Underwater Live Video Streaming Experiment Using Radio Frequency Communication for AUVs

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Abstract

Autonomous Underwater Vehicles (AUVs) require long-distance communication, especially in the deep sea. Radiofrequency (RF) communication provides a high data rate. However, electromagnetic wave is seriously limited by high attenuation in the water medium. In this study, we investigate Radiofrequency communication in seawater. The experiment results show the effects of the distance between the transmitter and receiver, and the stability of the antennas. We achieved HD video transmission with 25fps.

Keywords: AUV, Rf communication, Network.

1. Introduction

Developing Autonomous vehicles for underwater applications is an important topic in many sectors such as the exploration of marine resources, surveying seabed topography, and military applications [1].

The biggest challenge that faces researchers when developing AUVs is communication [2]. there are three main technologies used in underwater communication:

(i) Acoustics communication: this is the most common and used technology for underwater communication because it can provide long-distance propagation which can be in tens of kilometers. The major drawback of this technology is the latency in communication since the transmission baud rate is only up to several kilobits per second (kbps) [3].

(ii) Wireless Optical communication: by using wireless optical communication we can achieve a data rate of hundreds of Megabits per second (Mbps) with a distance of tens of meters, this is considered the best technology for a high data rate. However, the Line of

Sight (LOS) and the difficulty of aligning the transmitter and receiver are the disadvantages of this technology [4].

(iii) Radio Frequency (RF) communication: This technology provides a high data rate with less than 10 Mbps [5], but it is restricted by the high attenuation over a short distance.

In this study, we investigate the transmission speed of radio wave communication in seawater as well as analyze the underwater video framerate.

2. Experiment Setup and Design

2.1. *Experimental setup*

We used in this study for a stationary base station antenna a regular octagonal-shaped antenna with a diameter of 2m. And a rectangular antenna of 0.8 m by 0.5 m mounted on the AUV. The base antenna was mounted in the center of a pool with a size of (5.5m × 5.5m × 4.8m) as width, length, and depth respectively. Since the salinity of the water affected the conductivity, affected the connection as well, the experiment was conducted in seawater. Figure 1 illustrates the concept of the experiment.

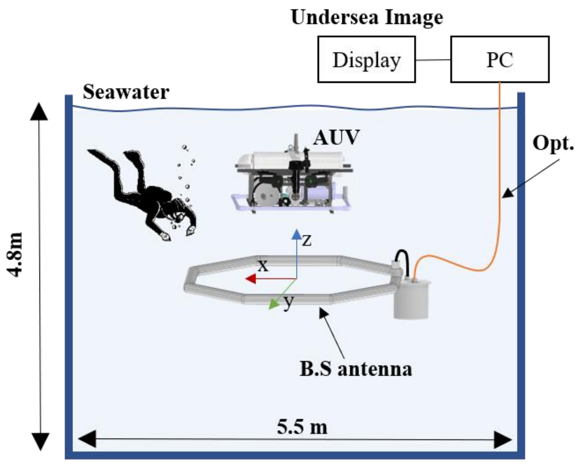

Fig. 1. Experimental design concept.

The communication speed has been measured with different distances horizontal and vertical between the two antennas with the origin of the center of the base station antenna.

The AUV used in this study is called Darya Bird. It is an Autonomous Underwater Vehicle developed by a number of graduate students at Kyushu Institute of Technology [6]. The Robot consists of several high-pressure resistance hulls, they are connected using a T-slot frame designed in a way to easily add and remove components on demand. Figure 2 shows the AUV Darya Bird.

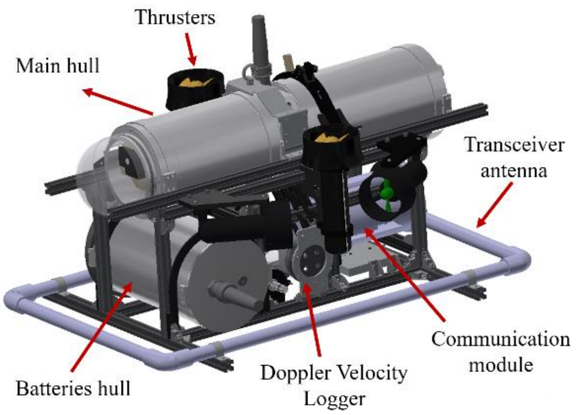

Fig. 2. The AUV used in the experiment (Darya Bird).

IP network camera used for video capturing. We used a Power over Ethernet (PoE) ejector to provide a 12 V PoE connection for the camera and the communication model. And we connect all to a LAN hub. The Ground PC was connected to the base antenna by an optical fiber cable, in addition, we used a wired optical connection to connect the AUV to the reference PC in order to capture the same streaming video. The reference video is used for the porpuse of comparison with the one taken by the wireless connection. The layout connection is shown in Figure 3.

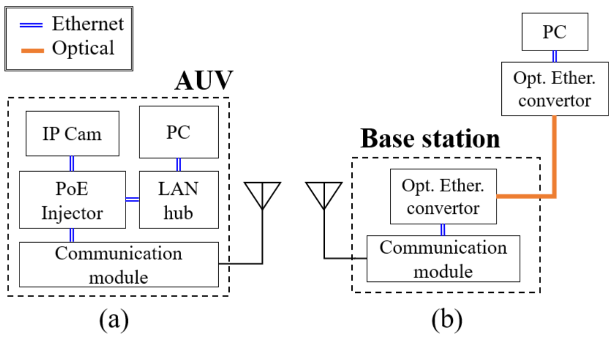

Fig. 3. The layout connection (a) the connection inside the AUV, (b) the connection between the ground PC and the stationary antenna

Table 1 illustrate the camera setup parameters.

Table 1. The network camera setup parameter.

Parameter	Value
Resolution	1028 × 720
Frame rate	25 fps
Codec	H264

2.2. *Experiment design*

The measurement of the transmission speed was conducted in different placements of the AUV.
First, we place the center of the AUV with the center of the stationary antenna, then we moved the AUV along the z-axis (starting from the z=0 which is the depth of 2.4m) and measure the signal.Then we move horezental on the x-axis, afterward, we repeat moving on z-axis.
The Wavelet OFDM System is used with 2 to 28 MHz for the standard mode with a symbol length of 8.192 us.

3. Results and Discussion

The results of this study are divided into two parts:

3.1. *Transmission rate*

Table 2 illustrates the transmission rate of UDP and TCP. The transmission rate is higher when x=z=0, and goes lower when we moved on the z-axis far from the base antenna.

Table 2. The transmission rate of UDP and TCP.

x [m]	z [m]	UDP [Mbps]	TCP [Mbps]
0	0	6.8	4.7
0	1	4.8	3.3
0	1.65	0	0
1	0	6.8	4.5
1	1	0.4	1.7
1	1.2	0	0
2	0	6.5	4.6
2	1	0	0

As it is clear that the transmission rate in UDP is 6.8 Mbps at the center (x=z=0). This rate is higher than the TCP mode which is 4.7 Mbps.
It can be noticed that we could achieve communication even when the AUV was moved far from the base antenna on the x-axis.

3.2. *Video streaming framerate*

The video streaming was taken in two scenarios:

3.2.1. *The AUV is placed in x=0m, and z=0.5m*

During this experiment, a diver jumped into the pool and swam in front of the AUV to see the smoothness of the obtained video. The receiving video using the wireless channel was compared with a video has been obtained by the wired optical connection.
Figure 4 illustrates the framerate of the received videos when z=0.5m.

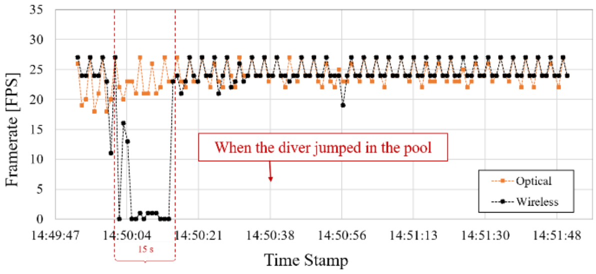

Fig. 4. The framerate of the received videos when z=0.5m.

It can be seen that the framerate decreased drastically to 0 fps for 15 sec when the diver jumped into the pool. While the rest of the framerate was stable with an average of 25 fps which is the same as the obtained one by wired connection, as well as the same as the camera's basic setting.

3.2.2. *The AUV is placed in x=0m, and z=1m*

In this experiment, the diver has jumped once again into the pool since the jumping has an effect on the received framerate. Figure 5 illustrates the framerate of the received video when z=1m.

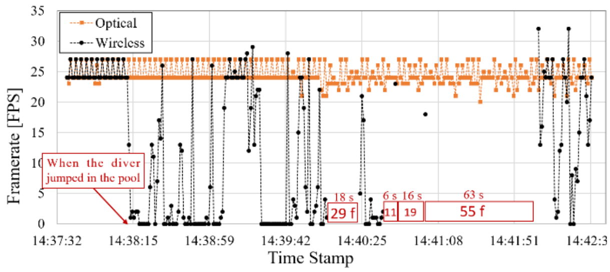

Fig. 5. The framerate of the received videos when z=1m.

In this scenario, the framerate has decreased drastically to 0 fps for about 10 seconds, however, the unstable connection continued for the rest of the video with a very bad connection in two parts: 29 frames in 18 seconds and 85 frames in 85 seconds.

Figure 6 shows snapshots from the received videos when z=1m. In the figure, we compare randomly obtained frames in both videos (wireless and wired).

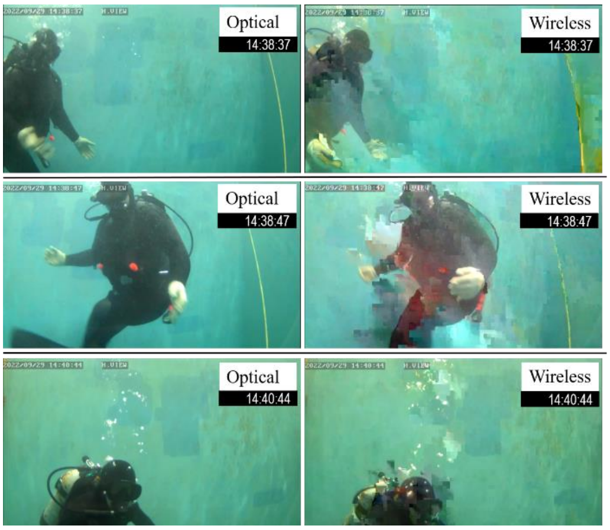

Fig. 6. Snapshots from the received videos when z=1m.

We noticed that even though the video streaming quality was not smooth, the snapshots of the same timestamp provide the same frame (the diver's position and his gesture are the same). However, two frames showed different timestamps for the same frame as shown in Figure 7.

Fig. 7. Snapshots from the received videos when z=1m (Mismatch timestamp).

The reason for the missed frames can be attributed to two points:

(i) The instability of the antenna: when the diver jumped into the pool, he caused a strong vibration in the base antenna and the AUV. in the first scenario (z=0.5) this vibration continued for about 15 seconds which caused framerate =0 fps. While in the second scenario, where the distance between the two antennas was 1 meter, which made the slight vibration of the antenna effects strongly the signal. And we noticed from the underwater monitoring video that the diver hit the rope which fix the base antenna, which made more vibration in the base antenna.

(ii) The bubbles caused by the diver: when the diver jumped into the pool, a huge amount of bubbles were generated. These bubbles made additional attenuation of the non-line-of-sight signals.

4. Conclusion

This study introduced an experimental study of underwater live video streaming for AUVs applications. Loop antennas were used, stationary antenna and one mounted on the AUV. We achieved HD video streaming with 25fps on average within a distance of 1 meter.
Further experiments are needed to confirm the effects of bubbles as well as the maximum distance to obtain stable streaming.

Acknowledgments

This study was part of commissioned research (No.02301) by National Institute of Information and Communications Technology (NICT), Japan.

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