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Airborne Wireless Optical Communication System in Low Altitude Using an Unmanned Aerial Vehicle and LEDs

Meiwei Kong[1], Zheng Tong[2], Xiangyu Yu[1], Yuhang Song[1], Aobo Lin[1], Jing Xu[1,*]
[1] Department of Ocean Engineering, Ocean College, Zhejiang University, Yuhangtang Road 866, Hangzhou, Zhejiang, 310058 P.R. China
[2] Department of Petroleum Equipment, RIPED, PetroChina, No.20, Xueyuan Avenue, Haidian District, Beijing, 100083 P.R.China

E-mail: jxu-optics@zju.edu.cn

Abstract. In this paper, we demonstrate the feasibility of airborne wireless optical communication system using an unmanned aerial vehicle and LEDs. Monte Carlo simulation method is used to evaluate the performance of the communication channel. Considering OOK modulation, we illustrate how the BER performance is affected by the link distance, the divergence angel and the deflection angel of the light source.

1. Introduction

Ships, planes and satellites are three traditional platforms that can be used to implement data transmission with underwater equipment, such as unmanned underwater vehicles, submarines, underwater wireless sensor networks. However, shipborne and airborne communications spend a lot of manpower, material and financial resources and are inconvenience in bad weather. And satellite borne communication needs a relatively long period to obtain information, which seriously affects the efficiency of communication especially in the case of an emergency. With the advantages of convenience, cost-efficiency, and good motoring performance, an unmanned aerial vehicle system, including platform system, information collection system and ground control system, has been a new developing momentum. At present, unmanned aerial vehicles are mainly utilized to implement the collection of high-resolution images. There are almost no reports about unmanned aerial vehicles used for optical wireless communications with an underwater target.

Acoustic communication is the dominant method for underwater communication. However, it has some obvious disadvantages, such as large time delay, limited bandwidth, and high energy consumption. In order to make up for the deficiency as mentioned above, underwater wireless optical communication is becoming an increasingly popular alternative.

Light emitting diodes (LEDs), taking advantages of low cost, high efficiency[1], low attenuation in the 400nm-550nm range [2], and high data rates (up to 1 Gbps over a few meters) in seawater, are used as light sources for the proposed wireless optical communication system.

Based on lots of theoretical study, we proposed the airborne wireless optical communication system in low altitude using an unmanned aerial vehicle and LEDs which allows the transmission of real-time data, images and videos.

2. System Description

Figure.1 shows the schematic diagram of airborne wireless optical communication system in low altitude using an unmanned aerial vehicle and LEDs. Unmanned aerial vehicles and underwater vehicles are two important components of the system and both of them are equipped with wireless optical communication system.

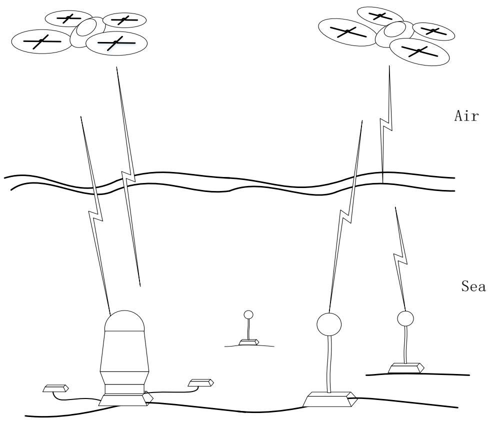
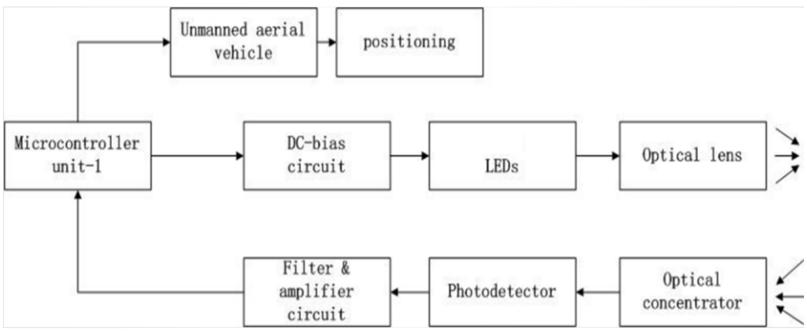
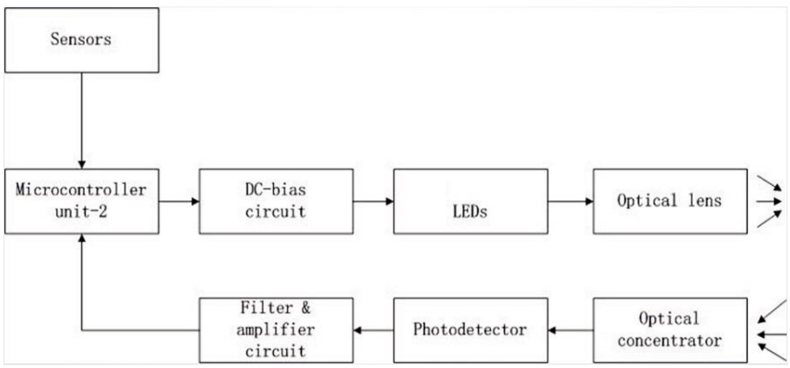


Figure.1. The schematic diagram of airborne wireless optical communication system in low altitude using an unmanned aerial vehicle and LEDs.

The principle diagram of the optical transmitter and receiver on the unmanned aerial vehicle and the underwater vehicles are presented in Figure.2 (a) and (b), respectively.



(a)



(b)

Figure.2. The principle diagram of the optical transmitter and receiver on: (a) the unmanned aerial vehicle (b) the underwater vehicles.

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The aircraft through the positioning and navigation technologies detects underwater vehicles mounted at the fixed position. Light beam of LEDs, with bigger divergence angle and higher peak power, is launched into the first convex lens. When scanning certain area of the sea surface, a request signal is first sent to underwater vehicles.

Along with the background light of sky, light pulse beam is received by the optical detector, suffering from the attenuation of different depth and mass of sea water. In order to improve the sensitivity of the detector, we apply the diversity reception technology of multiple detectors. Meanwhile a filter is adopted to suppress the fluorescence in the sea and the residual background light of sky. Amplifier circuit is used to amplify the signal and further improve the signal noise ratio (SNR) at the receiver.

When receiving the request signal, underwater vehicles begin to send data to implement the function of uplink transmission.

3. Simulation and discussions

In this work, we use the Monte Carlo approach to simulate the wireless optical communication channel considering on–off-keying (OOK) modulation. We take into account different system parameters such as the water type (T) , absorption coefficient (a), scattering coefficient (b), extinction coefficient (c), beam wavelength (λ), optical power (P), field-of-view (FOV) angel (ψ) of the detector, bandwidth (B) of the detector and aperture size (d) of the detector, the vertical distance between the unmanned aerial vehicle and the sea level(H_1) , the vertical distance between the underwater vehicles and the sea level(H_2) , which are shown in Table1. What's more, we use the Henyey–Greenstein (HG) model for photon scattering, and bit-error-rate (BER) is obtained from the SNR.

Table1. The parameters in the simulation

Parameters	Value
T	Coastal water
a	0.069
b	0.08
c	0.15
λ	532nm
P	1W
ψ	180°
d	20cm
B	250MHz
H1	20m
H2	50m

Figure.3 (a) and (b) show the light intensity distribution at the receiver when the underwater vehicle can align with the unmanned aerial vehicle and the divergence angle of the light source are 10°and 20° respectively. With the increase of the divergence angle of the light source, the light intensity at the receiver becomes weak. Furthermore, we use the BER to demonstrate how the divergence angle of the light source affects the communication quality. Figure.4 displays the BER distribution of the center of the light spot when the light has different divergence angles. We can see if the divergence angle is less than 15.2°, the BER will be lower than the FEC limit ($2x10^{-3}$). Figure.5 is the BER distribution of different distance from the center of the light spot when the underwater vehicle cannot align with the plane and the divergence angle is 11°. If the horizontal distance between the center of the light spot and the receiver is less than 3.25m, the BER will be lower than the FEC limit.

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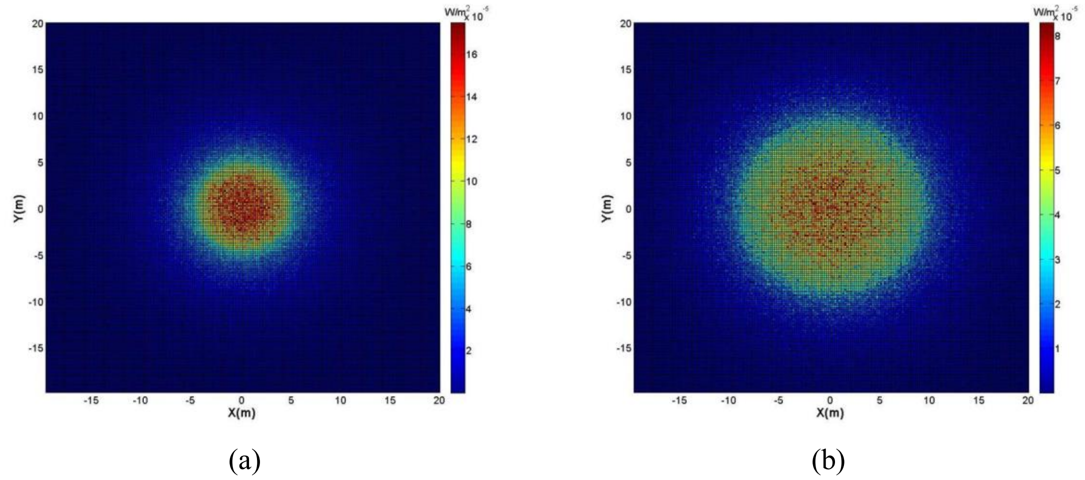

Figure.3. The light intensity distribution at the receiver: (a) the divergence angle of the light source is 10° (b) the divergence angle of the light source is 20°.

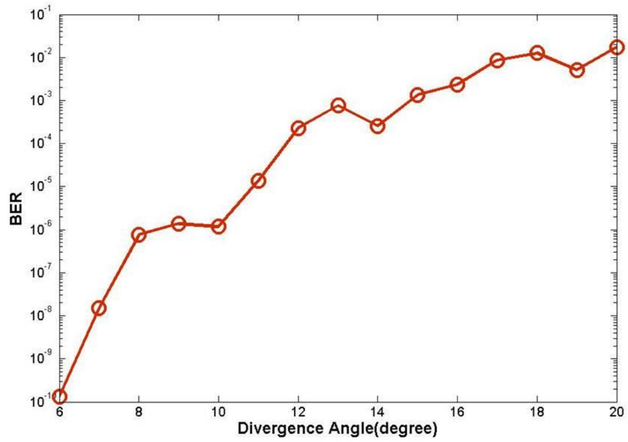

Figure.4. The BER distribution of the center of the light spot when the light has different divergence angles.

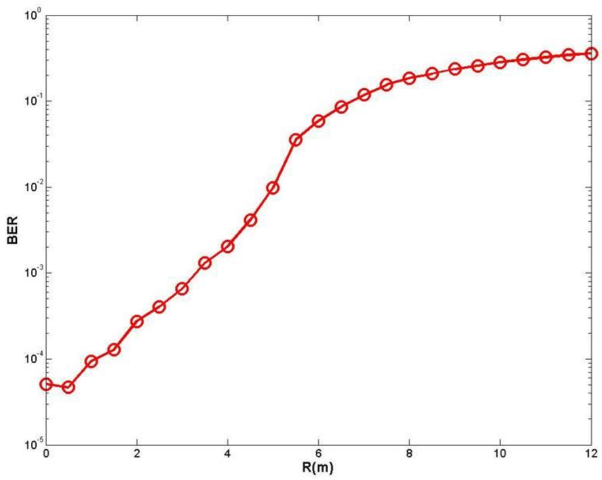

Figure.5. The BER distribution of different distance from the center of the light spot when the underwater vehicle cannot align with the unmanned aerial vehicle.

Figure.6 illustrates the BER distribution of the center of the light spot when the underwater vehicle cannot align with the unmanned aerial vehicle, the divergence angle is 11° and the light source has different deflection angle. If the deflection angel is less than 18°, the BER will be lower than the FEC limit.

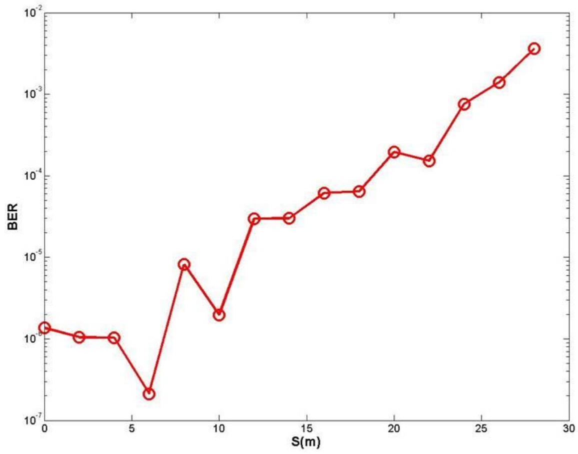

Figure.6. The BER distribution of the center of the light spot when the underwater vehicle cannot align with the unmanned aerial vehicle and the light source has different deflection angle.

Figure.7 is the BER distribution of the center of the light spot when the unmanned aerial vehicle is at different height and the divergence angle of the light source is 11°. If the height is less than 31m, the BER will be lower than the FEC limit.

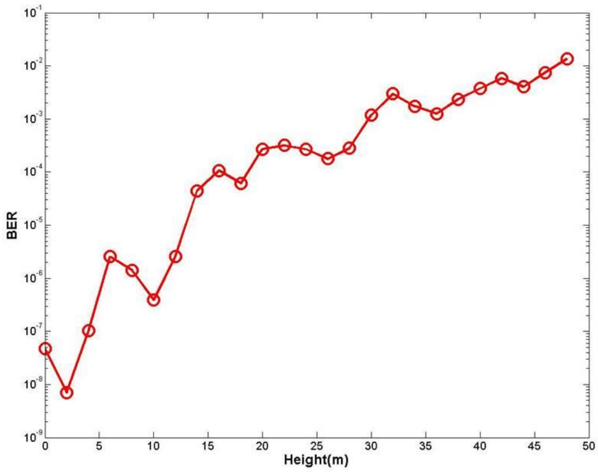

Figure.7. The BER distribution of the center of the light spot when the unmanned aerial vehicle is at different height and the divergence angle of the light source is 11°.

4. Conclusions and Future Work

In this paper, we have theoretically investigated the feasibility of airborne wireless optical communication system in low altitude using an unmanned aerial vehicle and LEDs and proposed the experimental scheme. Using Monte Carlo simulation method, we illustrate how the BER performance is affected by the link distance, the divergence angel and the deflection angel of the light source.

Building a mathematical mode, manufacturing product prototype, and testing in an underwater environment is the following work in the near future.

References

[1] Simpson J A 2008 A 1 Mbps underwater communications system using LEDs and photodiodes with signal processing capability (North Carolina State University Press)

[2] Chancey M A 2005 Short range underwater optical communication links (North Carolina State University Press)

Acknowledgments

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