

# A Combined Radio and Underwater Wireless Optical Communication System based on Buoys

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**Abstract.** We propose a system of combining radio and underwater wireless optical communication based on buoys for real-time image and video transmission between underwater vehicles and the base station on the shore. We analysis how the BER performance is affected by the link distance and the deflection angle of the light source using Monte Carlo simulation.

## 1. Introduction

With the rapid development of modern information technology and communication technology, communication systems are increasingly improved in many industries. However, the communication technology in underwater environments is still in a lower level. People are always confused about the underwater detection, control and communication. For example, if fishermen cannot get the information of fish resources and other underwater situation after overfishing, natural disasters or environmental pollution timely, there is no doubt that it will have a strong impact on the trading market of fisheries.

So how to monitor the underwater environment, collect underwater information, and transmit information to the shore is a serious problem to solve. As we all know that underwater vehicles transmit data to boats mainly by means of underwater acoustic communication which has low data rate and large time delay. And the collected data is saved to the memory and then analyzed on the shore. This method seriously restricts the development of large-scale, high-efficiency underwater operation.

In order to make up for the shortage of the method as mentioned above, we propose the scheme of combining radio and underwater wireless optical communication system based on buoys for real-time image, and video transmission between underwater vehicles and the base station on the shore.

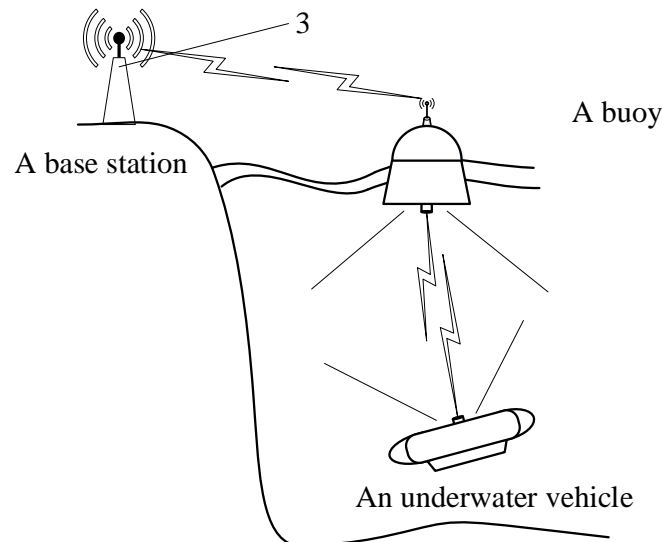
Compared with acoustic technology, optical technology has the advantages of high bandwidth, cost-effectiveness and low-energy consumption [1-2]. Furthermore, long lifetime, low power consumption and high efficiency are the prominent advantages of light emitting diodes (LEDs) as light sources of underwater wireless optical communication systems [3-4]. Blue and green light with the



outstanding advantages of low absorption loss and strong anti-interference ability is as preferred option.

## 2. System Description

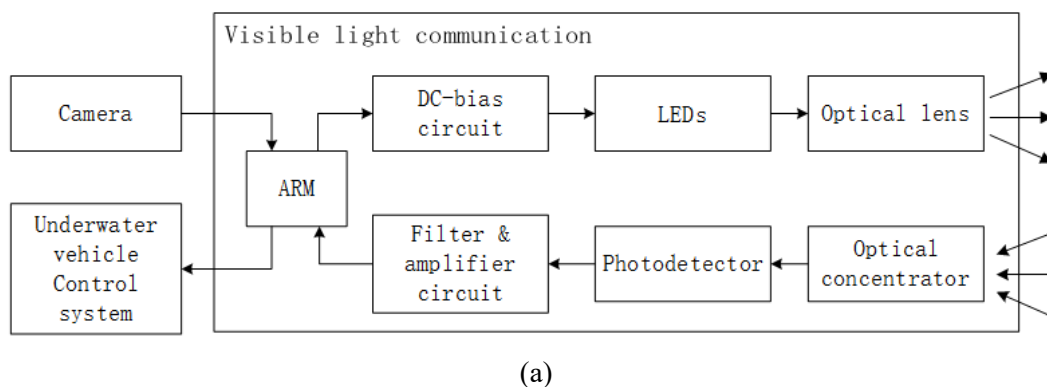
The schematic diagram of our proposed scheme employing combined radio and underwater wireless optical communication system between underwater vehicles and base stations on the shore is shown in figure.1. The whole system mainly consists of a base station on the shore, a buoy on the sea and an underwater vehicle.

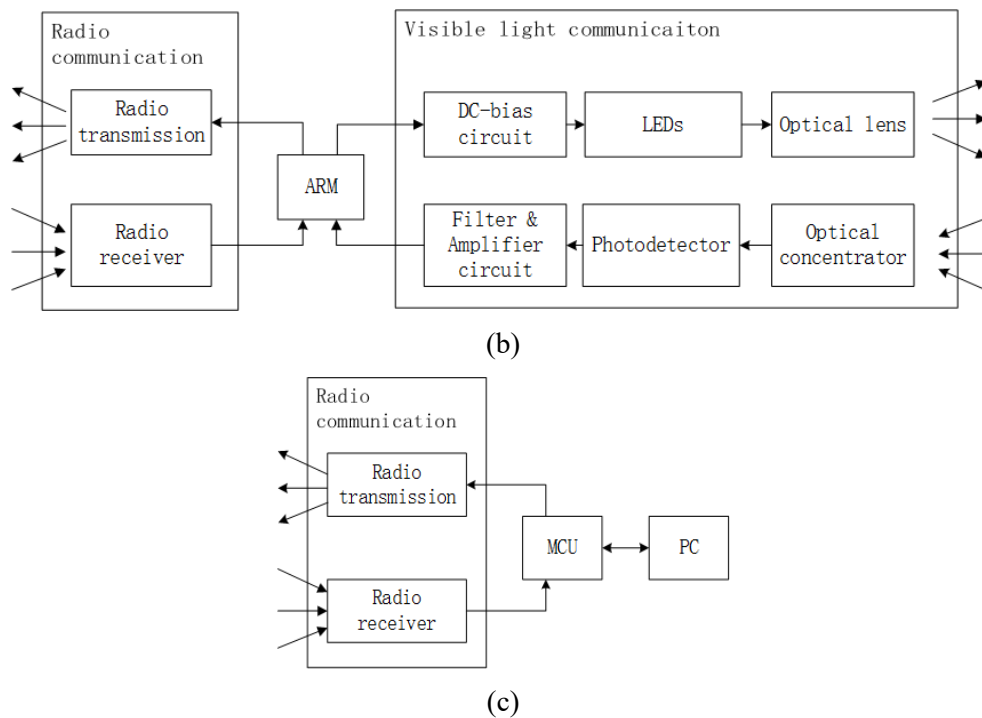


**Figure 1.** The schematic diagram of a combined radio and underwater wireless optical communication system based on buoys.

Underwater wireless optical communication is used to complete the transmission of image or video data and control signals between underwater vehicles and buoys. Radio communication is used for the transmission of signals between buoys and base stations. A main control unit equipped at the bottom of a buoy is utilized to process the light signal of visible light communication and radio communication.

Figure.2 (a), (b) and (c) show the principle diagram of the optical transmitter and receiver on the underwater vehicle, the buoy and the base station respectively.





**Figure 2.** The principle diagram of the optical transmitter and receiver on: (a) the underwater vehicle, (b) the buoy, (c) the base station.

For uplink transmission, underwater information is collected by a camera carried on an underwater vehicle and captured by the ARM. The signal is modulated to LEDs by utilizing a bias-tee (BT). After emitted from LEDs, the light is diverged, launched into optical lens, transmitted in seawater, fed into the optical concentrator of a buoy, and focused on the high bandwidth photodetector. Through filtering and amplifying, the signal is sent to the ARM. Then the signal is transmitted to the base station on the shore by means of radio, demodulated and transmitted to the PC.

For downlink transmission, the base station on the shore sends the control signal through the reverse link to monitor the position of buoys and control the operation of the underwater vehicle.

### 3. Simulation and Results Discussion

In this simulation, we consider comprehensive modeling of the underwater optical communication channel based on the Monte Carlo simulation method, and we only simulate the situation that the buoy was the transmitter and the underwater vehicle was the receiver. Monte Carlo approach firstly generates numerous photon, and then simulates the interactions between each photon and the medium in the seawater [5]. Finally, the light intensity distribution at the receiver and the BER is calculated.

**Table 1.** Parameters in the simulation

Parameters	Value
$\lambda$	532nm
$P$	1W
$\omega$	20°
$a(\lambda)$	0.069
$b(\lambda)$	0.08
$c(\lambda)$	0.15
$\theta$	180°
$d$	20cm

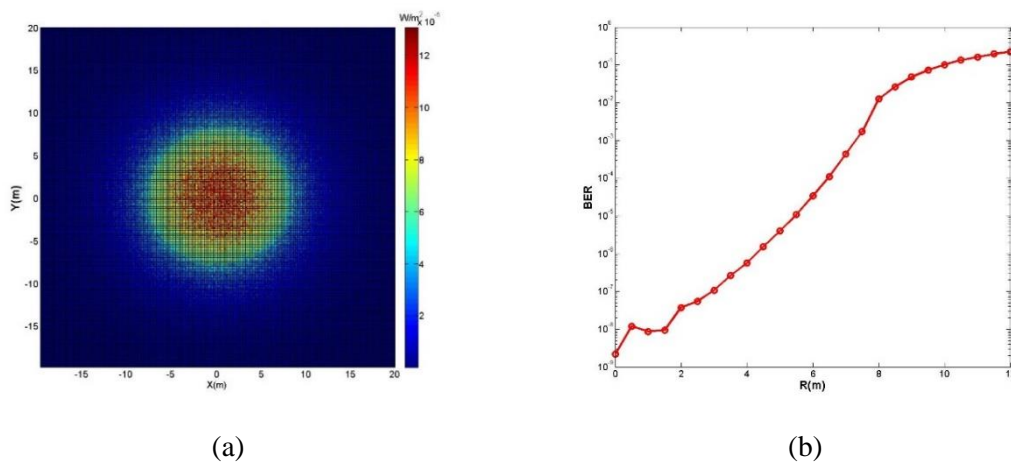
The main parameters which are taken into consideration in our Monte Carlo simulation are displayed in Table 1. The characteristic of the transmitter includes the beam wavelength  $\lambda$ , the optical power  $P$ , and the divergence angle of the light source  $\omega$ .

Absorption and scattering are the two main factors affecting light propagation in the seawater. These two effects are characterized by absorption coefficient  $a(\lambda)$  and scattering coefficient  $b(\lambda)$ , and the summation of them is defined as extinction coefficient  $c(\lambda)$ .

The characteristic of the receiver contains field-of-view angle  $\theta$  and aperture size  $d$ .

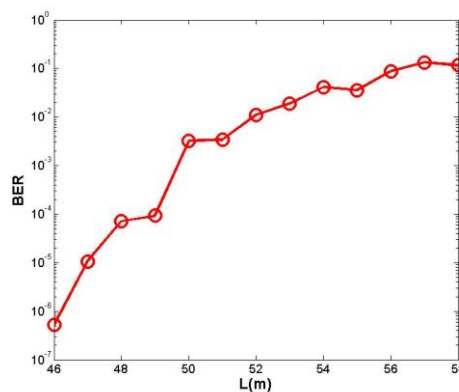
BER can be calculated by SNR considering OOK modulation. In the simulation, we consider that how the BER performance is affected by the link distance and the deflection angle of the light source.

To begin with, the underwater vehicle is right under the buoy, and the vertical length of the communication link is 45m and the light source has no deflection angle. Figure.3 (a) is the light intensity distribution at the receiver, and figure.3 (b) is the BER distribution of different distance from the center of the light spot. It shows that if the horizontal distance between the center of the light spot and receiver is less than 7.5m, the BER will be below the FEC limit ( $2 \times 10^{-3}$ ).



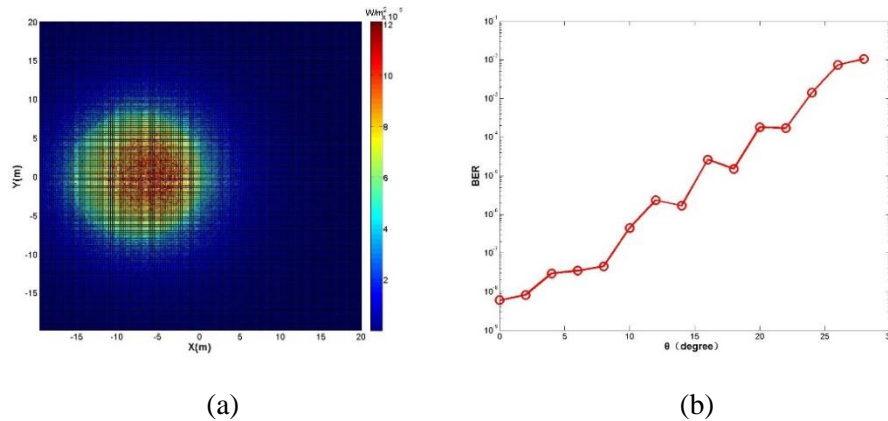
**Figure 3.** The vertical length of the communication link is 45m and the light source has no deflection angle. (a) The light intensity distribution at the receiver. (b) The BER distribution of different distance from the center of the light spot.

Then we only change the vertical distance between the buoy and the underwater vehicle from 46m to 58m. The result is displayed in figure.4, which shows that the maximum effective distance of communication can be 49.8m with the FEC coding.



**Figure 4.** The BER distribution of the light spot center when the vertical length of the communication link is changed and light source has no deflection angle

In the end, we keep the vertical distance at 45m and change the deflection angle of the light source. Figure 5(a) is the light intensity distribution at the receiver when the deflection angle is  $10^\circ$ . Figure 5(b) illustrates that the maximum deflection angle of the light source can be  $24^\circ$  with the FEC coding. And the communication system can overcome the impact of wave by adjusting the position of the underwater vehicle.



**Figure 5.** The vertical length of the communication link is 45m (a) the light intensity distribution at the receiver when deflection angle of the light source is  $10^\circ$  (b) the BER distribution of the center of the light spot when the deflection angle is changed.

#### 4. Conclusions and Future Work

The combined radio and optical communication system based on buoys has been proposed in this paper. We analyze that how the BER performance is affected by the link distance and the deflection angle of the light source, and verify the feasibility of this communication system using Monte Carlo simulation method.

Building a mathematical mode, manufacturing a product prototype, and testing in an underwater environment are the next steps that we have to complete.

#### References

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