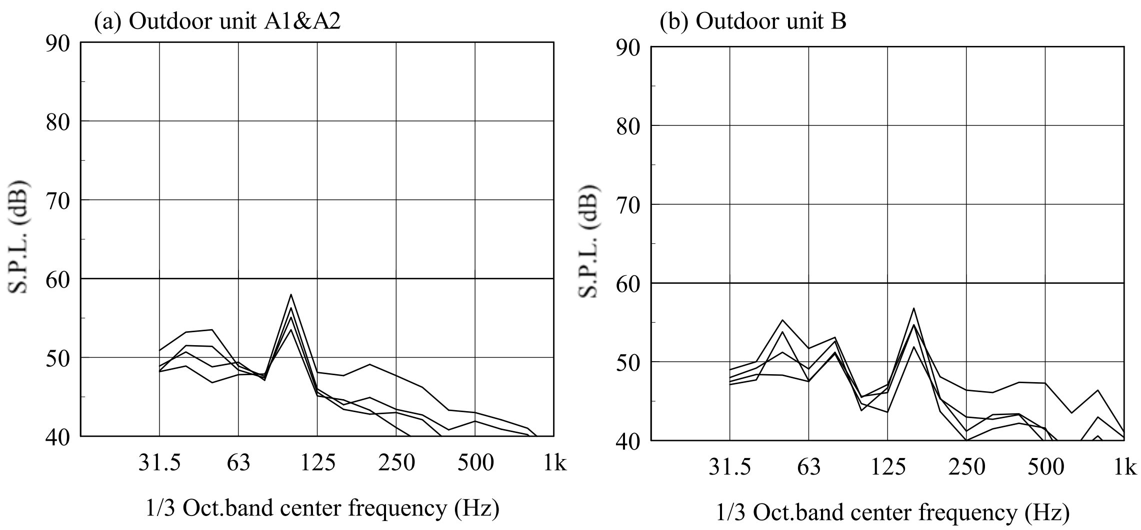

Figure 6: Frequency characteristics of machine sounds

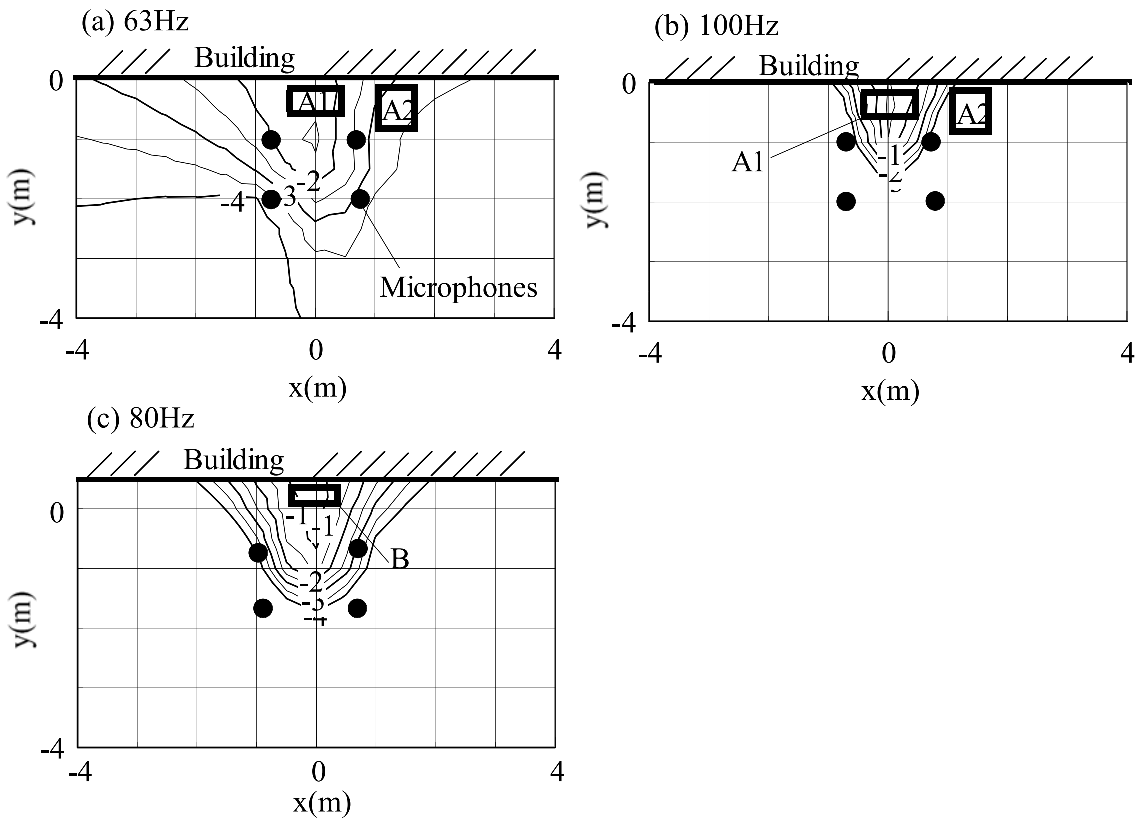

Figure 7: Estimated results of the sound source position on machine sounds

4 SUMARY

The sound source position of low frequency sound from cars and machines was estimated using multiple microphones. In each case, it was confirmed that the position of the sound source at 40-100 Hz can be estimated with an accuracy of 1-2 m.

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