Evaluation of Object Localization System with Thermophone

Shoya Nakade[1], Kohei Otani[1], Takaaki Asada[2], Shinichi Sasaki[2], Shizuko Hiryu[1]
[1] Doshisha University, Kyoto, Japan, [2] Murata Manufacturing Co., Ltd., Kyoto, Japan

Background, Motivation and Objective

Even in a complicated obstacle environment, bats can recognize the surrounding information by an ultrasonic sensing (echolocation) during flight with simple sensing mechanisms, i.e., one transmitter (mouth or nose) and two receivers (ears). An autonomous vehicle which imitates bat's sensing operation could improve the runability on obstacle routes [1], but it is still difficult to acoustically simulate the broadband FM ultrasonic pulse emitted by bats in a typical resonant sensor. That's why we developed a sensing system that can process echo in the real time and imitate the sensing operation of bats by utilizing the broadband characteristics of the thermoacoustic transducer "Thermophone".

Statement of Contribution/Methods

The signal processing of the proposed system was implemented based on Raspberry Pi ® 3, which conducts cross-correlation at 1 M samples/s between the transmitted signal and the signal received by the MEMS microphone to detect the arrival time of the target echo in the real time (2 pings/s). Thermophone transmitted the broadband ultrasounds with exponentially modulation from 80 kHz to 20 kHz for 10 ms which imitate bat's ultrasounds. Target objects (acrylic poles, φ=120 mm) were set at 500 mm and we compared localization performance of proposed system with resonant piezoelectric sensor (MA40S4S).

Results/Discussion

Figure 1 shows the cross-correlated echoes with the output signal in the case of Thermophone and piezoelectric sensor. Echoes of the piezoelectric sensor are superimposed due to its resonance characteristics whereas three objects could be separately localized in the case of Thermophone. The distance resolution at 80-20 kHz FM signal was approximately 5 mm, which is more accurate at least 10 times than that of piezoelectric sensor, and it can be further improved by extending the bandwidth of transmitted signal. Furthermore, we confirmed that signal to noise ratio is also improved by lengthening the signal duration, which allows us to detect farther distant targets (~2 m). The system which can flexibly adjust frequency bands and pulse length in the real time makes it possible to implement an efficient sensing operation of bats as a novel ultrasonic detection system.

References

[1] YAMADA, et al., Advanced Robotics. vol. 33. pp 169 - 182.2019

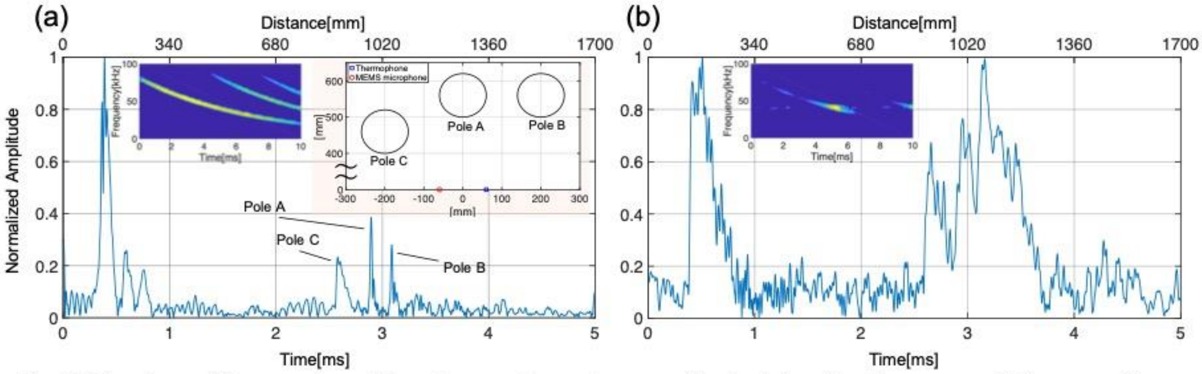

Fig. 1. Top view of the experimental environment, spectrogram of output signal and cross-correlation waveform. (a) Thermophone and (b) Piezoelectric sensor. The horizontal axis below is time, the horizontal axis above converts time to distance(340 [m/s] * Time [s]).