Implementation of Underwater Position Tracking Devices Using Underwater Acoustic Sensor and Spread Spectrum Communication Technology

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Signaling of Transmitting and Receiving

Abstract: In this paper, we design an underwater acoustic tag and an acoustic tracker that can receive its signals to identify and display underwater location. Here, the underwater acoustic tag is small in size and requires low power consumption. In other words, we devise a new type of cross correlator with a small memory size and computational complexity. To this end, the 16-bit A/D converter is removed, and a phase modulation technique is introduced to digitize the output to +1 and -1 to implement a very simple phase correlator, which is proven by a test at sea.

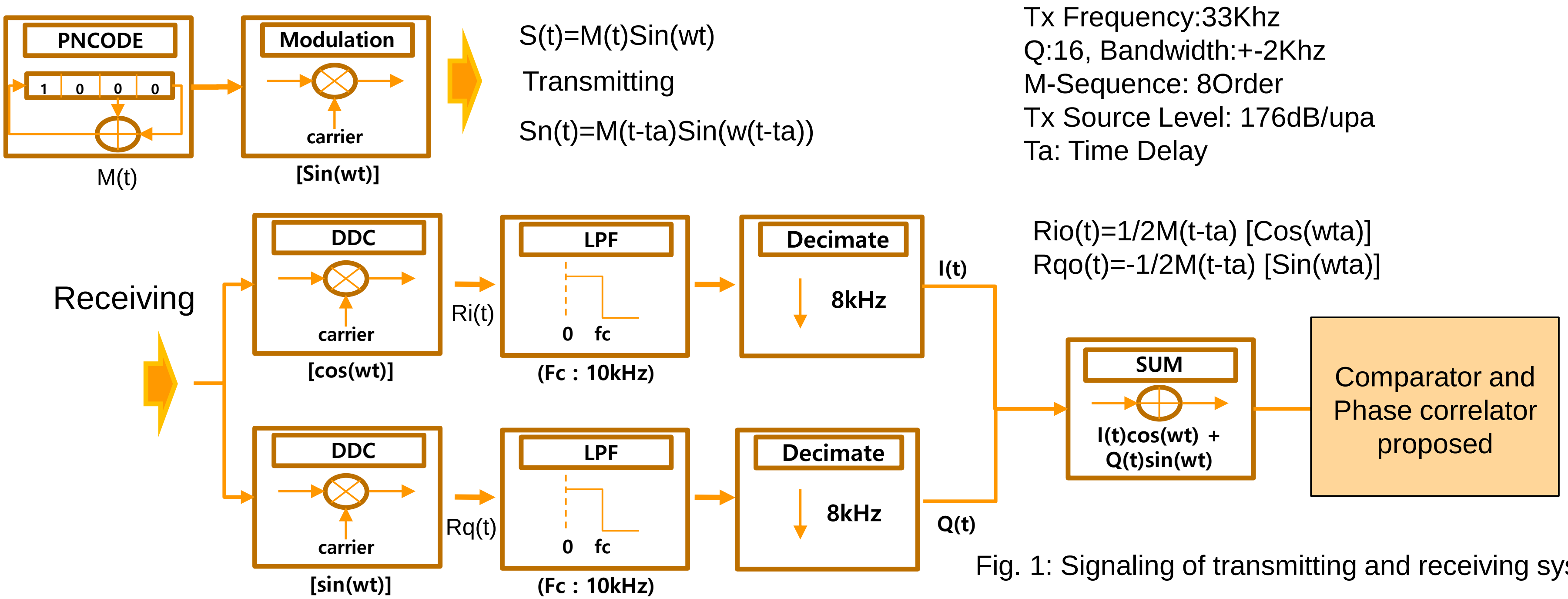


Fig. 1: Signaling of transmitting and receiving system

Ri(t)=M(t-ta)Sin(w(t-ta))*Cos(wt)=1/2M(t-ta)Cos(wta)-1/2M(t-ta)Cos(2wt-wta)

Rq(t)=M(t-ta)Sin(w(t-ta))*Sin(wt)=1/2M(t-ta)Sin(wta)+1/2M(t-ta)Sin(2wt-wta)

The first transmission signals are generated with a spread spectrum waveform by synthesizing a PN code with a sine wave. These signals are transmitted into underwater and received by the acoustic tag. The received signals are decomposed into a sine component and a cosine component, synthesized again, and phase correlation is performed through the thresholding process as shown in Fig. 1.

Phase Cross Correlators with Conventional and Novel

Structure of Convetional Cross Correlator

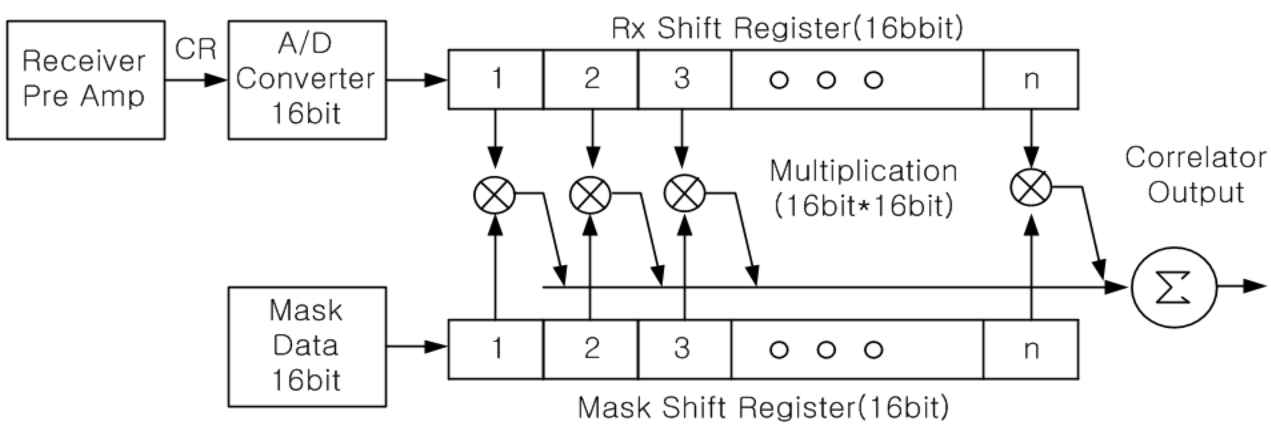


Fig. 2: Conveltional cross correlator

Typically, a 16-bit digital conversion is performed on the receive signal, and traditional cross-correlation is achieved by multiplying and summing the mask data through the receive signal shift register as shown in Fig. 2. Because the data size is 16 bits, the load on memory and hardware increases significantly.

Phase Cross Correlator proposed

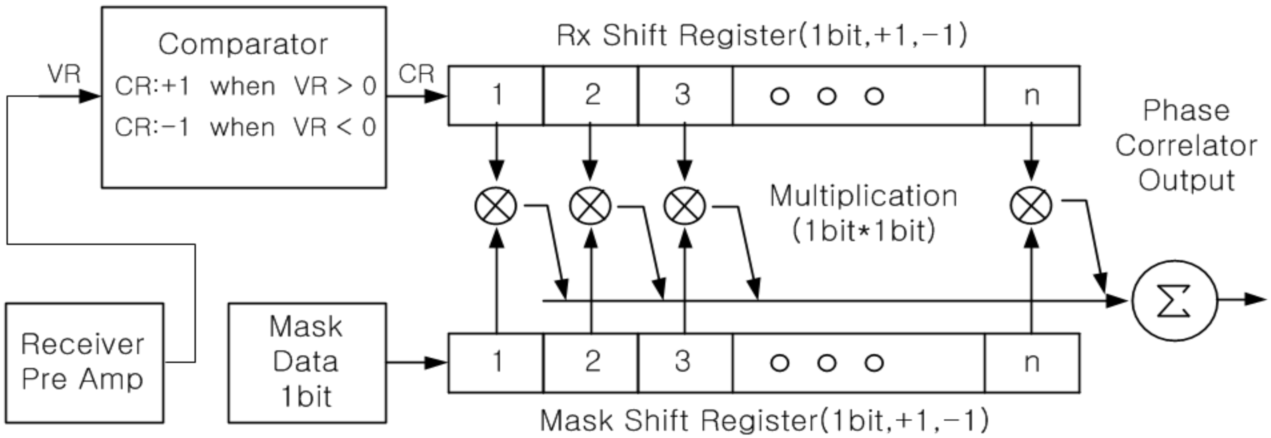
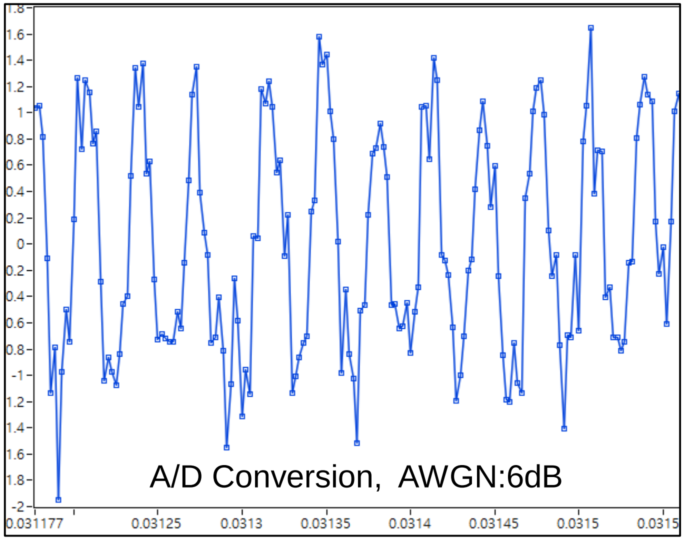


Fig. 3: Phase cross correlator proposed

Instead of the 16-bit A/D converter described above, the data size is reduced by converting the received signal into +1 and -1 through simple comparison as shown in Fig. 3. The cross-correlation process is performed on the transformed signal. The end results have the effect of slightly lowering the S/N ratio, but significantly reduced the hardware burden.

Simulated Signals of Cross Correlator Outputs



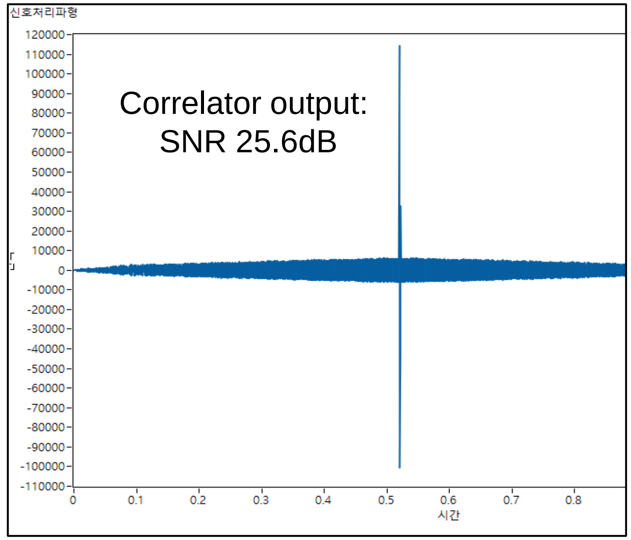
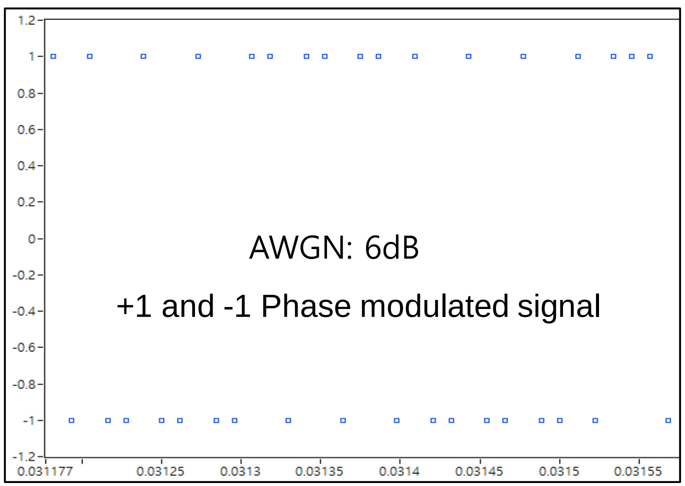


Fig. 4: Simulated for conventional correlator

Simulations are conducted to compare the characteristics of the conventional correlator and the proposed correlator. The received signal is a BPSK signal (20dB) in which a sine wave is modulated in PN code, and an A/D converter input signal is made by adding 6dB of AWGN noise assuming underwater noise. As a result, the S/N ratio is 25.6dB as shown in the Fig. 4. Of course, increasing the AWGN noise lowers the S/N ratio. In this figure, only relative results are shown.



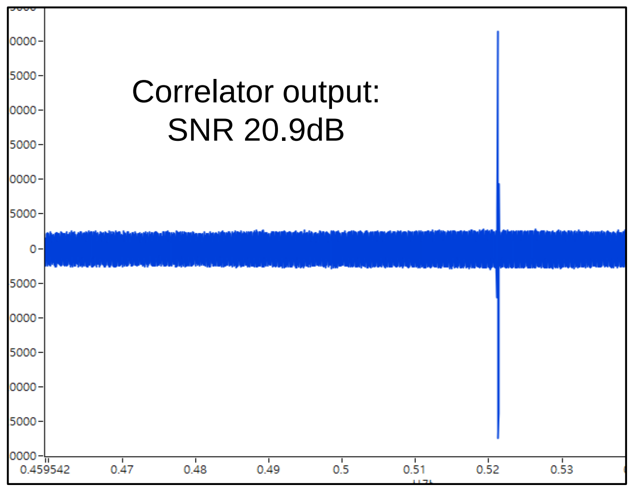


Fig. 5: Simulated for phase correlator proposed

In order to simulate the performance of the proposed phase correlator, the input signal used in Fig. 4 is converted into +1 and -1 according to the signal phase and the 16-bit A/D converter is eliminated. The simulation result is 20.9dB of S/N ratio as shown in Fig. 5 and this result is 4.7dB lower than shown in Fig. 4. However, the calculator structure has been greatly simplified from16bit into 2bit which is very useful for miniaturized acoustic tags and shows applicability.

Performance Test in Korean East Coast

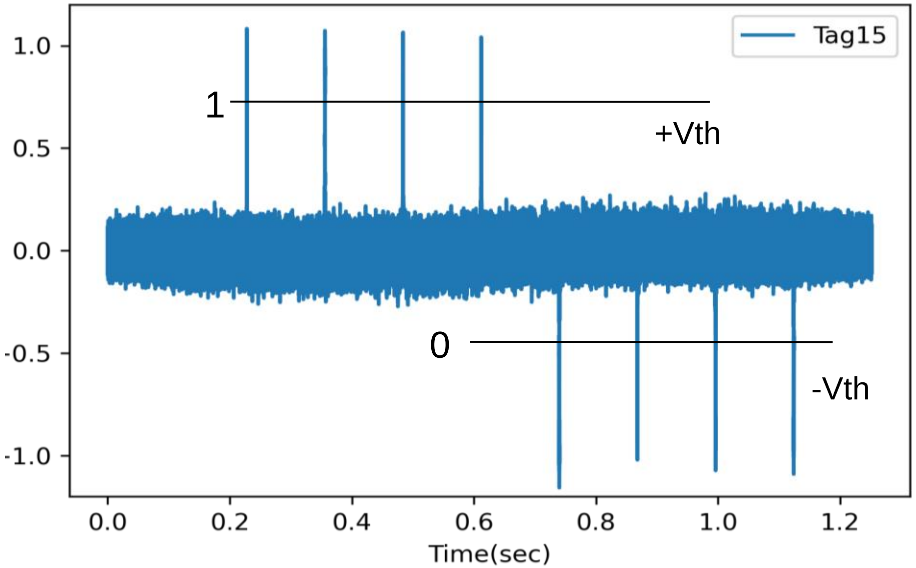


Fig. 6: Communication massage:11110000

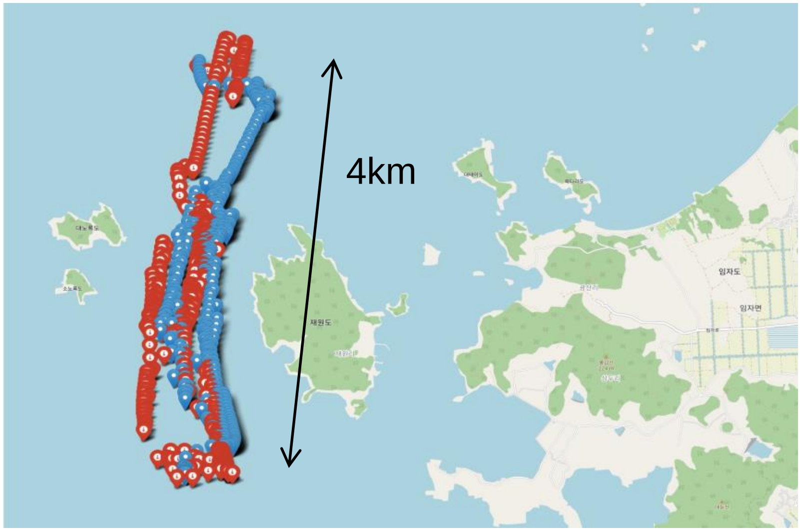


Fig. 7: Underwater communication test with the acoustic tag implemented

Fig. 8: Underwater acoustic tag used in the test

In this test, when the message is sent from the acoustic tracker on the ship, the acoustic tag receives the message and sends this information to the acoustic tracker on the surface to test shown in Fig. 6. In this case, the communication speed is very slow as about 50 bps, and the speed of the test ship is 5 knots. Under water, the Doppler effect and screw noise are found to be negligible.

As shown in Fig. 8, an acoustic tag is implemented based on the correlator proposed in this paper. As shown in Fig. 6, the same information message is sent and received as 11110000. The test area is in the East Sea of Korea and the communication success rate of 95% is shown at a communication proficiency distance of 4 km as shown in Fig. 7.

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Conclusions

In this paper, we propose a phase correlator applicable to a small acoustic tag for an underwater positioning system. After simulating the proposed algorithm, we are able to confirm the underwater communication distance of 4Km in the sea test at 50bps communication rate. Here, even if the communication speed is slow, the distance and direction to the acoustic tag can be calculated based on the signals of transmission and reception time difference and the signal phase difference information. The signal processing hardware used at this time is a 16-bit microcontroller without the A/D converter and the power consumption is 5V10mA. As a result, this method is suitable for simple and small modules. Future research will continue to theoretically verify the algorithm proposed in this paper and how to increase the S/N ratio at the correlator output.

References

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