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A Review on Underwater Wireless Optical Communication System

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***Abstract:*— In designing the underwater optical wireless system, there are many issues that are to be considered. Since water channel is highly attenuating for Ultrasound, Acoustic, RF and optical signal is a suitable candidate. Out of various techniques available for underwater wireless communication, acoustic sensors place a vital role in acquiring signals from various sources. However, the choice of wavelength depends on the water characteristics. Moreover in designing the optical transmitter system the modulation scheme that can perform better is to be studied. Though acoustic modems have long been the default wireless communication method for underwater applications due to their long range, the need for high speed communication has prompted the exploration of non-acoustic methods that have previously been overlooked due to their distance limitations. One scenario that drives this need is the monitoring of deep sea oil wells by AUVs that could be stationed at the well and communicate surveillance data wirelessly to a base station. Optical communication using LEDs is presented as an improvement over acoustic modems for scenarios where high speed, but only moderate distances, is required and lower power, less complex communication systems are desired.**

***Keywords*—component; undersea wireless optical link, optical channel, modulation techniques, and performance evaluation**

I. INTRODUCTION

A major driver of technology is to create machines that can perform tasks in place of humans. Whether the task is too repetitive and boring, requires more precision, or is too dangerous for a person to perform, a robotic system can provide the solution. Though people are no longer able to, or no longer wish to, perform a task, the state of artificial intelligence has not progressed to a point where people are comfortable being completely removed from the loop.

Robotic operators still need to communicate with their machines to various degrees – sometimes to completely control them, other times to monitor progress or review data collected from sensors.

The easiest technological way to communicate with a robot is through a physical connection, such as a copper or fibre optic tether. Though this allows for efficient and high speed communication, a tether provides many operational challenges when dealing with a mobile robot, limiting the range and maneuverability of the vehicle, as well as requiring an often cumbersome tether management system. For these reasons, wireless communication is a much more feasible solution to the problem of communicating with robotic vehicles. In aerial and terrestrial applications, radio and satellite communications provide adequate speed and range.

Underwater environments, on the other hand, have a much greater challenge in achieving wireless communication, while at the same time requiring wireless communication even more.

II. BACKGROUND

A. Wireless Communication Methods

There are two main mediums by which data can be transmitted wirelessly - acoustic waves and electromagnetic waves. Both of these are used extensively in terrestrial applications. Humans take advantage of wireless acoustic transmission when speaking to one another, while radios work thanks to electromagnetic transmission.

B. Acoustics

Though sound travels decently through air, it travels much better through water. The speed of sound in water is about 1500 m/s, compared to the approximately 340 m/s it travels in air. But the speed at which sound travels through water is highly dependent on the temperature, pressure and salinity of the water. As a result, the presence of thermoclines (temperature gradients) and haloclines (salinity gradients) in the ocean cause acoustic waves to refract when encountering these boundaries. This can drastically change the direction the sound is moving in,

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or even channel the sound and propagate it long distances (thousands of meters).

C. The Design Constraints

The previous research shows that underwater wireless optical communication could be a viable solution to the problem of an AUV needing to communicate with a base station at a deep sea oil well head. However, this scenario does impose some specialized design constraints on the system. Mainly, that the system will need to be integrated into a space- and power-limited AUV.

This means that the system needs to use minimal power and take up minimal space. It also means that the system needs to work even without perfect alignment of the transmitter and receiver, since the hovering AUV cannot hold a position without some margin of error. Since theAUV will be deployed and therefore not easily accessible by repair and maintenance crews for a long period of time, a simple system that requires little to no maintenance and has a minimal probability of failure is preferred. Finally, the communication system needs to be high speed (>=1Mbps) and transmit as far as possible. These priorities - high speed, low power, small size, low complexity, and maximum distance - are what must drive the system design.

III SYSTEM DESIGN

A wireless optical communication system is made up of a couple key components (see Figure2). The computer (be it a laptop or a microprocessor) sends data to the transmitter which converts the electrical signal into an optical signal. That signal passes through the transmission medium (in this case, water) and 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 receiving computer.

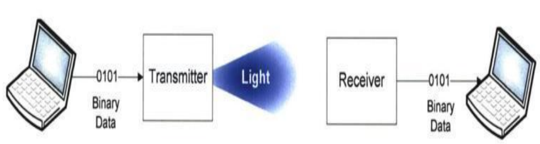

Figure1 Wireless optical communication overview

There are many different ways light can carry data, but the simplest way is called on-off keying (OOK).

In OOK, a binary one is represented as the light being on, and a binary zero is represented by the light being off. This means that the transmitter must be able to read in binary data and quickly and accurately change the state of the optical component accordingly. On the other end, the receiver use a photodetector to determine if the light is on or off and outputs binary ones and zeros accordingly. 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. In the following section, I will describe each subsystem in detail.

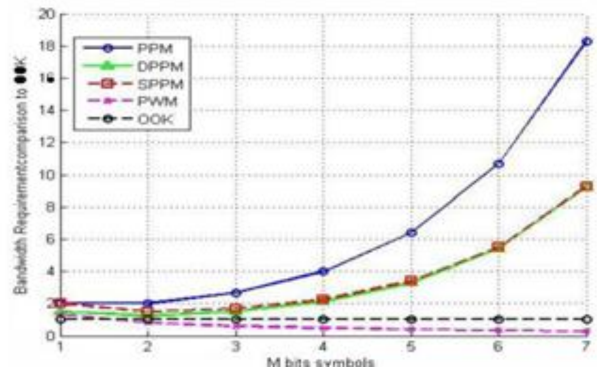

Figure2 Bandwidth requirement for different modulation scheme compared to OOK

Optical Transmitter

The optical transmitter converts the electrical data signal into an optical signal and projects that optical signal into the transmission channel. It consists of the photon source, which acts as the electro-optical converter, as well as auxiliary systems required to operate and condition the photon source. Figure3 shows a typical optical transmitter consisting of the input signal, the optical driver system, the photon source, and any light-beam conditioning optics required, such as reflectors and lenses.

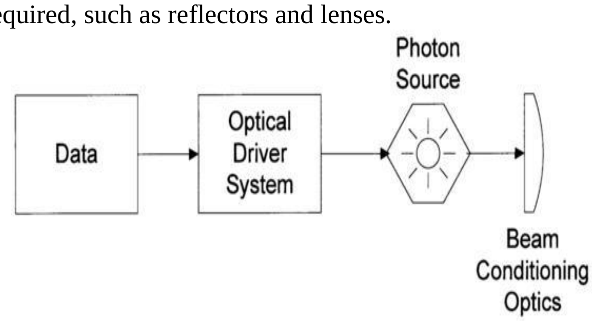

Figure3 Transmitter section overview

Photon Source Optical Data Driver- System Beam Conditioning OpticsFigure 3 Transmitter System Overview When designing an optical transmitter, the first step is to decide on your photon source, as the rest of the transmitter is designed to support the selected photon source. In order

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to determine the best photon source for a system, the available sources must be compared in terms of the goals and constraints

IV RECEIVER DESIGN

In an optical communication system, the function of the receiver is to convert a received optical signal into an electrical signal, which can serve as an input for other devices. The Bit Error Rate (BER) depends on several factors like received power level, detector sensitivity, noise level and data rate. In fact, BER and Signal to Noise ratio are interrelated. The exact relationship depends on the type of modulation and demodulation schemes used. That means detector is an essential component of the optical receiver and is one of the crucial element which dictates the overall system performance.

Additionally, it can take a couple of seconds for the photo resistor to return to its dark resistance after the light signal has ended. This is unacceptably slow for switching speeds of over 1 MHz. whereas photodiode does not have the light sensitivity as that of LDR but have rise time as short as picoseconds. Which means for fast switching application it is preferable to use photo detector which is very fast like Avalanche photodiodes, p-n photodiode and photomultiplier.

V COMPARlSON OF ERROR RATE FOR APD AND PIN PHOTON DETECTOR

The performance of the pulse digital receiver is usually measured by the BER. Performance criterion is the maximum attainable link distances for an average transmit optical power of 0.1 W. We consider the un-coded modulation using 470nm LED for Pure Sea, Coastal and Clear Ocean water with divergence angle of 0.6. On the receiver side, we consider the use of a PIN diode and APD (of maximum gain G=50) with quantum efficiencies of 0.82 and 0.78, respectively and the cut-off frequency of 300MHZ for different water types.

Though photomultiplier are very sensitive and fast, they are large and power hungry so taking size and speed into consideration fortunately, photodiode fit the requirements necessary for wireless underwater optical communication.

Once the photon detector is selected which is having fast rise times. The next step in the signal processing is to add an inverter voltage amplifier and comparator, LM7171 and AD790 is used for the high speed application because of its response time of 42 ns (LM7171) and short delay time of 45 ns (AD790). So it is preferred to use the PPM and DPPM encoder before the above shown LED driver circuit in order to achieve high speed and long distance communication

So for Coastal and clear Ocean water with the attenuation coefficient taken from [2], [3] one can have a similar plots for different modulation provided 470nm wavelength is used. The 470nm wavelength is the suitable choice for Pure sea, Coastal and Clean Ocean water.

VI. CONCLUSION

In the highly challenging underwater environment, the power resources are limited and their optimization is primordial. Taking line of sight, Link distance, attenuation nto consideration we have shown that the link distance increases by choosing the photon detector which has good rise time and small in size and also appropriate modulation technique at the transmitter provided we compromise on the one or the on order to better communication.

Compared to PIN Photo diode avalanche photo diode are potentially faster and have added advantage of high internal gain due to which attainable link distance has been increased but these can be achieved if we compromise on power because avalanche photodiode require high bias voltage to operate. Also since there are varied water types as seen from above results to have a allowable BER and link length we have to choose proper wavelength depending upon type of water and chlorophyll content. That means it is better to have an adaptive transceiver in order to have better communication.

VII. CONCLUSION

In the highly challenging underwater environment, the power resources are limited and their optimization is primordial. Taking line of sight, Link distance, attenuation into consideration we have shown that the link distance increases by choosing the photon detector which has good rise time and small in size and also appropriate modulation technique at the transmitter provided we compromise on the one or the other in order to have better communication. Compared to PIN photodiode avalanche photodiode are potentially faster and have the added advantage of a high internal gain due to which the attainable link distance has been increased but

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