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Study of Accuracy Improvement for Ultrasonic Positioning Method Installed in Sensor Network
センサネットワーク用超音波位置センサの高精度化の研究

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1. Introduction

Today, a network system which connects many sensors has been researched all over the world, and it is called “sensor network”. This system consist of many sensors (sensor node) which measure environmental parameters such as temperature, brightness and security, and one controller (center node) which processes the data gathered from the sensor nodes via wireless communications medium. In near future, we think “sensor network” is also used as home/office-circumstance monitoring for taking care of old people, preventing crime and maintaing security. Therefore, it is necessary for “sensor network” to detect or estimate position. So, we studied a novel ultrasonic position-detection method for “sensor network”. In this paper, we will present our proposed theory and basic experimental results for the new position-detection method.

2. Method

Extreme low-power consumption is required for each sensor node in the sensor network. A conventional pulse-echo method cannot be adopted in this system because the transmitter circuit must handle rather high-voltage pulses. Our proposed method is as follows:

(1) One sensor node transmits very small-amplitude continuous ultrasonic waves (CUWs) at various frequencies which correspond to discrete frequencies of IFFT.
(2) Other sensor nodes receive the reflected CUWs, and measure the relative amplitudes and phases between the transmitting and receiving CUWs, which are sent to the center node via the network
(3) Impulse responses which include distance information among the sensor nodes via reflected objects can be obtained using IFFT procedures in the center node.

This method provides very low-power consumption for sensor nodes because the center node is operated by another power supply, and accurate measurement can be achieved compared with a conventional method.

3. Basic Experiment

We made basic experiments to verify our proposal. A transmitter and a receiver are arranged 50 [cm] apart to each other. CUWs at dozens of frequencies around 40 [kHz] are sent, and relative amplitudes and phases are measured from received CUWs. Impulse responses obtained from IFFT are shown in **Fig.1** (Max amplitude point corresponds to measured distance). Fig.1’s result shows measured distance is 60.16 [cm]. However, actual distance is 50 [cm]. That leads to noticeable error and we must consider about it.

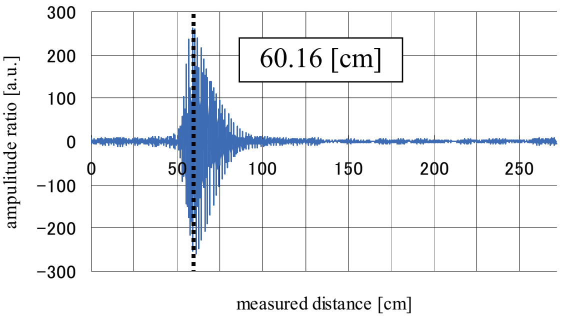

Fig.1 Result of IFFT (case of 50[cm])

4. Compensation procedures and Results

We investigate compensation for the above error and show improved methods in this chapter.

4.1 Phase compensation

We found that cause of the error in the above mention is phase characteristics of sensor transducers. First, we made experiments using the transmitter and the receives connected directly, which corresponds to distance of 0 [cm]. Results of IFFT are shown in **Fig.2**. Imaginary distance of 10.56 [cm] is produced by rather steep phase characteristics of both transducers. We examined phase compensation in frequency domain. We corrected measured phase data taking zero-distant phase characteristics as the

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standard phases. IFFT results using corrected data are shown in **Fig.3**. We obtained highly accurate distance of 49.48 [cm].

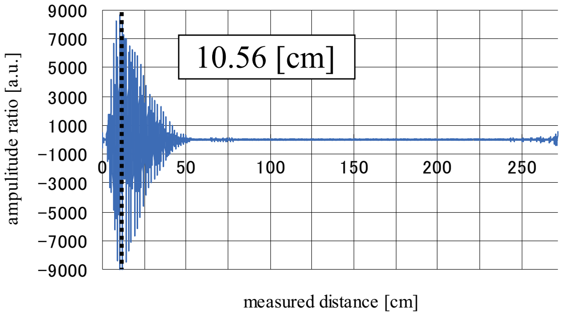

Fig.2 Result of IFFT (case of 0[cm])

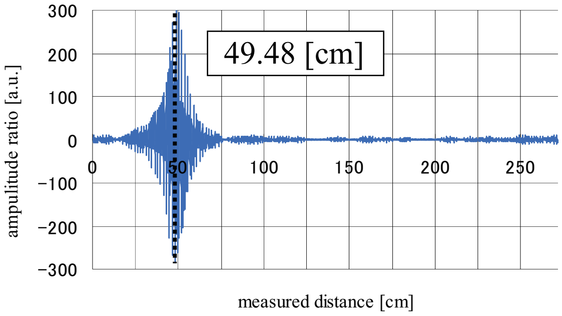

Fig.3 Result of IFFT with compensation of Fig.1

4.2 Resolution improvement

The principle of FFT requires sampling frequency, f_{samp}, larger than twice the maximum frequency of the time function. The transducer has about 5 % 3-dB bandwidth around 40 [kHz]. So, we use 100 [kHz] as f_{samp} in the experiments. Time resolutions, Δt, is $1/f_{samp}$ and maximum measurable time, T, is $1/\Delta f$. These values multiplied by sound velocity (≈340 [m/s]) provide the space resolution, Δl, and the maximum distance, L, respectively. The number of sampling points are defined as N = $f_{samp}/\Delta f$. Δt = 10 [μs] (Δl = 0.34 [cm]), T = 8 [ms] (L = 2.72[m]), and N = 800 were used in the experiments. In order to improve the resolution, we examined increase of N and f_{samp} keeping Δf fixed in the IFFT. Smaller Δt, i.e. Δl, can be obtained in this procedure, which provides improved resolution as the examples of N = 800 (type 1), N = 1600 (type 2), and N = 3200 (type 3) are shown in **Fig.4**. Resolution comparisons among them are shown in **Table.1**, which indicates validity of our resolution improvement method.

Table.1 values of result with Fig.4

	type 1	type 2	type 3
Max Amplitude Point	49.48 [cm]	50.34 [cm]	49.91 [cm]
Error of Measured	0.52 [cm]	-0.34 [cm]	0.09 [cm]

5. Conclusion

We present a novel ultrasonic measurement method, and validity of the method was confirmed from basic experimental results. Then, we also show two ways to compensate the experimental data, and accuracy better than 0.1 [cm] is obtained. After this investigation, we will further develop the method to apply it to actually complicated models.

Reference

1. K.Takimoto, K.Minami, Y.Hiraizumi and M.Hikita: proc. of symp. on Ultrasonic Electronic, vol.28, 2007, pp.373-374.

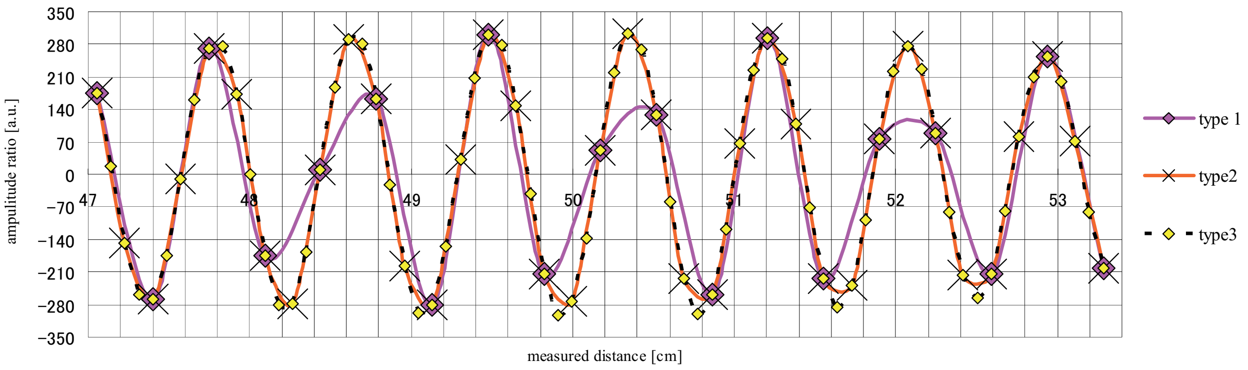

Fig.4 Resolution improvement