Underwater Communication System For Deep Sea Divers Using Visible Light

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Abstract— **This paper discusses a novel idea for transmission of voices in real time, underwater so that the system can be used by the deep sea divers for both lightning and data transfer applications simultaneously. Experiments were performed using white light, green and blue light respectively to transfer voice in real time in a water tank and the graphs were obtained. Based on the comparison study, we make recommendations for the selection of the right colour of light for communication efficiency in specified underwater environments.**

Keywords- Optical Wireless Communications(OWC); Light Emitting Diode(LED); On-Off Keying(OOK); Phase Locked Loops(PLL); Scattering and Attenuation; Geometrical efficiency Ratio.

I. INTRODUCTION

In Oceanography research, autonomous underwater Vehicles (AUV) and Unmanned Underwater Vehicles (UUV) are used to observe the environmental phenomena at a fixed location over a long period. But deep sea divers go around underwater on different mission. They set out to document the underwater world or scientific diving, including marine biology, geology, hydrology, oceanography and underwater archaeology.

Divers generally are trained to use hand signals to communicate within their group. They also use underwater writing boards, which allow better communication. Both these require light. If the water is murkier or if it is night time the communication becomes difficult.

Optical wireless is a suitable candidate which satisfies the demand for increased broadband wireless data transmission. Optical Wireless Communication (OWC) is a fast growing area where rapid researches are going on [1]. Many systems are demonstrated using IR LEDs but there is only a less research activity in the visible Light Spectrum region [2]. A novel idea for transmission of voice in real time, underwater over LED flash lights is proposed in this work. The system can be used for both lighting and data transfer applications simultaneously.

II. METHODOLOGY

Optical wireless communication is constraint by the underwater phenomena arising from the interaction of propagating light beams in the ocean water [3]. Measuring and interpreting the optical properties of ocean waters has been, and continues to be a challenging endeavor in oceanography. Just as the measurements of chlorophyll, temperature, salinity and density have vexed oceanographers for perhaps two centuries, so it goes in the struggle to understand ocean optical properties. Optical properties are influenced by a wide array of physical, biological and chemical processes. These processes can lead to large sources of optical variability [4]. The parameters like chlorophyll, temperature, salinity and density which lead to absorption and scattering of the transmitted signal can be accurately measured with the advancement of technology. The reasons of seawater scattering forming is composing of the pure water and suspending particle within seawater. The scattering from the pure water is affected by temperature and depth of sea generally, those from suspending article is affected by volume and thickness mostly. Atkins and Poole ever pointed out that those scattering, scattering angle at a range of 20-1550, is the result of refraction happened when light transporting through large and lucent mineral particle [5]. .Usually the attenuation depends on the wavelength of the light and 500nm range of wavelength exhibit low attenuation in sea water [6].

III. SYSTEM DESIGN

The system uses basic opto-electronic and electronic components, including LEDs, Voltage controlled Oscillators (VCO), PIN photodiodes and Phase-Locked Loops, to achieve a voice transmission with excellent signal-to-noise characteristics. The system consists of a transmitter module and a receiver module as shown in figure 1. In the transmitter side, data is transmitted by modulating (On-Off Keying) visible light LED's and in the receiver side photo detectors are used for detecting (direct direction) the modulated light signal. The idea behind this work is based fast switching and modulation characteristics of LEDs and spectral responsivity of the photo detector.

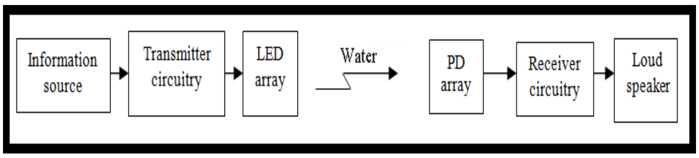


Figure1. Simple system model for establishing a simplex channel

A. Transmitter Module

The transmitter circuit must be designed in such a way that LED blinking is unperceivable to human eye so that it satisfies the conditions of both lighting system and transmit data simultaneously. main blocks in the transmitter module are microphone with an amplifier, modulator, LED driver and a power supply block. The audio signal is detected by using a miniature microphone. The microphone used must have a good response within the audible frequency range (20Hz-20 KHz). Here a readily available condenser electret type microphone manufactured by Panasonic is used. The audio signal from the microphone has small amplitude and hence amplification of this audio signal is necessary. An amplifier stage is used to amplify the weak audio signal and shift the average voltage level of the audio signal to a suitable level within the capture range of a Voltage Controlled Oscillator (VCO). Here VCO is used as a FM modulator and the amplified output of the microphone will serve as an input to the FM modulation circuitry. The amplified output of microphone will act as the control voltage to the VCO and the VCO circuit provides an oscillating output signal typically of square-wave or triangular waveform whose frequency can be adjusted over a range by a dc voltage. The square wave output of the VCO is given as input to a LED drive circuitry. The drive circuit is used to convert the information voltage signal into a modulation current suitable for a LED source. The operation of the LED requires the switching on and off of a current which is in the order of hundreds of mill amperes. This must be performed at high speed in response to the voltage levels at the driving circuit input. The optical power output of a LED is directly proportional to the current flowing through the LED. But if we increase the current further a maximum value, the life time of LED will decrease. The current flowing through the LED is controlled by the drive circuitry. So design of the LED drive circuit is most important while considering the proper functioning and life time of the optical system.

B. Receiver Module

At the receiver side the detector wavelength of maximum sensitivity must match with the spectral characteristics of the LED used in the transmitter side. This work integrates the concepts of underwater communication, modulation, signal processing and analog electronic circuit design. the receiver circuitry consist of a detector array, preamplifier, signal reshaping circuits, demodulator, filter, audio amplifier and a power supply block . The design of an optical receiver is much more complicated than that of an optical transmitter because the receiver must be able to detect week and distorted signals. At receiver side modulated optical signal is detected by using PIN photo detector and demodulation by using a Phase Locked Loop (PLL). A more detailed description of each stage is given below.

An optical detector or photo detector converts the optical input power falling on it into a current output. Here a photodiode (SFH 203P) is used for detecting high frequency modulated optical signal. The detector switching time i.e., rise time and fall time is specified in the data sheet as 5ns. The maximum sensitivity wavelength of the detector is just outside the visible region but 90% of the maximum sensitivity falls in this region. The electric current produced by the Photodetector is proportional to the optical power and, hence, to the modulated incident light. But this current is in the range of microamperes. A preamplifier will act as a transimpedence amplifier and converts this photo generated current into corresponding voltage. For further signal processing to carry out, a multi stage amplifier is used to provide sufficient gain. It is possible to use just one amplifier stage, but the signal distortion will be more and we need high gain amplifiers. The lower the gain factor in each stage, the better the sound quality. So a multi-stage amplifier, each stage with lower gain, is used to achieve high gain with reduced noise. The output of multistage amplifier is a distorted square wave. A comparator is used to produce perfect rectangular signal pulses. Frequency demodulation or detection can be achieved directly by using a PLL circuit. When the centre frequency of the PLL is designed at the FM carrier frequency, the filtered output voltage is obviously the desired demodulated voltage that varies in magnitude and in proportion to the signal frequency. The output signal from the demodulation stage contains many distortions. A low pass filter with suitable cut off frequency is used to filter out all the high frequency noise components. The output signal from the low pass filter is a pure audio signal. The final stage of the receiver circuit is an audio amplifier. The demodulated signal from the PLL chip is a low frequency analog signal in the order of a few millivolts. An audio amplifier is used to increase the signal to an acceptable level. The output of audio amplifier is connected to the loud speaker. The objective is to deliver audible messages through a speaker.

IV. Experimental Results

A pilot study has been carried out in this regard. An optical wireless communication link is established underwater with a transmitter-receiver separation of a fixed distance (50cm). A snapshot of the experimental setup is shown in figure 2.

The optical properties of sea water are functions of the salinity, temperature and concentration of dissolved organic and inorganic matter suspended particles. As it is common knowledge that optical signal attenuates due to absorption and scattering phenomena. The beams of different monochromatic light differ in efficiency in sea water. The Geometrical Efficiency Ratio of these beams can be calculated using the given formula [9].

$$\frac{Hr}{P} = \frac{\frac{e^{-ar}}{r^2} + \left[\frac{\left(2.5 - \frac{3}{2}\log(\frac{2\pi}{\theta})\right)\left(1 + 7\left(\frac{2\pi}{\theta}\right)^{\frac{1}{2}} e^{-kr}\right)ke^{-kr}}{4\pi r}\right]}{2\pi\left(1 - \cos\frac{\theta}{2}\right)}$$

where, Hr/P = geometrical efficiency ratio, Hr = monochromatic irradiance, P = total monochromatic power, a = 0.200 natural log-units per foot, K = 0.0570 natural log-units per foot for the water, θ = beam spread and r= source-distance.

Using this formula, we calculated the Geometrical efficiency ratio for various values of θ and r.

Table 1 Geometrical Efficiency Ratio for various values of θ and r

r (in feet)	$\left\|\frac{\mathrm{Hr}}{\mathrm{P}}\right\| \theta = 20°$	$\left\|\frac{Hr}{P}\right\| \theta = 5°$
0.98 (30cm)	9.694	157.22
1.64 (50cm)	**3.198**	52.57
3.28 (100cm)	0.671	11.39

For our experimental setup, source detector separation of 50 cm and the beam spread of 20^{o}, the geometrical efficiency is as shown highlighted in the table. It can be seen the efficiency decreases with beam spread and source detector separation. With this geometrical efficiency experiment were conducted and the results are discussed below.

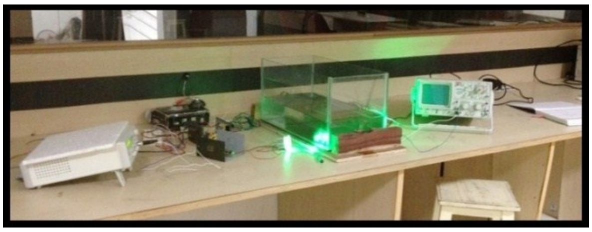
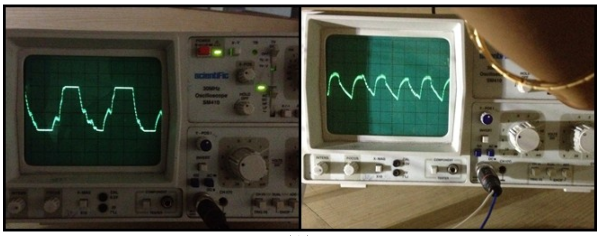
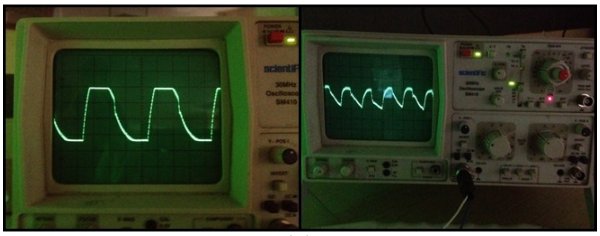


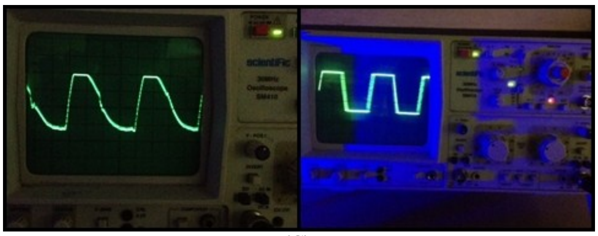
Figure2. Experimental Setup



(A)



(B)



(C)

Fig.3 The CRO output waveform underwater for (A) White Light, (B) Green Light & (C) Blue Light at 500Hz (Right) and 1 KHz (Left).

Three different colours of - White, Green and Blue LED arrays are used alternatively at the transmitter side and modulated using the voice signal/tune from MP3 player. The modulated light signal is transmitted underwater and detected at the receiver side. The study of voice transfer was examined closely.

In order to observe the changes due to the wavelength of transmission through the water, audio signal oscillator (square wave at frequencies of 500Hz and 1 KHz) were used to modulate the LED array and transmitted. The received signals were observed in the CRO. The snapshots of the received signals are displayed as figure 3.

As expected blue with the shortest wavelength has the least attenuation and showed better performance (maximum clarity of sound).

V. CONCLUSION

The pilot study conducted on the underwater communication reveals that blue light has least attenuation and can be used for designing the proposed system. Also, inorder to increase the geometrical efficiency, the transmitter geometrical design should be improved with lesser beam spread so that we can reach a far more distance as compared to the current study.

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