Underwater Wireless Optical Communication System Modulate 532nm along 7m by DD/IM

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ABSTRACT

In this paper experimentally investigated error-free underwater wireless optical communication (UWOC) system over 7m path in laboratory tap water with up to 46.808dB and BER less than 2.487×10^{-6}. The laser diode source of wavelength 532 nm with 50mW has modulated by intensity modulation/direct detection (IM/DD) technique, BER and S/N have inspected in an underwater optical wireless communication channel with five different water channels types. These are tap water, different concentration of Maalox ($Mg(OH)_2$ and $Al(OH)_3$) in order to obtain high turbid water and salt with Maalox. The analysis of BER has achieved for pulse width modulation (PWM) to transmit a text from optical transmitter to receiver. Results shows that salt and Maalox content decreases the received power, S/N and increase in BER. Also, that 532nm wavelength is the suitable choice for a clear water channel.

1. Introduction

Underwater optical wireless channels still undiscovered being more complexity than free space channels. The scientist's problem for underwater communication via a range of physical procedures in different kinds of underwater environments varying from coastal water to deep sea or oceans. The delay of propagation in underwater is higher five times in magnitude than the radio frequency (RF) terrestrial channels; High bit error rates and instantaneously losses of connectivity can be applied, due to the climax characteristics of the underwater channel, the bit rate is mainly as low as 10 Kb/s[1]. In addition, acoustic waves have much slower speed propagation underwater (1500m/s) than EM waves[2]. Furthermore, radio frequency-based terrestrial wireless technologies are also hurdle because that radio waves are fiercely attenuated in water.

2. Background and Theory

2.1 Transmission Consideration:

The new generation of high speed optical waves is still challenging in UWOC system with a purposed wavelength, usually in the blue-green window with a high transmission in water as shown in Fig. 1. the Minimum absorption happens at the wavelengths of blue–green, i.e. 430–570 nm[3]. Also challenges had been occurred since the 1960s to construct semiconductor lasers providing green light, the first nitride laser of green-light at ~532 nm did not demonstrate till 2009[4], after 20 years far along than the first blue LD, in spite of that blue light has a less absorption coefficient in pure water [5, 6], it has a disadvantage of more absorption and scattering in some natural waters with more concentration of particulates in this case is chlorophyll [7, 8]. In addition, a great potential had been made to investigate the probability of utilizing a direct modulation of green-light LDs in UWOC systems, in fact, that green-light LDs are very few

commercially available. but recently, a special 520-nm LD with a quite high cost for a 7-meter underwater transmission at 2.3 Gbit/s bit rate [9].
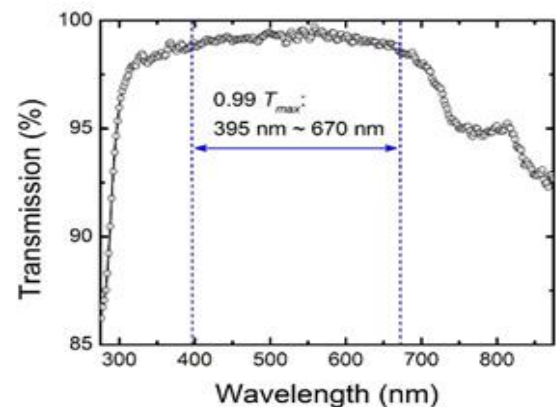

Fig. 1. Transmission spectrum of the water sample measured using UV-Vis spectrophotometer.

2.2 Attenuation consideration:

Particle scattering depending on the ratio of $2\pi r/\lambda$, where r is the spherical particle radius and λ is the utilized wavelength. In the case of small particles, where defined as spherical particle radius is less than 0.1 μm (r<0.1) μm, the Rayleigh scattering is dominating, when $2\pi r \leq \lambda$, such that the total scattering restricted as r decreased. However, the rate of large to small particles have increased, the Rayleigh scattering role has increased. Also, if the particle sizes are larger than the wavelength $2\pi r \geq \lambda$ the attenuation called Mie scattering. The attenuation coefficient of such laser beam, $\alpha(\lambda)$, is a measure of the decline of the unscattered light and has described by the Beer–Lambert law as

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

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Where P_T is the transmitted optical power, $P_R (\lambda)$ is the received optical power, and r is the path length in the water.

The transmittance of the beam in an underwater beam is defined by

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

Therefore, $\alpha(\lambda)$, can be expressed in terms of the transmittance as

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

where $\alpha(\lambda)$ changes with oceanic depth and temperature of water due to the non-homogeneous nature of sea water. The maximum expected range has calculated in terms of a measured value of attenuation expressed in dB/m. The corresponding expression then becomes

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

3. Experimental Setup

The experimental setup of an underwater wireless optical communication system based on a directly modulated laser diode shown in Figure 3. The electrical signal at the transmitter side has generated from a PC to Arduino which controlling the pulse width of the data transmitted bit stream. The signal has modulated in the form of (PWM). The operation voltage of the laser was 6V to provide optical power of laser equal to 50mW. The signal has used to modulate a semiconductor laser diode by using laser driver circuit which is an electronic circuit provides the signal by the higher switching speed and also provide the receiver by slot synchronization transmitted signal for each pulse as illustrated in schematic diagram in Figure 2.the optical signal has transmitted through water tank, it is dimensions are 1m along and 30cm×40cm are width and high respectively which filled with 60litter of water, Five water channel has set by adding Maalox and salt in order to increase turbidity of water. the transmission thickness of the glass was 3mm which was the minimum available thickness, the transmitted signal passing through water tank was reflected by an adjustable laboratory mirrors in order to increase the water link experimentally the information has acquired by photoresistor (LDR) to detect , convert the optical to electrical signals and analysis the received signal than reaches to an Arduino in order to demodulate the electrical signal in which converted by photosesistor then received to PC as received message.
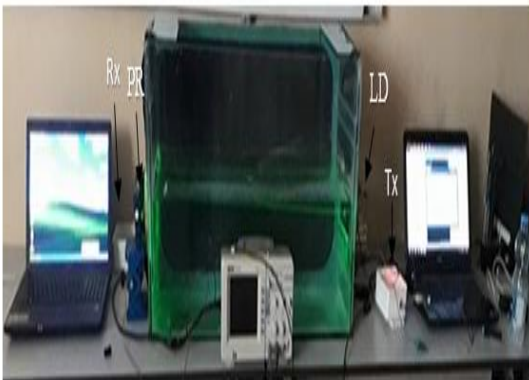
Figure2. Experimental setup of an underwater wireless optical communication system based on IM/DD in the form of (PWM) and a modulated 532nm laser diode.

To perform the detected signal, we used a digital storage oscilloscope (DSO) to display the received signal waveforms. Fig. 3 shows the aforementioned schematic setup with details.
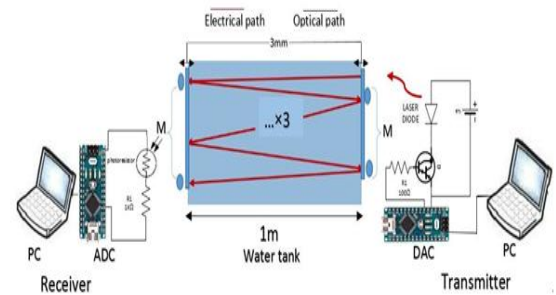
Figure 3. Experimental setup for underwater communication system: laser diode 532 (LD), mirror(M), photoresistor (PR), computer (pc), digital to analog convertor (DAC), analog to digital convertor (ADC).

4. Result and Discussion

It is clearly decreasing the reception power. Wherever, the achievable transmission link has decrease within increasing the turbidity of water. Moreover, in clear water channel maximum received power has achieved than the other concentrations, the 532nm performance error- free at 7m has achieved in contrast with turbidity water. This because strong scattering appears for green wavelength , particles with size around (≈500μm) which was maalox particles occurring Mie scattering that is strongly attenuated the 532nm wavelength [8] so that in higher concentration of Maalox and salt the transmission distance reaches to just 2m as shown in figure 4.
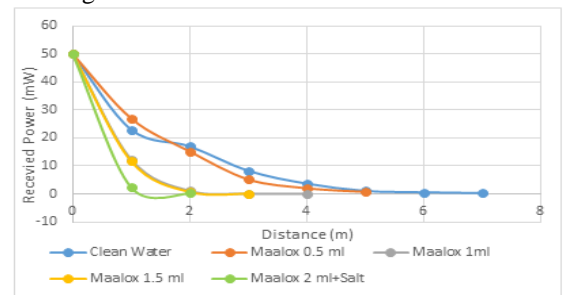
**Figure 4. Received optical power for 532nm wavelength vs. maximum transmission distance.**

the reception power demonstrate agreed with Iraqies water with same wavelength and power[10] , which utilized clear matched with Tigeres water, 0.5mL maalox resemble to Euphrates water, 1mL Maalox similar to Shat Al- Arab, also a 1.5mL maalox refers to Sea water. Finally, the utilized 2mL maalox and salt agreed with both of dusty water, NaOH of 5% and $NaBO_7$ OF 5%.

Signal to noise ratio at maximum transmission link has shown in Figure 5 for five underwater channels. as observed degraded in S/N which was 46.808dB along 7m through clear water drops to 36.77dB along 1m which is surpass 25dB in such water type[11]. Through high turbid water.
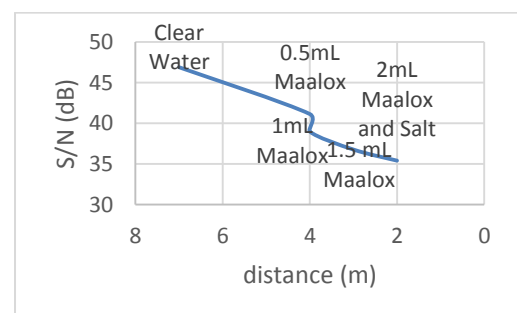

Figure 5.max. S/N for different water channel vs. max. transmission link.

BER has calculated depending on S/N value .In general, BER has increased while the turbidity of water has increased, a clear water has the smallest BER which was 4.49×10^{-6} which is exceed 2.23×10^{-4} also in 7m as [12] and rises to 2.15×10^{-4} in high turbid water which was 2ml Maalox and salt as shown in Figure 6. as illustrated S/N proportional inversely with BER, less received power has reached when increasing the optical path, therefore; the added particles scattered the 532nm strongly which is the dominate effect on reduction of received power.
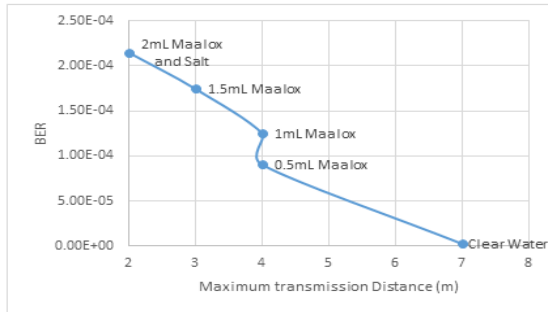
Figure6. BER for 532nm along maximum transmission range for different water channel.

the calculated attenuation has shown in Figure 7 has discriminately rises from 3.85567 dB/m in clear water at 7m to 5.5546 dB/m in 0.5 Maalox so that the transmission distance has reduced to 4m; therefore, increasing the turbidity of water leads to enlarge the attenuation value due to high scattering by Maalox particles. the best interpretation for this phenomena is that these particles have size less or/and equal to the utilized wavelength causing Mie and Ryleigh scattering. However, the maximum attenuation achieved at high turbid water when the concentration of Maalox is 2ml and salt which was 18.4945 dB/m.
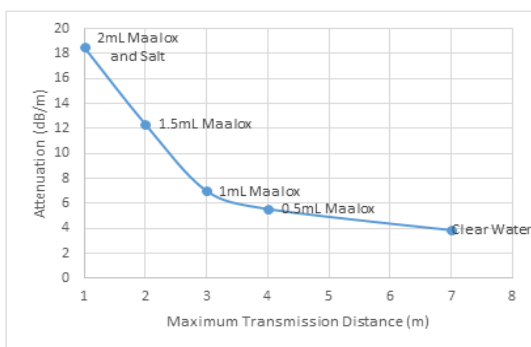
Figure7. Attenuation value for 532nm vs. maximum transmission link with five different water channel.

5. Conclusion:

In this paper, the feasibility of utilizing Intensity Modulation/Direct Detection (IM/DD). PWM has experimentally demonstrated in an UWOC. Increasing the salty and turbidity of water decreases the transmittance even few amount of Maalox can cause disturb the communication. Underwater channel including 2mL Maalox and 21g of NaCl cause the vast amount of decrease in the output power. 7m underwater wireless transmission of optical IM/DD signals modulated 532 nm. The utilized wavelength was having a preference in clear water channel with free error S/N of 46.808dB and BER of 4.49×10^{-6}. The utilized water channel has compared with Iraqi's water.

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