Design and Development of Underwater Vehicle

Submitted in partial fulfillment of the requirements
of the degree of

Bachelor of Engineering

By

Justin Ayroor 06

Suman Deb 15

Meghraj Deore 16

Akash Sinha 60

Supervisor:

Prof. Madhavi.S. Pednekar

Prof. Iqbal Hadis

Department of Electronics and Telecommunication
Don Bosco Institute of Technology
University of Mumbai

2016 - 2017

Don Bosco Institute of Technology
(Affiliated to the University of Mumbai)
Premier Automobiles Road, Kurla, Mumbai - 400070

CERTIFICATE

This is to certify that the project entitled **"Design and Development of Underwater Vehicle"** is a bonafide work of

Justin Ayroor	**06**
Suman Deb	**15**
Meghraj Deore	**16**
Akash Sinha	**60**

submitted to the University of Mumbai in partial fulfillment of the requirement for the award of the degree of **"Undergraduate"** in **"Bachelor of Engineering"**

Prof. Madhavi.S.Pednekar
Project Guide

Dr. Sudhakar Mande
HOD, EXTC Department

Dr. Prasanna Nambiar
Principal

Don Bosco Institute of Technology

(Affiliated to the University of Mumbai)

Premier Automobiles Road, Kurla, Mumbai - 400070

Project Report Approval for B.E.

This project report entitled **'Design and Development of Underwater Vehicle'** by **Justin Ayroor, Suman Deb, Meghraj Deore, Akash Sinha** is approved for the degree of **Bachelor of Engineering in Electronics and Telecommunication.**

Examiners

1. ______________

2. ______________

Date : / /

Place : **Kurla, Mumbai**

Declaration

I declare that this written submission represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea / data / fact / source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

Justin Ayroor

Suman Deb

Meghraj Deore

Akash Sinha

Date : / /

ACKNOWLEDGEMENT

A project is a teamwork which involves the contribution of many people. We would like to thank everyone who have contributed by taking interest in our work and motivating us all the way through. We would especially like to thank our Management of Don Bosco Institute of technology along with our Principal, Dr. Prasanna Nambiar for motivating and supporting us to develop the project for application of engineering technology in field of development. Also, we would like to thank our Head of Department, Dr. S.S. Mande for his valuable suggestions in Industry aspects, our project guide, Prof. Madhavi.S.Pednekar and our project co-guide Mr. Iqbal Hadis for their continuous valuable guidance, support, suggestions and their precious time in every way throughout the project activity.We would also like to thank Mr. Yogesh Gholap, Mr. Jithin Isaac and Mrs. Sneha Shivam for their continous suggestions and weekly check on our project.

Date : / /

ABSTRACT

An underwater vehicle is a remote controlled vehicle which can be used for underwater surveillance. The applications of underwater vehicles have shown a dramatic increase in recent years such as underwater mines clearing operation, feature tracking, cable or pipeline tracking and deep ocean exploration. An underwater vehicle is usedfor underwater environmentdetection or observation, it is better to make this vehicle smaller and exible in motion that it can go to smaller space easily.

This project report contains,

1. Introduction to Underwater Vehicle

2. Fundamentals of Underwater Vehicle

3. Review of Literature Survey and Research

4. Analysis and Design Aspects

5. Hardware, Software and Estimated Expenses

Contents

Chapter 1

Introduction

Underwater Vehicles (UVs) are remarkable robots that revolutionized the process of gathering ocean data. Their major breakthroughs resulted from successful developments of complementary technologies to overcome the challenges associated with autonomous/controlled operation in harsh environments.During the last decades, UVs have gone through notable developments. In the late twenties, the first prototypes required a tremendous effort and ingenious engineering solutions to compensate for the technological limitations in terms of computational power, batteries, and navigation sensors. To deploy these expensive vehicles navigating autonomously in a very unforgiving environment, and expecting them to return safely was a true act of faith in engineering, a down scaled version which can be remote controlled is required.

This section will cover the following topics:-

1. Problem Statement
2. Scope of the Project
3. Current Scenario
4. Block Diagram of Underwater Vehicle

1.1 Problem Statement

To design and implement a low cost, high range miniature underwater vehicle.

1.2 Scope of the Project

• To be able to implement sonar sensor in the Underwater Vehicle as to map the sea bed for it's surveillance.
• Water quality check by using carbon-dioxde sensor and pH of water sensor.
• To be able to transmit live stream of underwater scenario.
• Using high powered antennas and reducing losses, increasing depth and range of operation.

1.3 Current Scenario

UVs are built from well-proven technology products that are commercially available. In the control of these vehicles, the designer uses rate gyros and magnetic compasses from the aircraft industry, **high-speed radio modems** and small-form **GPS (Global Positioning System)** receivers from the satellite communications industry, **embedded controllers** and high capacity memory storage used in general data-logging applications, and standard fin and rudder sections as described in textbooks on aerodynamics. What is needed then is to integrate these technologies into building the machine using a set of skills encompassing software engineering, hydrodynamics of rigid bodies, hydrostatics, navigation, **electronics and control systems engineering**. What ultimately binds all these systems together is the amount of intelligence incorporated in the software created for the UV.

The types of Underwater Vehicle in present use:-
• AUTOSUB – designed and operated by the Southhampton Oceanography Centre, UK.
• REMUS (Remote Environmental Monitoring Unit) developed by Oceanographic Systems Laboratory of WHOI, USA.
• The SAUV – the solar powered AUV jointly developed by the Autonomous Undersea Systems Institute,USA.

1.4 Block Diagram of Underwater Vehicle

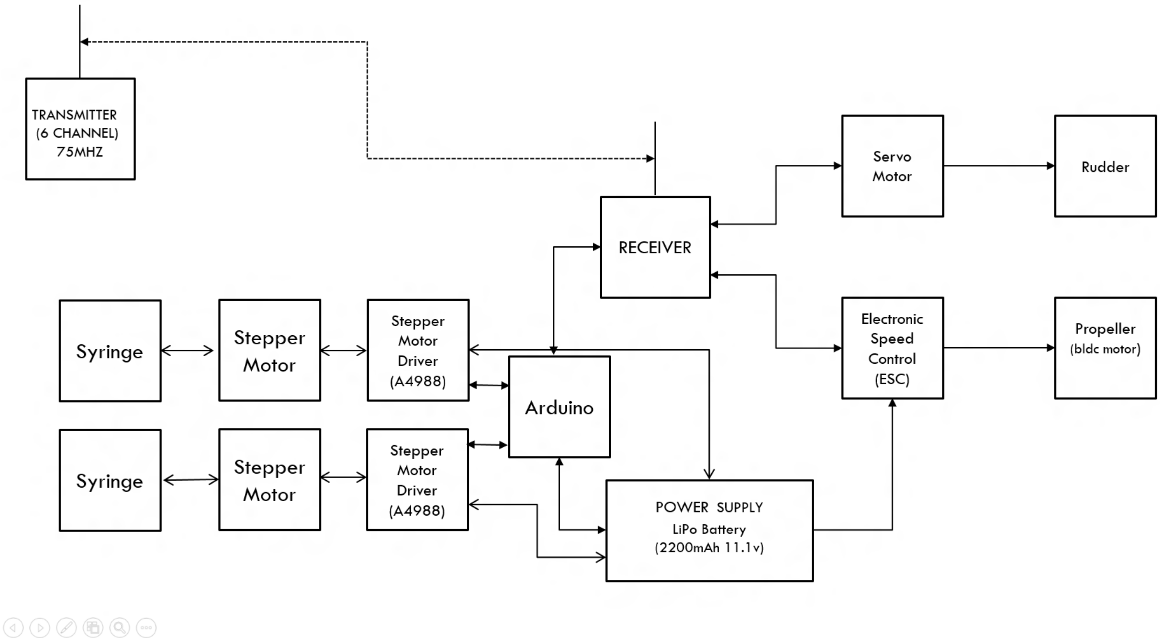

Figure 1.1: Basic Block Diagram.

Chapter 2

Underwater Vehicle Fundamentals

This section deals with the working and designing of the Underwater Vehicle.

It covers the following topics,

1. Objectives
2. Design Factors
3. Working Principle
4. Flow Diagram

2.1 Objective

1. To design and develop Underwater Vehicle (UV) using static diving technique.

2. Movement of the UV will be controlled with a remote using propeller, rudder and ballast tank system.

3. To be able to take underwater images.

2.2 Design Factors

The following points have to be taken into account for designing of the Underwater Vehicle:-

1. The depth of operation.

2. Operating velocity.

3. Rate of submerging (positive and negative buoyancy).

4. Frequency of operation and the number of channels required.

5. Weight and volume of the Underwater Vehicle.

6. Internal and external design in such a way that all components can be fitted as well as water tight body.

2.3 Working Principle

Static Diving Technique:-

Static Diving Underwater Vehicle (UV) have some means of changing the weight of the UV such as by filling ballast or dive tanks with water. This assists them in submerging. To return to the surface the vehicle dumps the water outside the ballast tank in order to regain buoyancy and return to the surface. Static diving systems may use electric motors, pumps or some form of compressed gas to fill or empty the ballast tanks.

In our UV we will be using syringe to store in water, the amount of water inside the syringe will be adjusted using a stepper motor.

Ballast Tank

A ballast tank is a compartment within a boat, ship or other floating structure (for our case UV) that holds water, which is used as ballast to provide stability for a vessel. Using water in tank allows for easier adjustment of weight than stone or iron ballast as was used in older vessel. It also allows for ballast to be pumped out to temporarily reduce the draft of the vessel when required to enter shallow water.

2.4 Flow Diagram

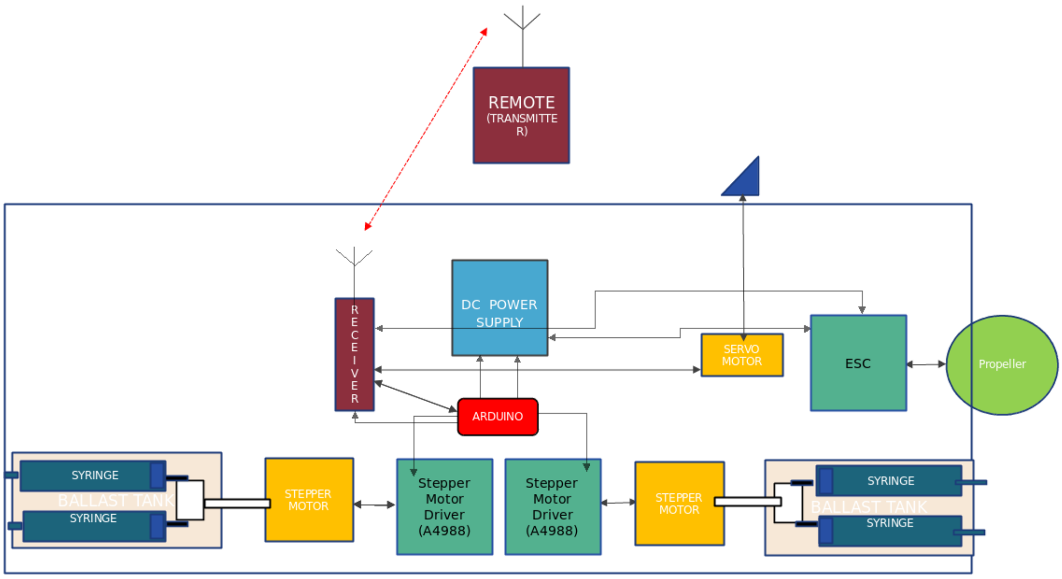

Figure 2.1: Flow Diagram.

Chapter 3

Literature Survey

3.1 RFID Underwater: Technical Issues and Application

“Once the value of water conductivity is known, it can be used to calculate the values of the penetration depth and of the attenuation. The penetration depth is the distance where the electrical and magnetic fields are reduced of a 1/e factor, and it can be calculated using the following formula:

d= 1 / sqrt(pi.f.u.s)

where f is the frequency of the electromagnetic wave, u is the absolute magnetic permeability of the conductor and s is the conductivity. While water is a diamagnetic material, their absolute magnetic permeability can be considered the same as the vacuum magnetic permeability,

i.e. 0 = 4*10 H/m.

d10kHz= 1/ sqrt(pi.f.u.s)

d10kHz= 1/sqrt(pi75.106410-7310-3)

d10kHz = 1m

Authors:

Giuliano Benelli and Alessandro Pozzebon -University of Siena, Department Information Engineering, Siena, Italy

Learning:

The chemical composition of marine water is influenced by several biological, chemical and physical factors and thus due to this large attenuation of signals takes place as compared to the air medium.

3.2 Underwater Radio Communication

“Water in its pure form is an insulator, but as found in its natural state, it contains dissolved salts and other matter which makes it a partial conductor. The higher its conductivity, the greater the attenuation of radio signals which pass through it.”

Authors:Lloyd Butler, Moore, Richard R. Radio Communications in the Sea, IEEESpectrum, Vol 4, Nov 1967.

Learning:
Attenuation of radio waves in water:-

• Attenuation (a) in dB/metre = 0. 0173 sqrt((fc))
where, f = frequency in hertz and c = conductivity in mhos/metre • Refraction loss (dB) = - 20 log (7.4586/106) x (f/c) • Wavelength (w) in meters= 1000 10/(fc)

3.3 Electromagnetic Wave Propagation into freshwater

“ For such a plane wave penetrating the fresh water, the total power loss is the sum of the transmission loss and propagation loss. Our analytical formulations describe both loss mechanisms.

Power Attenuation for Normal Incidence We formulate analytical equations to calculate the transmission loss and propagation loss for the scenario of Figure 1. The incident power is written as:

The transmission loss is due to the reflection at the air-water interface .

• The incident power is written as: Pi = Re —Ei—$^2/2n$

where, n:- Intrinsic impedance of water. Ei:- Incident Electric Field.

• Transmitted power in water is written as: Pt=Re —Et—$^2/2t$

where, :- Intrinsic impedance of air. Et:- Transmitted Electric Field. “

Authors: Shan Jiang, Stavros Georgakopoulos, Journal of Electromagnetic Analysis and Applications, 2011, 3,261-266

Learning: • Incident power and transmitted power of the rc remote and receiver

3.4 Submarine Main Ballast Tanks- Theory and Methods for Refined Structural Design

“The component of rise rate due to buoyancy is naturally dependent on the amount of ballast water blown, but it cannot exceed the velocity at which the drag force of the ship hull equals the buoyant force of fully-blown tanks. (The drag force is a maximum with the submarine moving perpendicular to its axis, and decreases as pitch angle in- creases)”

Authors:C.H.Pohler, D.S.Wilson, W.A.SkinnerHead Submarine Structural Mechanic Unit, Scientific and Research Section Of The Full System, NAVSEC, Bureau Of Ships.Commander, US-NAVY, Submarine Project Coordinator.

Learning: Types of Ballast Tank’s designing and operation:- • Action of water required to submerge the underwater vehicle.

3.5 Autonomus Underwater Vehicles

“Mechanism of the water-jet propulsion system The structure of one single water-jet propeller. It is composed of one water-jet thruster and two servo-motors (aboveandside). Thewater-jet thruster is sealed inside a plastic box for waterproof. And we use water proof glue on servo motors for water proof. Thethruster can be 5Development of a Vectored Water-Jet-Based Spherical Underwater Vehicle 4 Will-be-set-by-IN-TECH rotated by these two servo motors, therefore the direction of jetted water can be changed in X-Y pane, respectively.”

Authors: Nuno A. Abreu, N., Matos, A., Ramos, P. Cruz, N. (2010). Automatic interface for AUV mission planning and supervision.

Learning: • Designing of Outer body of the Underwater Vehicle.

• Highest Power consumption components in the vehicle

• Propellers: For each of them, the thruster has a working voltage of 11.2V and 3.5A current drain.

• Servo motor: IT can work under 5V with relatively small current.

• Therefore, we use two 3-cells LiPo batteries as the power supply for the propellers.

3.6 Aspects of Propeller Developments for a Submarine

“DESIGN PROCEDURE

The design procedure of the propeller should ideally include feedback to the design of the submarine hull and its control surfaces.

Cavitation margin

Most surface ships experience propeller cavitation during normal operation. The design effort for surface ship propellers is therefore directed towards avoidance of harmful cavitation in way of erosion and towards moderate levels of propeller excited noise and vibration. However, propeller cavitation must be completely avoided for a submarine in submerged condition in order to secure the lowest possible noise signature.

Reduction of wake-induced propeller forces

The most important parameter with respect to propeller- induced forces is the wake field itself which for many reasons should as fair as possible, be it surface ships or submarines.

Skew, pitch and camber distribution

The application of skew can reduce in particular the firstorder thrust and torque fluctuations and improve the cavitation behaviour as commonly seen in surface ships. However, a fairly large skew angle is needed to reduce torque and thrust fluctuations significantly.

Orthogonal blade length and circulation distribution

The circulation distribution has been discussed in 4.1 with respect to load relieving of tip and root in order to obtain sufficient margin against cavitation. However, the application of ”non-planar lifting surfaces” (Andersen et al. (2005)) changes the circulation significantly.

Authors:Poul Andersen1, Jens J. Kappel2, Eugen Spangenberg Carlton, J. (2007). Marine Propellers and Propulsion, Ross, D. (1987). Mechanics of Underwater Noise.

Learning: • Design Considerations for propeller -¿Orthogonal blade length -¿RPM -¿Diameter -¿Material

Chapter 4

Analysis and Design Aspects

This chapter covers all the analysis, analytical and design aspects along with the required equations and considerations in the form of the following topics,

1. Methodology Adopted

2. Design Considerations

3. Design Calculations and Equations

4.1 Methodology

1. Design of the Vehicle

2. Construction of the model

3. Testing of the prototype

4.1.1 Design Steps

1. Designing of the 1st pipe which contains the ballast tanks (Syringe Technique),Stepper motor ,stepper motor driver (A4988) and Arduino

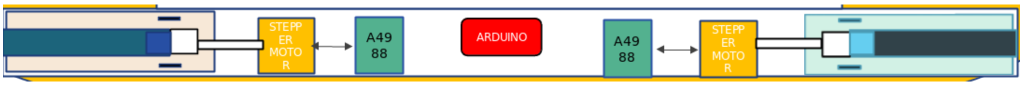

Figure 4.1: Diagram of 1st pipe.

2. Designing the 2nd pipe which contains the 4 Channel Receiver,Powersupply,Servo motor ,ESC(Electronic speed control),BLDC Motor .

Figure 4.2: Diagram of 2nd pipe.

3. Fixing the 2 pipes together and attaching the Rudder to the Servo motor Propeller to the BLDC motor

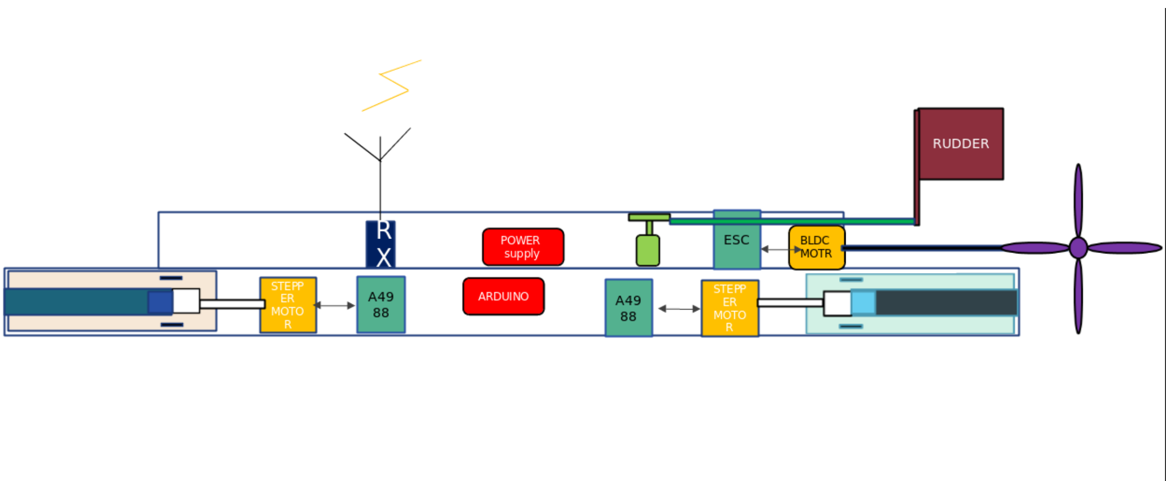

Figure 4.3: Diagram of pipe.

4. Fixing the entire inner body into a hull(Outer body)

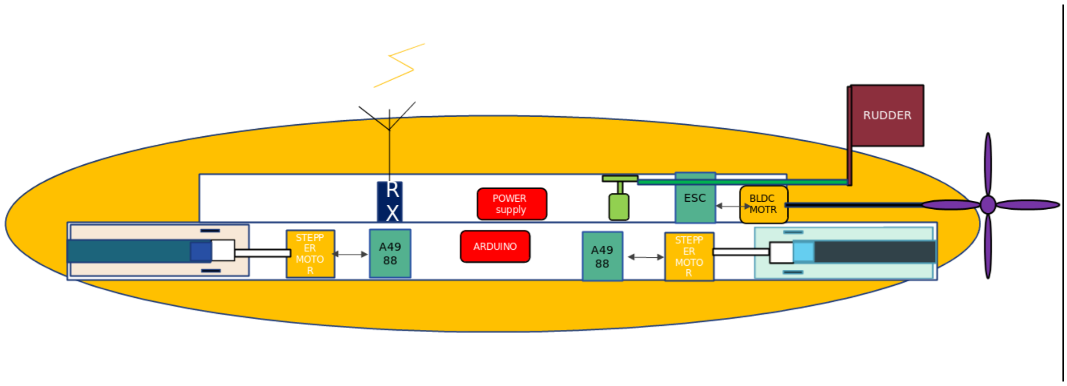

Figure 4.4: Diagram of .

5. Fixing the camera to the body which will be used to take photos of the

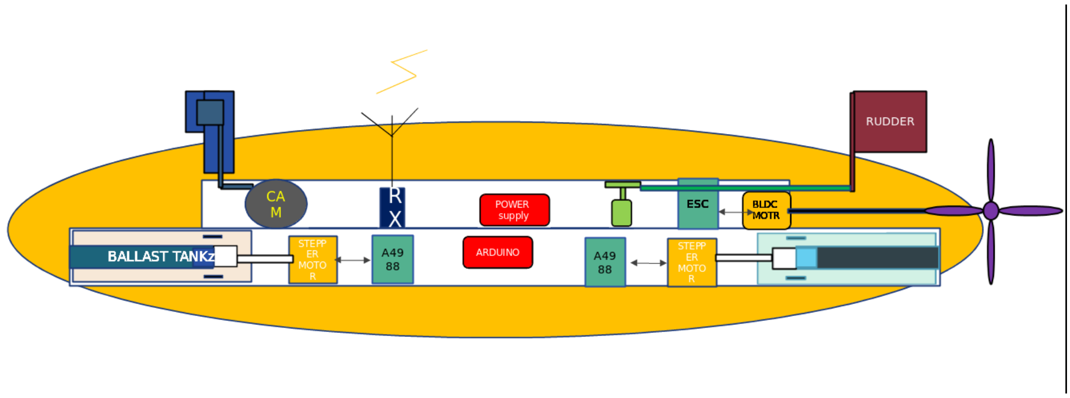

Figure 4.5: Diagram of .

6. Connecting all the devices to the power supply and to the Receiver

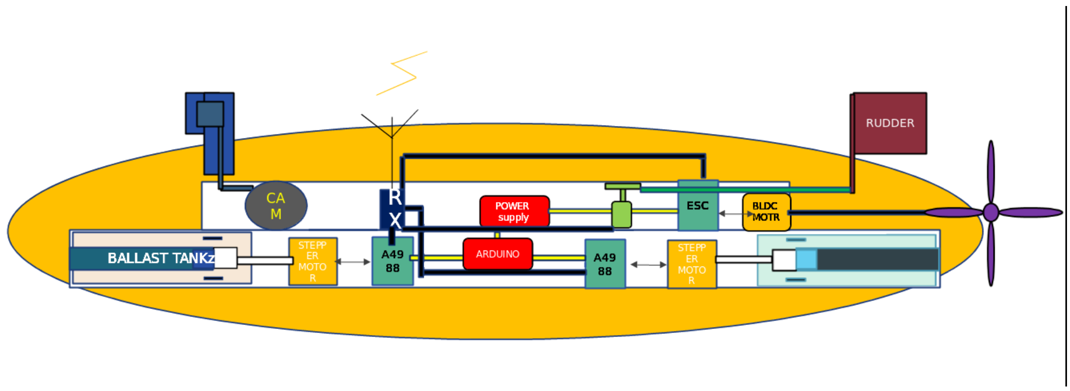

Figure 4.6: Diagram of .

4.2 Design Considerations

4.2.1 Operating Depth(Underwater):

0 to 1-5 Meters The Operating Depth of the UV is calculated to be about 0-1.5 Meters .This parameter is dependent on the frequency of operation that is chosen to be 75 MHz .A signal of frequency 75MHz can penetrate about a meter or a meter and a half deep by using the skin depth formula.

4.2.2 Maximum Velocity:1.8Kmph(0.5m/s)

Maximum Velocity of the UV is dependent on the specifications of the Propeller used in the system and also the weight of the whole system which is calculated to be in the range of 1.8km/hr.

4.2.3 Frequency of operation: 75MHz

Different signals with different frequencies have various penetrating depth in water. For this UV the desired depth is assumed to be 1 - 1.5m.Since the skin depth of the 75Mhz is approximately 1.5 meters we have selected 75MHz as the Frequency of operation

4.2.4 No. of channels required(Transmitter-Receiver):4

The TX-RX Remote control that is used in this project has 4 channels .Each is used to control 1 device in the system .One channel is allotted to the servo motor to control the rudder ,one to the ESC of the BLDC motor to control the propeller and the other 2 to the stepper motor drivers that is the used to control the stepper motors or the action of the syringe's i.e Ballast tanks .

4.2.5 Range Of Operation:25 meters

The Range of operation is dependent on the power of the signal which is calculated by using formulas in the literature survey to be approx. 25m

4.2.6 Camera Quality:

For this project we have used an HD camera that will be used to take pictures of the underwater scenes .The camera will have a resolution of 1080 x 920.

4.3 Design Equations

4.3.1 Frequency of Operation:-

The chemical composition of marine water is influenced by several biological, chemical and physical factors and thus due to this large attenuation of signals takes place as compared to the air medium.

d= 1 / sqrt(pi.f.u.s)

f= 1/(pix d$^2 x 4 pi x 10 - 7 x 3 x 10 - 3)$

f= 75MHz

- Where, d :- Skin Depth is assumed to be 1m.
- Thus, Frequency of operation=75Mhz

4.3.2 Attenuation of radio waves in water:-

- Attenuation () in dB/metre = 0. 0173 sqrt((fc))

where, f = frequency in hertz and

c = conductivity in mhos/metre

Refraction loss (dB) = - 20 log (7.4586/106) x sqrt(f/c)

- Wavelength () in meters = 1000 sqrt10/(fc)

4.3.3 Power Transmitted in Water :-

- The incident power is written as:

Pi = Re—Ei—$^2/2n$

where, n:- Intrinsic impedance of water.

Ei:- Incident Electric Field.

Transmitted power in water is written as:

Pt=Re —Et—$^2/2t$

where, :- Intrinsic impedance of air.

Et:- Transmitted Electric Field.

Chapter 5

Implementation

This chapter deals with the required software and hardware along with their specifications and purposes. It also includes the estimated expense for the project development.

5.1 Software Requirements

1. SolidWorks(Dassault Systems) – Mechanical Design

2. Arduino IDE – Code Deployment

5.2 Hardware Requirements

4.2.1Electronic components:-

1. Transmitter and Receiver (74MHz-4 channel)
2. Arduino
3. Stepper Motor (quantity:2)
4. Brushless DC Motor(BLDC Motor)
5. Electronic Speed Control(ESC)
6. Servo Motor
7. Camera

4.2.2 Mechanical Components:-

1. Outer Body
2. Acrylic Pipes
3. Syringes

4. 3-D Printed Pipe Coverings with Threading
5. 3-D Printed Rudder
6. Propeller Fan

Chapter 6

Summary

6.1 Conclusion

The present semester more focus was given on literature survey and designing aspects of the Underwater Vehicle. We have successfully designed the internal parts and working of the UV has been understood along with various sensors and actuators.

References

[1] Giuliano Benelli and Alessandro Pozzebon -University of Siena, Department of Information Engineering, Siena, Italy

[2] Lloyd Butler, Moore, Richard R. Radio Communications in the Sea, IEEE Spectrum, Vol 4, Nov 1967.

[3] Shan Jiang, Stavros Georgakopoulos Journal of Electromagnetic Analysis and Applications, 2011, 3,261-266

[4] C.H.Pohler, D.S.Wilson, W.A.Skinner Head Submarine Structural Mechanic Unit, Scientific And Research Section Of The Full System, NAVSEC, Bureau Of Ships. Commander, US-NAVY, Submarine Project Coordinator.

[5] Nuno A. Abreu, N., Matos, A., Ramos, P. Cruz, N. (2010). Automatic interface for AUV mission planning and supervision.

[6] Poul Andersen1, Jens J. Kappel2, Eugen Spangenberg3 Carlton, J. (2007). Marine Propellers and Propulsion, Ross, D. (1987). Mechanics of Underwater Noise.

[7] Lighthill, M. J. (1952). 'On Sound Generated Aerodynamically, I. General Theory'. Proceedings of the Royal Society of London, Series A, Mathematical and Physical Sciences 211(1107) (Mar. 20, 1952), pp. 564-587.

[8] Fossen, T. I. (1995). Guidance and Control of Ocean Vehicles, John Wiley Sons Ltd., USA. Guo, S., Lin, X. Hata, S. (2009). A conceptual design of vectored water-jet propulsion system, International Conferenceon Mechatronics and Automation, 2009. ICMA 2009, IEEE, pp. 1190–1195.

[9] Sangekar, M.,Chitre, M. Koay, T. (2009). Hardware architecture for amodular autonomous underwater vehicle STARFISH, OCEANS2008, IEEE, pp. 1–8.

[10] Le Page, Y. Holappa, K. (2002b). Simulation and control of an autonomous underwater vehicle equipped with a vectored thruster, OCEANS 2000 MTS/IEEE Conference and Exhibition, Vol.3, IEEE,pp. 2129–2134.

APPENDIX