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REVIEW ON UNDERWATER OPTICAL WIRELESS COMMUNICATION

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Abstract

Underwater wireless communication is a flourishing research area in the field of wireless communications. An improvement in underwater communication system is needed due to increased number of unmanned vehicles in space and underwater. Underwater optical wireless communication will provide an efficient and robust way of communication between surface vehicles, underwater devices and seafloor infrastructure. Due to low cost, small size, less power consumption and compatibility with other optical systems. In the last few year underwater optical wireless communication has play important role in submarine communication. This system is use for optical wireless communication between the underwater vehicle using laser and led.

***Keyword** :Underwater optical wireless, visible light, radio frequency, optical beam propagation,modulation.*

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1. INTRODUCTION

More than 70% of our planet is covered by water.human are limited in their ability to work underwater ROVs (Remotely operated vehicles) and AUVs (Automatic Underwater Vehicles). wireless communication is much more feasible solution to the problem of communicating with robotic vehicles. In the last few years, the interest towards optical wireless communication has increased for terrestrial, space and underwater links as it is capable of providing high data rates with low power and mass requirement.

Nowadays acoustic technology is mostly used for establishing wireless communication link Among divers and ships, or sending long range remote signals. This is because sound waves travel through water faster than in air, receiving very little attenuation. Electromagnetic waves, in the radio frequency range, is a good option for underwater wireless communication. when used for high data rate transfer in short distances. The speed of EM waves mainly depends upon permeability, permittivity, conductivity, and volume charge density. which varies according to the type of underwater conditions and frequency being used.

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, underwater wireless optical communications have high potential to augment acoustic communication methods. This paper shows the underwater optical wireless communication process using LED and LASER.

2. SYSTEM DISCRIPTION:-

2.1 Block Diagram

The system design for UOWC is shown in Fig-1. It consists of a source that generates the information to be transmitted. This information is applied to the modulator. which is then modulated on the optical carrier to be transmitted to longer distances with a high data rate.The transmitter is equipped with projection optics and beam steering elements in order to focus and steer the optical beam towards the position of the receiver.The information bearing signal is thenallowed to propagate through the underwater channel whose characteristicsvary according to the geographical location and time. At the receiving end, the collecting optics collects the incoming signal and passes it to the detector for optical-to-electrical conversion. The electrical signal is then allowed to pass through a signal processing unit and a demodulator for recovering the originally transmitted signal.

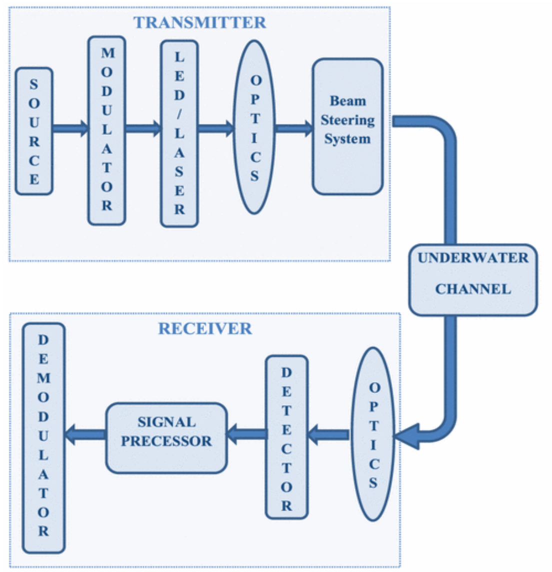

Fig-1: Block Diagram of uowc

3. HARDWARE DISCRIPTION :

3.1 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.

3.2 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. 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.

3.3 Optical receiver :

The optical receiver system detects the optical signal and transforms it into an electrical signal. Itconsists of a photo detector, which converts an optical signal into an electrical current.

3.4 Photo detector :

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.There are

different photo detectors such as photo multipliers[PMT], photo transistors, and photodiodes.

4. OPTICAL LINK CONFIGURATIONS :

There are three types of underwater optical link configurations: (i) direct LOS links, (ii) NLOS links and (iii) retro-reflector links.

4.1 Direct line of sight link :

Direct LOS link is the most simple, unobstructed and point-to-point underwater connection between transmitter and receiver. This link is fairly well to implement in case of static transmitters and receivers such as two sensor nodes at the bottom of the ocean. For mobile platforms such as AUVs, very sophisticated pointing and tracking mechanism is required to keep both transmitter and receiver bore-sighted. It works well in clear oceans where the transmitter directs a narrow beam signal towards the receiver. However, there are large chances of obscuration due to marine life growth, schools of fish or other obstacles. Therefore, in order to establish a LOS link, it is important to design a system which discourages the marine life from blocking the propagation path.

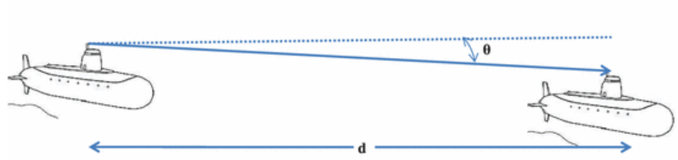

Fig-2: LOS link configuration

The lights that are considered optimal for optical communication underwater also attract schools of fish. Ocean

water fishes prefer blue-green wavelengths whereas fresh water fishes prefer yellow-green wavelengths. Therefore, in order to avoid fishes entering the LOS region, flashing or erratic lights are preferred .The received signal power, PR in a LOS link is given by,

$$P_{R\_LOS} = P_T \eta_T \eta_R L_P \left(\lambda, \frac{d}{cos\,\theta}\right) \frac{A_R cos\,\theta}{2\pi d^2 \left(1 - cos\,\theta_d\right)},$$

where PT is the average transmitter optical power, ηT and ηR are optical efficiencies of the transmitter and receiver, respectively, d is the perpendicular distance between the transmitter and receiver plane, θ is the angle between the perpendicular to the receiver plane and the transmitter-receiver trajectory, AR is the receiver aperture area and θd is the laser beam divergence angle. Typically ,the value of θd<< π/20.

The laboratory experiments for LOS links has been carried out using LEDs with green and blue light spectra in order to investigate the characteristics of laser beam propagation through different water types such as turbid level.

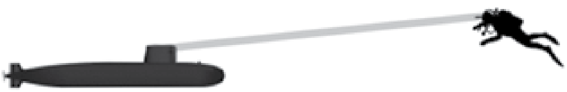

Fig-3: LOS link configuration

It is found that the viewing angle, propagation distance and turbid level play a significant role in the behavior of the blue light. Their results show the loss of communication above threshold viewing angle when one of the devices is rotated with respect to their LOS alignment. It was observed that even in turbid water, 5 Mbps can be achieved using high power laser.

4.2 Non line of sight links :

This link is not always possible in practical systems as it requires very tight pointing and tracking system and there are chances of beam blockage due to underwater marine life, bubbles and suspended particles. Therefore, a NLOS underwater communication is proposed where an optical link is implemented by means of back-reflection of the propagating optic signal at the ocean-air interface. These types of links are also called reflective links. Other way to implement NLOS links is to spread or diffuse the optical light from the LEDs or lasers in order to increase the field of view of the receiver. Such type links are also called diffuse links. Both reflective and diffuse scenarios are presented in Fig-4.

ComparedtoLOSlinks,theselinksdonotrequirestringent pointing and tracking requirements especially in a turbid environmentthatcausesspatialdispersionofcollimatedlight.

Forclearlakeoroceanwater,thedivergenceoflaserbeamhas to be increased by making use of array of LEDs or lasers to form a cone of light defined by inner and outer angles θminand θmax in the upward direction as shown in Fig (a).

Whentheangleoftransmittedlightisgreaterthanthecritical angle, the transmitted light strikes the ocean-air interface and is reflected back into the water due to total internal reflection (TIR).When the transmitter is at depth h, the illuminatedannularsurfacewithequalpowerdensityatdepth x will be given by

$$A_{ann} = 2\pi\ (h + x)^2\ (cos\,\theta - cos\,\theta_{max})\ .$$

The received power would then be given by

$$P_{R\_NLOS}\ (\theta) = A_R f_R\ (\theta)\ ,$$

where$f_R(\theta)$ is a auxiliary function dependent on P_T, A_{ann}, η_T,η_R, (h+x) and angle of transmission, θ_t.

A comparison of LOS and NLOS carried out showed that the 100 MHz bandwidth available for LOS link in turbid environment decreases to almost 20 MHz in NLOS environment even in clear water.Penguin automated systems (ON, Canada) developed ahighbandwidthUOWCsystemfor tele-robotingoperations consisting of array of LEDs in hemi-spherical configuration to enable larger FOV of the transmitter. In this experiment, first wireless underwater video pictures were transmitted at 1.5 Mbps up to around 15 m in turbid water environment. Other geometrical configuration used for NLOS link is icosahedron which is widely used in UOWC system due to its geometrical simplicity and its ability to provide complete free space coverage using LEDs. Other possible geometrical configurations are employing directional transmitters and omni-directional receivers or both transmitter and receiver being omni-directional.The latter case eases the pointing and tracking requirement and is mechanically the simplest solution. One such scenario is demonstrated by

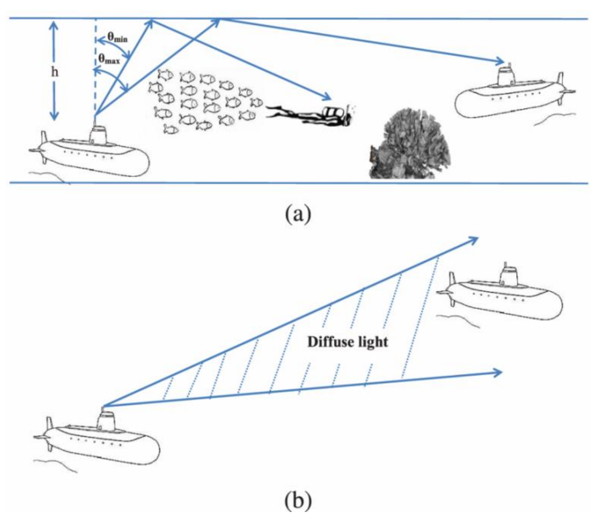

Fig-4: Nlos configuration (a) reflective ,(b) diffuse.

Fairetal, where omni-directional LEDs are used to provide the diffusion of light over full region of operation and are able to achieve omni-directional UOWC for 10 m. This work is particularly focused for AUV and fixed node applications in seafloor observatories. Link budget analysis is carried out for NLOS geometries considering attenuation only due to attenuation coefficients. Their investigation does not take into account multipath interference, dispersion (spatial and time) and multiple scattering. Therefore, the results are only valid for clear ocean or lake water.

4.3 Retro-reflector links :

Retro reflector links are used in limited duplex communication where receivers have low power to support full transceiver operations. Here, the source has more power and payload capacity than the receiver, therefore, it serves as an interrogator which sends modulated light signals towards the remote receiver. The receiver is equipped with a small optical retro-reflector which upon sensing the incoming interrogating beam from the source reflects it back to the UOWC source. The received power in this case is given as

$$P_{R\_Retro} = P_T \eta_T \eta_R \eta_{Retro} L_P \left(\lambda, \frac{d}{cos\theta}\right) \frac{A_{Retro} cos\theta}{2\pi d^2 (1 - cos\theta_d)} \times \left[\frac{A_R cos\theta}{\pi (d tan\theta_{Retro})^2}\right]$$

whereη_{Retro} is the optical efficiency of the retro-reflector, A_{Retro} is the retro-reflector aperture area, θ_{Retro} is the divergence angle of retro-reflector and other parameters are defined earlier. Link budgeting of underwater optical communication using retro-reflector is presented .

The retro-reflector underwater works in two scenarios:
(i)photonlimited
(ii)contrastlimited.

Thephotonlimited scenario occurs in clear ocean water or lakes. In this case, the link range and capacity is limited by the amount of photons falling on the detector due to absorption underwater.

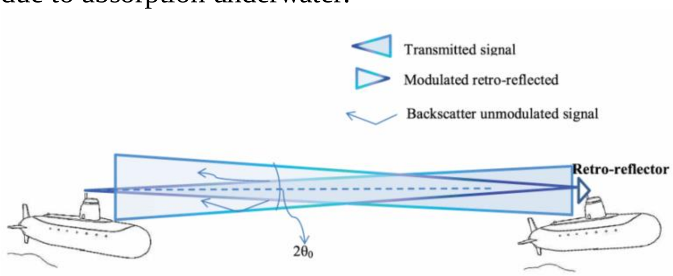

Fig-5: Modulating retro-reflector configuration

Moreover, pointing and tracking is crucial in this case as the information bearing retro-reflected signal is dependent upon the density per unit area of interrogating photons incident on the retro-reflector. Contrast limited scenario occurs in turbidharbors where scattering plays an important role in link range and capacity. This is a critical problem for applications related to underwater laser imaging. Here, the increased back-scatter component leads to reduction of photons and thereby,decreasesthecontrastoftheimage.Theback-scatter componentcanbesignificantlyreducedbyusing polarization discrimination.

TABLE: Comparison of different wireless underwater technologies.

Parameters	Acoustic	Rf	Optical
Attenuation	Distance and frequency dependent (0.1-4db/km)	Frequency and conductivity dependent (3.5-5db/m)	0.39db/m(ocean)- 11db/m(turbid)
Speed(m/s)	1500m/s	≈2.255×10^8	≈ 2.255×10^8
Data rate	~ kbps	~Mbps	~Gbps
Latency	High	Moderate	Low
Distance	Up to kms	Up to ≈ 10meters	≈ 10 – 100meters
Bandwidth	Distance dependent: 1000km<1 kz 1-10km≈10khz <100m≈100khz	≈ Mhz	10 -150 Mhz
Frequency band	10 -15 khz	30 – 300 Hz(ELF)(for direct underwater communication system) or MHz(for buoyant communication system)	10^{12} - 10^{15} Hz
Transmission power	Tens of watts (typical value)	Few mw to hundreds of watts (distance dependent)	Few watts
Antenna size	0.1 m	0.5 m	0.1 m
Efficiency	≈100 bits/joules		≈30,000 bits/Joules
Performance parameters	Temperature, salinity and pressure	Conductivity and permittivity	Absorption , scattering/turbidity,organic matter

Advantages :

Advantages of awoke system are :

- Ultra-high data transmission rate (up to Gbps)
- The lowest link delay
- The lowest implementation costs
- Small volume transceivers
- higher communication security

Application :

- underwater optical wireless communication is used for underwater observation and sea monitoring systems.
- Underwater optical wireless communication is used for Underwater video transmission.
- The application of underwater optical wireless communication are mainly for military purpose, especially in submarine communication.

5. CONCLUSION

An improvement in underwater communication system is needed due to increased number of unmanned vehicles in pace and underwater. Traditional underwater communication is based on acoustic signals and despite the substantial advancement in this field, acoustic communication is hard pressed to provide sufficient bandwidth with low latency.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 UOWC, this technology will be more promising with game-changing potentials in the near future**.**

5. FUTURE SCOPE

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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