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Development of a small and long-life ultrasonic biotelemetry system strong against sea ambient noise

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ABSTRACT

A highly efficient ultrasonic biotelemetry system would be desired to the ocean having a high underwater ambient noise that is especially from the temperate zone to the tropics. The four parameters were defined as the estimated factors for pinger system, long distance transmitting, battery life, pinger size and ability of recognition. The four parameters of the pinger were analyzed and investigated to design for the optimum ultrasonic biotelemetry system. The first parameter, long distance, must be considered the transmitting frequency, modulation, transformation and etc. The second, battery life, must be designed for the effective transducer and the low power dissipation electronic circuit. The third, smallest pinger size, must be adopted the microelectronics components. The last, high recognition, depend on the signal processing method of the underwater transmitting system . As a result, the first need was achieved over 1,200 meters transmission distance, the second was realized 300 days battery life when 30 seconds repetition by using the small battery SR626SW 32mAh. The third, the pinger size was realized the ϕ 8 mm diameter and 40 mm long. The last, the M sequence signal was used the pinger and the correlation processing of the receiving system was adopted for the high recognition against the noise and to avoid the collision of other pingers. The system consisted of the tiny pinger and the high performance receiving equipment including the transducer. The pinger could be transmitted the IDs and the depth information each repetition interval. The receiver processed to correlate the received M-sequence signal from the pinger using the FPGA chip and calculates the direction of the pinger. The raw data could be stored to the PC through the data conversion from analog to digital, 16 bits 192 kHz sampling. The actual experimental data will be presented to obtain in the Tokyo Bay and Osaka Bay using the developed system.

1. INTRDUCTION

The highly performance bioteremetry system would be desired such as a small, long battery life, long distance and high recognition pinger. The four parameters, small size, battery life, long distandce and recognition are defined to estimate the values of pinger system. These four parameters were analyzed and investigated to design the prototype pinger system. The actual experiment in the sea was done to use the prototype pinger system and estimated it.

2. FOUR PARAMETERS

The defined four parameters were a tradeoff relation as shown in Fig. 1. The conventional pinger system had been analized. It was very difficult to satisfy simultaneously the four parameters. For example, the smallest pinger was short battery life and the long distance one is a larger size. The performance of the conventional pinger and the target performance of the developing pinger system (Fig.2) . The solutions were investigated to achieve these four parameteres.

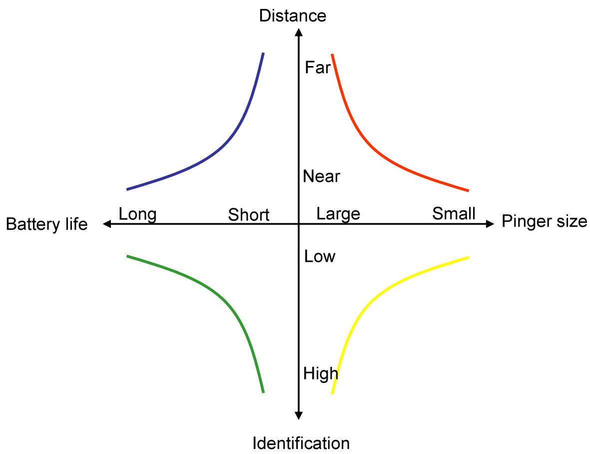

Fig.1 Defined four parameters for pinger performance

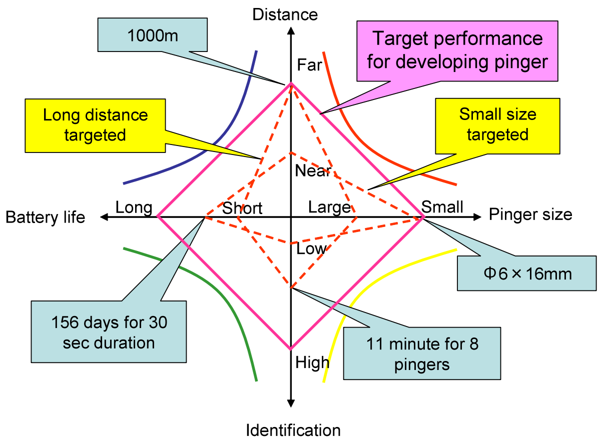

Fig.2 Comparison between target and conventional pinger

2.1 Smallest size

The solutions to achieve the smallest size were as follows;

a. Transducer → small size transducer element
b. Transmitter → simplest electoronic circuit
c. Electoronic circuit → minimized electronic parts
d. Print cercuit board → 3D displacement inside pinger

2.2 Battery life

The solutions to achieve the long battery life were as follows;

a. Transmitting power → high efficiency of transducer
b. Transmitting circuit → improvement of power factor
c. Electronic circuit → operating frequency, optimized programming and minimized waiting current dissipation
d. Transmitting information → minimized pulse width using wideband transducer

2.3 Long distance transmission

The solutions to achieve the long distance transmission are as follows;

a. Ultrasonic frequency → low frequency (tradeoff to pinger size)
b. TX power → optimised power (tradeoff to battery life)
c. Improvement to S/N → Maximum length sequence signal
d. Signal modulation → phase shift modulation

2.4 High recognition

The solutions to achieve the high recognition of multi pingers are as follows;

a. Identification → multi code of M-sequence signal
b. Collision and interference → 31-bit M-sequence signal
c. Multi information(ID, depth, etc) → multi code and pulse duration modulation
d. Receiving system → real time correlation by FPGA

3. DEVELOPMENT

3.1 Transducer

The pinger transducer should be high efficiency and smallest size. The layerd piezo-electronic element that was recently developed was adopted. But the own resonant frequency is high for small size PZT. Then the method of low frequency operating had been discovered to use a small PZT element. The prototype pinger transducer was using Langevin method (Fig.3). Its resonant frequency was 30 kHz and bandwidth was 10 kHz . The resonant frequency is related to the transducer lemgth including PZT element. The relation between resonant frequency and transducer length was show in Fig.4. The frequency characteristic of the prototype pinger transducers was show in Fig.5.

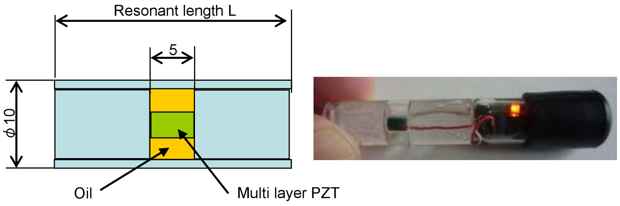

Fig.3 Transducer unit and prototype pinger

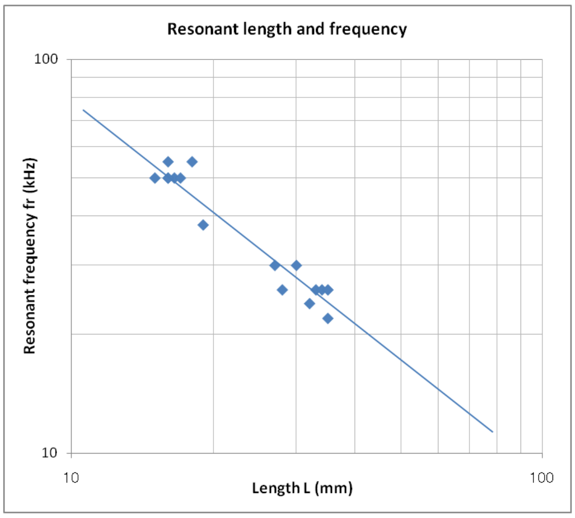

Fig.4 Relation between TD length and resonant frequency

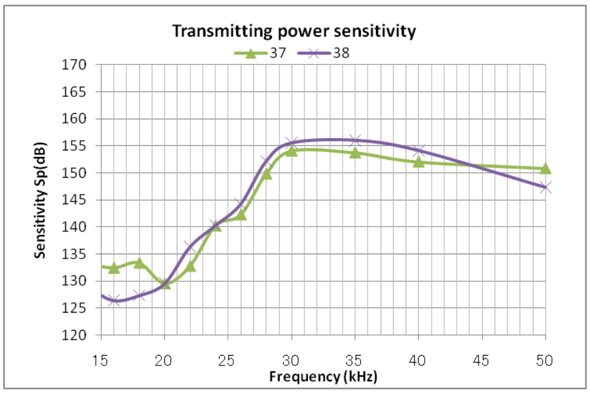

Fig.5 Frequency characteristic of prototype transducers

3.2 Maximum length sequence signal

Maximum length sequence signal was generally used to improve S/N ratio and had also wide applications. The pinger system was applied for the 31-bit M-sequence signal using the phase modulation. The wide band transducer could be obtained andthe transmitting response of the transducer was shown in Fig.6. The four wave numbers are applied to one bit of 31-bit M sequence signal. It was necessary the multi coded M-sequence signal to recognize the individual target. These multi-coded signals should not be interfered. The 24 codes are provided. Fig.7 shows the cross-correlation result for the 24 codes.

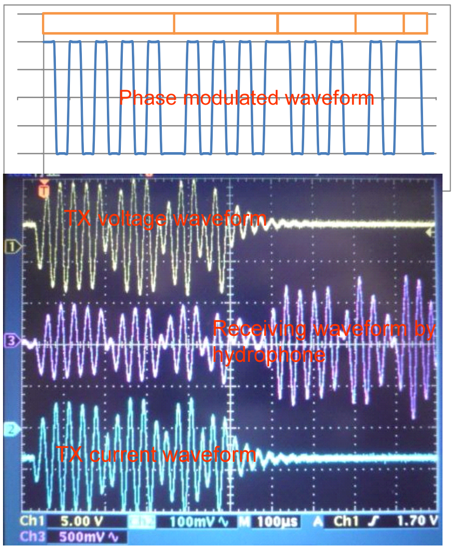

Fig.6 Phase modulation waveform

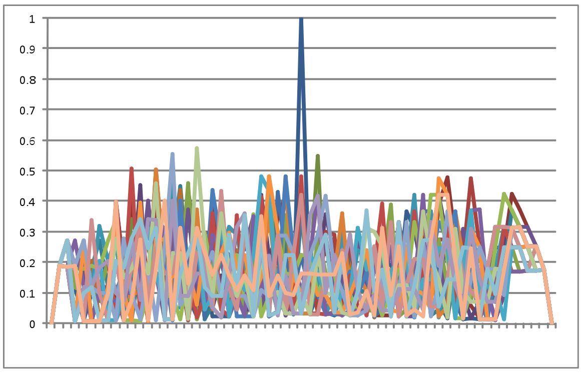

Fig.7 Cross correlation for 24-code

3.3 Frequency

The prototype pinger was designed and producedas a result 155 dBuPa transmitting source level was obtained. The propagation loss depend on the frequency were calculkated by two frequency 30 kHz and 60 kHz. Fig.8 shows the propagation loss curves at 30 kHz and 60 kHz. The difference of these two frequencies was 10dB at 1000-meter propagation. The 30 kHz was chosed as the pinger frequency. The directivity characteristics were obtained as non-direction sensitivity. Fig.9 showedhe directivity characteristic of the 10 pingers prototype.

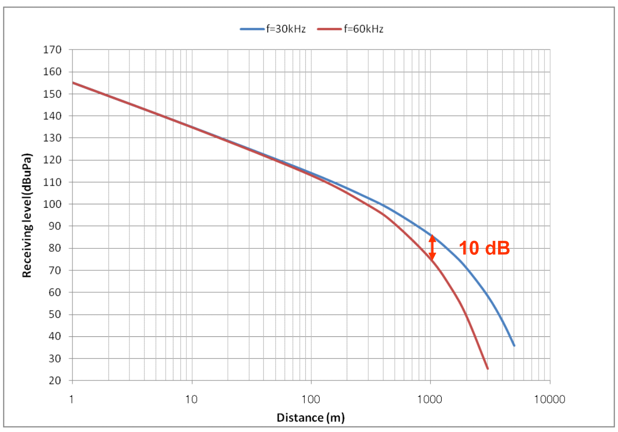

Fig.8 Propagation loss for 30 kHz and 60 kHz

3.4 Battery life

The battery life time was 7 days for 1 sec repetition ratio using the small bottun battery $\phi 6.8 \times 2.6$ mm(CR626SW 32mAh) for 4 ms pulse width and 155 dBuPa source level. One-year battery life could be realized for one-minute repitition interval.

3.5 Receiving signal processing

The receiving system was consisted of dual hydrophones, amplifires including the band pass filters and the correlators. The correlator was constituted by the FPGA having 1.6 million gates. The shift register length was 992 registers that was sampled by 8 times for 1 cycle of the carrier signal. The sampling clock frequency was 250 kHz(Fig.10).

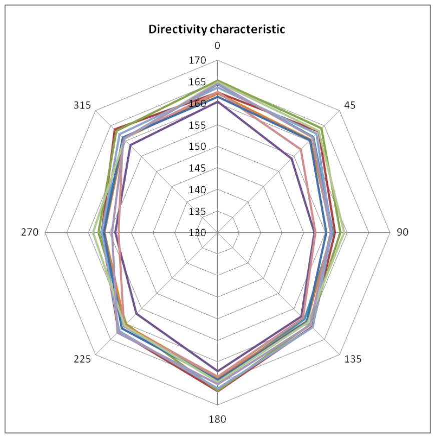

Fig.9 Directivity characteristic of prototype pingers

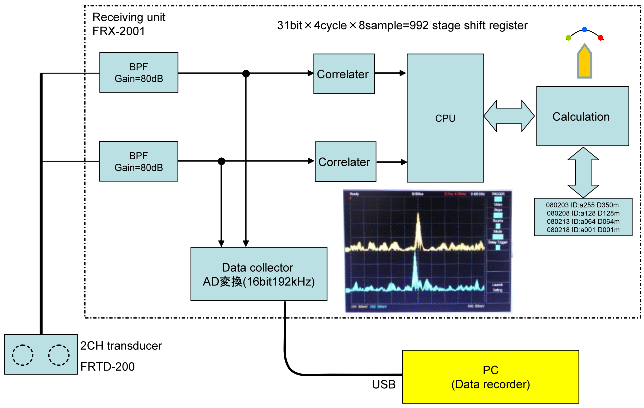

Fig10 Blockdiagram of the receiving system

4. EXPERIMENTS

4.1 Interference experiment

The receiving signal and the after processing signal correlated was shown in Fig.11. The seven pingers of different codes were inside the small area. The sharp correlated signal for own code was appear at center and no peak signals for other code signals were at left and right.

4.2 Transmitting experiment

Transmitting trial experiment had been done offing Kada near Osaka Bayat Aprel 2010. The receiving system on fishery boat was left from the pinger sinked in 4 meters depth (Fig.12). As a result the receiving signal after correlation could be observed at 1200 meters shown as Fig.13.

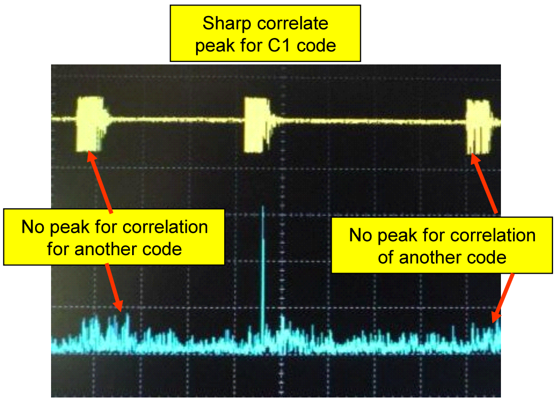

Fig.11 Correlation waveform from multi pingers

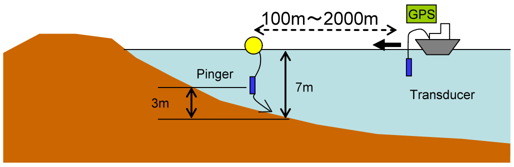

Fig.12 Transmitting trial

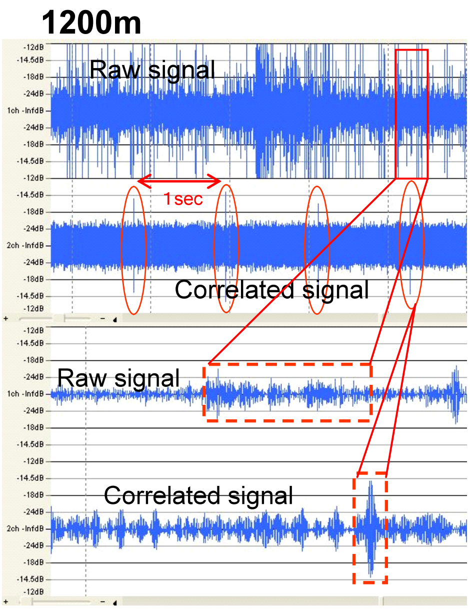

Fig.13 Receiving raw signal and correlated signal

4.3 Tracking experiment

The receiving system could be seach the target pinger using the time difference processing using dual transducers shown in Fig.14. The distance from the target pinger to the trial ship was around 400 meters. Firstly the system tracked the target pinger at the portside direction and then the ship steered to left. Fig.15 shows the tracking history of the steering from 90 degree left to just front direction.

5. CONCLUSION

The new developed pinger system could be accomplished the results of four parameters shown in Fig.16. The transmitting distance could be obtained 1200 meters, the battery life time was 300 days for 30 second interval, the recognition time was under one minute for 24-pingers and the size of pinger is ϕ 8 ×40 mm at this moment.

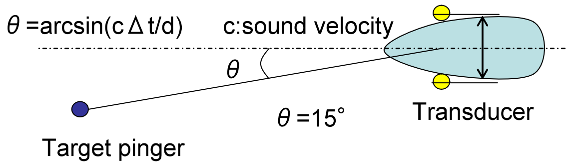

Fig.14 Receiving system principle for target trcking

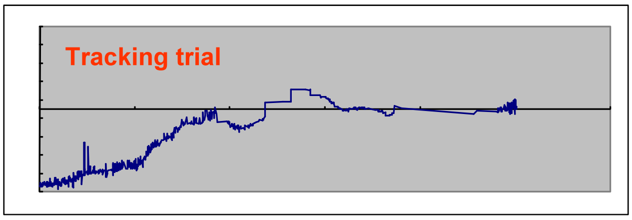

Fig.15 Tracking result of target pinger

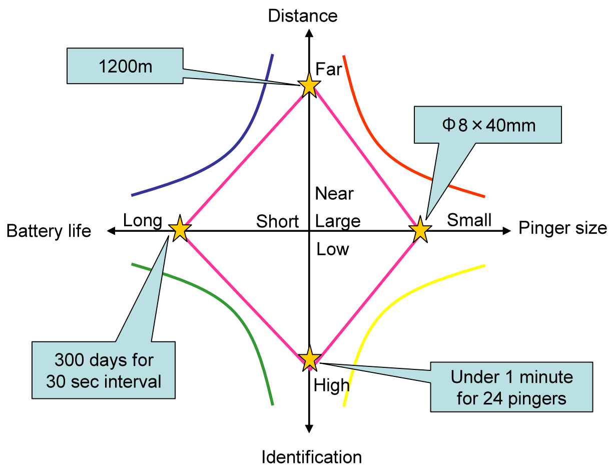

Fig.16 Four parameters of new developed pinger system

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REFERENCES

1) Yoshinori Miyamoto, Keiichi Uchida, Reiko Orii, Toshiharu Kakihara and Masahiko Furusawa : Validity of data filtering technique for the behavior analysis of crab in neritic and closed sea by ultrasonic biotelemetry, Fisheries Science, 71(2), p.211-213, 2005.
2) Alistair J. Hobday, Ryo Kawabe, Yoshimi Takao, Kazushi Miyashita, Tomoyuki Itoh: Correction factors derived from acoustic tag data for a juvenile southern bluefin tuna abundance index in southern Western Australia, Tagging and Tracking of Marine Animals with Electric Devices, Reviews:Methods and Tecnologies in Fish Biology and Fisheries, Vol.9 405-422. 2009.