Simulation of Time Delay Communication algorithm in the Shallow Underwater Channel

Byung-Woo Yoon*, Mustafa Eren Yıldırım*

Abstract

The need of data transmission in oceans and other underwater mediums are increasing day by day, so as the research. The underwater medium is very different from that of air. Propagation of electromagnetic wave in water or underground is very difficult because of the conductivity of the propagation materials. In this case, we usually use acoustic signals as ultrasonic but, they are not easy to transfer long distance with coherent method because of time varying multipaths, Doppler effects and attenuations. So, we use non-coherent methods such as FSK or ASK to communicate between long distances. But, as the propagation speed of acoustic wave is very slow, BW of the channel is narrow. It is very hard to guaranty the enough speed for the transmission of digital image data. In previous studies, we proposed this data communication protocol theoretically. In this paper, an underwater channel is modeled and this protocol is tested in this channel condition. The results show that the protocol is 4-6 times faster than ASK. Some relations and results are shown depending on the data length, channel length, bit rate etc.

Keywords : *Underwater communication, Time delay protocol, ASK, FSK*

I. Introduction

Telecommunication and Information technology has a big part in both industry and research with its various types such as; wireless, satellite, mobile communications. They are all important branches of information technology which are improving fast.

There are several branches of underwater applications. Underwater navigation and tracking are common requirements for exploration and work of divers, ROV, autonomous underwater vehicles (AUV), unmanned submersibles and submarines alike.

Unlike most radio signals which are quickly absorbed in the water, sound propagates far with a rate that can be precisely measured or estimated[6,8]. Thus, It can be used to measure distances between a tracked target and reference of baseline stations precisely. And we can triangulate the position of the targets. Seismic exploration involves the use of low frequency sound (< 100 Hz) to probe the condition of the sea bed. Despite the relatively poor resolution due to their long wavelength, low frequency sounds are preferred in the water. Because high frequencies are heavily attenuated when they travel the seabed. In underwater we use acoustics waves to transmit digital data over a long distance since the electromagnetic waves are able to propagate in only short distances [7,11]. Although we can overcome this distance handicap by using acoustic signals. We still have frequency-dependent propagation loss, multipath and low speed of sound compared to electromagnetic wave speed in the water[4]. Moreover, some other challenges are high bit error rates and temporary losses of connectivity (shadow zones) can be experienced. Underwater sensors are characterized by high cost because of a small number of suppliers. Battery power is limited and it is difficult to charge batteries; underwater sensors are prone to failures because of fouling and corrosion[2]. Multipath depends on propagation of the waves in water and also on the geometric characteristic of the medium such as waves, living organisms, rocks. Multipath causes inter-symbol interference(ISI) which brings lower bit rates in the medium, which is limited between sea surface and bottom.

The advantage of sound is that its speed increases to 1500m/sec in water since the density of the medium

* 경성대학교

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increases[5].

This study will show the results of a new idea which is simulated in the underwater channel that is modeled with multipath, fading and reflections. We specified the channel conditions as constant, and assumed the condition as a real.

The main keys are the time differences and delays between two-following pings. As default, the time difference between two acoustic pings is equal to T. Un like the traditional modulation method, we express informations in terms of time delays[13]. In other words, we send many bits at the same time with a time delay.

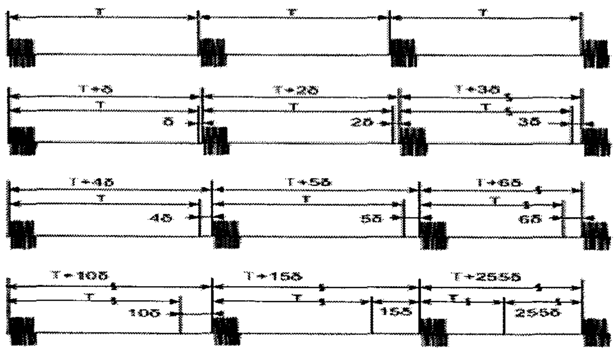

Figure.1. Digital data transmission method using time delay.

I. Simulation of the time delay protocol

The simulation result of TD protocol will be presented as graph. This simulation is performed with Matlab (2009b). To show the advantages of this new protocol, we compare it with ASK (Amplitude-shift-Keying).

In the development process of this test, data was only some numbers decided by us in order to design the code structure and make a successful recovery in the receiver. For TD protocol, these numbers were added as decimal coefficients of δ to the end of the sequence but in the case of ASK transmission, the binary equivalent of these numbers were sent as data.

Each signal has one ping consisting of 20 cycles which has 4 samples in each such as [0 1 0 -1]. These cycles are sinusoidal waves with a frequency of 40 kHz and the period T is determined from this frequency value. Length of this sequence is designed in order to cover all the replicas that occur because of the multipath so that the last replica will not interfere with the next ping. As a result, the receiver will be able to make an accurate detection. In this experiment, the length of the channel is 3184 samples and the last replicas starting point is at the 3184^{th} sample with a length of 80 samples so the last point is 3264^{th} sample. That's why we designed our acoustic signal as 80 samples per ping and 3187 samples for the duration after it, which makes a total of 3267 samples long enough to cover them all. Our algorithm works well also in this experiment and receiver is able to filter the channel affects and make an accurate data detection.

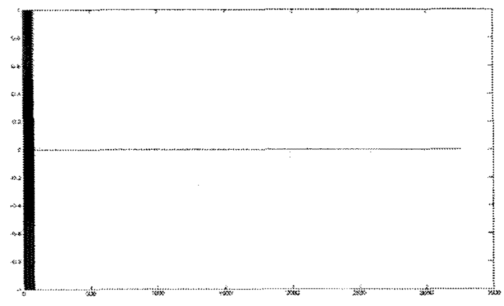

Figure.2. Fundamental acoustic ping for TD protocol.

The main properties of the channel are fast fading channel with random noise, distortion and reflection. [15] This channel has one direct and three multi-paths occurred by reflections in water from transmitter to receiver.

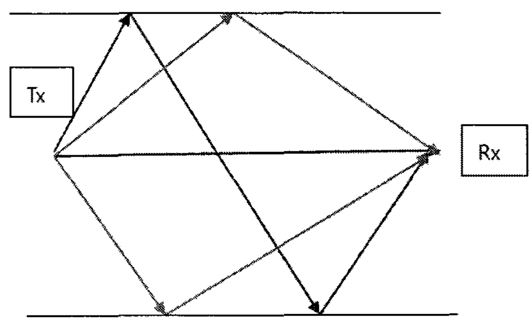

Figure.3. Channel Model for Experiment.

A transmitter and a receiver are at the same depth and 20 meters apart from each other. The distance between surface and transmitter level is 5 meters, and transmitter to bottom is 6 meters. The impulse response of this channel is;

$$h(t) = 0.999\delta(t) + 0.5\delta(t-1.6) + 0.25\delta(t-2.3) + 0.15\delta(t-19.9)$$

where [0.999 , 0.5 , 0.25 , 0.15] are attenuation coefficients and [1.6 , 2.3 , 19.9] are arriving delays of the replicas in terms of msec.

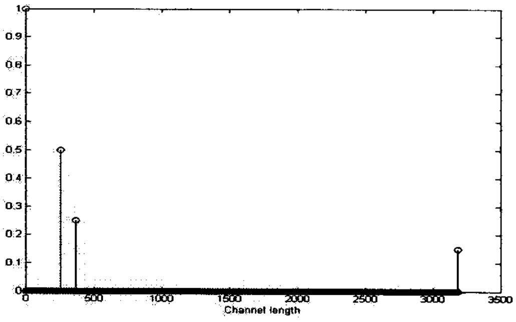

Figure.4. Impulse Response Of Channel.

Figure 4 shows the impulse responses in sample domain since this experiment is made in Matlab and Simulink is sample based rather than time based. The time delays of 1,6msec, 2,3msec and 19,9msec refer to 256, 368 and 3184 samples shift respectively in this experiment. Since the 3rd multipath occurs from two reflections, attenuation coefficient is smaller and time delay is larger than the others. In the figure above, no additive channel noise is displayed but as in all wireless transmissions, this protocol is also distoooed by an additive random noise that is continuous for the total length of the channel. This noise distorts our signal but since our information is kept in the time delays and this noise only effects the amplitude of our acoustic signal, in the recovery of the information no difficulty occurs for us. In this simulation the added noise power is weak compared to carrier signal.

In the detection, we decode the received signal with a threshold control technique and recover the accurate information sent by the transmitter. The additive random noise is as shown in Figure 5.

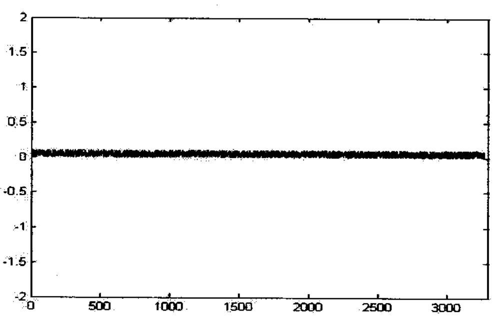

Figure.5. Additive Random Noise of the Channel.

Each data is expressed with 3,267 samples also in ASK and with 8 bits. 7 characters data is sent and transmission will be graphed as below;

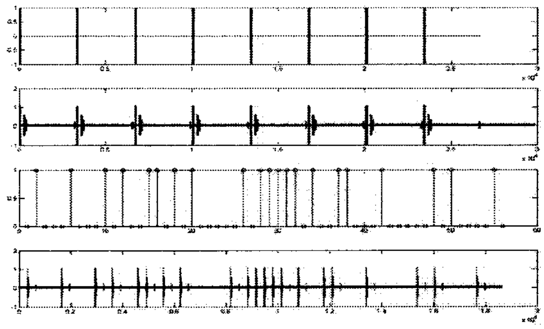

Figure.6. First test of TD protocol in Channel, (a) Data sequence in TD protocol (b) Data transmission with TD (c)Expression of the same data in binary (d) Data transmission with ASK.

The text sent in the figure above is " DSP_LAB". In the 1st plot, the ASCII codes of each letter is added to end of the duration after each ping. So each bar carries the information. One important point here is that since the information is carried on the difference, in order to recover the last data we need a dummy ping at the end to act as reference. In this TD protocol, to obtain N data, N+1 pings has to be sent otherwise last data will be lost. The signals both in ASK and TD are distorted and as it is seen the last replica is far from first two replicas of the ping. The 3rd plot is the binary representation of ASCII values that belongs to sent text. In the 4th plot, ASK modulated signal is shown after channel ,in this experiment each ASK bit is represented by 3276 samples and robust against ISI.

If we look at the length of output sequences it is obviously seen that; the output of TD protocol is 29,852 samples where as the ASK output is around 186,135 samples. When we convert this values to time domain and calculate the speeds, TD is 6.2 times faster than ASK. Next step is to send a data of 300 characters through the same channel.

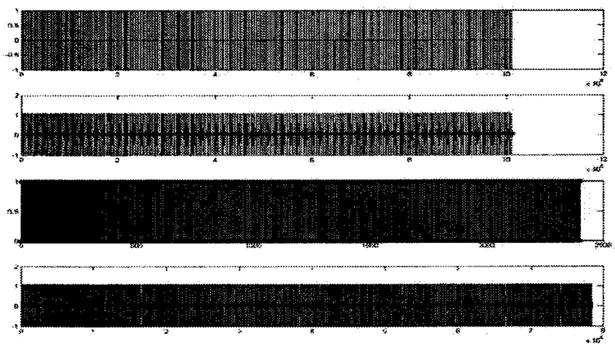

Figure.7. Transmission of long data with TD in Channel (a) Data sequence in TD protocol (b) Data transmission with TD (c)Expression of the same data in binary (d) Data transmission with ASK.

In figure 7, the plots seem dense blue since the sequence is too long and this plots show all the sequence. The speed ratio of this transmission to ASK is around 7.7. Another important point is that this ratio can have a very small change depending on the data content but during this comparison we can ignore it.

III. Effect of Input Length and Content on Transmission speed

Definition of this protocol is given and performances of the protocol in an underwater medium are examined. We could see that TD protocol is robust for multipath condition and much faster than ASK for non-coherent transmission. In other transmission methods, transmission speed is affected by the modulation type and channel characteristics. In this protocol, there are two more additional effects to those listed. These special effects are the length and content of the data.

Effect of Input Content on transmission speed

As it is explained in the introduction, the information is carried between the pings so in other words the receiver does not decode the data from any property or change in the coming signal itself. in tges in the arrival are carrying the information, so a bigger tititiifference between two pings tians the information has bigger value from the view of ASCII code. We also know that every character including latin characters, punctuation marks and numbers have iifferent ASCII codesetex. a=97,)= 41eeso the durations of the transmission sequences thll change the ievery iifferent character. Even thoug ithe amount of information is kept constant, the time spent for transmission of them will change therefore the bit rate will change since the main formula for calculating the bit rate is;

$$\text{Bit rate} = \text{number of sent bits} / \text{total time} \quad (1)$$

To prove this mathematically, characters '!' and '~' which have ASCII values of 33 and 126 respectively are sent through the same channel for some amount. The comparisons are made in two sections such as their speed and their speed ratio against ASK. The results are shown in Table 1,

Table 1. Effect of Input content on Transmission speed

Input Length	Speed of '!'	Speed of '~'
8	312bps	305bps
32	366bps	357bps
64	376bps	366bps

As shown in Table 1, there is big difference in bit rates between the transmission of two different characters. The bit rate for the transmission of '!' is higher than '~' since its ASCII decimal value is smaller than the other one. E.g if we consider 32bits case; the bit rate of '~' is 357bps where as the bit rate of '!' is 366bps. On the other hand, since the length of ASK sequence is constant for a constant number of data length, the ratio of TD over ASK is also changing and TD becomes more beneficial. In figure 8 it is seen that the speed changes rapidly in lower data lengths but the rate of change decreases after long lengths.

Effect of Input Length on transmission speed

Second factor affecting the speed is the length of input. When we send a text of N characters and another text of M characters where N>M , the sequence length of N is longer than M's, so in sample domain there will be more samples and therefore in time domain it will take more time to send. This also affects the ratio of TD to ASK, in longer data, TD protocol is getting more beneficial against ASK. Mathematical expressions are more efficient and helpful to explain this effect. Same equations used in the tests will be used below for the proof.

Let's consider the situation for the modeled channel, we are sending a text with N characters both with TD protocol and ASK, then the speed of TD and ASK can be expressed as;

$$\text{TDspeed} = (Nx8)/((L1x6.25)/1000000) \quad (2)$$

$$\text{ASK speed} = (Nx8)/((L2x6.25)/1000000) \quad (3)$$

where L1 and L2 are the sample sequence lengths of TD and ASK respectively and 6.25 is the time of 1 sample in microseconds. When we add 1 more character to input, in other words N+1 characters are sent then the equation will change to;

$$\text{TD speed} = ((N+1)x8)/((L1+X)x6.25)/1000000) \quad (4)$$

$$\text{ASKspeed} = ((N+1)x8)/((L2+3600)x6.25)/1000000) \quad (5)$$

As it is obviously seen, TD output sequence will increase by the decimal ASCII value of the character where as ASK sequence by 3600 samples since each character is 8 bit and each bit is expressed by 450 samples in this experiment. The range of ASCII values is between 0 and 255 so there is no way that ASK sequence will be same length or shorter than TD's.

$$0 \leq X \leq 255 \qquad (6)$$

Table 2. Effect of Input Length on Speed ratio of TD over ASK

Input Length	TD/ASK for transmission of '!'	TD/ASK for transmission of '~'
8	6.4618	6.3187
32	7.4925	7.2987
64	7.6999	7.4950

Table 2 shows the effect of input length on the ratio between TD protocol and ASK for two different characters "! and ~ '. It is obviously seen that with the increasing input length, the performance difference is also increasing. The rate increases from 6.4 to 7.6 while the text length increases from 8 to 64 for the character '!' which has a decimal value of 33 in ASCII code. On the other hand for the character '~', it increases from 6.3 to 7.5 since its decimal ASCII value is 126.

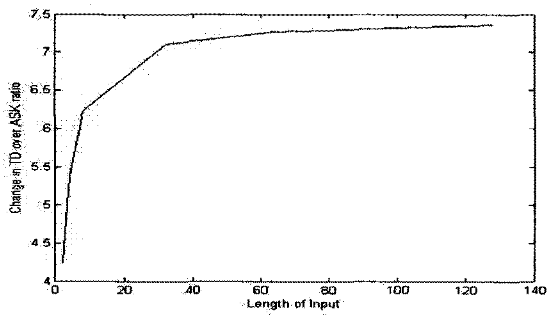

Figure.8. Change in TD over ASK ratio against Input Length.

Figure 8 shows the relation between TD-ASK ratio and input length. The rate of change is higher in short length data such as 2-32 and for the data with longer length the rate of change is lower. It is because, by adding more characters, the sample sequence is getting longer. After some number of addition, the current length is relatively much longer than the addition so that the addition can not affect the current one much but in the lower lengths of input, since the sequence length and addition lengths are close to each other, effect of it is much bigger.

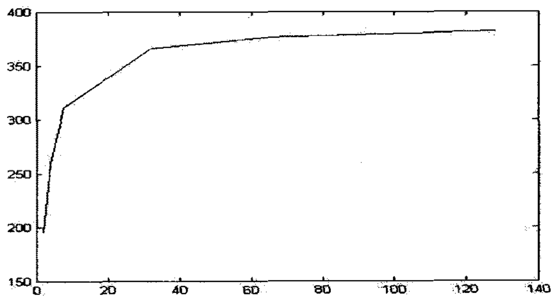

Figure.9. Change in Bit Rate against Input Length.

Figure 9 shows the relation between bit rate with input length. As it is seen, as the data length increases there is an obvious increase in bit rate. On the other hand, the amount of increase is decreasing as the bit length increases.

IV. Conclusions

According to calculations, a much higher transmission speed was found compared to ASK in every level of bit length and different types of data. An underwater channel was modeled in Matlab and text information was sent through this channel and decoded in the receiver. The performances were evaluated in 2 ways; first one is the speed of TD protocol and second one is its speed ratio to ASK. The same data was also sent by ASK and results were compared. In the results, there are huge gaps between the numbers of TD protocol and ASK. Moreover, some other tests are done to show the factors affecting the speed of this protocol such as data length and data content. Tests showed that TD protocols bit rate is changeable depending on the content of the information. Second factor is the length of input. When we send more bits at the same time, the transmission speed increases in TD protocol. So, we can see that TD is more beneficial during the transmission of longer information. These studies proved that TD idea is better and easy to implement. In the future, we will implement a real time system with DSPs.

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Byung-Woo Yoon received the B.S. , M.S. and Ph.D. degrees in electronic engineering from Busan National University in 1987, 1989, and 1992, respectively.

He worked for ETRI from 1993 to 1995. He is currently a professor in Department of Electronic Engineering.
His research interests include the areas of VLSI design, underwater acoustic communication.

Mustafa Eren Yıldırım received the B.S. degree from Bahcesehir University in Turkey, M.S. degree in Electrical Engineering from Kyungsung University in 2010.

He is currently working towards Ph. D. degree on Electrical Engineering.
His research interests include the areas of VLSI design, underwater acoustic communication.