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A Study of Variuos Methods to Establish Underwater Wireless Communication

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ABSTRACT: *Terrestrial communication has always been on the rise in terms of technological advancement. But in recent years the focus has been shifted on underwater communication. Deep seas and ocean have always been a source of great mystery to mankind. There is still a vast arena yet to be uncovered. Underwater wireless communication in particular is garnering a lot of attention worldwide. It is of great interest to military, scientific communities, tourist industrialist to name a few. It also plays an important role in oceanography research, pollution monitoring and to study aquatic flora and fauna. There has been a surge in underwater communication functionality due to increase in its possible potential applications. The objective of this paper is to make a comparative study of the available methods to implement underwater wireless communication. Finally we analyze these techniques and understand the reliability of each of these techniques.*

Keywords**:** *Underwater communication, Acoustics, RF, Optical, Acoustic modem, wireless Communication.*

I. INTRODUCTION

Earth is basically composed of seventy-one percent water and twenty nine percent land. In recent years the birth rates of human beings have increased as compared to death rate. Also with various medicinal advancements the mortality rates have significantly decreased. In near future this will tremendously increase stress on earth and there will come a point when no more land mass will be available for any usage. Keeping this in mind it is only natural that we must make optimum use of our most abundant resource i.e. the vast water bodies. To do so the most important requirement is to achieve a communication link between underwater and terrestrial regions. Underwater communication can be classified as two types:-wired and wireless.

Wired communication: - For wired communication fiber optic cables are laid on sea beds.

The major issue in using the wired medium is as follows:

- external interventions due to aquatic animals and ships
- Temporary experiments
- the deployment cost of cables
- Breaking of wires
- Experiment over long distances

Hence the alternative is to use wireless medium.

Wireless communication: - wireless domain is relatively less explored as it is more challenging than atmospheric communication. Sea water or ocean bodies comprise of different water columns. The quality of water at shallow coastal regions is vastly different than that of deep sea bed. Due to this, a method developed for one type may not work effectively in other regions of a same water body.

While developing an underwater communication link the following performance parameters have to be taken into consideration:-

- Absorption
- Scattering

- Salinity of water
- Multipath propagation
- Dispersion
- Physical obstruction
- Background noise

In the following sections we have detailed various wireless techniques which can be used for establishing underwater wireless communication.

To the end we have enlisted our observation on these techniques and their feasibility in various underwater environs.

II. METHODOLOGIES:-

2.1 RF Waves:-

Electromagnetic magnetic waves in Radio frequency are used extensively in terrestrial communication. They provide high data rates for short distances. But the same cannot be said for underwater environment. RF waves get heavily attenuated by seawater. Still RF waves are used in some parts of UWC. UWC communication using RF can be carried out in two ways.

The first method is as shown in figure:

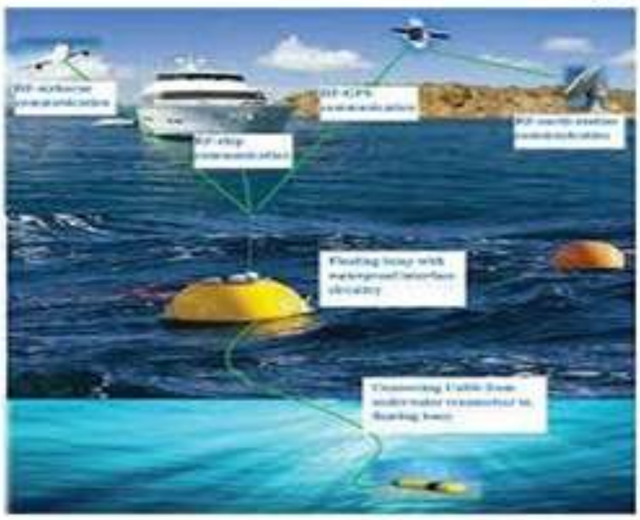

Fig.1: Buoyant RF communication

It has a communication link between terrestrial and underwater. This method is called buoyant RF communication. The second method consists of point to point communication between trans-receivers where one pair is inside water and other pair in air. This method is called Direct RF communication. It is as shown:

Fig.2: Direct RF communication

The first ELF project was developed in 1968 for communication between deeply submerged submarines. In this project, an alerting system was used to call the submarine to the surface for high bandwidth communication using terrestrial radio links [1]. It has been reported in [1] that 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 in the order of 100 W. However, it requires sophisticated antennas design and high transmission power.

2.2 Acoustic Waves:-

Acoustic is one of the most important method using which aquatic animals communicate with each other. Mimicking them, UWC using acoustic waves was developed. With increasing interest in the UWC domain in the past decade Acoustic communication has been advanced by leaps and bounds. A variety of hardware and software acoustic modems have been developed. Acoustic modems are capable of operating at 100 and 5000 bps over moderate link distances or at higher data rates for shorter distances. Acoustic modems have been extensively used for various commercial applications like offshore oil exploration and production, scientific research, etc.

The main hurdle in achieving an UWC communication link is the presence of various obstacles in the path of the signal. This is the major reason leading to multi-path distortion. This problem can be overcome using acoustics up to a certain extent. In the event of presence of obstacle acoustic waves will simply choose a round-about way around the obstacle or travel through it.Therefore, acoustic communication communication does not strictly require line-of-sight. This is a major plus point of acoustic networking.

Table 1:- typical bandwidth for different ranges in underwater acoustic links:

Distance	Range (km)	Bandwidth (kHz)	Data Rate*
Very long	1000	< 1	~ 600 bps
Long	10 - 100	2 - 5	~ 5 kbps
Medium	1 - 10	≈ 10	~ 10 kbps
Short	0.1 - 1	20 - 50	~ 30 kbps
Very short	< 0.1	> 100	~ 500 kbps

A basic block diagram of UWC using acoustic modems networking is as shown:

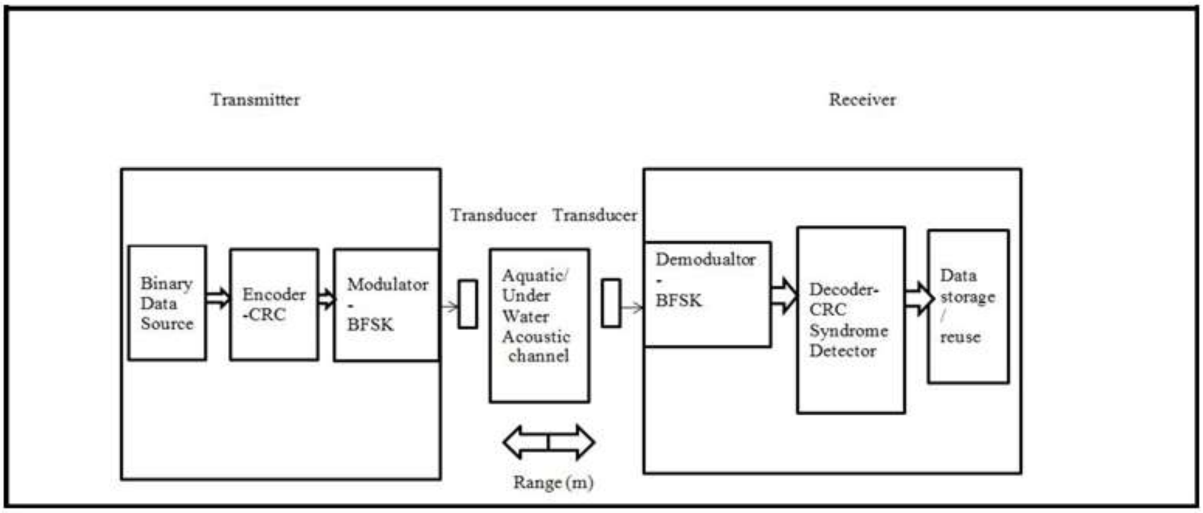

Fig. 3

Underwater acoustic networking is popular due to several reasons:

- Acoustic signals can be propagated over long distances in magnitudes of several kilometers, providing a notably large effective-range for transmission.
- Acoustic signals can be broadcasted. Hence they provide a wide field-of-view. Acoustic communications, however, have several drawbacks:
- The speed of acoustic waves is slower as compared to RF waves resulting in a slow propagation
- The data rates achieved is less.
- Consequently, acoustic communications results in highly limited bandwidth.
- They have a high power requirement

We may potentially increase the frequency at which the acoustic signal is broadcasted, but increasing the frequency will result in larger attenuation and higher energy consumption.

2.3 Optical Waves:-

This is a relatively new technique on which extensive research is going on. Speed of light is far more than speed of sound. Acoustic waves are basically transmission of data through echo signal. Due to diversity in the water bodies ranging from shallow coastal water to deep seas and oceans, signals transmitted using acoustic link gets heavily attenuated which in turn reduces its data rates. In order to overcome these problems UWC using optical links was proposed.

Various theoretical and experimental studies have been carried out for observing the behavior of optical beam underwater [1].

Underwater optical link can be realized using following configurations:

(i) Direct LOS links, (ii) NLOS links and (iii) retro-reflector links. Direct LOS links:-

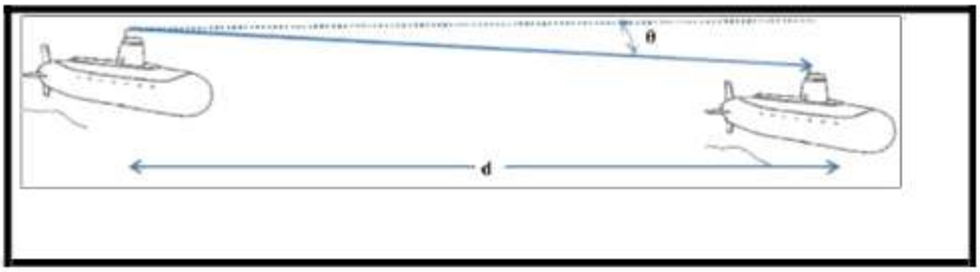

Fig.4

As can be seen from the diagram, this type of configuration establishes a line of sight link between the transmitter and receiver.
This is the simplest method of all. But it is seldom implemented as the possibility of encountering obstacles in LOS is high which will disrupt communication.

NLOS links:-

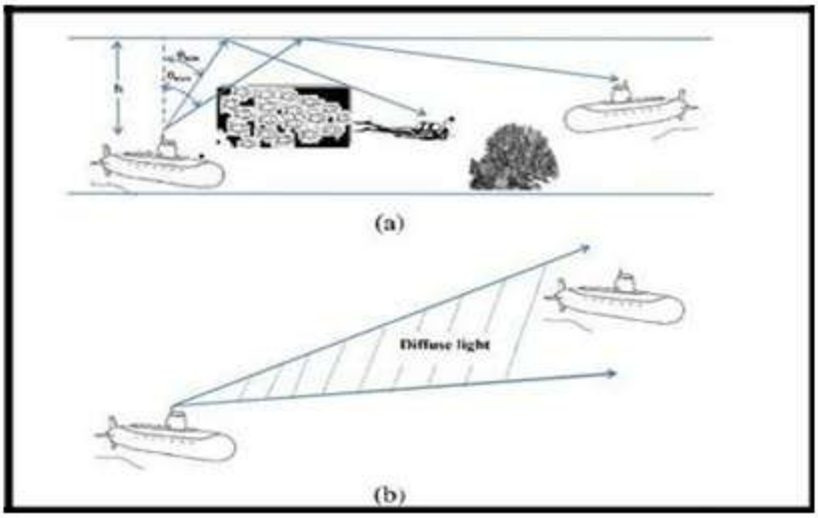

Fig. 5:- NLOS configuration (A) Reflective **(**B**)** Diffuse

The problem of LOS direct link is solved by using NLOS communication. Here there are no stringent constraints on pointing of transmitter and receiver.

Retro-reflector links:-

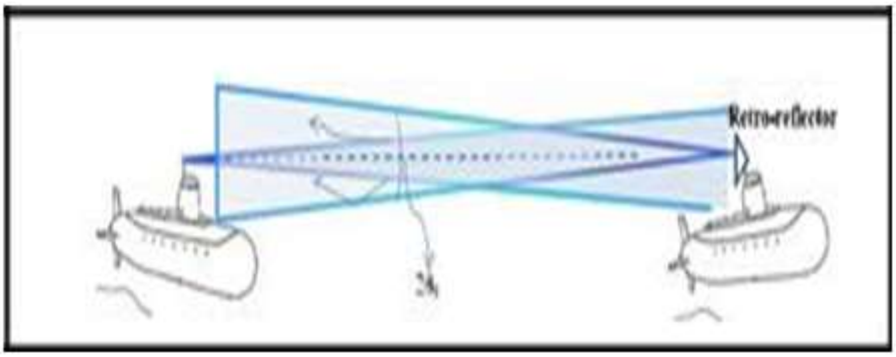

Fig. 6:-Modulating retro-reflector configuration

The retro- reflector works in two scenarios:
(i) Photon limited and (ii) contrast limited.
The photon limited 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.

Contrast limited scenario occurs in turbid harbors 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, decrease the contrast of the image. Optical waves have the following advantages over acoustic links:-

- It can provide speed in Gbps at a distance of few hundreds of meters due to high frequency of optical carrier.
- Very high data rates.
- higher bandwidth at lower energy consumption rate
- lower propagation delay
- low power requirement

Although UOWC provides very high data rates it has following limitations:-
- Optical waves undergo larger attenuation as compared to acoustic waves.
- They have narrower field of view
- They often require LOS links.
- Absorption and beam scattering is also high in case of UOWC.

2.4 Hybrid Acousto-optic system:-

Acoustic and optical communication links both have their individual plus points which are equally important to develop an underwater communication system of high efficiency. In order to reap maximum benefits a new model is proposed wherein both these methodologies will be combined.

Although exhaustive research is to be done on this technique, this method has a lot of potential. As of now it is on development stages only. Any commercial, large scale deployment of hybrid link has not been reported yet. A schematic diagram of how a hybrid acoustic system looks is as shown:

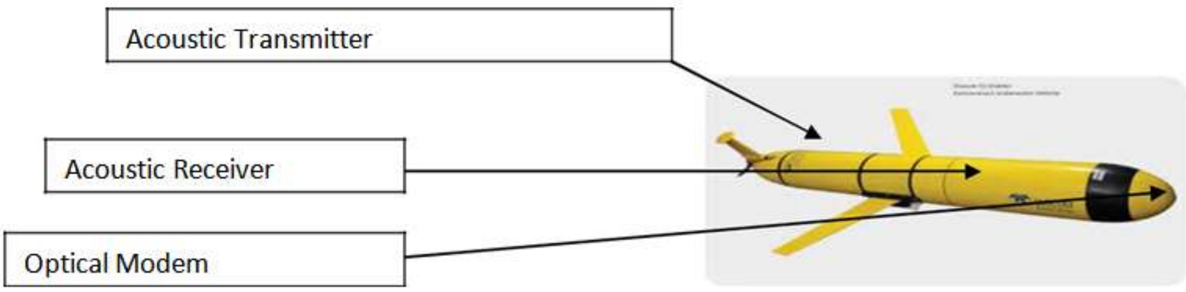

Fig 7

The significant energy consumption gap between the acoustic only and hybrid cases for the small amount of received data. However, the gap becomes distinct as the received data increase.energy consumptions of the modems were plotted against the amount of data received.It is shown that there is no

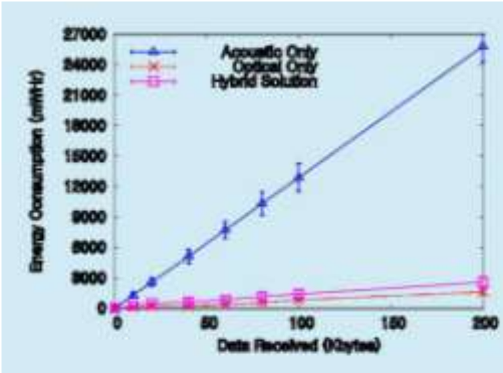

Fig. 8:- Energy consumption with varying data size [7].

In Figure 9, the average throughput of hybrid and acoustic only approaches are plotted against the offered load. For the throughput of acoustic modem only case, it shows that the acoustic channel gradually saturated as the offered load increases. For the hybrid case, acoustic modem is used for long distance and optical modem is opportunistically used for short distance after alignment assisted by acoustic communications.

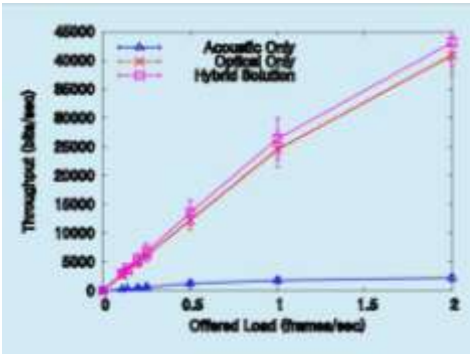

Fig. 9:- throughput gained against varying load.

III. OBSERVATION

A comparison between different wireless underwater technologies is presented in Table 2. A more extensive discussion and comparison of underwater communication systems with their pros and cons is found in [1].The underwater world is highly diverse. This makes establishing a communication link very challenging. Various aspects and their complimentary losses are needed to be considered while developing an UWC network. The parameters which define the reliability of each method are attenuation (depending on water column between transmitter and receiver), data rate, distance and bandwidth.The above table provides a comparative study of RF, Acoustics and Optical method based on the earlier mentioned parameters.

Parameters	**Acoustic**	**RF**	**Optical**
Attenuation	Distance and frequency dependent (0.1 - 4 dB/km)	Frequency and conductivity dependent (3.5 - 5 dB/m)	0.39 dB/m (Ocean) - 11 dB/m (turbid)
Speed (m/s)	1500 m/s	≈2.255x10^8	≈2.255 x 10^8
Data rate	~kbps	~ Mbps	~ Gbps
Latency	High	Moderate	Low
Distance	Up to kms	up to≈10 meters	≈10– 100 meters
Bandwidth	Distance dependent: 1000 km < 1 kHz 1-10 km≈10 kHz	≈MHz	10 - 150 MHz

	< 100 m≈100 kHz		
Frequency band	10 - 15 kHz	30 - 300 Hz (ELF) (for direct underwater communication system) or MHz (for buoyant communication system)	$10^{12} – 10^{13}$ 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

Attenuation in case of acoustics and RF is dependent on distance and frequency whereas for optical it depends on the quality of water. In terms of speed optical waves perform way better than acoustic and RF.Data rates for optical is Gbps whereas it decreases to Mbps for RF and to Kbps for acoustics. Transmission power for RF waves is distance dependent. It ranges from few MW to hundreds of Watts. Optical requires a few watts for transmission. Acoustics too require tens of watts for transmission. In terms of distance acoustic waves can travel longer distances as compared to RF and Optical. Bandwidth capabilities range from KHz to Mhz.

IV.CONCLUSION

An improvement in underwater communication system is needed due to increased number of unmanned vehicles in space and underwater. An overview of various existing underwater techniques was presented in this paper. This paper summarizes the ongoing research going on in underwater communication. From the comparative study of all the above mentioned methods, we draw the following conclusion:-

Optical fiber cables are one of the methods employed to establish communication link between overseas countries. This wired communication technique is not efficient due to various factors like deployment cost of cables, breaking of wires, external interventions due to aquatic animals and ships and various other issues. RF waves even though they provide high efficiency communication in terrestrial regions; its underwater performance is not so commendable. RF requires transmit data. Also it was seen that RF suffers from high absorption in underwater environs. Hence RF can be used for UWC only in certain ELF range.A relatively new method of using optical modems is being researched on as it has capabilities of overcoming the shortcomings of acoustic modem networking. This method also is not widely employed since it requires LOS communication in most cases. Acoustic networking provides various advantages like large range for data transmission, higher bandwidth with moderate data rates. As of now, UWC using acoustic modems has been fairly popular. It is used extensively for educational as well as commercial purpose. They are robust in design and quite feasible. A hybrid method using the qualities of acoustic as well as optics to provide a maximally efficient communication link is proposed. This technology is fairly new and is still in research.

Based on this study we finally conclude that till now acoustics has been the prime player in UWC. Though in coming future we will definitely see a hybrid approach to overcome the present technology's shortcomings and provide us with a solution which will change the scenario of UWC as we have known till now.

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