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Underwater Wireless Communication Using Visible Light

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Abstract - *Underwater wireless information transfer is of great interest as there's a rise in number of vehicles and devices deployed underwater, which require high bandwidth and thus high capacity for information transfer underwater. Several progress has been made in the field of underwater communication using acoustics but it is limited by bandwidth. Electromagnetic (EM) waves is used as an alternative to acoustics. Electromagnetic (EM) waves, within the frequency (RF) range, is a good option for underwater wireless communication when used for top rate transfer briefly distance. However, it requires complicated antenna design and high transmission power. All this has led to the increase in fame of underwater optical wireless communication (UOWC), because the data transmission rate is higher than the normal acoustic communication system and consumes low power. This paper proposes implementation UOWC in light spectrum.*

***Key Words*: Acoustic waves, Electromagnetic waves, Low Latency, Underwater Optical Wireless Communication, Visible Light**

I. INTRODUCTION

Underwater wireless information transfer from a various underwater networks (that may include unmanned underwater vehicle (UUV) or sensor networks) has been under active research over many decades. These underwater networks require high bandwidth and high capacity for information transfer underwater.

Wired underwater communication like fibre optic cable and copper cable can provide high data rate and low latency but it is not flexible as it requires significant maintenance. Therefore, there is a need for underwater wireless communication. Underwater wireless communication are often implemented either using acoustic waves or EM waves.

Among the two types of waves as mentioned above, acoustic waves are used as the primary carrier for underwater communication due to their relatively less absorption and long distance coverage. The use of EM waves (in RF range) in underwater wireless communication has been explored for further improvements in data rates as it provides higher bandwidth and greater velocity in underwater environment. The RF waves can range from as low as few tens of Hz to GHz.

II. EXISTING SYSTEM

Underwater acoustic communication could also be a way of sending and receiving messages below water. There are several ways of employing such communication but the foremost common is by using hydrophones. Factors such as multi-path propagation, time variations of the channel, small available bandwidth and powerful signal attenuation, especially over long ranges make underwater communication tedious. Compared to terrestrial communication, underwater communication has low data rates because it uses acoustic waves instead of electromagnetic waves. In [1], the underwater wireless communication is implemented using acoustic waves.

The paper [1] describes the challenges in acoustic communication. The underwater acoustic channel is extremely variable and thus the signal transmission can change with respect to environmental factors, just like the temperature, pressure, or salinity of the water. Underwater communications face variety of the foremost unique challenges, first and foremost is that the high attenuation that happens in an underwater environment in conjunction with high bit error rates, large and variable propagation delays, and low bandwidth of acoustic channels.

A better alternative to acoustic waves is EM waves. As a development, underwater wireless communication was implemented using EM waves in RF range(from few tens of Hz to GHz). Electromagnetic waves operating at extremely low frequency (ELF) i.e., 30 - 300 Hz is extensively utilized in military applications or in establishing communication paths between terrestrial and underwater bodies. they're used for long distances propagation and are successfully deployed for communication with naval submarines. For RF system design which involves a communication link between underwater and terrestrial transceiver, any frequency range from MHz to GHz works effectively. Such communication systems are called buoyant RF communication system which they are not truly underwater communication. Other design configuration involves direct RF communication link between two transceivers submerged underwater or one set inside the water and other set within the air. this type of system design is known as direct RF communication system and it makes use of ELF or low frequency (LF) for communication. RF frequencies in MHz range are capable of propagating in sea water up to distance of 100 m by using dipole radiation with high transmission powers within the order of 100 W. However, it requires sophisticated antennas design and high transmission power. High data rates can be achieved at 2.4 GHz and 5 GHz but only at short ranges because the path loss in water increases with the increase in propagation distance.

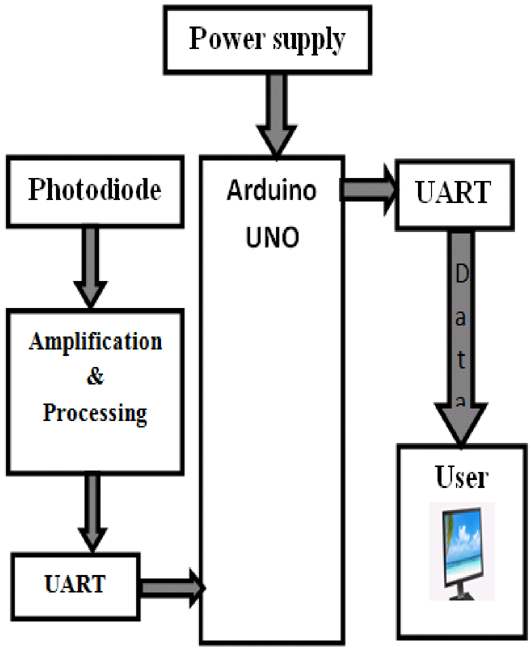

Figure 1: Transmitter

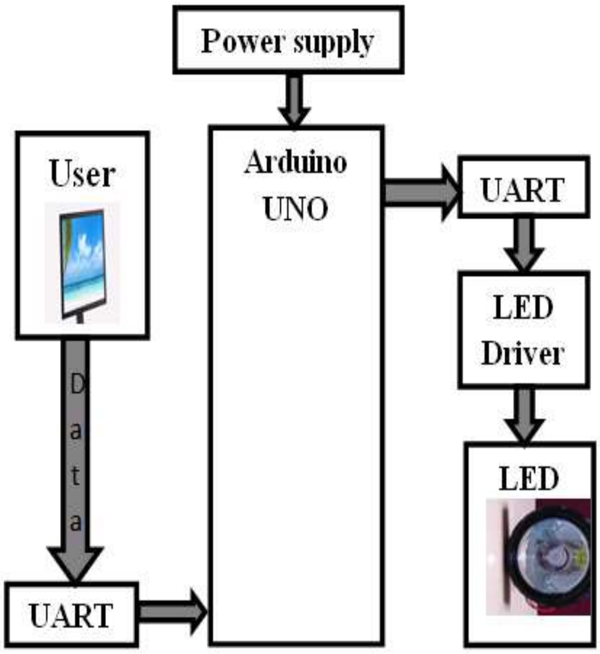

Figure 2: Receiver

III. PROPOSED SYSTEM

As RF signals require huge antenna size, large transmitter power in fresh water and suffers from high attenuation in sea water, the next obvious choice for underwater communication to support high data rate is using optical signal. UOWC is capable of exceeding Gbps at a distance of few hundreds of meters due to high frequency of optical carrier. Although optical signals in underwater environment face several extreme challenges due to water absorption or scattering caused by suspended particles or due to strong disturbance caused by the Sun, there are still many evidences for broadband optical link underwater over moderate ranges.

In the proposed system, underwater wireless communication is implemented using optical signals (in visible light spectrum). The system takes advantage of LED's which can be pulsed at very high speed without noticeable effect on the light output. The system has two main modules – transmitter and receiver as shown in figure 1 and figure 2 respectively. Transmitter modulates visible light with the given message data. At the receiver end, modulated light is detected with the help of photodiode. The message is extracted from the detected light signal and is given to the user at receiver end via UART. A GUI is designed to send and view the message data by the user.

IV. RESULT

The result of the proposed system is successful wireless data communication underwater with visible light signal as the carrier. The light signal is successfully modulated with respect to the message and propagated through the water without much attenuation for shorter distance. The proposed system is tested with varying propagation distance and different water condition. It is observed that there is increase in attenuation with increase in propagation distance and also with increase in the suspended particles in water.

V. MERITS AND DEMERITS

The proposed system overcomes some of the drawbacks of acoustic communication and RF wave communication underwater. Some of the merits are:

(I) **High bandwidth**: The visible light spectrum ranges from 400 THZ to 789 THz (380 nm to 750 nm). Hence the visible light communication provides higher bandwidth compared to acoustic wave communication.

(II) **High capacity:** Due to the large bandwidth, underwater wireless communication can support high data rate applications. Underwater wireless communication using visible light supports data rates in the range of Mbps, whereas, acoustic wave communication can only support data rates in the range of Kbps.

(III) **Low transmission power:** The proposed system consumes less power for data transmission as it uses LED's to modulate visible light. Thus the proposed system overcomes the major disadvantage of underwater RF communication which required large size antenna and high transmission power.

(IV) **Low latency:** The speed of the light in water is 2.25 ⍰ 10^8 m/s , whereas speed of acoustic waves in water is 1531 m/s. Thus the proposed system is has low latency when compared to acoustic wave communication.

Major drawbacks of the proposed system are:

(I) **Absorption and scattering:** The two main phenomenon that result in the loss of intensity or change in direction of optical signal underwater are absorption and scattering, respectively.

(II) **Turbulance:** Variation in the refraction index along the propagation path caused due to fluctuations in the density, salinity and temperature of the underwater environment leads to large fluctuations in the intensity of the signal at the receiver.

(III) **Pointing and alignement:** Since the optical beam is very narrow, maintaining the LOS for reliable optical link is very critical in UOWC. Due to the movement caused by underwater vehicles, ocean current or other turbulent sources A constant tracking between transceivers is very essential to maintain a uninterrupted reliable link due to the movement of the underwater vehicles.

(IV) **Physical obstruction:** As the optical beam is very narrow, any living organism such as school of _sh or marine animals will cause momentary loss of signal at the receiver. This requires the use of appropriate error correction techniques, signal processing techniques and redundancy measures to ensure re-transmission of data when lost.

VI. FUTURE SCOPE

UOWC provides high data rates with no latency over moderate distances.It reduces power consumption and therefore promotes reliable underwater monitoring and surveillance applications for longer durations. UOWC finds its applications in environmental monitoring, oil/gas monitoring and security. UOWC will provide an effcient way of communication between surface vehicles, underwater devices and seafloor infrastructure.

There are still many areas to be investigated and researched for long term survival of UOWC.By studying the underwater properties of the light source, the underwater wireless communication can be developed further.

The intensity of the light source can be varied inorder to obtain longer range of communication.Hence there is a need for further investigation and analysis of new theoretical model to understand the laser beam propagation through underwater channel.

VII. CONCLUSION

Traditional underwater communication uses acoustic signals and despite the substantial advancement in this field, acoustic communication could not provide sufficient bandwidth with low latency. RF signals for UOWC can only be used at extremely low frequency due to the high absorption of electromagnetic signals at radio frequencies. The use of optical fibers or co-axial cables limit the range and maneuverability of underwater operations. Optical underwater communication provides great potential to augment traditional acoustic communication due to its high data rates, low latency, less power consumption and smaller packaging. Also, this technology can benefit meaningfully from the progress made in the terrestrial optical wireless communication. However, the distance and scope of optical beam underwater is affected by water type, abortion, scattering and various other propagation losses.

We conclude that though acoustic waves are the robust and feasible carrier in today's scenario but with rapid technological development and active ongoing research in underwater optical wireless communication, this technology will be more promising in the near future.

VIII. NOMENCLATURE

EM Electromagnetic

RF Radio Frequency

UOWC Underwater Optical Wireless Communication

ELF Extremely Low Frequency

LF Low Frequency

UUV Unmanned Underwater Vehicle

LED Light Emitting Diode

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