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Design and Analysis of Optical Communication for Underwater Applications

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Abstract

This paper presents design and implementation of underwater optical communication system . The system consists of transmitter, water channel, and receiver. The laser diode used as a transmitter at 530 – 540 nm wavelength in CW mode with 100 mw power. The channel is about glass pool its dimensions (1m, 0.5m, 0.5m) with different samples of water . The receiver consists of photodiode detector and amplification circuit. This system transmits data from PC to another PC through water channel at different samples. The result shows the difference in the received signal at different tested water samples..

Index Term: *optical communication, laser diode, LED , amplification.*

INTRODUCTION

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 used 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 compared to acoustic communication methods.

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. 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.

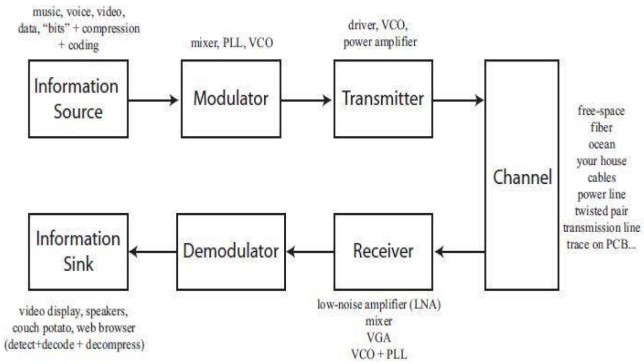

Figure 1. Wireless optical communication system overview

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.

Experimental work

The completed system consists of two parts, first part capable of simultaneously transmitting information (transmitter). Second part is able to receive transmitted signals (receiver).The electronic circuits of the system is express in figs. (2) and (3).

The first part (transmitter) is an electronic circuit made by using laser diode, Max232 IC, capacitors, resistors, and transistor. The circuit is connected to power supply (5volt) and PC by the RS 232 cable as shown in fig. (2).

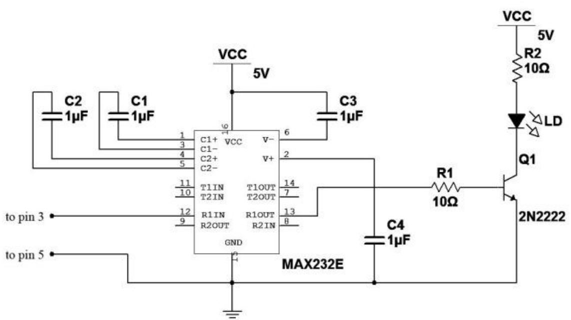

Fig. 2 circuit diagram for optical transmitter

The second part (receiver) is an electronic circuit. It is made of photodiode (as detector), Max232 IC, 1747IC, capacitors, power supply (5volt), and RS232 cable to connect the circuit with PC shown in fig. (3).

The data are sent via the RS-232 standard interface with a bit rate of 110 Kbps from PC1 by line receiver to convert the data from electrical levels (-12/+12 V) into TTL level (0/5 V). The intensity modulation on/off keying was the way to modulate this data using laser diode that have 532nm wavelength. This laser source is used to convert the encoded data from electrical levels into output optical power levels transmitting through water pool.

Laser as a communications medium has some unique properties compared to other forms of media. A line-of-sight laser beam is useful where wires cannot be physically connected to a remote location. A laser beam, unlike wires, also does not require special shielding over longer distances.

At the receiver side there is an optical receiver circuit which receives data using a photo diode and a MAX 232 IC used to convert the TTL levels (0/5 V) to electrical levels (-12/+12 V). This IC includes a charge pump, which generates ±12V from a single 5V supply; also include two receivers and two transmitters in the same package.

Digital data from a PC1 can be transferred via RS-232 cable to a drive circuit of the transmitting unit of the underwater communication system. A converter MAX 232 drives current which is responsible for the intensity modulation of the laser beam. The transmitted laser beam passes a distance of one meter in the water pool before it is arrive the photo detector. With the help of a detector, the optical signals are converted back to a digital data stream by using MAX232.

The RS-232 standard supports two types of connectors – a 25-pin D-type connector (DB-25) and a 9-pin D-type connector (DB-9). The type of serial communications used by PCs requires only nine pins. In RS-232 parlance, the device that connects to the interface is called Data Communications Equipment (DCE) and the device to which it connects is called Data Terminal Equipment (DTE). This standard was mainly designed to connect DTE that is sending and receiving serial data (such as a computer) and DCE that is used to send data over long distances (such as a modem).[8

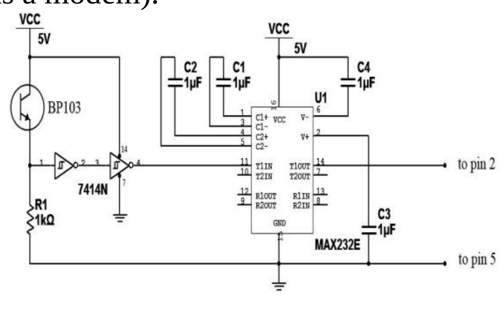

Fig . 3 wireless optical receiver circuit diagram

A Schmitt-trigger inverter 7414IC was used to invert the signal at the receiver side 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.

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.

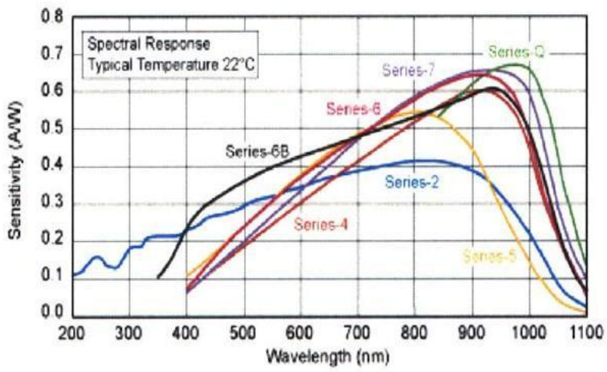

Figure 4. Spectral response of various photo diodes

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.

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.

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, figure 6, and figure7 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,.

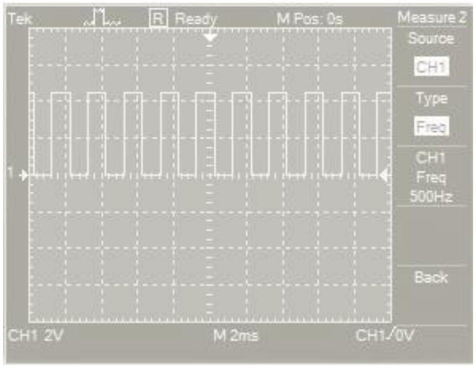

Figure 5 .Transmitting signal

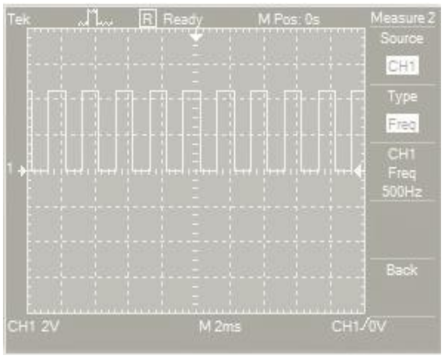

Figure 6 .Received signal

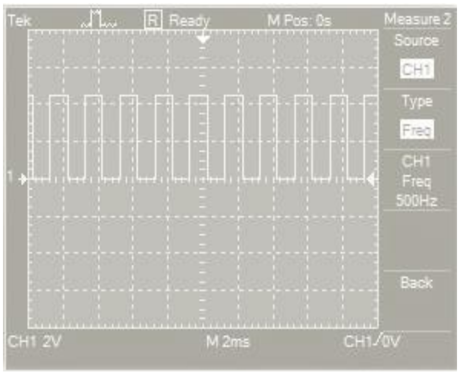

Figure 7 .Received signal after amplification

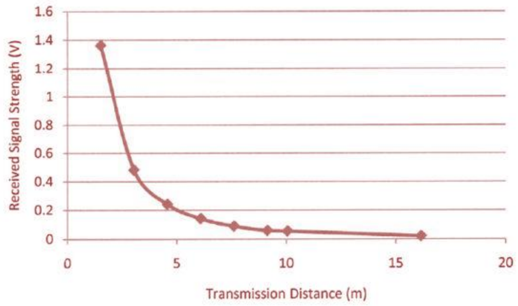

Figure. 8. Graph of received signal strength at various distances

CONCLUSION

The signal 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 above distance of 5 m.. Even though the received signal was very low at 10 m distance, 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.

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