3P2-6

Spurious Response Analysis of Microphones for Difference Sound Measurement

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1. Introduction

The nonlinear interaction of sound waves in air has been extensively employed in the reproduction of audible sound by an ultrasonic transducers array system including parametric loudspeakers. This process entails emitting ultrasonic waves of distinct frequencies, resulting in the creation of an audible sound at the difference frequency, which is used for indoor announcements and to reduce environmental noise at acoustic traffic signals.[1)]

In addition, ultrasonic transducers are expected to be used for various applications in the future because of their compact size and versatile installation capabilities. As a result, research into their utilization has been actively pursued. In research using ultrasonic transducers, control of the directivity of audible sound and control of the sound field in a specific range have been investigated by changing their layout. For example, there is an omnidirectional sound source reproduction by an ultrasonic transducer array in which ultrasonic transducers are arranged in a facing array.[2)]

The development of an ultrasonic transducers array system including parametric loudspeakers requires the use of a wideband, high-resolution recording system to comprehensively assess acoustic characteristics. However, measurements conducted using that system might yield a differential sound pressure that exceeds the anticipated value, as depicted in **Fig. 1**.[3,4)] This is due to a spurious differential sound measured by the interaction of two ultrasonic waves input to the microphone.[5)] Notably, this spurious sound is a manifestation that does not genuinely exist in the air.

The presence of this spurious sound during measurements introduces challenges in properly evaluating acoustic characteristics, as the actual audible sound present in the air (spatial difference sound) is difficult to precisely measured. Consequently, it is necessary to meticulously evaluate the results of spurious sound measurements.

In this study, we undertake measurements of ultrasonic waves emitted from ultrasonic transducers and analyze spurious response of microphones. In this experiment, we evaluate the spurious sound by combining the angular characteristics of the microphone and the multiple nested acoustic filters. Based on these methods, we propose and establish a system capable of selectively measuring only the spatial difference sound.

2. Experimental method

We reduce the spurious difference sound by suppressing the sound pressure of the ultrasonic waves input inside the microphone. Due to its angular characteristics, the ultrasonic sound is attenuated when the microphone is tilted at 90° to the direction of sound. Wind screens, which are a type of acoustic filter, are known to reduce sounds in the ultrasonic band. Therefore, as shown in **Fig. 2**, the microphone is tilted 90 degrees and the wind screen is overlapped like a matryoshka doll to measure ultrasonic waves.

We use two types of ultrasonic transducers for our measurements: 250ST160 with a center frequency of 25 kHz, manufactured by Prowave, and UT1612MPR with a center frequency of 40 kHz, manufactured by SPL. Therefore, we mainly use output signals with frequencies varying from 20kHz to 45kHz in our experiments. Two measurement microphones (4939, BK) are placed 15 cm away from two ultrasonic transducers of the same type. We calibrate the distance from the ultrasonic transducer so that both microphones measure the same sound pressure. The loudspeaker outputs a sound equal to

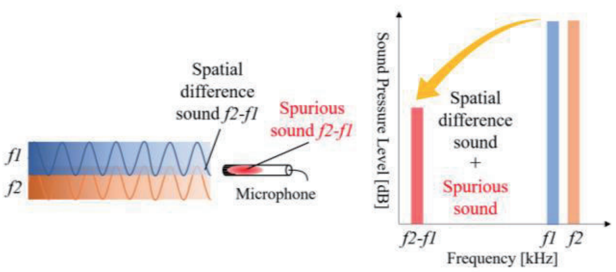

Fig. 1 Generation of spurious differential sound

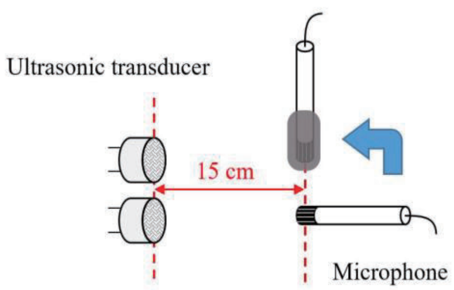

Fig. 2 Experimental equipment

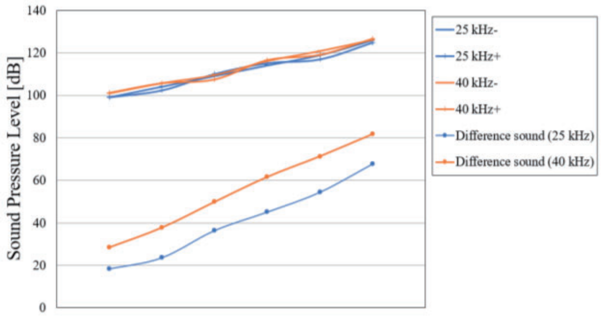

Fig. 3 Amplitude characteristics of the difference sound vs. ultrasonic sound pressure

the frequency of the difference sound as a reference tone.

3. Experimental results

First, we measured the differential sound pressure when the ultrasonic sound pressure was varied. **Fig. 3** shows the results of measurements at center frequencies of 25 kHz and 40 kHz, respectively, when the ultrasonic sound pressure was varied. It was found that the measured sound pressure of the difference sound increased rapidly as the ultrasonic sound pressure increased. The difference in sound pressure was larger at a center frequency of 40 kHz than at a center frequency of 25 kHz, even when ultrasonic waves of the same sound pressure were measured. This is because the higher the frequency, the stronger the nonlinear interaction of ultrasonic waves.

We then measured the spurious sound. After tilting the microphone 90°, we nested wind screens over the microphone one by one and measured the ultrasonic waves each time. The center frequencies of 25 kHz and 40 kHz, with a difference frequency of 2 kHz, are shown in **Fig. 4** and **Fig. 5**, respectively. After the difference sound became smaller than the sound pressure of the reference tone, the measured difference that became constant. This is because the spurious sound generated inside the microphone became smaller than the sound pressure of the audible sound (reference tone) in the space.

Therefore, **Fig. 4** shows that at a center frequency of 25 kHz and a difference frequency of 2 kHz, more than 37.74 dB of spurious sound was measured when the ultrasonic wave input to the microphone was greater than 107.6 dB. **Fig. 5** shows that at a center frequency of 40 kHz and a difference frequency of 2 kHz, the spurious sound level was 47.92 dB or higher when the ultrasonic wave input to the microphone was 106.4 dB or higher.

4. Conclusion

In this study, we measured ultrasonic waves using a measurement microphone and evaluated the measured the difference sound. We found that the higher the frequency of the ultrasonic wave input to the microphone, the greater the measured difference. We also evaluated the spurious response by suppressing the ultrasonic input to the microphone. We have demonstrated a system to accurately measure spatial difference sound by combining the angular characteristics of the microphone and the multiple nested wind screens.

Based on the proposed evaluation method, it leads to an accurate evaluation of the acoustic characteristics of a system using an ultrasonic transducer array.

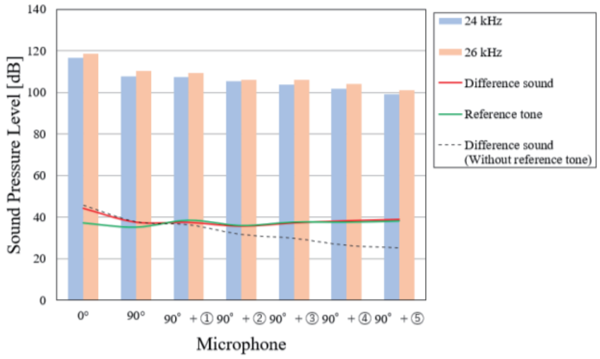

Fig. 4 Amplitude characteristics (center frequency, 25 kHz: difference frequency, 2 kHz)

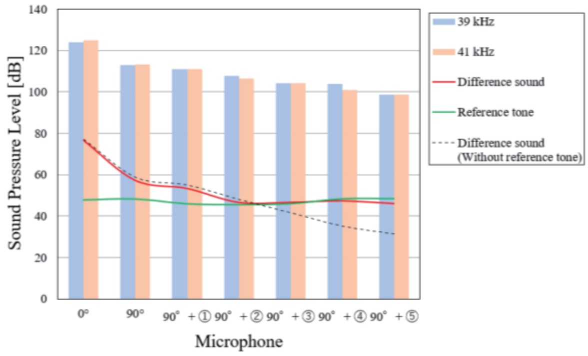

Fig. 5 Amplitude characteristics (center frequency, 40 kHz: difference frequency, 2 kHz)

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