The Sixteenth International Symposium on Artificial Life and Robotics 2011 (AROB 16th '11),
B-Con Plaza, Beppu,Oita, Japan, January 27-29, 2011

New Acoustic Positioning System for Under Water Robot Using Multiple Frequencies

XiuJing Gao , Feifei Zhang , Masanori Ito

(Tokyo University of Marine Science and Technology, Japan)

***Abstract*:** Recently, positioning system for under water robot becomes a very important subject. The conventional positioning system is based on the time difference or phase lag. However, the systems are expensive and complex, and we proposed a new system using sound propagation loss. In this system, we separated the direct wave from received wave, and measure the amplitude or power of it. Using this data we calculated the distance. However, the signal accepted the influence of reflected waves, and it couldn't obtain correct distance for long distance where the direct wave can't be separated from reflected waves. In this study, we propose a new analysis method based on multiple frequencies. This method uses several different frequency sounds, and sends them sequentially. The distance can be calculated from taking the average power of received signals. The advantage of this method is not necessary of separating process, and can measure longer distance.

Keywords: Underwater Positioning, Propagation Loss, Multiple Frequencies, Direct Waves, Mixture waves

I. INTRODUCTION

In recent years, the research for the oceanic survey or development of oceanic natural resource is actively advanced. The needs of the underwater robots used for those purpose have been becoming higher and higher. For the autonomous underwater robot, positioning system is one of the important subjects to exercise their full performance. The conventional positioning system in the water is based on the time difference or phase lag of transferred sound from source to receiver. It measures the distance between moving object and station where the position has already fixed. When 3 stations are prepared, we can fix 3 dimensional coordinate of object.

However, the systems are expensive and complex. Then it is difficult to measure the position in real time and expand work area of the robot. From 2006, we are proposing a new system using sound propagation loss. In this system, the distance can be calculated using the relation between the propagation distance and sound propagation loss. In the former study, we separated the direct wave from received wave, and measured the amplitude or power of it. Using this data we calculated the distance. However, we cannot separate direct wave and reflected waves from the received signal in usual case and it couldn't obtain correct distance. Figure 1 is the simulation result with this method for 5m and 50m distance of 1m depth. Top graph shows the received waves without reflected wave. Second graph shows the received waves of 5m distance and third graph is the result of 50m. It shows that the part of direct wave is clear in case of short distance, but in case of long distance, the reflected wave appears at the first stage of received wave.

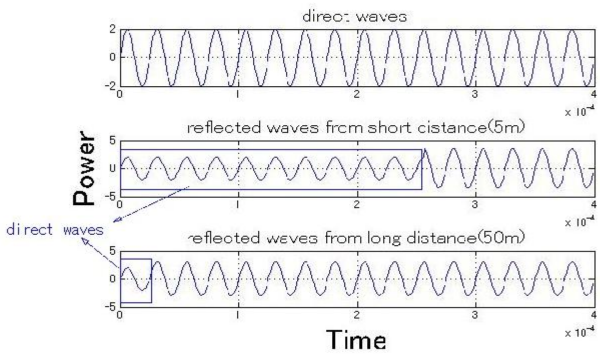

Fig.1Simulation Results for Propagation of Sound Wave

In that case, the distinction and the separation of the direct wave from the received wave are impossible. So, in this study, we paid attention to the reflected waves, and used them actively in the data analysis. In this system, instead of the single-frequency sound, we use several different frequency sounds, and send them sequentially. In the step of data-analysis, we use mixed wave which contains direct wave and reflected wave, and take the average power of received wave. This signal is used to calculating the distance. The performance of this method was proved with simulation and experiment. The advantage of this method is that it can measure longer distance.

II. Experimental system

It is called propagation loss that the sound pressure level damps depending on a distance when a sound propagates in the water/air. The relations of the propagation loss PL[dB] and propagation distance R[m] can be presented as follows.

$$PL=20\times\log10(R)+\alpha\times R \qquad (1)$$

Here, loss coefficient α [dB/m] is calculated with SOAP equation as follows

$$\alpha=\frac{0.11\times f^2}{1+f^2}+\frac{44\times f^2}{4100+f^2}+3\times10^{4}\times f^2 \qquad (2)$$

On the other hand, in this system, PL can be calculated with

$$PL=20\log10(Tv/Rv)+Tg+Ts+Rs+Rg \qquad (3)$$

The parameters are defined as follows:

Tv[V] : Transmitted signal voltage
Rv[V] : Received signal voltage
Tg[dB]: Transmission gain
Rg[dB]: Reception gain
Ts[dB]: Transmission sensitivity
Rs[dB]: Reception sensitivity

It is clear that the propagation distance R can be calculated from the transmitted and received signal (Tv and Rv).

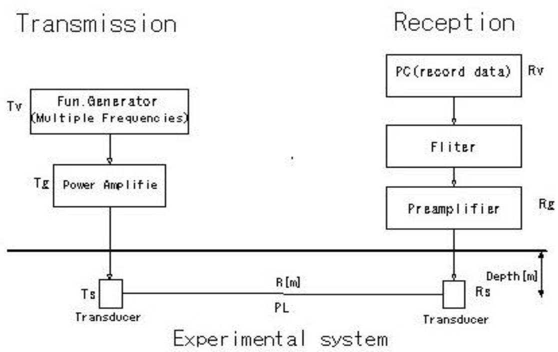

Fig.2 Experimental System

Figure 2 shows the experimental system. The transmitting unit consists of a function generator to generate the multiple frequencies sounds with same voltage of Tv, a power amp to amplify the level of the signal with gain Tg and transducer to transmit the signal into the water with the sensitivity of Ts. The receiving unit consists of a transducer to catch the signal with receiving sensitivity of Rs, a pre-amplifier to amplify the received signal to a necessary level, a band-pass filter to clearing the noises and a computer to record the data.

Ⅲ. Simulation and Experiment

1. Simulation

Before experiments, we made simulation study for the decision of sound frequency.

At the condition of constant depth and propagation distance, we suppose the amplitude of each transmitting wave is 3[v], the amplitude of the direct waves at the receiver is 2[v] and the amplitude of the delayed and reflected waves is setting by random, and we examined about each received signal.

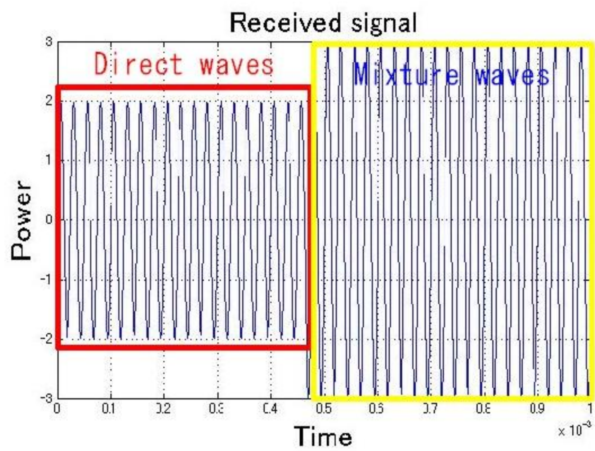

Fig.3 Received Signal (40 kHz)

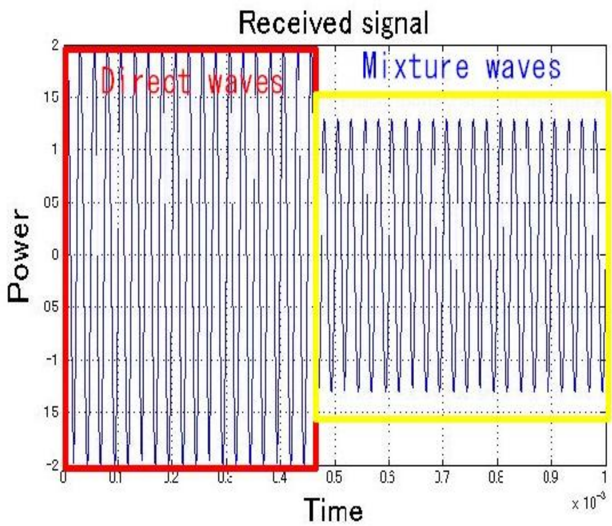

Fig.4 Received Signal (38 kHz)

Figure 3 and figure 4 show the received signals when the depth is 1[m] and the propagation distance is 3[m].

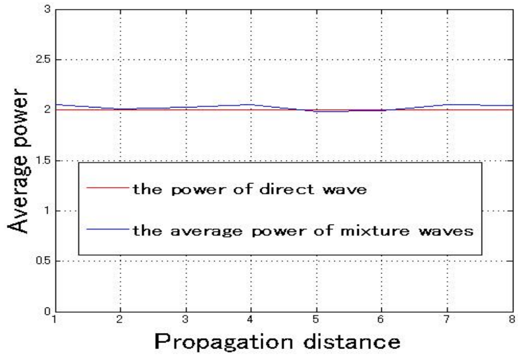

Fig.5 Comparison of Powers (1)

Figure 5 is the results of simulation with changing the propagation distance at same depth. It shows that the power of direct waves and average power of the mixed waves are nearly equal on every propagation distance.

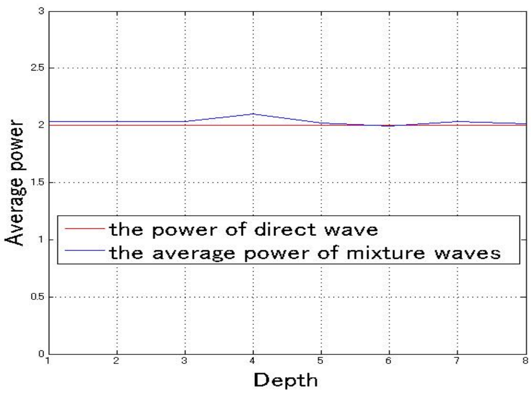

Fig.6 Comparison of Powers (2)

Figure 6 is the results of simulation with changing the depth of transmitter and receiver at same depth under same propagation distance. It shows that, at the same propagation distance, the power of the direct waves and average power of the mixed waves are also nearly equal with changing the depth of the transmitter and receiver who are at the same depth.

The results say that the level of received wave changes because of the change of phase lag depending on the frequency of transmitted wave. However, when we used multiple frequencies of 40kHz, 39kHz, 38kHz, 37kHz, 36kHz, 35kHz, 34kHz, 33kHz and 32kHz as transmission signals, the average level of their received signal is corresponding to the level of received signal of the direct waves. And there exist many groups of frequency that shows such kind of characteristics. So, we can decide the useful combination of frequency with the simulation.

Ⅳ. Experiment and Results

2.1 Experiment

Fig.7 Water Tank in TUMSAT

We made the experiments in the water tank in TUMSAT which has the size of 10m(W)×50m(L)×2m(D) as showed in Fig. 7.

All instruments are put on the moving train. We put down the transducer for transmitting sound into the water at depth of 1m and fixed it at center axis of the water tank (Equidistance from both side wall: 5m) with a crane. The transducer for reception is put into the water at depth of 1m and fixed on moving train. We moved the train with every 1m to change the distance between transmitter and receiver.

2.2 Results

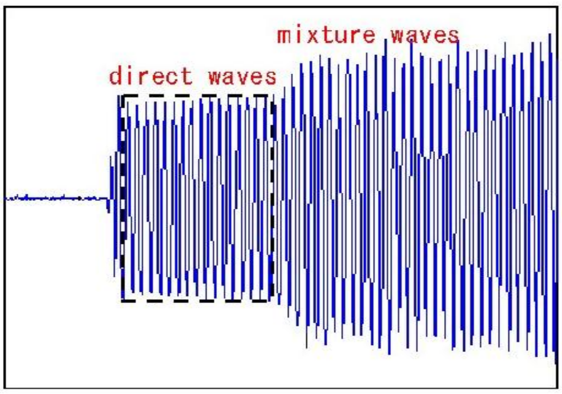

Fig.8 Example of Received Wave

Figure 8 shows a example of received wave. The first part of this wave is direct wave which is arrived firstly. The following part is mixed wave that contains direct wave and reflected wave. In this study, the received signal is measured with taking the average of power gained through FFT to mixed signal.

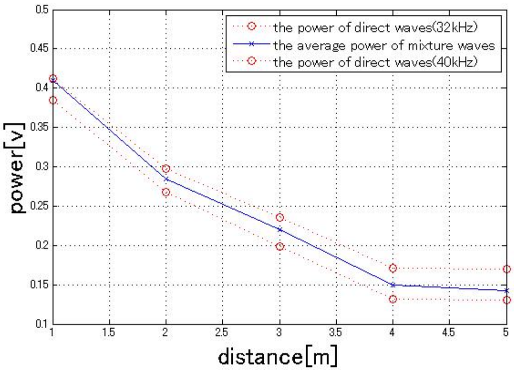

Fig.9 Comparison of Power for Received Waves

Figure 9 shows the results measured the power of received wave from direct wave of single frequency (32 kHz and 40 kHz) and average of the mixed wave of multiple frequencies for 1 to 5m distances. There exists no clear difference.

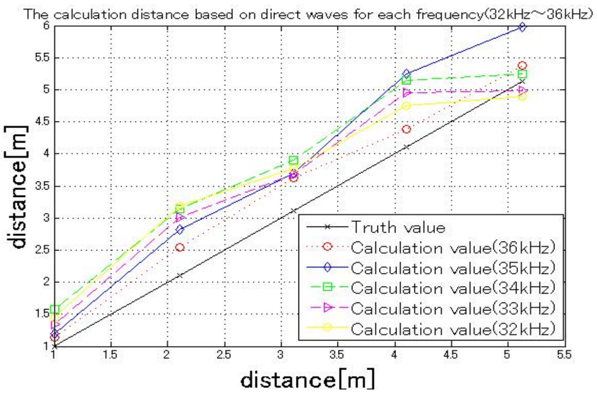

Fig.10 Calculated Distance Based on Direct Waves of Each Frequency (32kHz～36kHz)

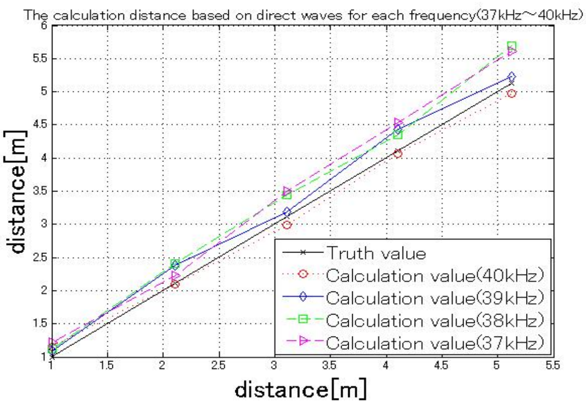

Fig.11 Calculated Distance Based on Direct Waves of Each Frequency (37kHz～40kHz)

Figure 10 and 11 show the distance calculated by the conventional method that uses the power of the direct wave from received signal. In these results, the influence of reflected waves appears clearly and the accuracy becomes not stable.

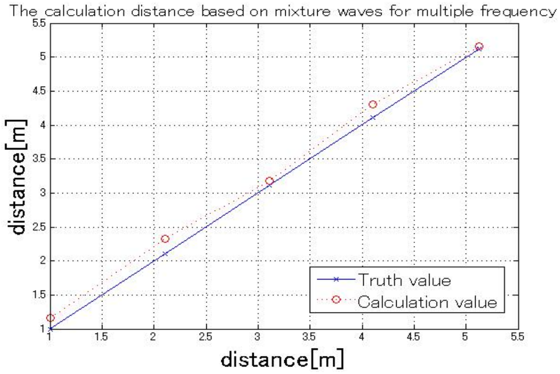

Fig.12 Calculated Distance Based On Mixed Waves of Multiple Frequency

On the other hand, we show the distance calculated from average power of the mixed wave that contains the direct wave and the reflected wave in Fig. 12. Comparing those results, we can say that new method has higher accuracy than conventional method.

Ⅴ. Conclusion

(1) In this study, we propose a new method to get the collect distance that is transmitting several frequency wave and taking average of power including direct and reflected wave from received signal. We confirmed the availability and performance of this method with experiment and simulation.

(2) As the next tasks, we will make a experiment in the real sea area for long distance and prove the practicality of this method.

(3) On the basis of this method, we will construct a sensor network system and establish real time positioning system for underwater robot.

References

[1] The Marine Acoustics Society of Japan, Fundam entals and Applications of Marine Acoustics, Seizan do 2004

[2] Yosikawa,Fluid Acoustics of Sound Source, Tokyo: korona, 2007

[3] FuBin, A New Positioning System for Under Water Based on Sound Propagation Loss and Sensor Network, 2008