# The Air Bubbles Effect for Underwater Optical Wireless Communication Using 650 nm Wavelength

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***ABSTRACT–*** *In this research, texts were sent by pulse width modulation (PWM) in the channel of clean water using Arduino hardware and software for an underwater wireless optical communication system (UWOC). The air bubbles device utilized the disturbance at different distances from the transmitter source within the channel of clean water. The total length of the channel is (1) m. In this study, the source of transmitter wavelengths 650 nm was used with the power of 80mw. The results showed that the received power was 32 mW in the clean water, while when air bubbles pump within the channel of clean water at 0.2m, 0.5m and 0.8m away from the transmitter source, the received power was 28 mW, 27.5 mW, and 27 mW respectively. This paper shows that max. Signal to Noise Ratio (S/N) and min. attenuation (α) in the clean water were (24.637dB) and (3.979dB/m) respectively. The practical results showed that the Symbol Error Rate (SER) in the case of the air bubbles pump was maximum (0.03) when the value of (S/N) was minimum (23.899).*

***Keywords***- *Underwater wireless Optical Communication System (UWOC), Signal to Noise Ratio (S/N), Attenuation (α), Symbol Error Rate (SER), (PWM) pulse width modulation.*

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## 1. Introduction

Underwater wireless optical communication (UWOC) has been presented as a good substitutional technology for underwater communication with high data rates over transmission spans that is relatively medium [1–3]. The rapid emergence of UWOC resulted from laser diodes (LDs) and high-performing visible LEDs that have the smallest attenuation in seawater [4,5]. In UWOC links, factors as absorption, scattering, and turbulence mainly degrade system performance. In the absorption process, the energy of photons is lost because of the interacting water molecules and else particulates with the light. The absorption by water is evident, however; it is important to find that absorption due to various dissolved particles, which are of variable concentration. The spectral absorption of water is a combination of the absorption by pure seawater, phytoplankton, Colored Dissolved Organic Matter (CDOM), and detritus [5].

$$a(\lambda) = a_w(\lambda) + a_{chl}(\lambda) + a_{CDOM}(\lambda) + a_{\det ritus}(\lambda) \quad (1)$$

The process of directing the photons of light out of the initial path after their interaction with air bubbles and particles in water is referred to as scattering. Rain and breaking surface waves mainly generate air bubbles in the oceans [6]. Most of the time, they have the spherical shape in the water. When the optical signal transmits through a bubbly underwater channel, the amplitude of a given signal occurs a distortion according to refraction and reflection at the water-bubble interface by which the light is strayed into different directions. Thus, air bubbles presence in water shows an apparent effect on the scattering properties of the water body.

Underwater optical turbulence (UOT) refers to the random refractive index differences that impact on the beam as it moves through a column of water. The index heterogeneity can be according to density changes, salinity, or localized temperature in water [6]. In the last few years, research on UWOC has witnessed a considerable improvement in both theoretical and experimental levels. However, the main focus of many relevant studies was on the influences of scattering and absorption by particles on the optical channel [7–10], demonstrations and system-level design [11–14], and underwater turbulence [15–17], and there are a small number of studies that focus on the UWOC channels will be affected by the air bubbles [18].

## 2. Background and Theory

As known, rain and breaking surface waves are the main reason for air bubbles in the oceans [19].

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As reported by several authors, they exist with diverse sizes, and in most cases, they have a spherical shape in water [20–22]. Many oceanographic processes are carried out with the help of air bubbles, for example, propagation and scattering of acoustic waves [23], bacteria transport, and organic-particle formation [24]. When the path of an optical signal is through an underwater channel that contains bubbles, the amplitude of a given signal is distorted as a result of refraction and reflection at the interfaces of bubble and water that strays light into different directions. The properties of the scattering of the water body are profoundly affected by the air bubbles.

The relation of signal power to the noise power is referred to as the signal to noise ratio (SNR). It has calculated in terms of voltages or powers [25]. In order to calculate it in terms of powers, the equation below is used [26].

$$SNR = 10\log_{10}\left[\frac{P_S}{P_n}\right] \qquad (2)$$

Where $P_s$ is the average symbol power while $P_n$ is the average noise power.

The coefficient of beam attenuation, α (λ), is a measure of the decay of the un scattered light and can be expressed the Beer–Lambert law as [27]:

$$P_R(\lambda) = P_T e^{-\alpha(\lambda) r} \qquad (3)$$

Where $P_T$ (λ) is the transmitted optical power, $P_R$ (λ) is the received optical power, and r is the path length in the water. The following expression can determine the transmittance of an underwater beam [27]:

$$T(\lambda) = \frac{P_R(\lambda)}{P_T(\lambda)}$$

(4)

For that reason, *α(λ)*, using the units of $m^{-1}$, or nepers, and can be written in terms of the transmittance as [27]:

$$\alpha(\lambda) = \frac{1}{r}\ln\frac{1}{T(\lambda)} \qquad (5)$$

Where α(λ) varies with water temperature and depth. Then, the corresponding expression will be [27]:

$$\alpha(\lambda) = \frac{1}{r(m)} 10\log_{10}\frac{P_T}{P_R} \qquad (6)$$

The equation of symbol error rate (SER) is as illustrated in eq.6 [28]:

$$SER = \frac{total\ number\ of\ error\ symbol}{total\ number\ of\ received\ symbol} \qquad (7)$$

## 3. Experimental Setup

The experimental setup of the underwater wireless optical communication system is based on pulse width modulation (PWM). The texts are written by the computer and converted to a digital signal sent from the computer to Arduino (DAC) in the transmitter side which controls the pulse width of the sent texts, Pulse width depends on the type and number of text characters, These texts were sent through the water channel between the transmitter and the receiver which contains clean water and air bubbles pump. The receiver side contains the photoresist o to detect the laser signal and to Arduino (ADC) as a demodulator and from it to another computer to show the texts, the schematic diagram of UWOC is shown in Figure1.

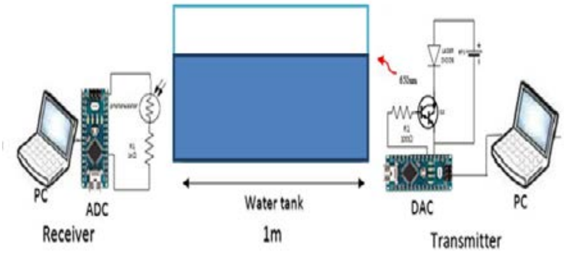



**Figure 1: Schematic diagram of the UWOC system.**

UWOC consists of many parts, as follow:

1. UWOC Transmitter which consists of:

a) Laser diode 650um wavelength with a power of 80mW and operating at a voltage of 5.5 Volts.

b) Personal Computer (PC): It used for writing and sending texts to the Arduino.

c) Arduino Microcontroller type (AT mega 328): It receives texts from (PC) to modulate the signal of characters and convert them into square waves with a different pulse width depending on the program inside the microcontroller.

d) Electronics driver circuit: It transfers the square signal from the Arduino to the laser diode for converting it into a light signal transmitted through the underwater channel.

2. Underwater channel: the water tank dimensions are 1m length, 30 cm width and 40 cm high. That filled with 60 liters of water, the transmission window of the glass has 3mm thickness. The water channel contains the air bubbles pump, as shown in Figure 2. They are placed in 3 different places at a distance of 0.2 m, 0.5 m, and 0.8 m of transmitter respectively, as shown in Figure 3.

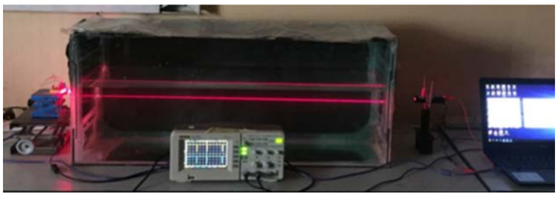
3. UWOC The receiver that consists of:

a) Photocell (LDR): (LDR) or light-dependent resistor is a variable resistor which is controlled by the incident light, it converts the optical signal on it into an electrical signal, and its work is like the work of a photodetector. The maximum Operating voltage is 150 volts, max. Power is 100mW, the operating temperature is 25C$^o$, and the spectral peak is 0.6 at 950 nm wavelength.

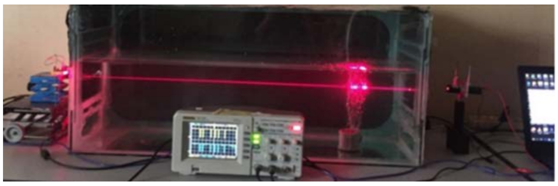
b) Arduino Microcontroller type (AT mega 328): It receives the electrical signal from the resistance, demodulate, and converts it into text and sends it to the computer.

c) Personal Computer (PC): It shows the received text. The experimental setup of UWOC is illustrated in Figure 3.

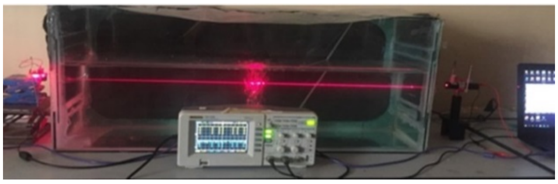
**Figure 2: Electric motor (air bubbles pump).**



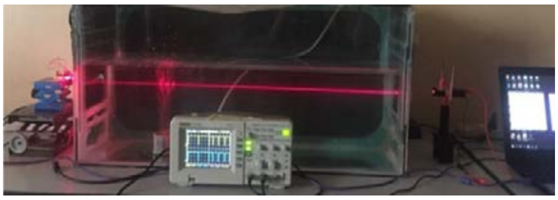
**a**



**b**



**c**



**d**

**Figure 3: Experimental setup of an UWOC system based on PWM and a modulated laser diode (650) nm in four water cases: (a) Water without turbulence. (b) Water with air bubbles (0.2) m from the transmitter. (c) Water with air bubbles at middle. (d) Water with air bubbles (0.8) m from the transmitter**

## 4. Result and Discussion

In this research, first, a transmitter of laser diode 650 nm wavelength with a power of 80 mW was sent through a channel of clean water without turbulence. The received power, signal-to-noise ratio, attenuation, and SER were calculated for a distance of 1 m from the transmitter. Second. The same lasers were sent through a channel of clean water with an air bubbles pump which represents the turbulence; the air bubbles pump was placed 0.2 m, 0.5 m and 0.8 m away from the transmitter and the same parameters were extracted as above.

1) Received Power

In Figure 4, the first case, when the air bubbles did not exist, we noticed that the received power decreased from 80 mW in the transmitter to 32 mW in the receiver at a distance of 1 meter using power meter due to absorption of the light. Second case, when the air bubbles were present in the water, we noticed that the received power is less than in the first case due to absorption and scattering of the light, the received power was 28 mW when the air bubbles were 0.2 m from the transmitter and became less (27 mW) when the air bubbles approached the receiver as shown in figure 3, this means that as air bubbles close to the receiver, the power received is reduced due to absorption and more scattering of the light.

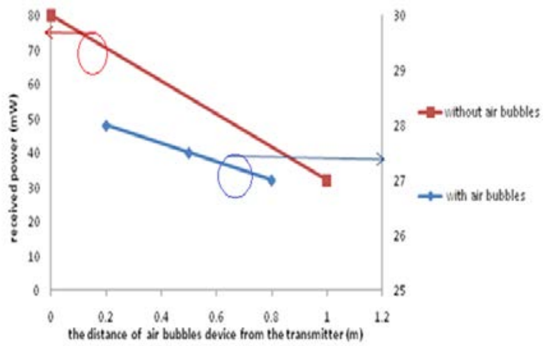



**Figure 4: Received power without and with air bubbles in clear water using (650) nm wavelength.**

2) Signal to Noise Ratio (S/N dB)

In Figure 5, the first case, when the air bubbles did not exist, we noticed that the (S/N) decreased from (28.62dB) in the transmitter to (24.637dB) in the receiver at a distance of 1 meter using equation (1) due to absorption of the light. Second case, when the air bubbles were present in the water, we noticed that the (S/N) is less than in the first case due to absorption and scattering of the light, the (S/N) was (24.057dB) when the air bubbles were 0.2 m from the transmitter and became less (23.899dB) when the air bubbles approached the receiver as shown in Figure 4, this means that as air bubbles close to the receiver, the

(S/N) is reduced due to absorption and more scattering of the light.

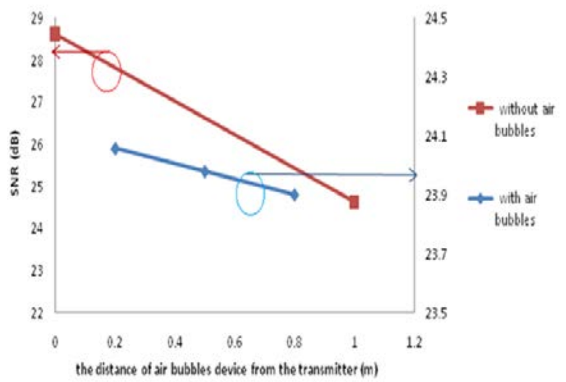



**Figure 5: SNR without and with air bubbles in clear water using (650) nm wavelength.**

3) Attenuation (α dB/m)

In Figure 6, the first case, when the air bubbles did not exist, we noticed that the (α) increased from (0 dB/m) in the transmitter to (3.979dB/m) in the receiver at a distance of 1 meter using equation (4) due to absorption of the light. Second case, when the air bubbles were present in the water, we noticed that the (α) is higher than in the first case due to absorption and scattering of the light, the (α) was (4.559dB/m) when the air bubbles were 0.2 m from the transmitter and became greater (4.717dB/m) when the air bubbles approached the receiver as shown in figure 4. It means that as the air bubbles approach more and more of the receiver, the amount (α) increases due to absorption and more scattering of the light.

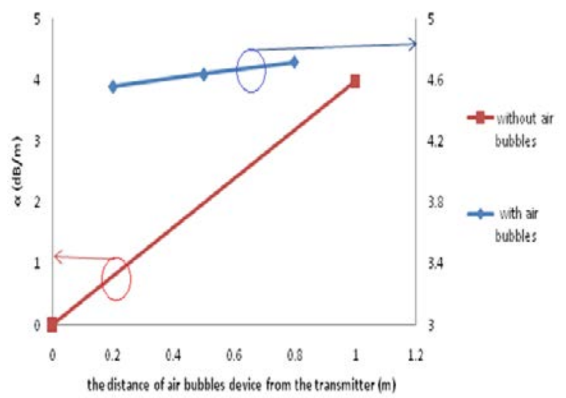



**Figure 6: Attenuation coefficient without and with air bubbles in clear water using (650) nm wavelength**

4) Symbol Error Rate (SER)

In Figure 7, the first case, when the air bubbles did not exist, the value of (SER) was zero in the receiver at a distance of 1 meter using equation (6) due to the absorption of the light. Second case, when the air bubbles were present in the water, we noticed that the (SER) is more significant than in the first case due to absorption and scattering of the light, the (SER) was (0) when the air bubbles were 0.2 m from the transmitter and became greater (0.03) when the air bubbles approached the receiver, This means that as the air bubbles approach more and more of the receiver, the amount of (SER) increases due to absorption and more scattering of the light, so the value of (SER) was maximum (0.03) when the value of (S/N) was minimum (23.899dB) and the (SER) value decreased as the (S/N) increased, until the (SER) value became (zero) when the (SNR) value increased to (24.057dB) as shown in Figure 7.

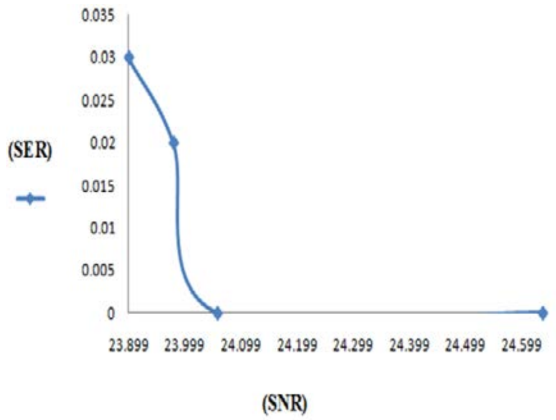



**Figure 7: SER versus SNR without and with air bubbles in clear water using (650) nm wavelength.**

## 5. Conclusion

In this research, we have demonstrated that the amount of losses in power received in the case of air bubbles is higher than if it does not exist. (The results showed that in the absence of air bubbles device, the received power was 32 mW, while when air bubbles pump within the channel of clear water at 0.2m, 0.5m and 0.8m away from the transmitter source, the received power was 28 mW, 27.5 mW, and 27 mW respectively. This paper shows that Signal to Noise Ratio (S/N) in the absence of air bubbles pump (24.637dB) is higher than the signal in the case of air bubbles pump in the water channel. While attenuation (α) in the absence of air bubbles pump is (3.979dB/m) which is less than attenuation in the case of air bubbles device within the channel of clean water. The practical results showed that the Symbol Error Rate (SER) in the absence of air bubbles pump is less than (SER) in the case of air bubbles pump within the channel of clean water. The value of SER was maximum (0.03) when the value of (S/N) was minimum (23.899), and the SER value decreased as the (S/N) increased.) The closer the air bubbles from the optical receiver, the more loss of power received and the higher the attenuation. We observed an increase in the amount of SER as the air bubbles approached the optical receiver. So when the value of SNR increases, the SER value decreases, as shown in Figure 7.

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