Asian Journal of Applied Science and Technology (AJAST)
Volume 1, Issue 5, Pages 25-29, June 2017

A Review on Underwater Communication with an Aerial Platform

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Article Received: 14 May 2017 *Article Accepted: 03 June 2017* *Article Published: 05 June 2017*

ABSTRACT

The underwater communication is an emerging and fast growing field. Underwater communication finds a wide range of applications such as coastal surveillance systems, communication between submerged objects, and collection of scientific data from ocean stations, Autonomous Underwater Vehicle (AUV) operation, national security and defense. This paper gives an idea about the techniques being used for underwater communication and the modifications to be done to acquire a better communication, higher data transfer rates over longer distances. Acoustic communication which was used is replaced by laser communication and researches are going on to overcome the limitations of laser communication between submerged objects and aerial platform

Keywords: Underwater communication, submarines, blue light laser, laser communication.

1. Introduction

In our Two-third of the planet Earth we live on is covered by water which makes underwater communication an important need for modern communication. Thus it finds a wide range of applications. Communication between an underwater body and aerial platform is a most challenging and necessary technology. It includes ship to submarine, submarine to submarine, submarine to satellite communication and so on. The new underwater wireless communication techniques lead to the exploration of oceans and other aquatic environments.

Underwater communication by nature has the harsh wireless and most complex channel. The reason behind this is that the channels in marine environment are affected by noise, limited bandwidth, and the ambient underwater conditions. Hence underwater channel exhibits high attenuation, frequency dispersion, multipath effect, and constrained bandwidth.

During the World War I and II submarines made use of short waves or other radio signaling which made the vessels vulnerable. To overcome this in 1950's US navy proposed Extremely Low Frequency (ELF) antenna systems. The ELF communication was a one way link and the data transmission rates were very slow. Then came the Acoustic communication which made use of acoustic signals which can travel only a shorter distance in water due to high attenuation and absorption effect in a marine environment. However acoustic information is now been replaced by laser communication which overcomes all the limitation of previous technologies.

Submarines operating deep underwater would ascend up to the periscopic depth at a pre assigned time schedule and raise their antennas to communicate with satellites. These can be detected by enemy satellites and hack the information. However laser communication eliminates the need of submarines to ascend up to communicate with satellites and make it an emerging technology.

For maximum penetration in sea water blue green laser is been used. This light also propagates through clouds in a fairly predictable fashion. This blue green laser along with optical setup helps to establish a communication between a space or aircraft and submerged objects. Blue green waves exhibit lower attenuation when compared to other signals and is most suitable for underwater communication. However these are applicable only for shorter distances. This limitation of laser communication makes acoustic communication shown in fig.1 the best technology as of now.

Hence many experiments were conducted to check laser communication merits and demerits and techniques were proposed to improve the communication between an submerged object and an air platform.

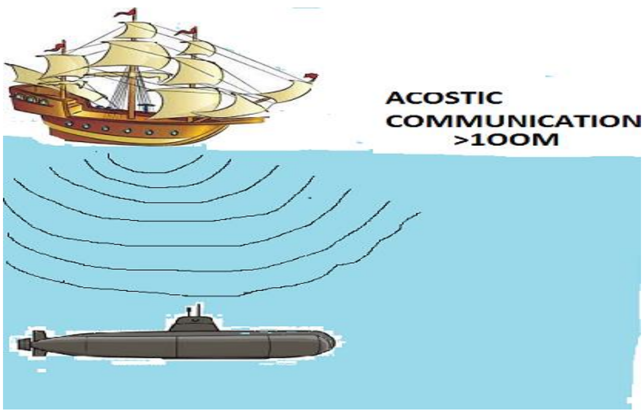

Fig.1: Acoustic Communication

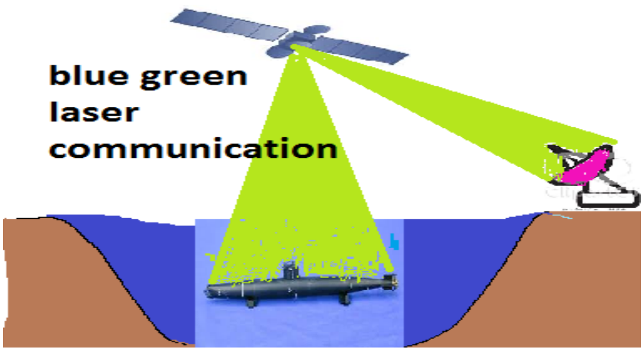

Fig.2: Blue Green Laser Communication.

2. SURVEY OF PREVIOUS TECHNIQUE

1. VLF BAND FOR SUBMARINE COMMUNICATION

Very low frequency band is a radio band consisting of frequencies between 10KHz to 30KHz. This technique consisted of antennas with huge structure with a height of around 300m. Thermal noise was also a factor of this technology. The submarines had to be at a distance of 10m under the water to transmit or receive data which wasn't safe for the submarines. The efficiency didn't even cross 50 percent. This lead to the limitation of this technology. Fig a and b shows the vlf transmitter and receiver.

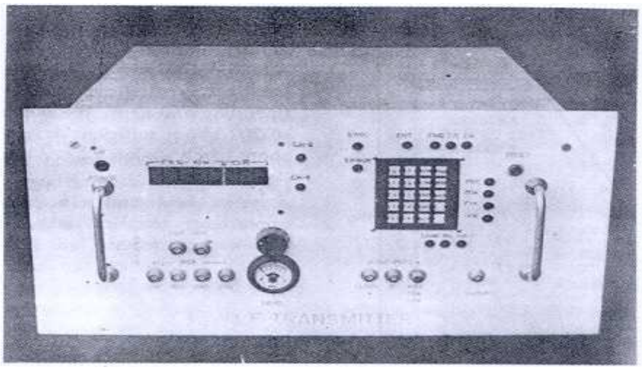

Fig A: VLF Transmitter

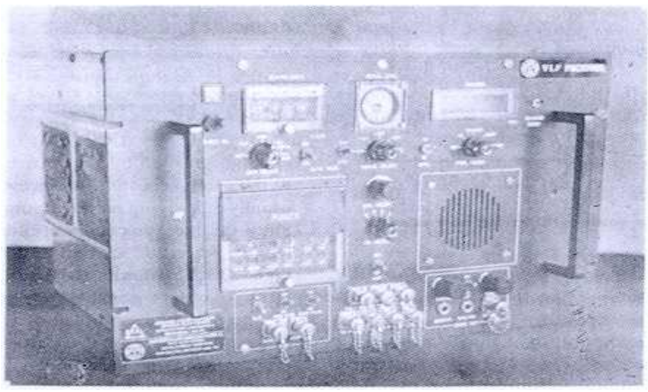

Fig.B: VLF Receiver

2. ELF COMMUNICATION

Extremely low frequency signals operate within 3 to 300Hz. Electromagnetic waves can penetrate underwater at a depth of 100m. This technology operates at longer wavelengths. ELF waves are generated by lightning and natural disturbances in earth's magnetic field. Building an antenna for operating at such longer wavelengths was a difficult task. This technology made use of three schemes which are i) spiral top loaded antenna ii) a vertical wire from helicopter iii) loop in vertical plane. All these made use of large aerial structure and were impractical.

3. ACOUSTIC COMMUNICATION

Acoustic communication operates at its best at low frequencies i.e; between 10 to 15 KHz and the system is wideband. These make use of the acoustic waves hence the name acoustic communication. It is one of the technique which is being used from a long time. It absorbs the data from water. Due to the temperature gradients, density, and non-homogeneities of water the acoustic channel is too complex. The commonly used techniques for modulation and demodulation include Frequency Shift Keying (FSK), Amplitude Shift keying (ASK), and is been restricted to analog voice communications. But researches have been proved that acoustic communication with other modulation techniques such as Orthogonal Frequency Division Multiplexing (OFDM) the technique can be extended to digital communications. Though it's been used technique it has limitations which make underwater communication complex. The limitations include limited bandwidth, lower data rates, and short distance communication.

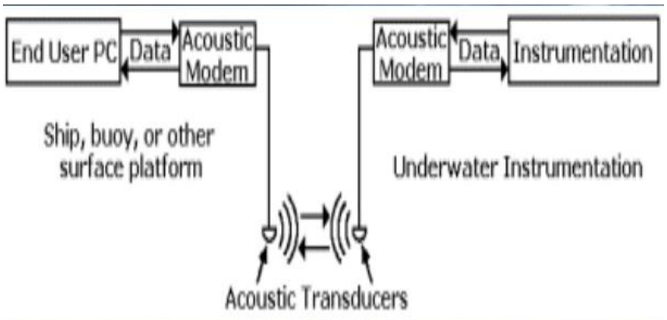

Fig.D: Acoustic Communication

Hence to overcome the limitation of the above techniques an experiment was conducted using optical communication link which employs a blue-green laser.

3. DESIGN OF OPTICAL COMMUNICATION LINK

The optical correspondence connect comprises of a transmitter and receiver. The optical transmitter comprises of a 635nm diode laser and its related driver circuit.

In spite of the fact that blue-green laser is the best for submerged correspondence for exploratory reason and accessibility they had picked 635nm red laser, which was appropriate for research center purposes and its outcomes were practically equivalent to the blue-green laser.

The optical receiver comprises of a silicon photon detector, trailed by an operational amplifier, a comparator. The fundamental non concurrent serial correspondence convention RS-232 has been utilized to set up correspondence.

The information from the RS-232 terminal is changed over to a level suitable for the protected driving voltage of laser through the converter IC MAX232. The yield of MAX232 IC is in TTL voltage level (0 to +5 V).

This TTL good voltage level is presently appropriate to drive the laser. An extra assurance is given to the laser by making utilization of BC547 NPN transistor.

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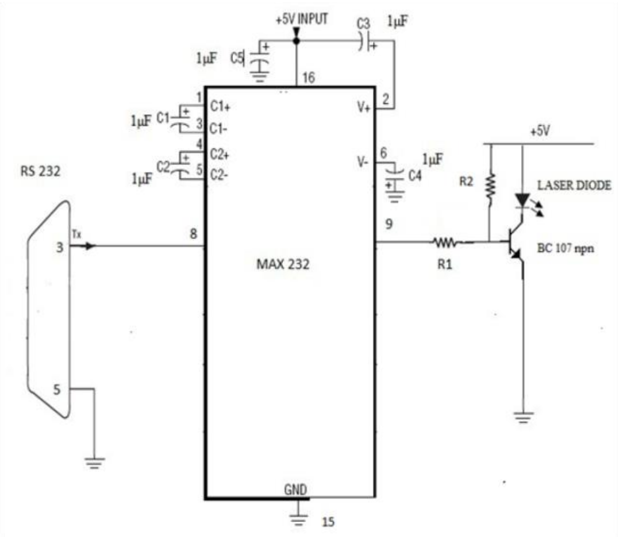

Fig.3: Circuit of a Transmitter

The BC547 transistor gives voltage swing at the yield between 0 V and 5 V. In this way, the voltage provided to drive the laser will be inside 5 V. In this way BC547 shields the laser against plausibility of high voltage flag of RS-232 coming to the laser in case of any flaws with the MAX232 converter IC. BC547 yield is a copy of the voltage motion from the MAX232 converter and the voltage swing is all the more entirely limited between 0 V and 5 V.

The fig.3 demonstrates the transmitter circuit in an optical correspondence interface. This signal is used to modulate the laser. The laser diode is connected at the collector terminal of BC547 as shown in Fig.3. Thus by varying the collector current by means of biasing resistors the laser was switched between fully ON and partially ON state. The selected diode laser uses a maximum current of 67µA. The light from the laser act as a carrier, by superimposing the data, transmission has enabled with ON-OFF keying modulation.

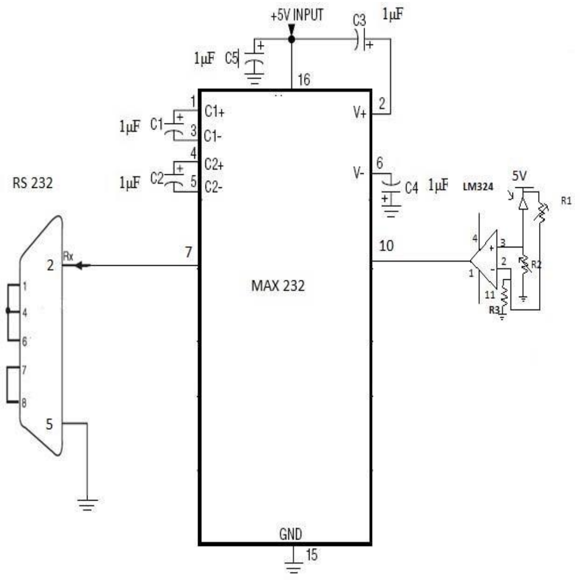

Fig.4: Circuit of a Receiver

The light is detected by the silicon photo detector at the receiver side. The light falling on the detector is converted into voltage levels which are between 0 V and maximum value of 5 V. The voltage output from the detector is given to the non-inverting terminal of LM324 operational amplifier IC. The operational amplifier circuit is wired as a comparator circuit. This compares the voltage across resistor R1 in Fig.4 to a reference voltage.

The output of operational amplifier is given to MAX232 IC which will convert it to RS-232 compatible voltage levels. The MAX232 IC generates +10 V and –10 V voltage swings using a dual charge-pump voltage converter from a single +5 V DC rail. A program written in MATLAB is utilized for sending different sorts of information like content sound and picture records. The LABVIEW program running on collector PC is utilized to gather the serial information from serial port of beneficiary PC. The fig.4 demonstrates the receiver circuit in an optical communication link.

4. EXPERIMENTAL SETUP

The transceiver is setup in a bread board and tested in free space. Fig. 5 is the arrangement used to test the circuit in free space.

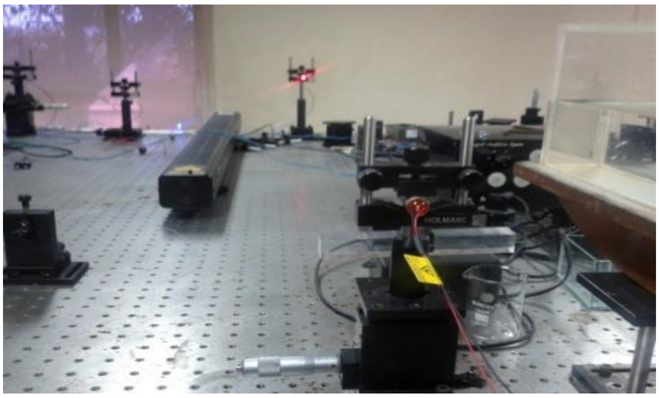

Fig.5: Free Space Communication in Air

Here the transmitter comprising laser source and receiver including photo detector is set in optical breadboard at different separations of < 1 m and a most extreme of 1.5 m.
With the assistance of this setup correspondence was confirmed utilizing distinctive baud rates which was bolstered by RS-232. The baud rates of RS-232 fluctuated from 9.2 Kbps up to 110 Kbps. The baud rate of 10Kbps was confirmed by transmitting 9200 bits serially from transmitter PC and catching the same at first at hyper terminal of receiver PC. This was later confirmed by the LABVIEW program running on the receive gadget. The 635 nm laser source is set beneath a glass tank with refractive index of 1.5 and measurements 30 × 10 × 10 cm3 to process the constriction in light waves by various media. The detector is placed over the glass tank at various statures of 10, 20 and 30 cm. At first the glass tank was vacant and estimations were taken. What's

more, it was found there was a diminishment in the optical power got and found that the reason was because of the weakening which was created by the reflection from glass tank. Now the empty glass tank was filled with 3*l* of water to a height of 10cm. The Beer Lambert's relation was used for calculating the attenuation coefficient from the received power. The expression is given by,

$$I \; I_0 e^{Dl}, \qquad (1)$$

Where I is laser intensity in mW at a distance in meter from transmitter, I0 is the initial intensity in mW and D is the attenuation coefficient of media involved. The attenuation coefficient obtained for different media is reported in Table A. All the experiments were conducted at room temperature. The value of attenuation coefficient in air is found to be close to the theoretical value.

Media Involved (T = 300K)	Attenuation (dB)	Attenuation Coefficient
Air	0.060	0.015
Glass + Air	0.201	0.487
Glass + Water + Air	0.369	0.851

Table.A: Attenuation of Laser Beam at Different Media

Presently the test was directed utilizing a glass tank of measurements 1.81 × 0.3 × 0.52 m^3 keeping in mind the end goal to comprehend the weakening of light from laser source because of various water sorts like waterfront, harbor and turbid. The 635 nm laser source is set beneath the tank and the detector is set over the glass tank at a stature of 0.5 m. The glass tank was loaded with water for a tallness of 0.3 m and the overall link distance was around 1 m.

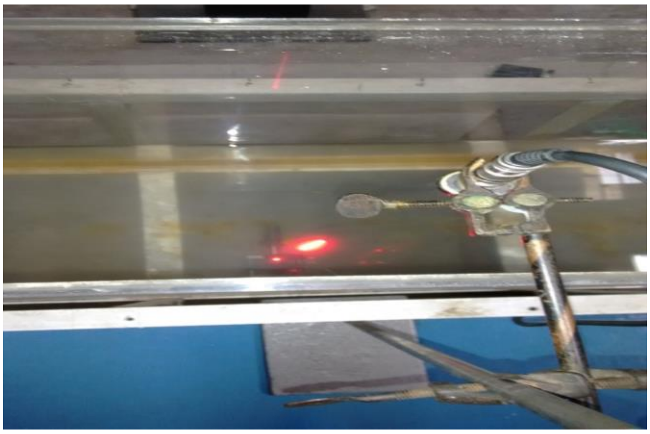

Fig.6: Laser and Detector Arrangement

The above fig.6 demonstrates the experiment setup masterminded. The scattering of light can occur because of sudden variation in refractive index of medium and because of turbid nature of water. The turbid water condition was accomplished by adding Maalox to the water. The glass tank is loaded with 100*l* of water Initial estimations were brought with new water as medium. 3m*l* of Maalox is included progressively and voltage crosswise over resistor R2 which goes about as voltage to current converter and power at receiver is measured using digital multimeter and optical power meter, respectively.

The experimentally observed parameters and attenuation coefficients computed using Eq.(1) are given in Table B. As the water become more turbid, scattering of light beam gets more pronounced and hence attenuation increases. The plot of attenuation vs Maalox amount is shown in fig.7.

Water Type	Maalox (ml)	Received Intensity (mW)	Voltage (V)	Attenuation (dB)	Attenuation Coefficient
Fresh	0	4.29	3.83	0.15	0.057
Coastal	3	2.89	3.55	1.77	2.033
Harbour	6	1.71	2.67	4.04	4.654
Turbid	9	0.98	0.99	8.45	7.442

Table.B: Attenuation of Light with Various Water Types

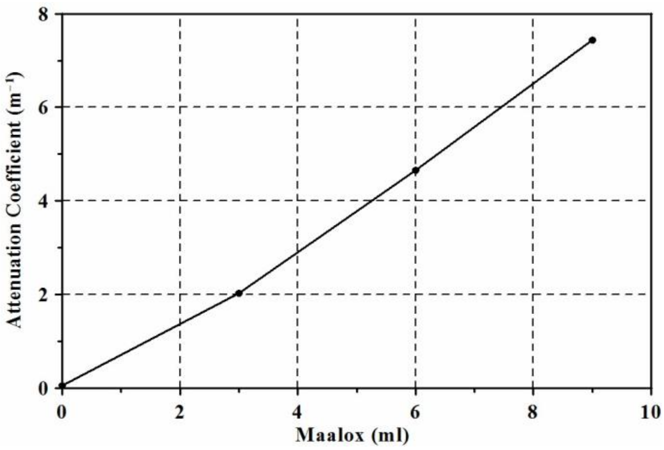

Fig.7: Attenuation Vs Maalox Amount

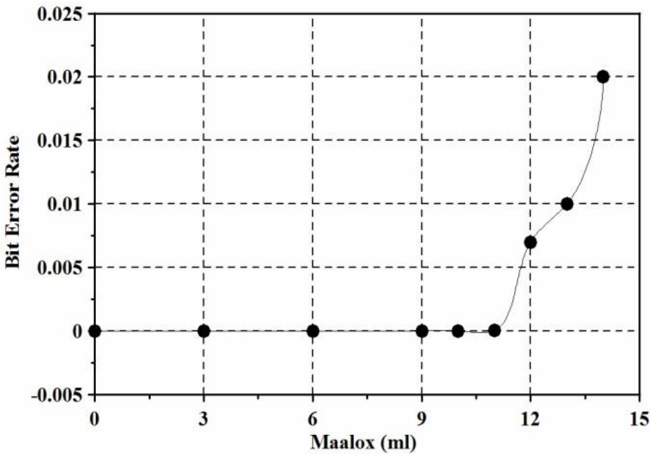

Fig.8: Bit Error Rate Vs Maalox Amount

It is observed that when received power and voltage across the resistor R2 decreases below a certain voltage, bit error rate start to increase and when turbidity again increased by adding additional amount of Maalox it is observed that communication has failed completely below a threshold voltage of 0.584 V.

The attenuation of light in water is wavelength dependent phenomenon, where blue green window (445–520 nm) provides the minimal attenuation.

5. RESULTS

The various techniques for establishing communication between submersibles and an aerial platform have their own merits and demerits. Each one before emerging into a new technology as to go through the previous technologies, what was it, how was it working, what lead to the revolution of new technology. This makes a person to think of a new method to overcome the limitations and improve the need. Similarly the previous technologies VLF, ELF, Acoustic communication were studied and an experiment was conducted to see if the results had improved than the previous techniques. The experiment was conducted using 635nm red laser which can be replaced by BLUE-GREEN LASER in actual ocean systems and the results would be better feasible. It has been observed that the attenuation coefficient under turbid condition for red wavelength is 7.442 m–1. This experiment was conducted using MAX-232 IC and TTL logic which consume more power and slower. Hence ECL and TTL systems can be combined to achieve best performance.

6. FUTURE OF UNDERWATER COMMUNICATION

Now a days underwater communication is fast and emerging technology. Several improvements are made not only for communication but also to explore the ocean and underwater world. This include Autonomous Underwater Vehicle (AUV) and Remotely Operated Vehicle (ROV). The AUV stands for Autonomous underwater vehicle and is ordinarily known as unmanned submerged vehicle. AUVs can be utilized for submerged review missions, for example, recognizing and mapping submerged wrecks, rocks, and deterrents that can be a danger to route for business and recreational vessels.

An AUV conducts its overview mission without administrator mediation. At the point when a mission is finished, the AUV will come back to a pre-modified area where the information can be downloaded and handled. A remotely operated vehicle (ROV) is an abandoned submerged robot that is associated with a ship by a progression of links. These links transmit charge and control motions between the administrator and the ROV, permitting remote route of the vehicle.

A ROV may incorporate a camcorder, lights, sonar frameworks, and an articulating arm. The articulating arm is utilized for recovering little protests, cutting lines, or connecting lifting snares to bigger articles. These are designed to be operating at lower speeds and shorter distances. These also employ a camera which gives the oceanographic images of higher resolution. But make use of acoustic waves to transmit the data. If AUV and ROV are been employed with BLUE-GREEN LASER communication then the communication between submersibles and aerial platform will be much better.

Autonomous Oceanographic sampling network (AOSN) is suggested by the Office of Naval Research and the National Science Foundation. This AOSN suggests that AUV and other underwater vehicles can increase their potential by utilizing solar energy. Hence the difficulty of charging these vehicles also will be reduced and making use of other modulation techniques and level shifting techniques a better communication can be achieved.

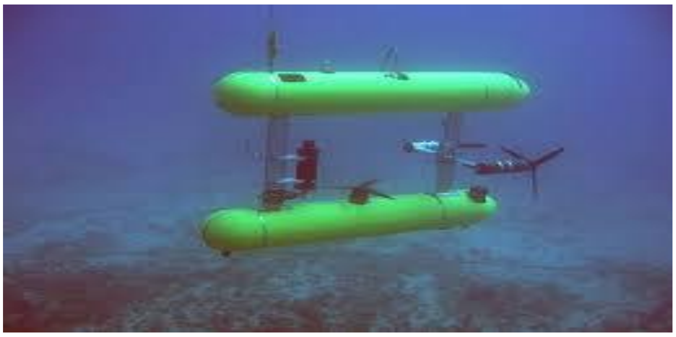

Fig.9: AUV

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