International Journal of Early Childhood Special Education (INT-JECSE)
DOI:10.9756/INTJECSE/V14I5.35 ISSN: 1308-5581 Vol 14, Issue 05 2022

OCEANIC OPTICAL WIRELESS COMMUNICATION

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ABSTRACT

Oceans are one of the most challenging environments on the earth, it is not only a home for nearly a million species but also the home for many military submarines and deep-water Research vehicles. The oceans have been classified into 5 different zones namely the sunlight zone, the twilight zone, the Midnight Zone, the Abyssal Zone and the Hadalpelagic Zone.

The proposed project focuses on the Indian ocean's twilight zone by transmitting International Morse code through On-Off Keying (OOK) using a 650nm semiconductor laser that is operated in pulse mode to transmit pulses. Since the longer wavelengths are absent in the deep waters, the information transmitted is visibly invisible. A photo-transistor-based receiver estimates the values by measuring the time interval between the pulses which is then processed by the microcontroller and the error correction is done using the Huffman algorithm. Finally, the predicted data is displayed as the output, thus we use a simplex data communication system to demonstrate underwater wireless optical transmission.

Keywords**:** Morse Code, On-Off Keying OOK, Twilight zone, Huffman Algorithm

1. INTRODUCTION

The oceans are the body of salt water that covers approximately 70.8% of the total surface of Earth and contains 97% of the total Earth's water. The ocean is the principal component of Earth's hydrosphere, therefore integral to life on Earth. Acting as a huge heat reservoir, the ocean affects climate and weather patterns, the carbon cycle and the water cycle. Oceanographers have divided the ocean into different vertical and horizontal zones based on physical and biological conditions. The pelagic zone (open waters) consists of the water column from surface to ocean floor throughout the open ocean. The water column is further categorized into zones depending on the depth and the light passed through. The zones are as follows,

- the Epipelagic zone or upper ocean (upper surface to 650 feet deep);
- the Mesopelagic zone or middle ocean (650 to 3,300 feet deep);
- the Bathypelagic zone or lower ocean (3,300 to 13,000 feet deep);

- the Abyssopelagic zone or abyss part of the ocean (13,000 to 20,000 feet deep);
- the Hadopelagic zone or deep ocean trenches (20,000 feet and deeper).

Radiofrequency (RF) radiation, which includes radio waves and microwaves, are at the low-energy end of the electromagnetic spectrum. The RF waves, for their nature, are the more common and diffused technique used in terrestrial communications, despite their tremendous performance in terrestrial communication, while subjected to underwater tests, even they are not suitable underwater because they are strongly attenuated. One method was by using the Very Low Frequency (VLF) in the worst case using Extremely Low Frequency (ELF) was used to communicate with submarines. The VLF being more popular after world war-II is still being used to communicate with submarines by many countries. Because of the narrow bandwidths available, voice transmission is impossible, only slow data transmission is supported. VLF data transmission rates are around 300 bits/sec, so data compression was essential.

Acoustic communication is defined as communication methods from one point to another by using acoustic signals. Acoustic systems have enjoyed great success underwater owing to their ability to communicate over many kilometres pushing the research in this field to further improve this technology. Extensive studies are conducted to improve the performance of acoustic communication channels. Nevertheless, its performance is linked to the physical nature that limits the bandwidth, causes high latency, produces high transmission losses, time-varying multipath propagation and Doppler’s spread. These limitations do not allow Autonomous Underwater Vehicles (AUV) and Underwater Acoustic Sensor Networks (UASNs) to transmit real-time video in high definition via acoustic communication. Therefore, complementary technology is needed that can achieve broadband underwater communications, indeed, real-time video transmissions, including the teleoperation of underwater vehicles and remote monitoring of underwater stations, are becoming an important asset for underwater applications.

In recent days, the use of wireless communications is very common in a wide range of terrestrial devices due to its security, capacity and portability. But in the underwater world, the application of wireless communications is of great interest to the military, industry, and the scientific community. While speaking of underwater, they not only houses millions of species but also act as a home for various underwater research vehicles, and most importantly act as a battlefield for submarines of various nations under one motive which is to protect their country from being invaded by the enemy.

2. RELATED DOCUMENTS

Sanjay Kumar, Shanthi Prince, et al., proposed the paper titled “Analysis of the effect of salinity in underwater wireless optical communication” published in the Marine Geo resources & Geotechnology journal in 2019; this deals with the effect of salinity variation on underwater wireless optical communication (UWOC). The effect of different concentrations of salt on underwater optical communication has been carried out experimentally in terms of received power at different link lengths. Based on the experimental data, a mathematical model has been proposed to describe the saline water channel. A simulation study is performed for different data rates and link lengths. It is seen that with increased salinity, the attenuation is higher and the UWOC system performance degrades with a higher data rate and increased link length. To analyze the performance parameters of the received signal of the UWOC saline water channel, simulation has been carried out using Opti-System software and performance parameters are analyzed in terms of Q-factor and BER. The eye diagram is also analyzed which gives the information regarding the quality of the received signal. It has been found that Q-factor and BER decrease with link length and the quality of the signal degrades with increased salinity and data rate [1][11-15].

Vladimir I. Haltrin, et al., proposed the paper titled “Chlorophyll-based model of seawater optical properties” in the journal of Applied optics published in 1999, the author presents a one-parameter model of the inherent optical properties of biologically stable waters was proposed. The model is based on the results of in situ measurements of inherent optical properties that have been conducted at different seas and oceans by several researchers. The results of these investigations are processed to force this model to agree satisfactorily with an established regression model that connects the colour index with the chlorophyll concentration. The model couples two concentrations of coloured dissolved organic matter (concentrations of humic and fulvic acids) and two concentrations of suspended scattering particles (concentrations of terrigenous and biogenic particles) with the chlorophyll concentration. As a result, this model expresses all essential properties of seawater by a single parameter. This model may be applicable for case 1 waters and for case 2 waters with optical properties in stable biological equilibrium (BioSt waters). This model is not applicable for case 2 (coastal) waters with a sandy and dirty bottom, especially during several days after stormy weather conditions [2][18-20].

R.Sauzede, et al., published the journal “Vertical distribution of chlorophyll-a concentration and phytoplankton community composition from in situ fluorescence profiles: a first database for the global ocean” in the year 2015; the author takes Vivo chlorophyll-a, fluorescence is a proxy of chlorophyll-a concentration and is one of the most frequently measured biogeochemical properties in the ocean. Thousands of profiles are available from historical databases and the integration of fluorescence sensors into autonomous platforms has led to a significant increase in chlorophyll fluorescence profile acquisition. To our knowledge, this major source of environmental data has not yet been included in global analyses. A total of 268127 chlorophyll fluorescence profiles from several databases as well as published and unpublished individual sources were compiled. Following a robust quality control procedure detailed in the present paper, about 49 000 chlorophyll fluorescence profiles were converted into phytoplankton biomass (i.e., chlorophyll-a concentration) and size-based community composition (i.e., microphytoplankton, nanophytoplankton and picophytoplankton), using a method specifically developed to harmonize fluorescence profiles from diverse sources. The data span over 5 decades and includes observations from major oceanic basins and seasons, and depths ranging from the surface to a median maximum sampling depth of around 700 m. Global maps of chlorophyll-a concentration and phytoplankton community composition are presented here. Monthly climates were computed for three of Longhurst’s ecological provinces to exemplify the potential use of the data product [3,16].

Morel and Hubert Loisel proposed the paper titled “Apparent optical properties of oceanic water: dependence on the molecular scattering contribution” Applied Optics published in the year 1998; describes the relationships between the apparent optical properties and the inherent optical properties of oceanic water bodies that have been reinvestigated by this solution of the radiative transfer equation. This re-examination deals specifically with oceanic case 1 waters (those for which phytoplankton and their associated particles or substances control their inherent optical properties). In such waters, when the chlorophyll content is low enough, the influence of molecular scattering by water molecules is not negligible, leading to a gradual change in the shape of the phase function. Practical parameterizations are proposed to predict in case 1 waters, and at various depths, the vertical attenuation coefficient for downward irradiance ($K\ d$) as a function of the IOPs and solar angle. These parameters are valid for the spectral domain where inelastic scattering does not significantly occur (wavelengths below 590 nm) [4,17-20].

3. PROPOSED SYSTEM

As underwater wireless optical communication is an emerging trend among researchers, there are many proposals in this specific area. In their research, they have used either Light Amplification by Stimulated Emission of Radiation (LASER) or Light Emitting Diode (LED) and in some cases both. Since underwater has a narrow optical window, this allows them to use optical sources configured to a specific frequency to transmit data wirelessly through an underwater medium.

Optical wireless modulation schemes can be categorized into two main classes: intensity modulation (IM) (a.k.a. noncoherent modulation) and coherent modulation (CM), which can be implemented either by a direct or an external modulator.

The IM is carried out by modulating the intensity of the light source by a direct or an external modulator. If the receiver demodulates the received light by a Direct Detector (DD), the overall system is referred to as IM/DD modulation. IM/DD is the most prominent modulation scheme due to its low cost and simplicity, as there is no need for phase information. In follows, we present and compare common IM schemes from the spectrum, power, cost, and monetary efficiency. The simplest form of the IM modulation is the OOK scheme where the “1” and “0” are represented by the presence and absence of light. OOK utilize return-to-zero (RZ) or non-return-to-zero (NRZ) pulse formats. The NRZ format occupies the entire bit length to represent “1” while the RZ format only occupies part of the bit length. The performance of OOK severely decreases with the channel variations. Thus a dynamic threshold mechanism could improve the overall performance by updating the detection threshold according to the channel state estimation. The low power consumption, bandwidth efficiency, and simplicity make OOK a popular and practical scheme, that is theoretically and experimentally. PPM is one of the most widely used techniques which modulates each of M transmitted bits as a pulse within 2M time slots whose position corresponds to the message sent. PPM provides higher power and spectral efficiency in return for a complicated transceiver. Even though it does not need a dynamic threshold mechanism, tight synchronization requirements cause significant performance. Conventional PPM was improved by its variants such as differential PPM, digital pulse interval PPM, differential amplitude PPM and multilevel digital pulse interval modulation.

We propose to achieve a simplex method of underwater laser communication by implementing international morse code through a 650nm semiconductor laser that is being operated in pulse mode that transmits a train of pulses in deep ocean waters. Our region of focus is the twilight zone which has a depth profile of 200m to 1000m underwater. Since the red pigment is invisible in deep waters makes them convenient to transmit secure messages from and to the submarines and underwater autonomous vehicles (UAV).

This proposed solution implements Return-To-Zero On-Off Keying (RZ-OOK) as it is simpler and more convenient to be operated in a pulsed mode. Moreover, by implementing Huffman coding the error correction is well and good. The generalized block diagram in figure 1 consists of a transmitter that converts the incoming electrical signal into optical pulses to transmit the morse code in the twilight zone. These pulses travel across the ocean waters and reach the receiver where the receiver decodes the received pulses to produce an electrical output. This is then displayed as the message that was being transmitted.

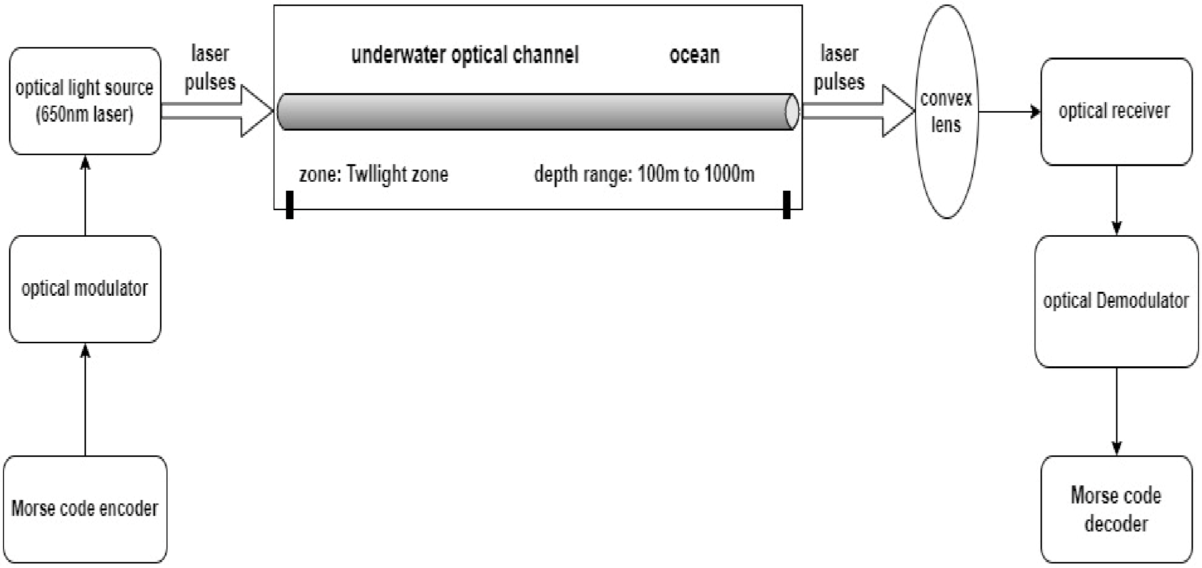


Figure 1 Generalized block diagram of OOWC

The proposed solution uses the return to zero on-off keying modulation technique as it has a greater advantage in high-speed data transmission for optical signals. We use morse code for our data transmission as it does not occupy a large amount of bandwidth and it is less complex. These codes are encoded in such a way that the “dit” corresponds to bit ”0” and the “dash” corresponds to bit “1”. The time interval between dit and dash are chosen appropriately as per the international morse code time interval rule. Based on the rules we have set our Dit timing as 0.5 seconds and dash timing as 1.5 seconds. These values make the optical pulses minimize the propagational delay to a considerable amount, making our solution versatile.

The channel modelling is one of the most essential parts of our solution. There is a certain parameter that has to be considered while developing or creating a model underwater. The working of the proposed solution is as follows

Step 1: Obtain the information to be transmitted from the sender

Step 2: Convert them to upper case letters if the data is entered in uppercase, then proceed towards the next step.

Step 3: Separate every character and encode them into their respective morse codes. This is done by the program fed into the microcontroller (Arduino UNO in our solution)

Step 4: Assign each “dit” as bit ”0” and each “dash” as a bit “1”, thus each dit and dashes are to be converted as 1’s and 0’s.

Step 5: Now these trains of 1’s and 0’s from the microcontroller are being modulated by an optical power source such as a 650nm laser diode and are transmitted through an underwater communication channel.

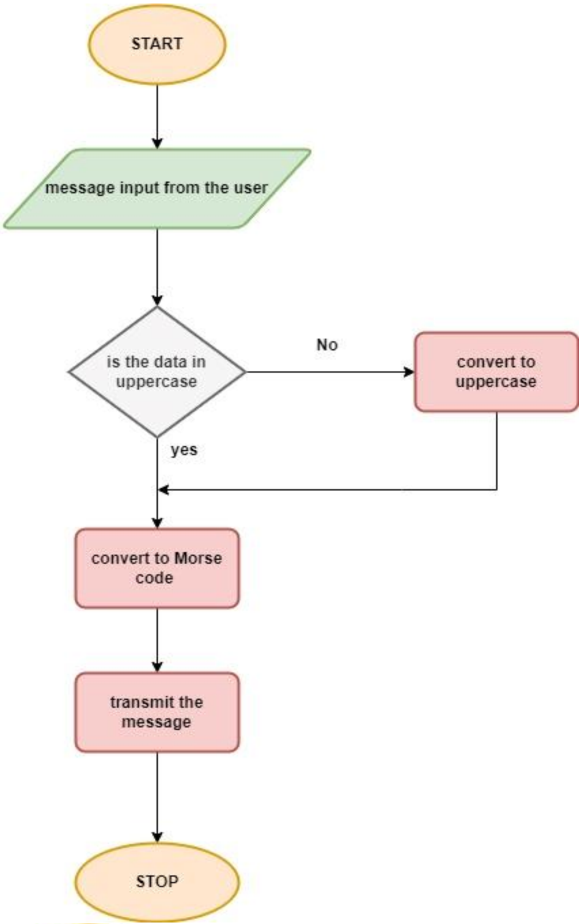
Step 6: The transmitted pulses after passing in the underwater medium reached the optical receiver (a phototransistor in our case), where the optical signals are demodulated to their corresponding electrical signal.

Step 7: This electrical signal is amplified and sent to the microcontroller for further processing.

Step 8: Once the signals reach the microcontroller, it gets decoded to their respective morse code signals and then get predicted to their original information and displayed as the output.

The chart below explains the complete execution in blocks, The message is obtained from the user, and the code checks whether it is in uppercase letters. If it is yes then the uppercase letters are converted into morse code for transmission. Next, the converted morse codes are transmitted by the laser transmitter module. If the obtained message is not in uppercase, it is automatically converted into uppercase that is programmed inside the code.

The optical receiver waits until the light source falls on the sensor. Once the light source falls on the receiver sensor, it starts to decode the message. That is the morse code is converted into a text message. Later the received light is shown as the output. Further receiver subsequently checks to receive the signal from the source.


START
message input from the user
is the data in uppercase
No
convert to uppercase
yes
convert to Morse code
transmit the message
STOP

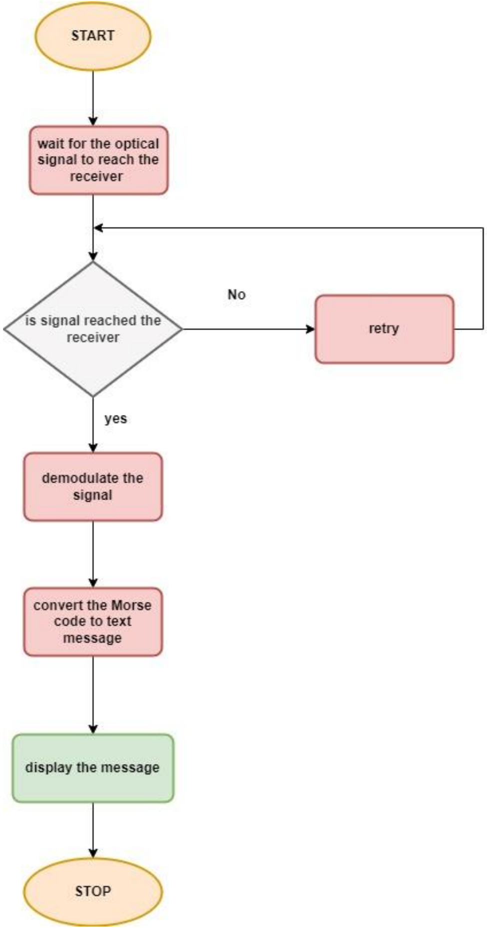
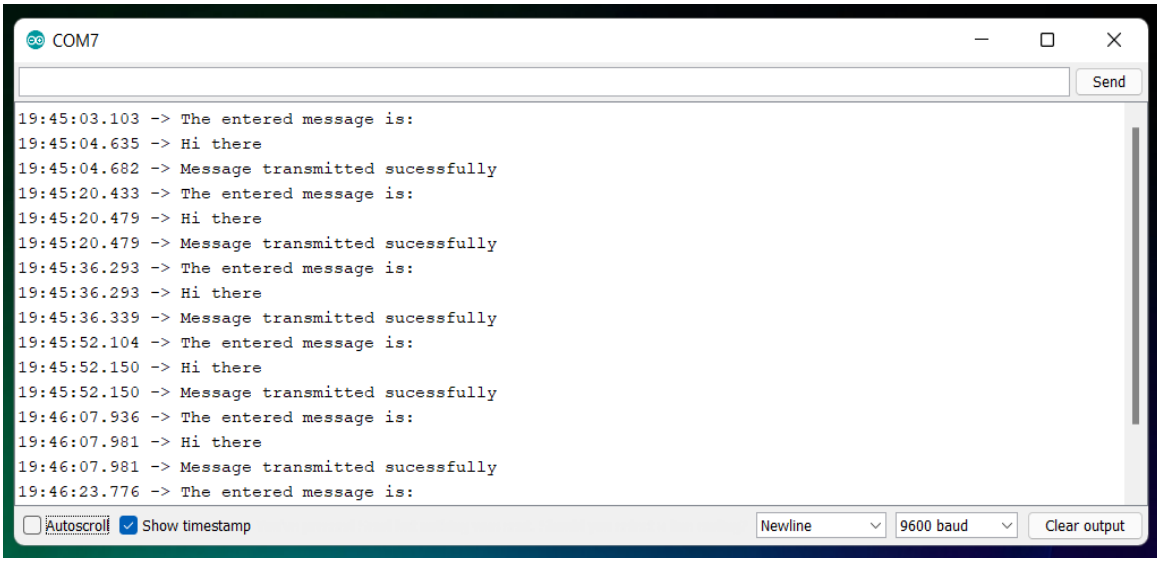

START
wait for the optical signal to reach the receiver
is signal reached the receiver
No
retry
yes
demodulate the signal
convert the Morse code to text message
display the message
STOP

Figure 2 Flow chart of transmission and receiver sections

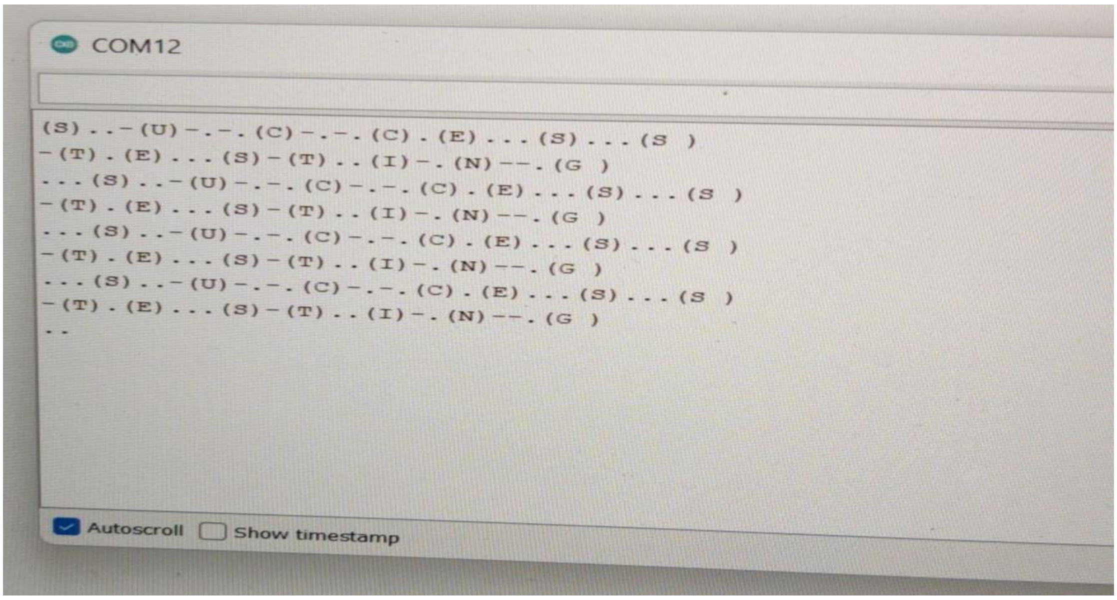
4. RESULTS AND DISCUSSION

The proposed solution for Oceanic Optical wireless communication was tested in various depths and the result was way beyond expectation thus the result was satisfactory. The outputs of the transmission programs are displayed in Figures 3 and figure 4.



```
19:45:03.103 -> The entered message is:
19:45:04.635 -> Hi there
19:45:04.682 -> Message transmitted sucessfully
19:45:20.433 -> The entered message is:
19:45:20.479 -> Hi there
19:45:20.479 -> Message transmitted sucessfully
19:45:36.293 -> The entered message is:
19:45:36.293 -> Hi there
19:45:36.339 -> Message transmitted sucessfully
19:45:52.104 -> The entered message is:
19:45:52.150 -> Hi there
19:45:52.150 -> Message transmitted sucessfully
19:46:07.936 -> The entered message is:
19:46:07.981 -> Hi there
19:46:07.981 -> Message transmitted sucessfully
19:46:23.776 -> The entered message is:
```

Figure 3 Transmission message is displayed



```
(S)..-(U)-.-.(C)-.-.(C).(E)...(S)...(S )
-(T).(E)....(S)-(T)..(I)-.(N)--.(G )
...(S)..-(U)-.-.(C)-.-.(C).(E)...(S)...(S )
-(T).(E)....(S)-(T)..(I)-.(N)--.(G )
...(S)..-(U)-.-.(C)-.-.(C).(E)...(S)...(S )
-(T).(E)....(S)-(T)..(I)-.(N)--.(G )
...(S)..-(U)-.-.(C)-.-.(C).(E)...(S)...(S )
-(T).(E)....(S)-(T)..(I)-.(N)--.(G )
..
```

Figure 4 Received message is displayed

Figure 5 displays the transmitter segment of our proposed solution. This consists of the laser diode module KY-008 connected with an Arduino UNO board, thus making our transmitter simpler, portable and power efficient. The receiver segment consists of a receiver module which is ISO-203 connected with the microcontroller that is Arduino UNO thus completing the receiver segment and it is shown in figure 6.

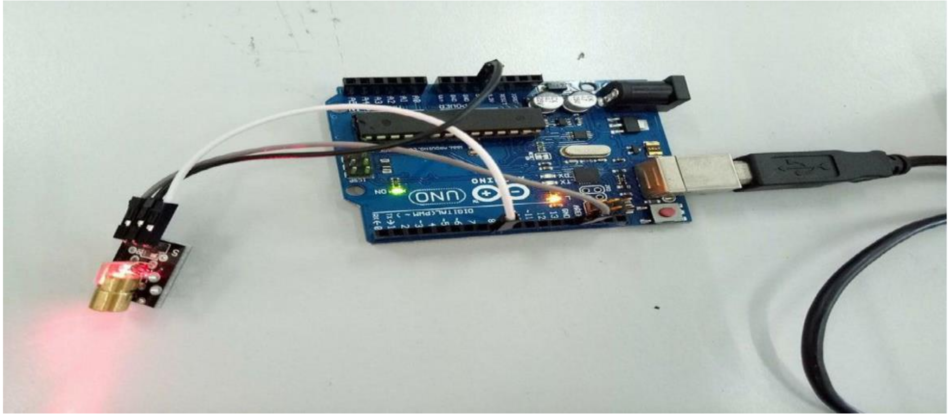


Figure 5 Transmitter segment

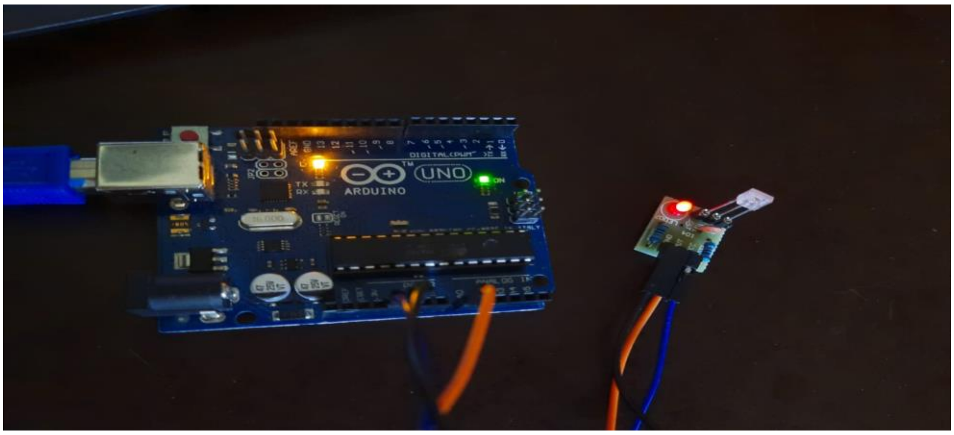


Figure 6 Receiver segment

5. CONCLUSION

Today communicating under the water is a challenging job. Though they find a way to communicate it has its drawbacks. Our work, Oceanic Optical Wireless Communication is absolutely the easiest simplest way to communicate laser pulse in the seas and ocean. Here the aspects of designing and assembling electronic devices are concerned with the previously existing systems, where each system lacks any of the important features or characteristics in them. Considering these details, our work was built to eliminate most of the previous drawbacks. The codes are fed into the microcontroller for transmission and reception. It uses less power and works extraordinarily at this stage. Hence the outcome is with maximum accuracy.

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