Real-Time Video Transmission for Underwater Wireless Optical Communications System

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Abstract

In this paper, it designed and experimentally demonstrate an underwater wireless optical communication system by using a multi-beam green laser diode. The system was capable of transmitting a data video with pulse width modulation (PWM). Two laser diode (532 nm) used to carry the data (video) and two photodiode utilities as a receiver. It used $MgSO_4$ and $Mg(OH)_2$ as a suspended particles. The main purpose of adding these compounds is to a simulation of the water in nature. Also to find the difference between the affect of adding each chemical compounds to clean water on the transmitting of data (video). The gain, loss, SNR and BER have calculated for each one. It is found that $MgSO_4$ affect was greater than $Mg(OH)_2$ on the received video signal.

I. Introduction

The importance of underwater wireless optical communications (UWOC) is becoming increasingly because it has high transmission rates. For short- and medium-range applications, wireless optical technology is usually trusted solution under water [1]. Undiscovered underwater radio channels are still more complex than free satellite channels and scientific problem of underwater communications across a range of physical processes in different types of underwater environments ranging from coastal waters to deep sea or oceans [2].

The most important characteristic of laser in underwater optical communications is the possibility of information transmitting through it at a higher speed and better accuracy than sound and radio waves [3]. The delay in the propagation of sound waves in water is more than five times of radio frequencies. In addition to that, sound waves propagate much slower under water (1500 m / s) than electromagnetic waves [3].

II. Theoretical Background

The attenuation mainly represented by absorption and scattering, which are the main cause of light loss in water [4]. It is obviously that increasing the turbidity of clean water decreases reception power [5,6]. Due to that attenuation which emerges from absorption and scattering in the water. Best transmissions are achieved in clean water because less attenuation occurred due to less absorption and scattering. Larger attenuation is occurred for high concentrations of salts [7].

The absorption by water itself is known, but the absorption by different dissolved particles need to study. The concentrations of these dissolved particles is variable. The spectral absorption of water is a combination of the absorption by pure sea water, phytoplankton, detritus and Colored Dissolved Organic Matter (CDOM).

III. Experimental Setup

The wireless optical communication system using multi-beams as shown in figure (1). The data (video) transmitted from the computer (CP) to the Transistor-Transistor-Logic (TTL) (Model: CP2102) circuit which is the process of modulation and then transferred to the laser sources (two green lasers with wavelength 532nm). the laser signal travelling through a glass water tank with dimensions (100×40×30) cm^3, and filled with (80 liters) of clean water. It has been added $Mg(OH)_2$ and $MgSO_4$, to the clean water for increasing the turbidity.

The added concentrations of compounds to the water shown in table in (I).

Table (I) the added concentrations of compounds to the water

compounds	Concentrations (mg)								
$MgSO_4$	25	50	75	100					
$Mg(OH)_2$	25	50	75	100	125	150	175	200	225

The transmitter signal received by using pair of photodiodes (BPX65), which work to convert the signal into the TTL circuit. Where the TTL circuit included the process of demodulation the signal and the reception video transferred to the computer (CP) to observe by the screen.

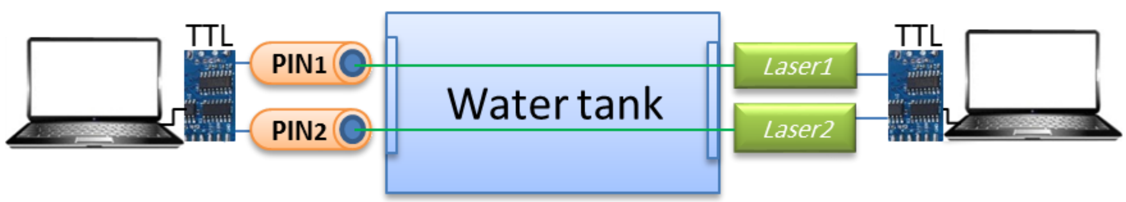


Fig (1) Shows Experimental setup for underwater communication system.

A digital storage oscilloscope (DSO) used to display the received signal waveforms.The power received for each source was measured using the Power Meter.

A 25 mg of $Mg(OH)_2$ and $MgSO_4$ added to water in the tank. The mixture was mixed to get the homogeneity of chemical compounds with the water. It have increasing the concentration of the compounds by adding the compounds step by step.

Loss (L) in dB calculated by using eq (1) [8].

$$L_{dB} = 10log_{10}\frac{P_{in}}{P_{out}} \qquad (1)$$

Signal to noise ratio (SNR) has calculated based on DSO measurement. Equation (2) employed to calculate SNR [9] depending on the maximam and minimum amplitude of voltage in the receiver part.

$$SNR(dB) = 20\log_{1o}\frac{High - Low}{Low} \qquad (2)$$

Where High is the measured amplitude value at the photodiode when the LD_s are on (signal with noise), Low is the condition when the LD_s are off (noise only).

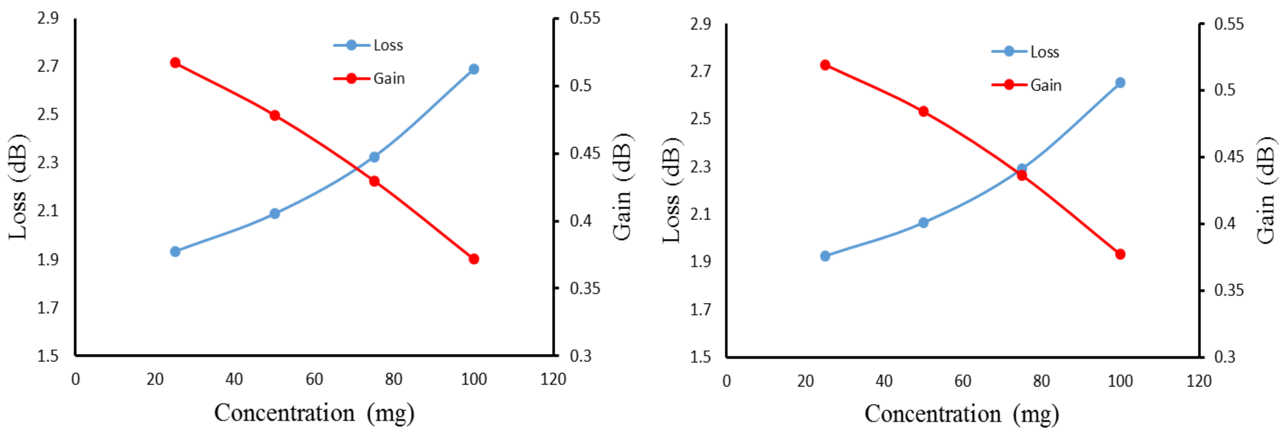
Taking advantage of the SNR values under study that were calculated from an equation (2) , the Bit Error Rate (BER) values were calculated based on an equation (3) [10]:

$$BER \approx \left(\frac{2}{\pi SNR}\right)e^{-\frac{SNR}{8}} \qquad (3)$$

IV. Result and Discussion

The loss is calculated for clean water which has values (1.747, 1.797)dB for photodiode1 (Rx_1) and photodiode2 (Rx_2) respectively. For Gain value of clean water was (0.5724, 0.4923)dB for Rx_1 and Rx_2 respectively.

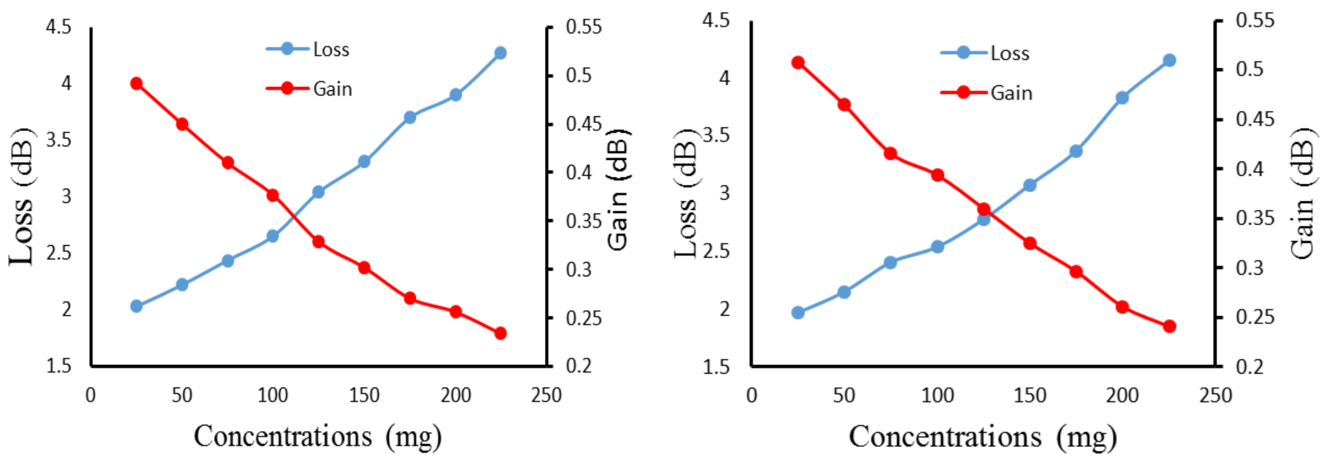
Fig (2) shows the Gain and Loss of clean water with adding of $MgSO_4$. When $MgSO_4$ added to the water the turbidity begins to increase. This added leads to increase in loss, with increasing concentrations of $MgSO_4$.On the other hand side, Gain decrease when the concentrations of $MgSO_4$ is increasing.



(a) (b)

Fig (2) Gain & Loss for $MgSO_4$: (a) 1st beam. (b) 2nd beam.

Fig (3) shows the Gain and Loss of clean water with adding of $Mg(OH)_2$. When $Mg(OH)_2$ added to the water the turbidity begins to increase. This added leads to increase in loss, with increasing concentrations of $Mg(OH)_2$.On the other hand side, Gain decrease when the concentrations of $Mg(OH)_2$ is increasing.



(a) (b)

Fig (3) Gain & Loss for $Mg(OH)_2$: (a) 1st beam. (b) 2nd beam.

From Figure (2) it is note that the maximum loss were (2.690,2.652)dB for Rx_1 and Rx_2 respectively to $MgSO_4$ at concentration 100mg. While the maximum loss were (4.274,4.152)dB for Rx_1 and Rx_2 respectively for $Mg(OH)_2$ at concentration 225mg.

As for Gain , it is note that the minimum Gain were (0.3717,0.3770)dB for Rx_1 and Rx_2 respectively to $MgSO_4$ at concentration 100mg. While the minimum gain were (0.2339,0.2408)dB for Rx_1 and Rx_2 respectively for $Mg(OH)_2$ at concentration 225mg.

This means that less gain was obtained for $Mg(OH)_2$ compared to $MgSO_4$. Therefore $MgSO_4$ is more gain than $Mg(OH)_2$.

Figure (4) shows the SNR for $MgSO_4$. It is observed SNR was (22.278, 21.938 , 22.110)dB for both photodiods (Rx_s) , first (Rx_1) ,and second photodiods (Rx_2) respectively for clean water. These values have declined to (20.319,20,20.214)dB for Rx_s,Rx_1,and Rx_2 respectively at the adding of concentration (100mg).

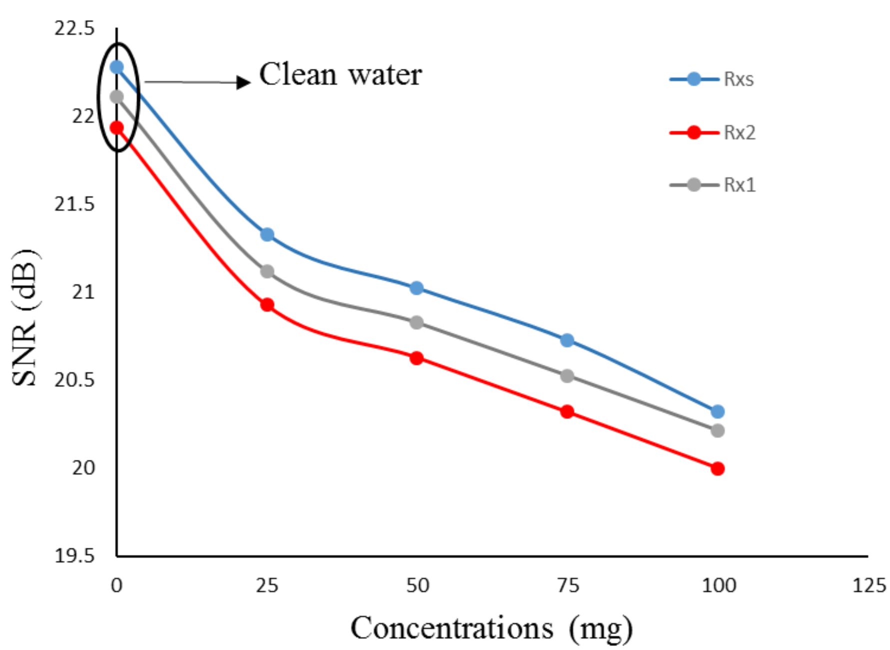


Figure (4) Signal to noise ratio for $MgSO_4$

Also SNR was calculated for $Mg(OH)_2$ as shown in fig (5). It is obvioused that SNR was (22.278, 21.938 , 22.110)dB for Rx_s, Rx_1, and Rx_2 respectively for clean water. The SNR for $Mg(OH)_2$ decreased to (19.204,19.204,19.204)dB for Rx_s,Rx_1,and Rx_2 respectively for the adding concentration at (225mg).

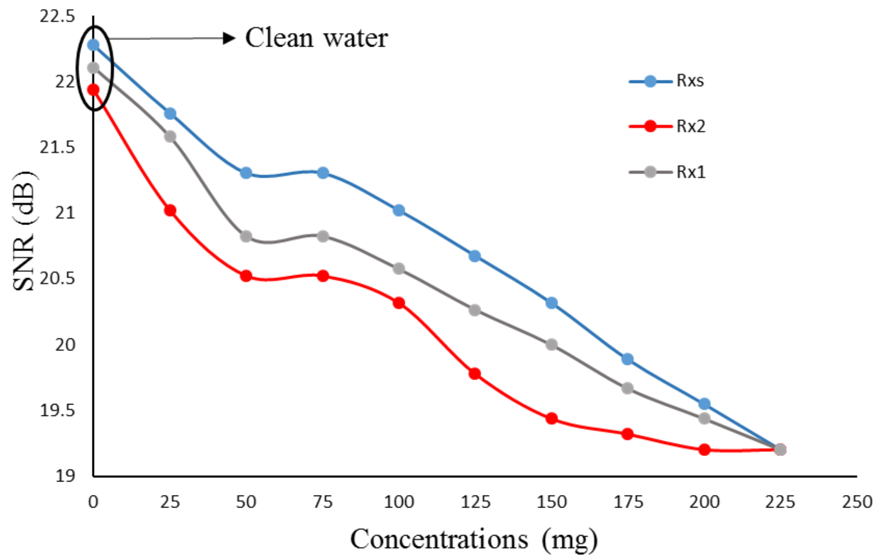


Figure (5) Signal to noise ratio for $Mg(OH)_2$

The effect of the increase turbidity on the quality of received video were studied as shown figures (6-7) where some of video images received for pure water and in the case of some additions for $MgSO_4$ and $Mg(OH)_2$ under study. It is noticed a clear deformation when the turbidity increases by increasing the concentration of added chemical compounds.

(a) (b) (c)Figure (6) shows received videos :(a) for clear water. (b) For 25mg of $MgSO_4$. (c) For 75 mg of $MgSO_4$.

(a) (b) (c)

Figure (7) shows received videos :(a) for clear water. (b) For 25mg of $Mg(OH)_2$. (c) For 75 mg of $Mg(OH)_2$.

Also it is observed that $MgSO_4$ has more effect on the laser beams compare with $Mg(OH)_2$.

It is noted that the concentration of $MgSO_4$ effect more than $Mg(OH)_2$ and required to reach the concentration of 225 for $Mg(OH)_2$ to obtain the deformation as shown in the figure (8), where figure (8-a) shows received video for 100 mg of $MgSO_4$. As for the figure (8-b) shows received video For 225 mg of $Mg(OH)_2$.

Figure (8) show received video for: a. 100 mg of $MgSO_4$. b. 225 mg of $Mg(OH)_2$

It is observed that BER was (0.00176, 0.00186, 0.00181) for (Rx_s) , (Rx_1) ,and (Rx_2) respectively for clean water. These values have increased to

(0.002471, 0.002612, 0.002516) for (Rx_s) , (Rx_1) ,and (Rx_2) respectively at the adding of concentration (100mg) as shown in figure (9).

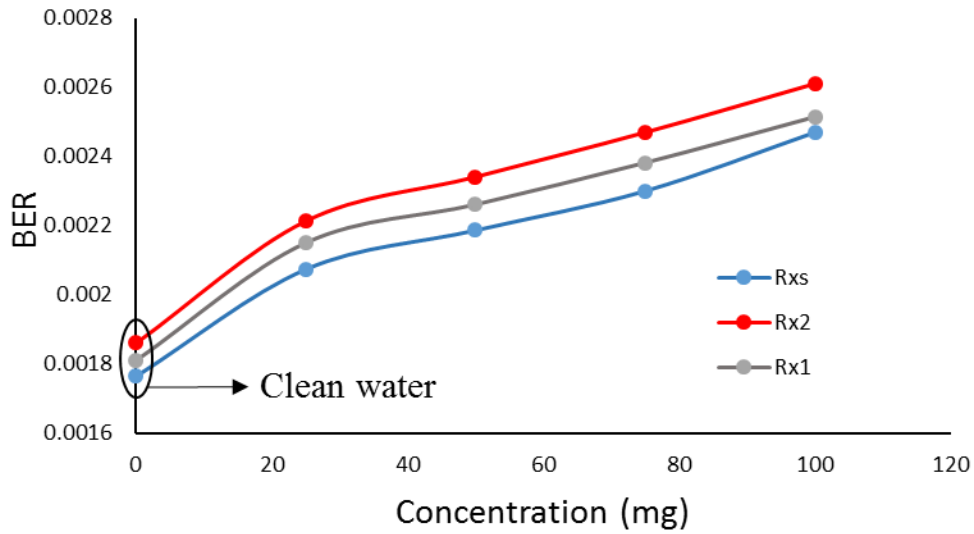


Figure (9) shows BER for $MgSO_4$.

Figure (11) shows BER for $Mg(OH)_2$.Where BER was (0.00176, 0.0018 , 0.00181) for (Rx_s) , (Rx_1) ,and (Rx_2) respectively for clean water. These values have increased to (0.00300, 0.00300, 0.00300) for (Rx_s) , (Rx_1) ,and (Rx_2) respectively at the adding of concentration (225mg).

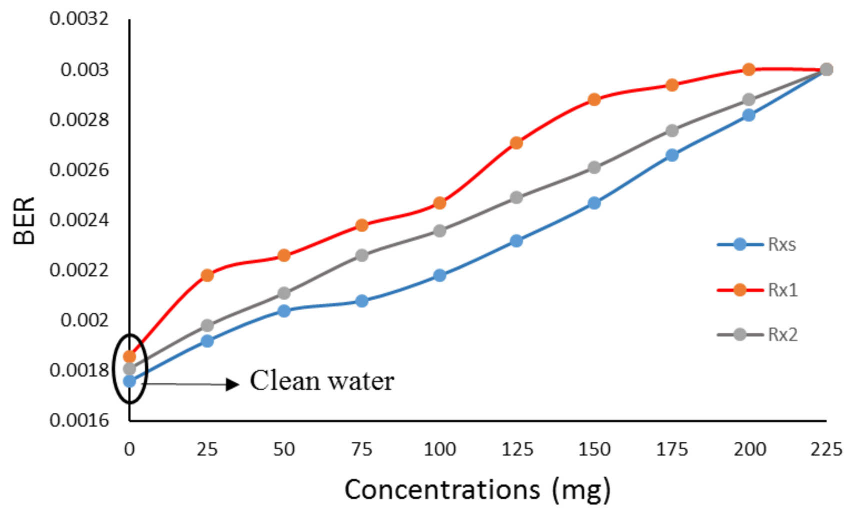


Figure (11) shows BER for $Mg(OH)_2$

V. Conclusion

It is shown that the effect of $MgSO_4$ was greater than the effect of $Mg(OH)_2$. This means that the effect of suspended substances represented by $MgSO_4$, is greater than the effect of suspended substances by $Mg(OH)_2$. Therefore, $Mg(OH)_2$ has an advantage over $MgSO_4$ for the transfer of video where the turbidity for $Mg(OH)_2$ is less compared to $MgSO_4$.

It is obvious that the received signal suffers from the attenuation by $MgSO_4$ compared with $Mg(OH)_2$. Also, noted that, the received image of video has more high resolution for water turbidity compound $Mg(OH)_2$ in water. Beside, low error in the received data (video) reception when the concentration of suspended particles is decreasing.

References:

[1] J.W.Giles and I. N. Bankman, "Underwater optical communications systems. Part 2: basic design considerations," *MILCOM 2005. IEEE,* vol. 3, 2005.

[2] H. Kaushal and G. Kaddoum, "Underwater optical wireless communication," *4,* vol. 4, 2014.

[3] I. F. Akyildiz, D. Pompili, and Tom-maso Melodia, "Underwater acoustic sensor net-works: research challenges Underwater acoustic sensor networks," *Ad Hoc Networks,* pp. 257-279, 2005.

[4] B. C. a. L. Mullen, "Free-space optical communications underwater - in Advanced Optical Wireless Communication Systems," J. B. S. Arnon, G. Karagiannidis, R. Schober, and M. Uysal, Ed. no. 201-239): Cambridge University Press, 2012.

[5] Y. J. Gawdi, "Underwater free space optics," 2006.

[6] A. Keskin, F. Genç, S. A. Arpali, Ö. K. Çatmakaş, Y. Baykal, and Ç. Arpali, "Effects of focused and collimated laser beams on the performance of underwater wireless optical communication links" in Optical Wireless Communications (IWOW), 2015 4th International Workshop on, 2015, pp. 41-45.

[7] Mazin Ali. A. Ali , Salah A. Adnan ,Maha sadeq, and Arif A. Al-Qassar, "Underwater wireless optical communication system modulate 532nm along 7m by DD/IM", Electrical Engineering, Elixir Elec. Engg. vol.113 (2017) pp.49051-49053.

[8] W. Stallings, "Data and computer communications" p. 100, 2007.

[9] Y.-h. Kim and Y.-h. Chung, "Experimental outdoor visible light data communication system using differential decision threshold with optical and color filters," Optical Engineering, vol. 54, pp. 040501040501, 2015.

[10] A. E. N. A. Mohamed, A. N. Z. Rashed, and M. S. Tabbour, "Transmission characteristics of radio over fiber (ROF) millimeter wave systems in local area optical communication networks," Int J Adv Network Appl, vol. 2, pp. 876-86, 2011.