Distinction and Tracking of Multiple Pingers Using a Single Frequency

Hyeon Ok SHIN, Etuyuki HAMADA and Hiroshi SUZUKI
Tokyo University of Fisheries
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단일주파수에 의한 복수의 초음파핑거의 식별 및 추적

申鉉玉 · 濱田悅之 · 鈴木 裕
東京水産大學
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초음파핑거(ultrasonic pinger)에 의한 광범위에 걸친 고기의 추적은 1개의 핑거를 사용하여 개체어에 대하여 행하는 것이 보통이지만, 여러개의 핑거를 사용하여 어군으로서의 복수어를 동시에 추적하는 것도 생각할 수 있다. 특히, 그물 속이나 호소, 만 등 제한된 수역의 경우에는, 고정위치에서의 수신이 가능하므로 복수의 핑거를 이용하는 것이 용이하다. 복수의 핑거를 이용하는 경우에는, 각각의 핑거로 부터의 신호가 혼신하지 않도록 다주파를 이용하는 것이 일반적일 것이다. 그러나, 이러한 주파수분할방식에서는 핑거의 수 만큼 주파수를 달리하는 수신기를 필요로 하게 되어 실용성이 적다.

본 연구에서는, 단일주파수에 의한 소위 시분할 방식을 이용하여 펄스간격을 적당하게 정하면 혼신을 어느 정도 피할 수 있을 뿐 아니라 각각의 핑거의 식별도 가능하다는 것에 착안하여 그 방법에 관하여 검토하였다.

시분할방식에서는, 복수의 핑거로 부터의 신호를 동시에 수신하여 핑거의 위치를 계산하는 것은 불가능하다. 그렇지만 핑거의 펄스폭은 10*msec*정도인데 반하여 펄스주기는 수 *sec*정도이므로, 복수의 핑거의 신호가 동시에 수신되는 확율은 적다. 단, 복수의 수신점에서 수신하는 경우에는, 어느 수신점에서 수신되기 시작하여 모든 수신점의 수신이 끝날 때 까지 다른 핑거로 부터의 신호가 수신되어서는 안되기때문에 혼신의 확률은 크게 된다. 그러한 이유에서, 핑거의 수, 펄스폭, 펄수주기 및 수신점의 배치를 바꾸어가면서 시뮬레이션을 행하고, 혼신에 의한 핑거의 위치계산불능의 확률을 구하였다. 더 나아가 50*kHz*의 복수의 핑거를 동시에 추적하는 실험도 행하였다.

실험에서는, 혼신이 있어도 펄스주기의 상이를 이용하여, 각각의 핑거를 식별, 추적할 수 있었다.

Introduction

It is desirable to track not only single swimming fish but some fish in schools. Therefore, our study was aimed at the method of distinguishing each pinger. There are two forms of this techinque, one of them is the frequency division scheme and the other one is the time division scheme. The former requires the multiple frequencies receiver in accordance with the number of the pinger, and the latter is necessary for a more complicate algorithm than the former. From a practical point of view, the authors adopted the latter form which uses both the pulse interval and the phase defference of the multiple pingers.

Materials and Methods

Multiple Pingers

Three miniature pingers of $50kHz$ which have been developed by the authors on the previous study[1] were used. The pulse width and the pulse interval of them are $10ms$ commonly and $2.2sec$, $2.4sec$, $2.8sec$. Its acoustic source levels are 147 dB(re μPa at 1 m).

Construction of system

The scheme diagram of the system is shown in figure 1. The receiving and the processing system consist of four hydrophones, a four-channel receiver, and a personal computer. The pulse signal from the pinger is received by four directional hydrophones. The beam angle and the receiving sensitivity of the hydrophone are 60° at $-6dB$ point, -179 dB(re $1V/\mu Pa$). The received signal is amplified in the receiver. The maximum gain of the receiver is 110 dB, and its receiving band width is 1500 Hz at $-3dB$ point.The amplified analog signal is converted to a digital signal of 1bit by a hysteretic comparator. The digital signals of the four channels are supplied as a 1 byte signal to the computer through four photo couplers. As the digital signal is received, it interrupts onto the personal computer so that the signal can be processed. The sampling rate of the system is $33.3\mu s$. This system has an external timer to distinguish each pinger. The time for the distinguishing of the pinger is recorded to an accuracy of 1 ms, when the normal signal is received.

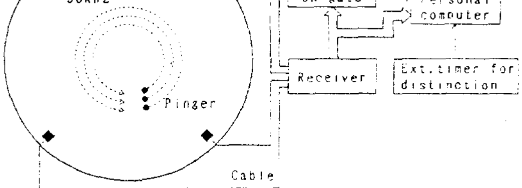

Fig.1. Diagram of system and method of experiment.

Distinction of Multiple Pingers

Figure 2 shows the time division scheme for the distinction of the multiple pingers. We assume that there are three pingers of the same frequency and pulse intervals are 3, 4, 5 sec. The transmitted pulse signal from each pinger is received as a form of the pulse train without any identification of the pinger.

From this pulse train, the technique of how to distinguish each pinger may be shown as follows :

a) Assuming that the pulse interval of each pinger is between the minimum value and the maximum value of the pulse interval(in this example, the minimum is 3 sec and the maximum is 5 sec). If a pulse interval is the minimum is 3 sec and the maximum value, this is considered as an available pulse interval. When received three pulses from one pinger which has regular and available pulse interval, the pinger could be identified from another pingers. The tracking of that pinger could be prefomed for its next receiving time is predictable. For other pingers, they are capable of distinguishing with the same method.

b) In the received time of 0, 2, 3 sec pulse, there is an available pulse interval of 3 sec but its periodical pulse interval is not found.

c) As the pulse of 6 sec is received, a period of 3 sec is found among the 0, 3, 6 sec pulse. It, therefore, is acquired as the pinger -1.

d) In the pulse of 8 sec, it is only recognized as not the pulse of the pinger-1. There is not found a periodic pulse interval.

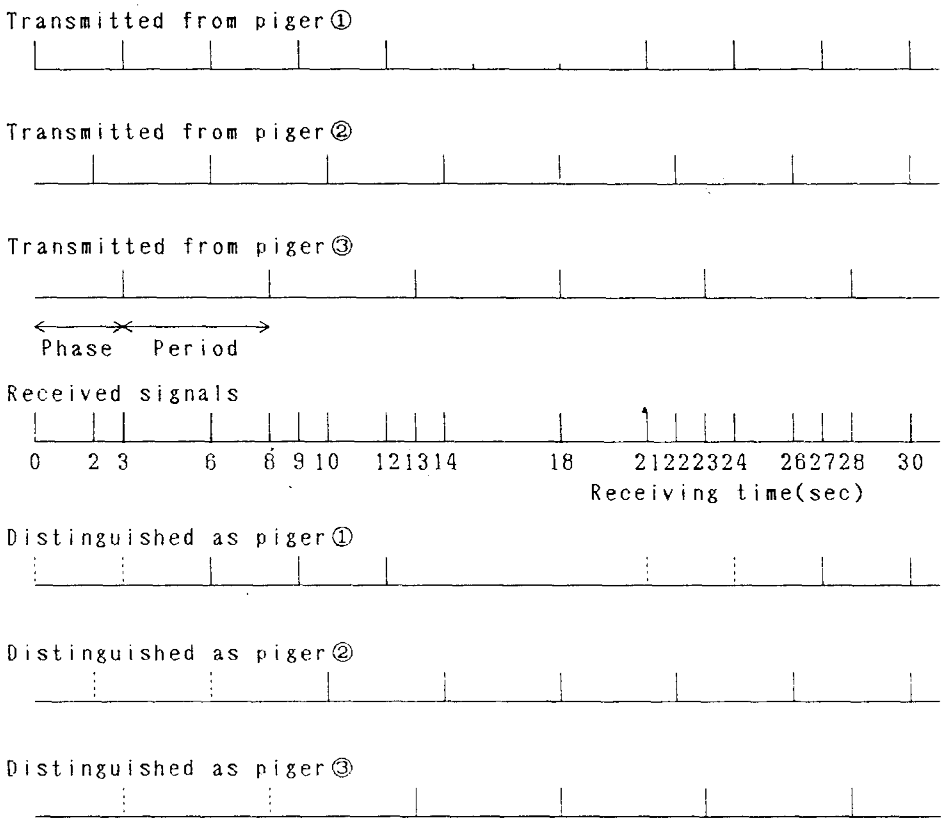

Fig.2. Transmitted and received pulse train from multiple pingers of single frequency (upper) and identified pulse train as pinger 1, 2, and 3 (lower).

e) The pulse of 9 *sec* is on the time extension of the 3,6 *sec* pulse, and it is distinguished as the pinger-1

f) As the pulse of 10 *sec* is received, a periodic pulse interval of 4 *sec* is found between the 2, 6 *sec* pulse. It is acquired as the pinger-2.

g) The 12 *sec* pulse is on the time extension of the 6, 9 *sec* pulse, and it is distinguished as the pinger-1.

h) As the pulse of 13 *sec* is received, a preiodic pulse interval of 5 *sec* is found between the 3,8 *sec* pulse. It is acquired as the pinger-3. Up to here, three pingers were acquired.

The above techniques may be applied to the other pingers which have the smae intervals of pulse because we use both the pulse interval and the phase difference of the pinger. Similarly, it will correspond to the depth sensor pingers of which pulse intervals are varied smoothly.

In the time division scheme, the pulse oberlapping will occur (bold lines of 3, 6, 18, 30 *sec* pulse in figure 2). The dot line pulses show undistinguished pulse. The overlapped pulses can be distinguished, however it cannot be used for a position calculation.

Probability of Positioning Failure

The position of multiple pingers are calculated with each pinger. If some pulses are received at the same time, it is so difficult to know which pinger is transmitting the pulse that its positioning may fail. The probability of the pulse overlapping usually depends upon the number of the pinger, the pulse width, the pulse interval and the maximum distance between the hydrophones. The more or higher of these values except the pulse interval, the more the probability is increased.

Figure 3 shows a simulated probability of the pulse overlapping. The used parameter in the simulation is as follows: The pulse interval of the used parameter in the simulation is as follows: The pulse interval of the first pinger is 2.1 *sec*, and it is increased 0.05 *sec* step by the number of the other pinger referred to the first pinger (i.e. The given pulse intervals are 2.10, 2.15, 2.20 *sec*, etc.). The number of the pinger and the maximum distance are fifteen and 12*m*. The used pulse widths were 10 *ms* and 20 *ms*. From this figure, the probability of the pulse overlapping is no more than 30% as far as the number of pingers is not exceeding ten.

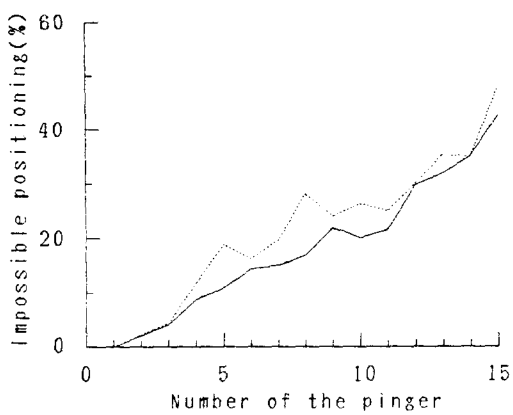

Fig.3. Simulated probability Opositioning failure. Pulse interval of each pinger is given as 2.05 *sec* + 0.05 *sec* x number of pinger. Maximum distance between hydrophones is 12 *m*, and pulse width of solid line is 10 *ms*, dot line, 20 *ms*.

Results and Discussion

To test time division scheme, we performed some experiments in a circular water tank (13 *m* in diameter and 1*m* deep). A result of that is shown in figure 4. The 2-dimensional position of the pinger was calculated by the method of hyperbolic line of position calculation[2]. The resolution of the time difference on the base line is 2.5*cm*. In experiments, the multiple pingers of a single frequency were distinguished and tracked successfully.

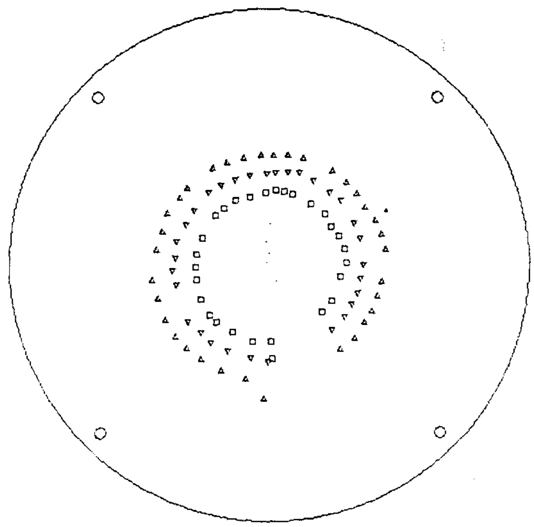

Fig.4. Trace of each pinger distinguished.

When the experiment is carried out in the water tank, some multi-path pulses always occur. To delete it, several 10 *ms* of time delay is inserted onto the program after a group of the normal signals are received. Some normal pulses are not received by the time delay, however there is no problem, practically, for the distinction and the tracking of the pulse.

In 2-dimensional positioning, the pinger position can be calculated with three hydrophones. However, if four hydrophones are available, the positioning accuracy will be higher than three hydrophones only by some techniques. Another good feature of the use of four hydrophones is that the positioning of the pinger is capable if a hydrophone fails in receiving them.

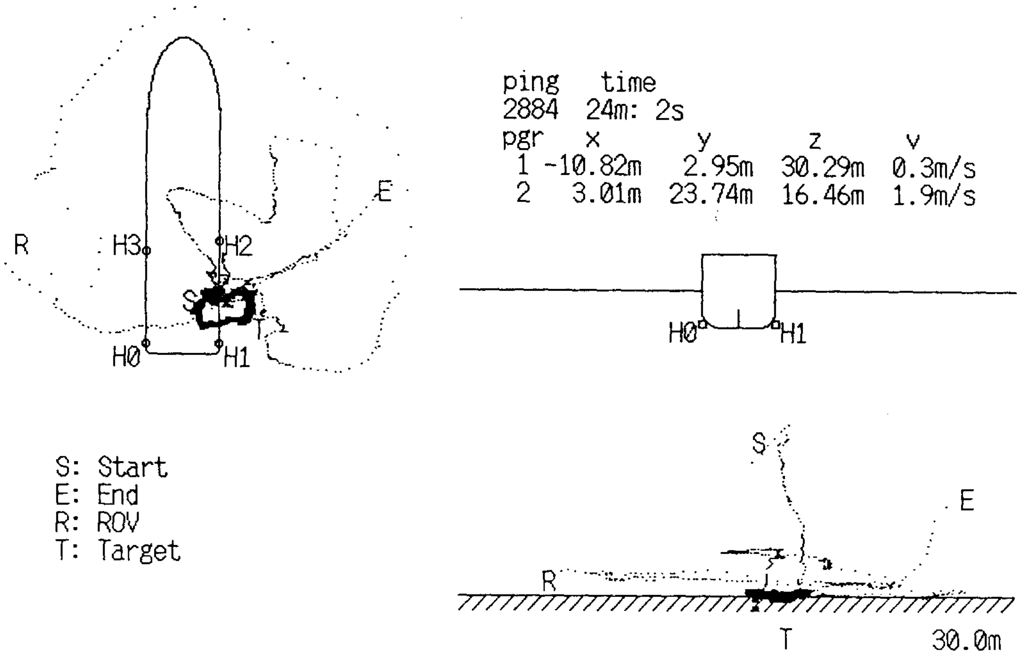

Fig.A1. Guided trace of ROV to target. Left is plane view on sea bottom and right is side view.

We also tested this distinguishing method in the field using another type pingers (APPENDIX A).

APPENDIX A : Field test

The field test was carried out in Tateyama Bay at around 30*m* depth. We used two pingers of 50*kHz* which have depth sensor. The pulse intervals of them are varied with the depth (0.95 *sec* to 3 *sec* at 0 *m* to 200*m* deep). The two pingers have 20 *ms* of pulse width commonly, and its acoustic source levels are 160 *dB* (re 1μPa at 1 *m*).

To guide the Remotely Operated Vehicle (ROV) to a target is not easy without the assistance of a locating system. We, therefore, tried to display, in real time, both the locations of a ROV and a target by the use of multiple pingers attached to them. A results of the experiments is shown in figure A1. Each pinger was destinguished clearly, and the guidance of ROV to the target pinger is achieved with ease.

References

1) Shin, H. O., E. Hamada and H. Suzuki (1990) : Miniaturization of the pinger for biotelemetry using a bimorph vibrator. Proceedings of 11th International Symposium on Biotelemetry, in press.

2) Shin, H.O., E. Hamada and H. Suzuki (1990) : Guidance of ROV using multiple pingers of a single frequency. The Journal of Japan Institute of Navigation, 83, 7-11.