Wireless Optical Communication for Underwater Applications

C.T.Poomagal*, M.Athappan**
*(Department of Electronics and Communication Engineering, Sri Venkateswara College of Engineering, Chennai
** (Department of Electronics and Communication Engineering, Sri Venkateswara College of Engineering, Chennai

***Abstract*—Wireless optical communication can be presented as an alternative to acoustic modems for scenarios where high speed, moderate distances, lower power and less complex communication systems are desired. Wireless communication is much more feasible solution to the problem of communicating with robotic vehicles. In this paper, wireless optical communication for the underwater criteria is designed and analysed. The focus of the paper is to construct light emitting diode based links at low cost with faster data rate of 1Mbps, wirelessly under the water. The choice of using LEDs instead of Lasers was largely economic. However, the underwater environment can be very challenging optically and many of the advantages that lasers have in terms of beam quality can be rapidly degraded by scattering and turbulence.**

Keyword: Moderate distance, Wireless optical, Super bright blue LED.

I. INTRODUCTION

More than 70% of our planet is covered by water. It is widely believed that underwater world holds ideas and resources that will fuel much of next generation of sciences and business. Since human are limited in their ability to work underwater ROVs (Remotely operated vehicles) and AUVs (Automatic Underwater Vehicles) such as robots have been in service since 1950's to perform underwater tasks. The easiest way to communicate with a robot is through a physical connection such as a copper or fibre optic tether. Though this allows efficient and high speed communication, a tether provides many operational challenges when dealing with a mobile robot, limiting the range of vehicle, management of links. For these reasons, wireless communication is much more feasible solution to the problem of communicating with robotic vehicles. In underwater, radio waves do not propagate more, acoustics will be hard to provide sufficient bandwidth at the same time and have difficulty in penetrating the water. This suggests that high bandwidth, short range underwater wireless optical communications have high potential to augment acoustic communication methods.

II.SYSTEM DESIGN

A wireless optical communication system is made up of optical transmitter and receiver. The signal transmitted allowed to pass through the transmission medium (water) and it is picked up by the receiver. The receiver detects the optical signal, converts it back into an electrical signal and passes that data back to the respective system.

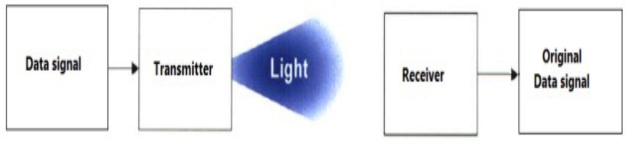

Figure 2.1. Wireless optical communication system overview

There are many ways for the light to carry data, but the simplest way is called On-Off Keying (OOK). This means that the transmitter must be able to read in binary data (ON and OFF), quickly and accurately change the state of the optical component accordingly and outputs binary one. On the other end, the receiver use a photo detector to determine if the light is ON or OFF and outputs accordingly as the input signal. The speed and reliability of the system is determined by how fast the transmitter can switch the state of the optical component and how quickly and accurately the receiver can determine the state of the light.

III. OPTICAL TRANSMITTER

The optical transmitter converts electrical signal into optical signal and projects that optical signal into the transmission channel. It consists of photon source, which acts as electro optical convertor as well as auxiliary systems required to operate and condition the photon source. Figure 3.1 shows the typical optical transmitter.

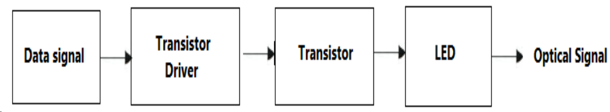

Figure 3.1 Optical Transmitter

When designing an optical transmitter, the first work is to design photon source as rest of the transmitter is designed to support the selected photon source. To determine the best photon source for a system, the available sources must be compared in terms of goals and constraints on the system.

Table 1. Comparison of LEDs and LASER diodes

Characteristic	LED	LASER
Optical spectral width	25-100 nm	0.01-5 nm
Modulation bandwidth	<200 MHz	>1 GHz
Minimum output beam divergence	Wide(about 0.5degree)	Narrow(0.01 degree)
Temperature dependency	Little	Temperature dependent
Special circuitry required	None	Threshold and temperature compensation circuit.
Cost	Low	High
Lifetime	Long	Medium
Reliability	High	Moderate
Coherence	Incoherent	Coherent
Eye-safety	Eye Safe	Must take precautions

Photon Source

Selecting the photon source drives the design of the rest of the optical transmitter. Though any photon source could be used, light emitting diodes (LED) and laser diodes (LD) have satisfies the trade-off between switching speed, system complexity and system cost. The choice between LEDs and LASER diodes is shown in the table 1. Since the goal is to transmit the signal as far as possible, the maximum amount of optical power in the 470nm is needed. This can be accomplished by choosing super bright LEDs and also by using multiple LEDs. To maximize light output, more LEDs are desirable, but this must be balanced with the power limitations placed on the system.

LED driver

The transmitter should contain LED as source. To control the LED ON and OFF, a LED driver is needed, but the commercially available are work with lower speed switching applications, in this situation, a transistor can be used to start and stop the flow of current through the LEDs, turning them ON and OFF. A metal oxide semiconductor field effect transistor (MOSFET) is best suited for this application. On comparing all the transistors, MOSFET is efficient for this purpose, it provide constant voltage and limit the current through LED. For this reason, MOSFET that needs to switch high power loads very quickly and employs a MOSFET driver. It takes the input signal and source current to MOSFET gate.

IV. OPTICAL RECEIVER

The optical receiver system detects the optical signal and transforms it into an electrical signal. It consists of a photo detector, which converts an optical signal into an electrical current. Figure 4.1 shows the system level receiver design.

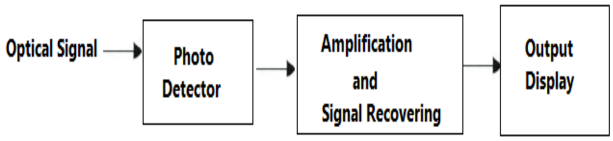

Figure 4.1. Receiver design

Photo Detectors

There are different types of opto-electrical devices that can be used as photo detectors. photodetectors will respond quickly to all incident photons sent by the transmitter without introducing additional noise. Additionally it would be small, robust, cheap and power efficient. In the application, switching speed is the top priority for a photon detector, followed by light sensitivity. Of course, this is assuming that power and size constraints are met.

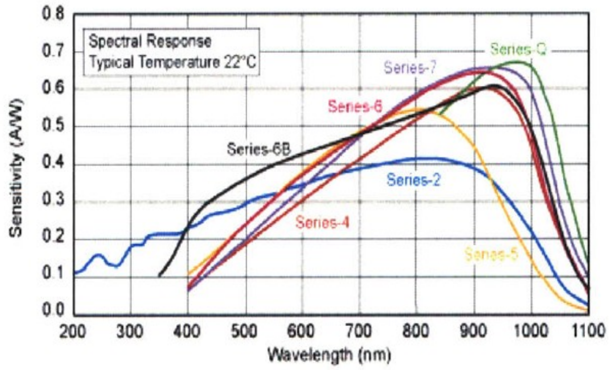

Figure 4.2. Spectral response of various photo diodes

There are different photo detectors such as photo multipliers, photo transistors, and photodiodes. Photodiodes can work fast with moderate power consumption and especially, photodiodes which is highly responsive for the wavelength of 420nm(wavelength of blue color) range is more suitable for wireless UWOC(Under Water Optical Communication). Though avalanche diodes are faster, high internal gain, it requires high bias voltage so P-N photo diode is more suitable in this case and also the NEP(Noise Equivalent Power) is 3.2x10^-14, it is better to use. Spectral response of various photo diodes is shown in figure 4.2.

Signal Processing

Photodiodes act as current sources when exposed to light, but most electrical devices work based on changes in voltage levels. For this reason, the current signal coming from photodiode must be converted to voltage signal. There are two ways to achieve this transformation. A resistor placed across the current source converts current signal into proportional voltage signal and an improved current to voltage convertor is called transimpedence amplifier. The next step in the signal processing is to add an inverting voltage amplifier.

This changes the signal from a negative voltage to a positive voltage and amplifies it, so that even very small signals, received when the transmitter is far away from the receiver, can be detected. The final step is to convert the data signal into voltage levels that receiving system could accept. Since the previous step is an amplifier running off a +12V power rail, the signal coming from the amplifier can be anything between 0 to +11volts, depending on the amplitude of signal going into the amplifier from the photo diode.

V. SIMULATION AND TESTING

The optical communication system for underwater purpose is successfully designed. This system should be tested before its real time implementation to prove its working efficiency. So, initially Multisim simulation software is used for testing the circuit. In circuit design, the signal to be transmit, the transmitted signal with added noise due to water medium and the signal after amplification are shown in figure 5.1, figure 5.2, and figure 5.3 respectively.

Simulation Results

From the below figures, the result of the simulation can be concluded that the transmitted signal and the signal received after amplification are retained, so the data signal can be transmitted by this designed wireless optical communication system, without heavy loss. Even though the system gives good results at simulation level, while by the hardware implementation only we can analyze the real time problems like extra light interferences, distance criteria, etc,.

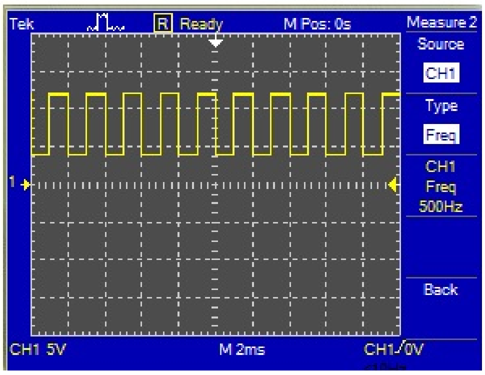

Figure 5.1.Transmitting signal

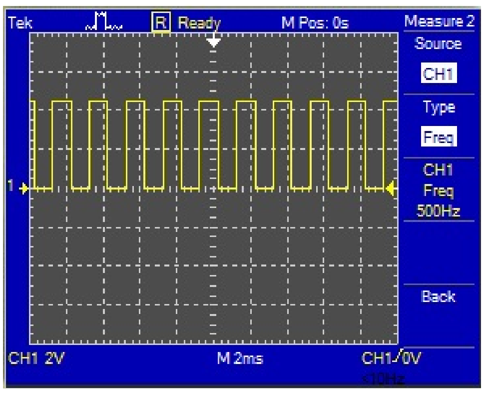

Figure 5.2.Received signal

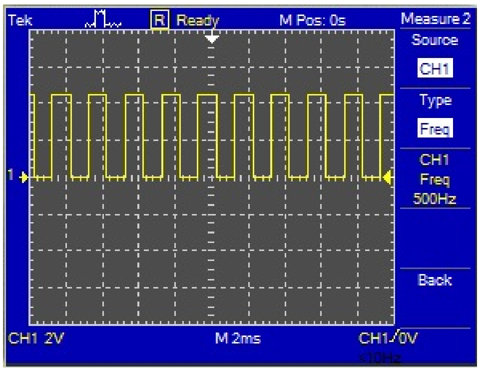

Figure 5.3 .Received signal after amplification

Hardware Testing

Bench testing on a breadboard was done to confirm the system design before moving to printed circuit board. Working on bread board is challenging, so the components were placed as close together as possible and wire runs were kept short and neat.

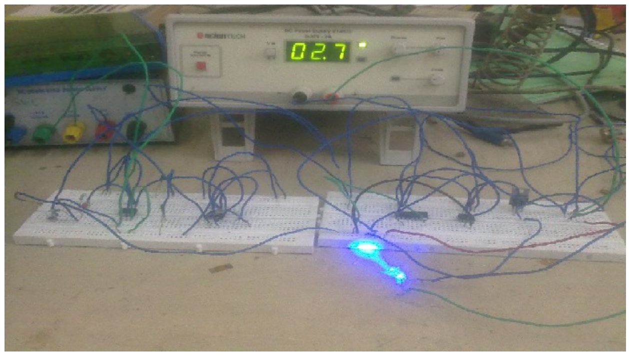

Figure. 5.4. Hardware Setup of Transmitter and Receiver circuit

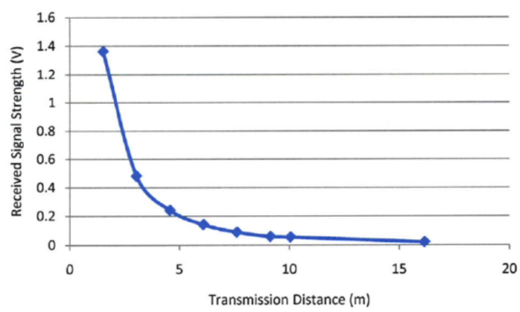

Figure. 5.5. Graph of received signal strength at various distances

VI. CONCLUSION

The signal which is received in the receiver is as similar as the signal which is transmitted. As expected, the received signal dropped off as the transmitter was moved further from the receiver. Even though the received signal was very low at long distances, the amplification and comparator stages were enough to enable successful transmission. Though receiver get the output as original data sent, it has some ringing effect due to circuit noise.

FUTURE WORK

The optical communication system can be implemented for the different types of water and to improve the distance of transmission by changing the type of LED and photo detector, this can also improve the speed of transmission.

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