UNDERWATER COMMUNICATION WITH CHEMICAL SENSOR

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Abstract

This paper present the novel idea of detailed calculation of chemical composition of the propagating medium in which the light signal is transmitting. The light signal when transmitting under the water there are multiple factors that act over the signal such as salinity, temperature, density and other composition. These composition effects in many ways as on frequency, wavelength, strength of signal.

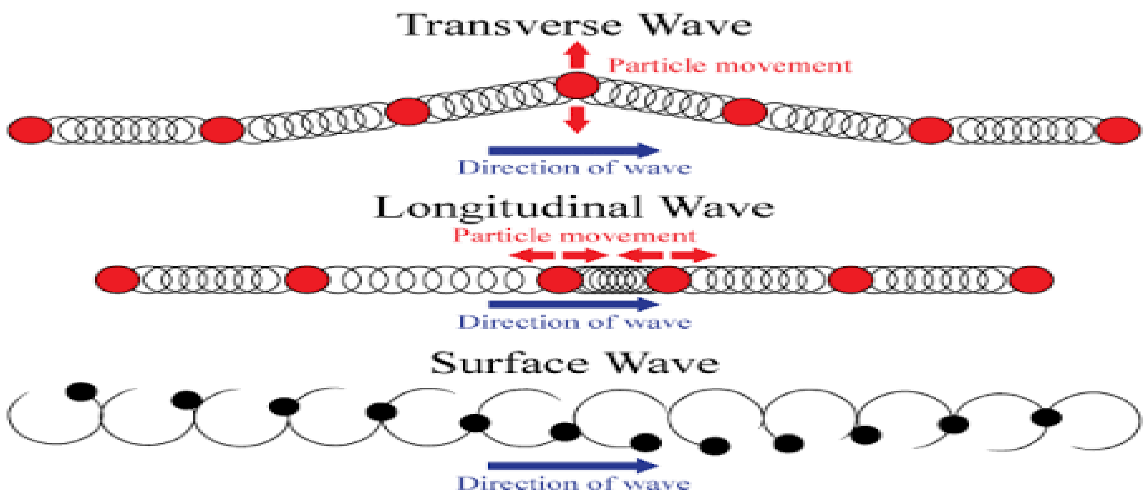
So there are two ways to work over this problem first one is to rectify these issues and the other one is to use these issues for the calculation of chemical properties of the propagating medium. In this paper we propose to work on the second way to calibrate the properties.

1. INTRODUCTION

With the growth in the high speed underwater communication methods, the underwater devices and advance sensor technology come into the picture. In the communication system, the three major components are always plays a very important role. First one is the, type of the waves by which the data is going to be transmitted , second is the medium in which the wave is going to be transmitted and third is the factors which effects on the transmitted signal like attenuation[1] of the signal, absorption, diffraction, spreading of the signal wave etc.

1.2 Types of the waves

1.2.1 Mechanical wave: Mechanical wave are those waves in which vibration of the atoms needs a medium to travel.



1.2.2 Types of Mechanical Waves

1. Transverse wave: In these waves atoms of the medium vibrate up and down perpendicular to the direction of the movement of the wave.

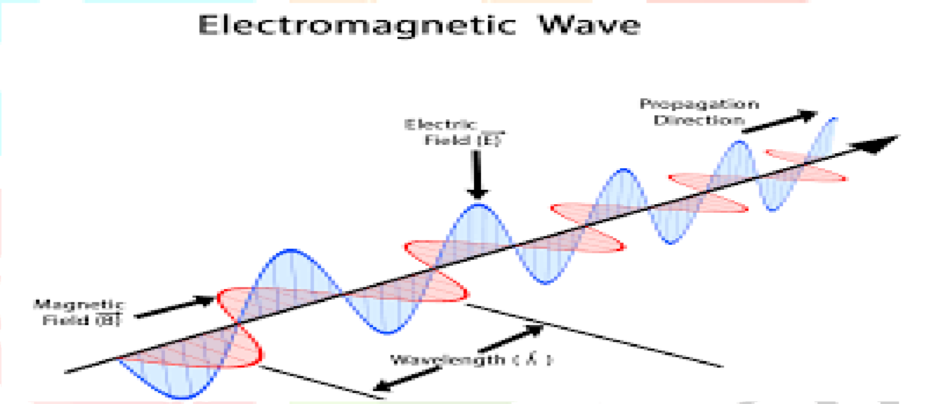
2. Longitudinal wave: In these waves, atoms of the medium vibrate back and forth parallel to the direction of the movement of the wave.

3. Surface wave: In these waves, atoms of the medium vibrate both up and down and down and forth, so they end up moving in a circle.

4. Acoustic waves: In these waves, pressure variation propagates through a material.

1.3 Electromagnetic waves

Electromagnetic waves are those waves in which vibration of the atoms don't need a medium to travel and direction of vibration of atoms is perpendicular to the direction of wave motion. Example light, radio wave etc.



Second one is the medium in which the data signal is transmitted example- air, water or vacuum. Third one is the factors which affect the signal wave energy and other physical properties of the waves such as

1. Frequency: Frequency is the number of cycles completed by the wave per second.

F= 1/T   where T is the Time period and unit is Hz.

2. Wavelength: The wavelength is the maximum distance between one crest to adjacent crest or trough to trough. Symbol is λ and unit is meter.

3. Speed: The distance travelled by the signal in unit second is its speed. Unit is meter per second.

4. Intensity: Intensity is the energy spread per unit area.

5. Absorption: Absorption of electromagnetic radiation can be define as the energy of the photon that is taken out by the medium through which photon is travelling or on which photon is falling.

1.4 Propagation losses:

When acoustic waves propagate, in the medium the intensity of the waves gradually reduces, because of geometric spreading (divergence effect) and absorption of acoustic energy by the medium in which wave travels. This absorption and propagation losses is a main parameter of the acoustic system, it limits the amplitude of the signal received.

2. Geometric spreading losses

In geometric spreading[2] acoustic wave transmit energy in a larger and larger surface. As energy is preserve and the intensity decreases proportionally to the inverse of the surface.

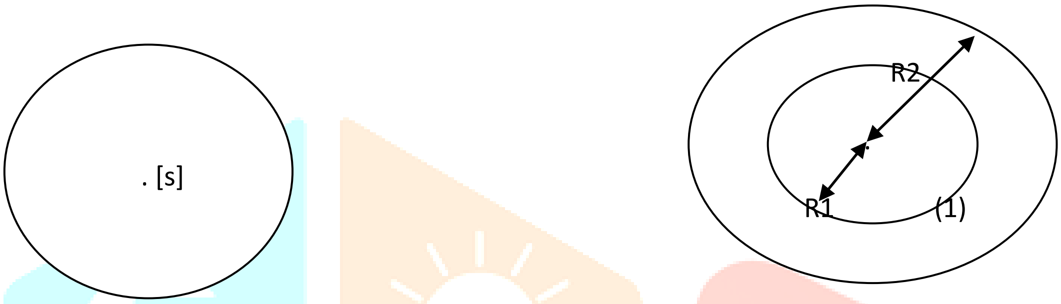


Fig1. Spherical spreading : the acoustic intensity decreases with distance from the source, in inverse proportion to the sphere surfaces.

$$I2/I1=\sum 1/\sum 2=4\pi R_1^2/4\pi R_2^2=(R_1/R_2)^2$$

Here R_i are the radial distance from the source this formula shows that the intensity decreases in $1/R^2$, and pressure in 1/R. The spreading transmission loss, calculated from the reference unit value of distance (R_{1m}=1m) can be expressed in dB as:

$TL=20\log(R/R_{1m})$

It is expressed in TL =20log R with no reference to the unit distance.

2.1 Absorption losses

Generally, we use underwater drones and underwater devices for the sea water analysis because these are so big water bodies that we are not able to explore them manually whereas in case of small water bodies like lakes and ponds exploration can be done manually also. Sea water is a thermo-dynamically open system and propagating medium. The sea water medium absorbs some part of the transmitted wave energy, due to viscosity or chemical compositions (thermal conduction being weak in water).

Absorption is a limiting factor in acoustic propagation. Its amount strongly depends [3] over the propagation medium and the frequency. In sea water absorption comes from three factors:

- **Pure water viscosity**: the effects of this increases at a square rate of frequency.
- **Relaxation of magnesium sulphate** ($MgSO_4$) molecules below 100kHz.
- **Relaxation of boric acid** ($B(OH)_3$) molecules below 1kHz.

3. EXISTING METHODOLOGY

In the past few years, many new designs and technologies are developed and deployed for the scrutiny and research purpose of the water bodies[6] These are very large and major scale projects.

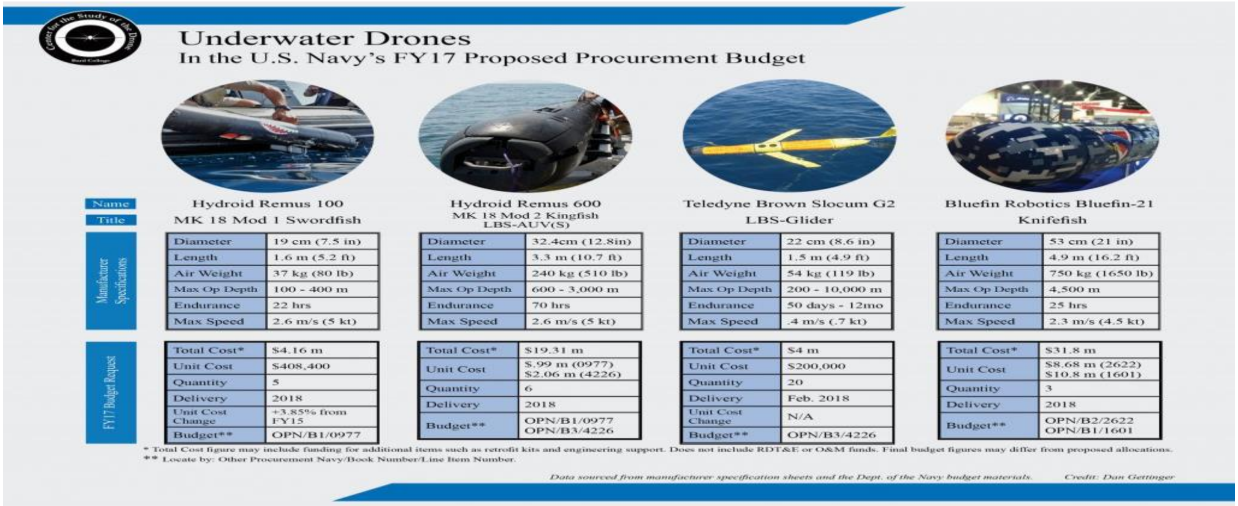


Fig 2. Detailed description of the new and advanced underwater devices.

The underwater system which are used currently by different organization are suffering from major problems [4] which are:

3.1 Cost: The cost which is invested in the underwater drone or device development have a major stake of sensors which are used in the drone for the estimation and experiment purpose.

3.2 Power: The power consumption is also be a major issue as the sensor which are used in the drone for calibration need high amount of power supply so a constant power supply is needed for these sensors.

3.3 Size: Due to a constant power supply the drone must be equipped with the power generator which are big in size and proportion.

4. PROPOSED METHODOLOGY

The issues which arises during the underwater transmission can be encountered in two ways -

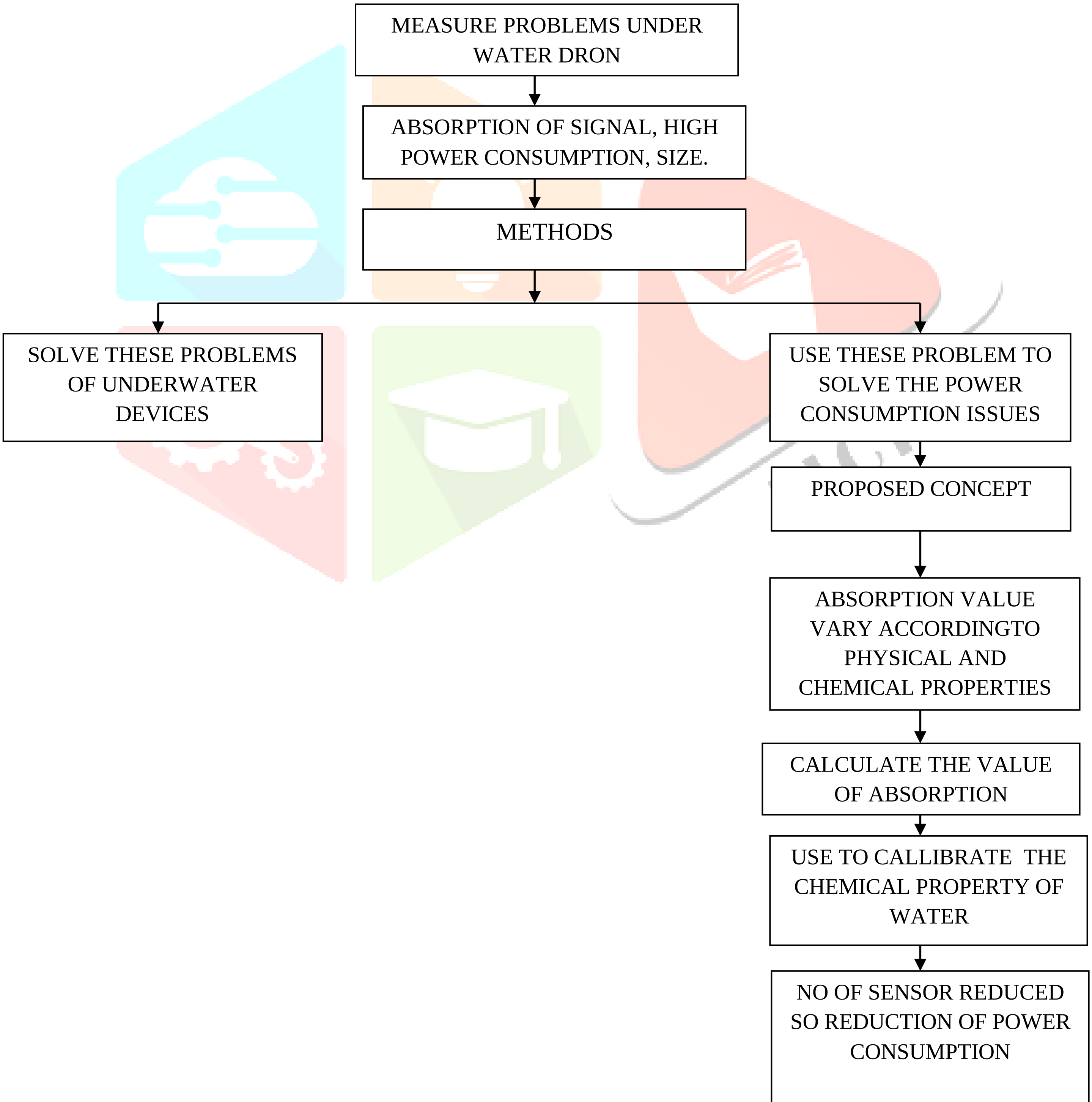
A. First one is to work out to resolve and correct the issues.

B. Second one is to use these issues for our own purpose and use the variation of the laser properties from the original laser data for our own research part and calibration which we are trying to do. We estimate the value of absorption of signal wave in order to calculate the chemical composition of the propagating medium[7].

The increasing demand of expeditious sensing and detection in remote areas requires the development of compact and cost-effective mid infrared sensing devices. It is also important because all the issues related to current devices must also be encountered. We focus on the miniaturization of the sensors using the discrete optical components (mid infrared spectroscopy). The concept is that whenever a laser light travel from a medium some physical properties of laser get effected due the absorption of the laser by the chemical composition present in that medium.

The researcher of university of Vienna has developed a tiny laser [5] and a light detector chip set as a single unit. The light is transmitted to the detector according to waveguide. These chips are to small as they seem as invisible .They use the infrared beam for the detector as the absorption of infrared beam is different by different chemical composition. This all technique is known as absorption spectroscopy, it measures the absorption of radiation as a function of frequency and wavelength.

This chip can be used to calculate the value of salinity of the water using the model of Francois – garrison. As in this model we know that the equation of seawater absorption coefficient at frequency (kHz) is contributed by-



Total absorption	=	Boric Acid Contribution	+	Magnesium Sulphate Contribution	+	Pure Water Contribution

$$\alpha = \frac{A_1 P_1 f_1 f^2}{f_1^2 + f^2} + \frac{A_2 P_2 f_2 f^2}{f_2^2 + f^2} + A_3 P_3 f^2$$

This formula will help us to calculate the value of total absorption when we have the values of frequency (f) and values of water temperature(T) and depth(D) at a standard value of salinity and acidity. But with the use of this mid infrared chip instrument we can calculate the updated value of salinity and acidity (not to take static value) .

The contribution of boric acid $B(OH)_3$ consist of :

A1 = (8.86/c)10^(0.78pH-5) **(1)**

Where A_1 is the constant and c is the speed of light.

c = (1412+3.21T+1.19S+0.0167D) **(2)**

Where T is the temperature and D is the depth.

$$f_1 = 2.8\sqrt{(S/35)}*(10^{4-1245/(T+273)}) \quad (3)$$

From the first formula we can drive a new formula to calculate the value of acidity

$$(\log(A_1c/8.86)+5)/.78) = pH$$

From the second formula we can drive a new formula to calcualte the value of salinity

(c-1412-3.21T-.0167D)/1.19=S

From the third formula we can calculate the value of temperature as we already have the value of frequency which we calculated from the amount of absorption of wave in seawater.

$$T= ((8-2490-243*(\log(f_1/2.8)^2*35/S)) / (\log(f_1/2.8)^2*35/S))$$

Frequency, F	2	(kHz)
Temperature, *T*	12	(Celsius)

Depth, *D*	9	(km)	
Absorption, *α*	0.026	(dB/km)	(Francois and Garrison 1982)
Salinity, *S*	48	(ppt)	
Acidity, *pH*	7		

By using all these drived formulas from the francois – garrison model we can calculate the value of salinity, acidity,temperature which generally have a predefined value (S=35 and T=8).This will help reduces the number of additional sensors which we needed.

The methodology of this research paper is a combination of three modules and each module has its unique and sequential work. The module division of the methodology help to encounter the problems in most effective manner.

Module 1: In this module we collect the information regarding what type of issues and problems come across will be communicate or transmit the signal underwater. The problems are generally related to either transmission of the signal underwater like absorption of signal, limited bandwidth, propagation delay and other one is the issue related to the drone like –size, cost and power consumption.

Module 2: In this module we come up with two ways for this problem. First one is to rectify the issue and second is to use these issues to solve our other problems related to the drone devices. We accept the second way and work over it. By this way we can solve the problems of drone which are – power consumption, cost and size.

Module 3: In this module we use the related the relationship between the absorption of signal wave in order to calibrate the chemical composition of the water. We use the model of francois –garrison to establish this relationship. To calculate in the absorption of the signal we use chip based on the mid infrared sprectroscopy. By this method we get the salinity, acidity and temperature values of the medium, so this will reduces the use of multiple of sensors .By this we can reduces the power consumption, size and cost of the development of the underwater drone and devices.

5. Conclusion:

As we know that the current underwater sensor devices and drones are having the two major problems first one is the power consumption and second one is the size of the device. In this paper we try to come up with a solution to resolve these issues, to counter the first issue reduce the power consumption we come up with a idea to reduce the number of sensors which are used in drones. In this method we use the mid infrared spectroscopy technique sensor which are developed by researcher of Vienna. It works on the concept of absorption of light signal during its propagation in open environment of seawater. This technique helps us in calculating multiple chemical properties of water as salinity, temperature, acidity of water. This will reduce the number of sensors as a single sensor can perform the number of tasks so it reduces the power consumption also.

To counter the second issue the chip set which is designed is so miniaturized that overall size of the drone is also be reduced.

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