Experimental Demonstration of Underwater Optical Wireless Communication

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Abstract- The military, industry, and scientists are interested in underwater wireless communication (UWC). It is important for tactical surveillance, pollution monitoring, oil management, and maintenance. Limited bandwidth, capacity, energy efficiency, and transmission delay are the main limitations in UWC. Therefore, complementary technology, such as underwater wireless optical communication (UOWC), will be implemented. This paper designs a prototype using a KY-008 laser module and an Arduino UNO microcontroller with the Arduino IDE platform for software implementations. This prototype used the line-of-sight technique to transfer text data at 2 meters. Results were compared between the wavelength at the beginning of the visible light spectrum and the wavelengths with the minimum attenuation in the same visual, of the transmitting distance and the transmitting power. Optical communication offers higher data rates for effective data transmission and fulfilling the services or challenges requiring higher data rates.

Index Terms- Underwater wireless communication, Integrated optics, Nonlinear optics, Optical fiber communication.

I. Introduction

Water covers seventy percent part of Earth's planet. On the other hand, attention toward the underwater environment becomes larger over time due to countless demands just as changing in climate, education of oceanic animals, observing oil rigs, surveillance, anonymous operations, etc. These implementations demand a channel to convey the undersea atmosphere to the rest of the world [1]. Over the last few decades, the research of underwater wireless routes has seduced more noticeable aquatic links.

The structure of UOWC consists of a transmitter and receiver that produce data to convey from one source after that modulated on the optical channel so that it can travel longer distances with a great amount of data rate [2]. The source is facilitated by a laser beam to pass indication toward the receiver [3]. In this way, a laser beam is projected towards the receiver through a medium of underwater vision, which varies according to location and time.

A. *Underwater communication methods*

Different methods are used for underwater communication, which is as follows.

1) *Acoustic Waves*

Like sound explorations in air, it quite good travels in water. But in water, sound travels depending upon temperature, pressure, and many other factors [4]. United States using SSB amplitude modulation, the first audio underwater communication was established at frequencies between 8-15khz, using pulse shaping filters and voice band [5]. The received signal requires the ability to detect by a human ear due to the poor quality of the signal and the need to process a distorted signal [6].

2) *RF Waves*

RF waves can also be useful for underwater wireless communication, providing better data rate, velocity, and higher bandwidth for underwater environment communication. RF wave range depends upon system architecture from tens Hz to GHz [7].

3) *Optical Waves*

As we know, RF signals face higher attenuation in seawater, and freshwater requirements of RF signals are large antenna size and high transmitter power; after that, to complete high data rates in underwater communication, we used optical signals [8]. Due to the high-frequency optical carrier underwater, optical wireless communication can exceed data rate into Gbps, covering a few hundred meters distance [9]. While optical signals also face many challenges in the underwater environment, including absorption and sprinkling [10].

B. *Why use Optical Sources?*

Some outstanding methodological qualities of underwater optical wireless communication are lower costs, high transmission rate, lower link delay, high security, and transmission rate compared to others. Techniques used in different research papers are:

In [3], Monte Carlo simulation is used for underwater optical wireless communication. While we use the Simple laser technique for the transmission of text data.

In [5], Infrared wireless communication is used to transmit data in which the data loss rate is very low, but the data speed rate is also very low. While the Optical technique we used for transmitting data provides a high data rate because the light is the fastest of all things in the universe, the data loss rate is also high.

The technology used in [6] is Beam Spread Function in Underwater Wireless Optical Communication. While we use a Single pointed red beam for Underwater Wireless Optical Communication.

In [8], the Underwater wireless optical communication method is used by directly modulated 520 nm blue laser diode. While we used the underwater wireless optical communications method by using a directly modulated 520 nm red laser diode. The use of a red laser transmitter is due to the low cost; if we use a blue laser module, it is 4 to 5 times more expensive than a red laser module.

II. METHODOLOGY

In this paper, our focus is on the received SIR of test users from randomly chosen BS. In the coupled scenario, the Test user will connect to the base station from which it receives maximum downlink power. In the decoupled scenario, the Test user will connect to the base station from which it receives minimum path loss.

A. Background

Different Underwater optical wireless system provides an awareness of data transmission to the martial, industries, business, and technical communal. The underwater system plays a significant role in research and control and monitoring investigation, n including change of climate monitoring, maintenance and monitoring of pollution, environmental changes in sea and lake, boats, floats, and ocean research. We need to install several vehicles underwater to implement our desired activity. We required efficient unnamed devices with higher capacity and bandwidth to transfer data underwater. Interest in underwater optical wireless communication has extensively increased.

B. Methodology

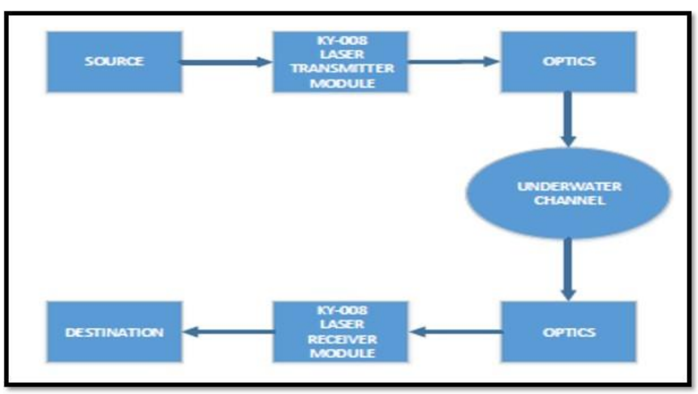

FIGURE 1. **Block Diagram of the Model**

The structure of UOWC consists of a transmitter and receiver that produce data to convey from one source after that modulated on the optical channel so that it can travel longer distances with a great amount of data rate as shown in figure 1.

A laser beam facilitates the source to pass an indication toward the receiver. This way, the laser beam is projected towards the receiver through an underwater vision medium, which varies according to location and time.

The following formula can calculate the power transmitted by the red laser module at the transmitter side.

Transmitter power (PTx)= O/P power + path losses-receiving power

If we talk about receiving site, it collects a laser beam, which is transmitted by the transmitter. Then the receiver conveys the beam to the detector, which is transferred from optical to electrical energy.

The power which is received at the output side is estimated by using the Beers law

$$P(z)= P0e-c(\lambda)zP(z)= P0e-c(\lambda)z \quad [8]$$

C. Technical Specifications

Table 1 shows the technical specifications which are used.

TABLE I
TECHNICAL SPECIFICATIONS

Parameter	Value (if applicable)
Microcontroller	ATmega2560
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	54 (of which 15 provide PWM output)
Analog Input Pins	16
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	56 KB of which 8 KB is used by the bootload
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz
LED	13
Length	101.52 mm
Width	53.3 mm
Weight	37 g

D. Circuit Diagram

Figure 2 shows the circuit Diagram of the Model is shown below. Since this is designed on proteus software to deliver the noises created by the water medium, we have added noise to show underwater effects.

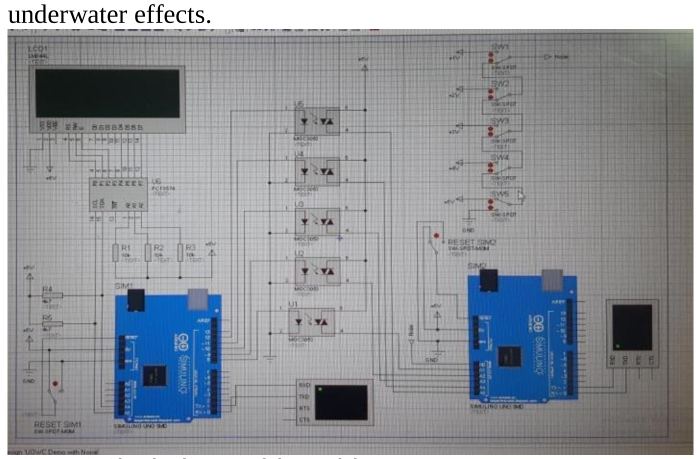

FIGURE 2. **Circuit Diagram of the Model**

E. Equations

Mathematicians calculated the path losses that occur in an optical channel over a distance d is given as

$$A = dka(f)d \qquad [5]$$

K = path loss exponent whose value is between 1 and 2.
a(f) = absorption factor that depends on the frequency f.

The absorption coefficient of seawater is related to conductivity as

$$\alpha_{sea\ water} \approx p\ \pi f\ \mu\sigma \qquad [9]$$

Where α is the absorption coefficient, f the operating frequency, μ the permeability, and σ the conductivity. For this reason, most of the work is carried out at low frequencies to support long-distance communication.

III. RESULTS & DISCUSSIONS

A. Serial Plotter Results

As our project can receive messages in a sentence (alphabets), it would not be able to display any graph. So, we edited the coding of UOWC and prepared new coding which gives output in binary digits (1 or 0). '1' means high, and '0' means low. This way, we can plot a graph following the RZ (Return to Zero) technique.

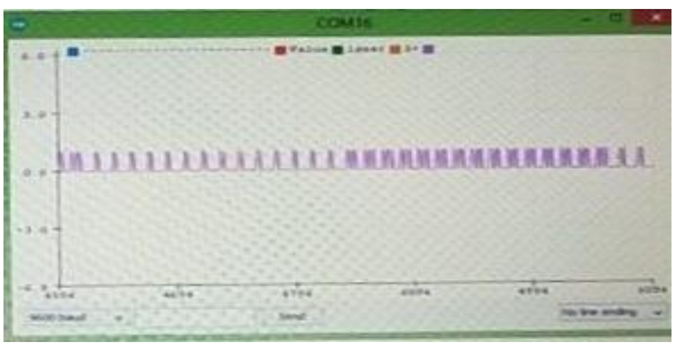

FIGURE 3. **Graph of the Serial Plotter**

Figure 3 shows the serial plotter result of this communication. Here we can see that (1 or 0) spikes on the graph of the serial plotter.

To check our output on an oscilloscope, we connect our oscilloscope to the Output of our project, i.e., LCD, so we get the graph as shown in figure 4.

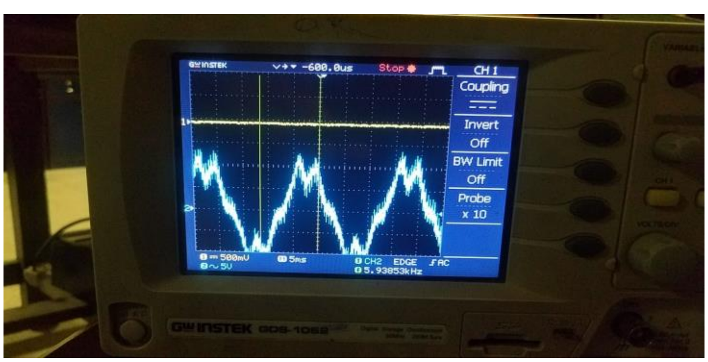

FIGURE 4. **Oscilloscope output of the Serial Plotter**

In air communication, when we are not getting any noise due to a clean path (i.e., free from water), different sorts of lights (That of surroundings) also strike our photodiodes at the receiver side, so the graph which we observe from our serial plotter is shown in figure 5.

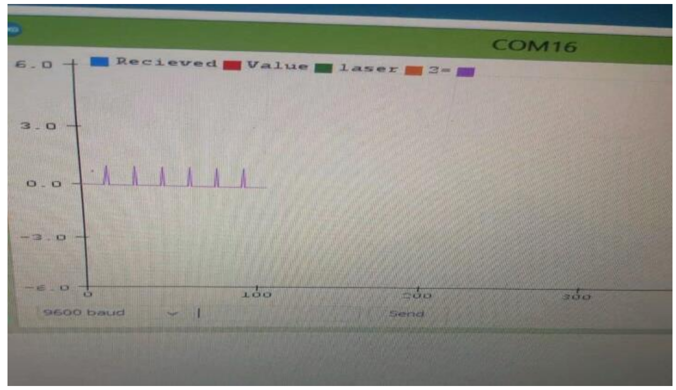

FIGURE 5. **Graph of the Serial Plotter (free from water)**

A. Serial Monitor Results

Figure 6 shows that the message sent by the transmitter is efficiently received by the receiver, which means that the objective of the UOWC system has been achieved.

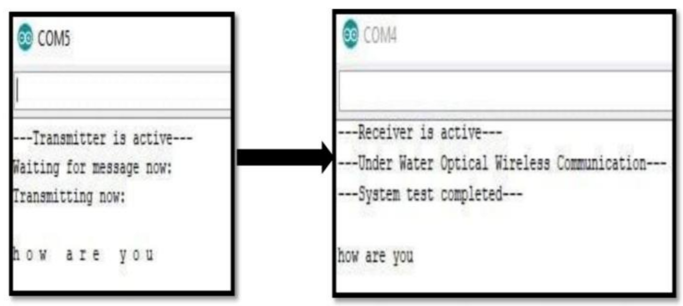

FIGURE 6. **Serial Monitor Result**

The results are evaluated based on simulation, to check the functionality of our proposed system, we simulate the results on the proteus software, which is shown in figure 7.

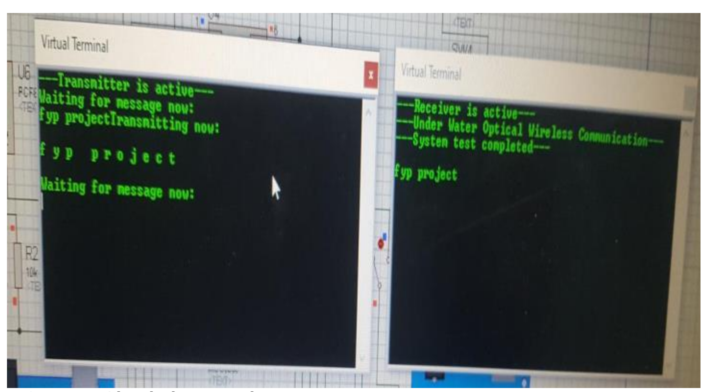

FIGURE 7. **Simulation Result**

Figure 7 shows the result, if we get 100% result, but if we get any bit loss in our system, then we can get alphabets lost error which is shown in figure 8.

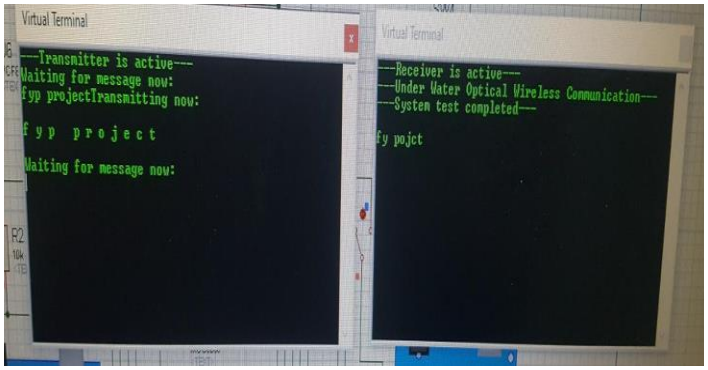

FIGURE 8. **Simulation Result with error**

Figure 8 shows that we suffer some noise in our path, so some alphabet has been lost which can be seen above clearly.

Figure 9 shows that our underwater optical wireless communication hardware is a prototype structure of approximately a 2-meter distance between the transmitter and receiver side to establish our communication.

FIGURE 9. **Line of sight communication**

TABLE II
DIFFERENT AMOUNTS OF SALT DISSOLVED IN WATER

Salt Dissolve per Gram	pH of WATER
10 g	7
20 g	7
30 g	7
40 g	7

Table 2 shows the pH of water checked when different amounts of salt are dissolved in a 2m Area, when NaCl is dissolved in water, it breaks down into ions of sodium and chlorine. Neither of them reacts with water, so the salt will only change the volume of the water, not its pH.

TABLE III
COMPARISON OF RESULTS

Technique Used	Bit Rate	Circuit Complexity	Wavelength
Monte Carlo simulation	very small	complex	540-590 NM
Infrared wireless communication	<1MHz	moderate	800-1000NM
UWOC	3 MHz	simple	360-480 NM
Proposed Work	1 MHz	simple	630-670NM

Table 3 shows the overall comparisons of the results extracted from the proposed system with the current related technologies.

IV. CONCLUSION

Underwater optical wireless system provides an awareness of data transmission to the martial, industries, business, and technical communal. The underwater system plays a significant role in research and control and monitoring investigation, including change of climate monitoring, maintenance and monitoring of pollution, environmental changes in sea and lake, boats, floats, and ocean research. We required efficient unnamed devices with higher capacity and bandwidth to transfer data underwater. Interest in underwater optical wireless communication has extensively increased. Optical communication offers higher data rates for effective data transmission and fulfilling the services or challenges that required the higher data rates.

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