International Journal of Scientific & Engineering Research, Volume 11, Issue 8, August-2020
ISSN 2229-5518

Acoustic Release using fusible link

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Abstract— Finding that there was a gap in the market for an acoustic release that was fast-acting, protected from the bio marine elements and not dependent on the salinity of the water, a device with a replaceable fusible link to remotely decouple coupled objects by applying the appropriate electrical resistance was devised. It is a new method to melt or fuse a metal link almost instantaneously by supplying electrical charge which is high powered that would release a secondary link which would be held in place a lever mechanism instrumental in decoupling coupled objects. It works well with light loads and shallow to medium depths. It is faster than the electrolytic method and more dependable than the mechanical lever release system. It also adds mechanical strength to the fusible link that is in control of the key lever and includes a signal delivery system that can be activated remotely to avoid human interference in a delicate and dangerous environment. It is an inexpensive and reliable model which can be used as an acoustic release in specific situations saving energy and capital

Index Terms— acoustic release, electrical replacable link, fusible link, mooring, ocean engineering

1 Introduction

Common remote sensing equipment and major source of oceanographic data are radiometer, for measuring sea surface temperatures, scatterometers which estimate the surface wind speed and direction and wave disturbances and high precision altimeters that measure the topography and deformation.

The in site ocean observations provide data of varying degrees of quality but the highest quality data is collected from scientific research programs that design instrument buoys, which could either be moored or free drifting, that are deployed by special purpose ships that are used to collect environmental data and coastal information.

Based on the method implemented and the vessel used, there is still the case of the deployment of the module under the surface of the ocean to collect the data. They would have to remain undisturbed and hardy enough to last the duration required to collect enough data. A combination of this in situ data and the global trends from the satellite, blended, gave a clear picture of the global ocean and weather conditions.

After discussing the in situ data collection, we realized that we need a method to retrieve the valuable underwater equipment. This recovery was done by an acoustic release. It has its own battery backup and can last multiple years while having the flexibility of being deployed in multiple terrains and ocean topographies. It is made to avoid diving in deep and protected regions to retrieve the equipment as it can be very dangerous for humans as well as the native ecology.

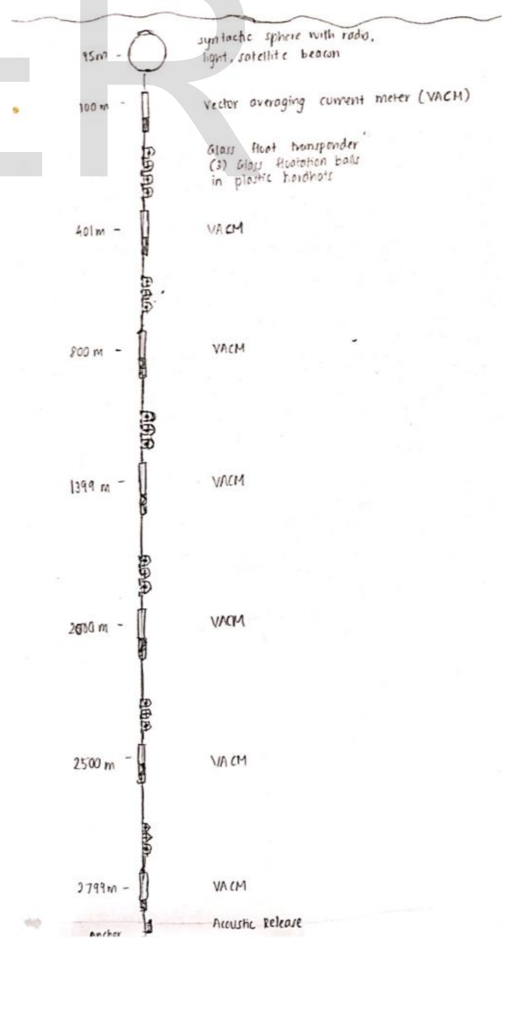

Figure 1

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2 Choosing Fusible Link

The following are the reasons for choosing the fusible link as the core mechanism for the acoustic release [1]:

1. The release mechanism of the core system will not require any kind of insulation, thermal or otherwise
2. The release works very rapidly, within a few seconds as compared to which might take from minutes to hours
3. The mechanism is not affected by any kind of bio-fouling or any other interaction with the marine environment.
4. The salinity of the water does not affect the operation of the fusible release.
5. It does not require as much battery backup as others, as it is an instantaneous action with a singular electrical pulse.
6. It can work with a variety of load ranges, from light to about medium heavy.
7. It is an inexpensive and a reliable model.

3 Working

3.1 Hardware

1. Sensor Module
2. Control Unit
3. Communication Unit
4. Mooring including buoy and anchor

3.2 Software

1. Data analysis and retrieval
2. Health Check
3. Encoded release communication

3.3 Flowchart

3.3.1 Diagram

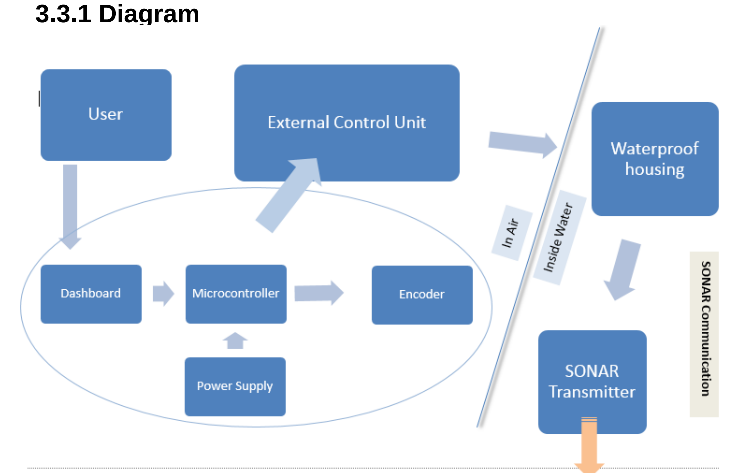

Figure 2

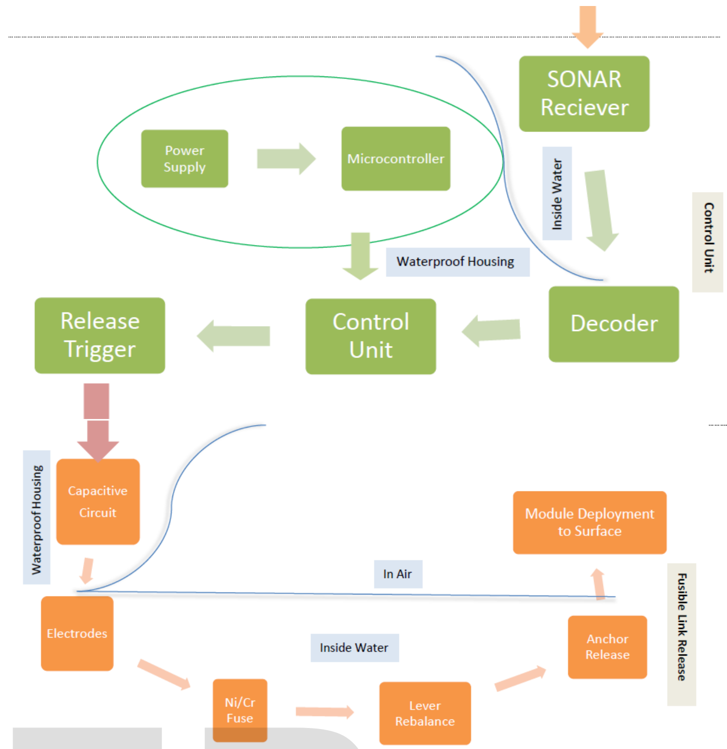

Figure 3

3.3.2 Working Methodology

3.3.2.1 Part One

1. Users - The acoustic release is usually used by marine engineers, students, navy, oceanographic researchers, port authorities, coastal government and fishermen.
2. External Control Unit - The external control unit on the surface of the water consists of the dashboard, micro controller, encoder and a power supply. The dashboard is the unit from which we send the command signal to the release system. It is also used to determine the condition of the system.
3. The command signal sent from the dashboard goes to the encoder whose function is to encode the signal and to make sure that signal goes to the respective acoustic release system as each release system has its own unique identifier code.
4. Waterproof Housing - The encoded command signal further goes through

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the waterproof housing and to the sonar transmitter connected to the acoustic transducer which converts the electrical signal to an acoustic signal which then transmits the pulse of sound generated using a sonar projector, consisting of a single generator, power amplifier and electro-acoustic transducer to locate the acoustic release.

5. The sonar receiver which is located on the acoustic release system listens for the echoes of the sound wave transmitted. The system will respond to the transmitter indicating how far from the transmitter it is located and that it is still operating.
6. The sonar receiver is further connected to an acoustic transducer which converts the acoustic signal to an electrical signal.

3.3.2.2 Part Two

1. Command signal delivering system - This acoustic transducer is connected to the command- signal delivering system through the underwater housing. The command-signal delivery system is electrically connected to the capacitor charge delivery system.

2. Encoding -The signal has to be encoded while transmitting for two reasons- to maintain the integrity of the strength of the signal and also to make sure that the signal is caught and used by the right module. A single terrestrial control unit interacts with multiple underwater modules. At the same time, there would be multiple control units, manufacturers and domains of researchers using various devices, hence it has to be made sure that the right trigger is sent to the right acoustic release.

3.3.2.3 Part Three

Capacitive Circuit

1. When the capacitor charge delivery system receives the command signal from the command signal delivery system, the actuator switch closes to complete the circuit to ground.

2. It includes a battery connected to a capacitor charge circuit to control the capacitor charging, which is connected to a bank of capacitors with low equivalent series resistance or internal impedance which is about 0.018 ohms that acts as a power reservoir.

3. The power reservoir is three capacitors totaling to about 100000 microfarad and is charged to a voltage of about 30 V. These capacitors are connected to the fusible link and the actuator switch. The actuator switch is the part that receives the command signal input. Thus, delivering the capacitor charge across to the fusible link (Nickel Chromium wire).

Electrodes

1. The electrical terminals are two long stainless steel posts. Both these posts have a female thread at the top end and an Allen head screw that is screwed into the female thread.

2. The fusible link is wrapped one-half turn around the first post and then over to the second post and then again wrapped one half turn around the second post.

Fusible Link

1. The fusible link type wire is generally used for electric heater elements. It generally has a length of about 6 mm and an electrical resistance of approximately 8.860 ohms per meter.

2. However, the link can be made up of any material which satisfies the mentioned requirements. The fusible link has the capacity to uphold a strength of about 18 kg and with the hinged lever, adding mechanical advantage thus increasing the maximum load to around 54 kg. This fusible link is required to be replaced each time an object needs to be deployed into the water.

Lever Rebalance

1. The hinged lever arm is made of non-corrosive materials or low-friction materials which also include self-lubricating materials. Examples would include metals such as stainless steel, titanium, plastics such as nylon, PVC. Any structure can be possibly used in place of the lever arm, the only requirement is that it

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should provide mechanical advantage of releasing. As only one part moves during the release action, the probability of failure of the release mechanism is much lower than in mechanical releases.

2. As soon as the electrical charge through the electrical terminals is delivered to the fusible link, it immediately starts melting, thus releasing the hinged lever and decoupling the secondary link. It takes about 2 to 4 milliseconds to melt the fusible link. The object is deployed to the surface of the sea floor.

4 BUOYANCY CALCULATIONS

4.1 Mooring

Mooring Parameters [2]:

Initial length of mooring line: - **Lo (m)**
Number of mooring lines: - **N (m)**
Weight of mooring line: - **Wm (N)**
Pre-tension of mooring line to: - **(N)**
Anchor point ra: - **(x, y, z)**
Mass density of mooring line: - **m** **(kg** m^{-3}**)**
Elasticity of mooring line: - **E (N** m^{-2}**)**
Diameter of mooring line: - **D (m)**
Clump weight connection points along mooring: - **sc (m)**
Buoy connection points along mooring line: - **sb (m)**

1. Length of mooring line L (m): Length of mooring line can stretch, due to elasticity.

$$L = \int_{Buoy}^{Anchor} ds \quad \ldots Eqn\ 1$$

2. The strain of the mooring line: The amount of line has been stretched. It can be given as a ratio, a relationship between the original length and the stretched mooring line length.

$$\epsilon = L - \frac{L}{L_0} \qquad \ldots Eqn\ 2$$

3. Tension in mooring line T(s) N: When a mooring line is subjected to maximum cyclic loads it creates Tension in the mooring line. It is vital to determine the tension in mooring design for accurate analysis of load and fatigue present in a mooring line.
In the following equation the tension for a linear stress-strain relationship can be given:

$$T = EAe, where\ A\ and\ E\ are\ the\ cross\ sectional\ area\ and\ the\ Young's\ modulus\ of\ the\ \ the\ mooring\ line \qquad \ldots Eqn\ 3$$

4. The tension is constant throughout in a Taut Mooring line design.
5. Environmental Inputs: Waves, wind, current, the variation in water depth due to the tide and many other factors and environmental inputs drive and affect the mooring line dynamics.

4.2 Electronic Half-Life

As we can see from the table below, the electronics that are to be used in the module are more than capable of lasting on a small drainage power and a single electrical pulse of up to 10 seconds reliably for the duration of a single deployment of five years.

Electronic Name – Type	*Half Life*
SONAR Transducer	5-7 years
Microcontroller – Arduino	49 days
MOSFET	180 min
Nickel Chromium fusible wise	10-20 years
Lithium Ion battery	3- 4 years
Encoder	9-10 years
Decoder	8-10 years
Capacitors	Up to 20 years
Resistors	Up to 100 years

Table 1

5 IMPORTANT APPLICATIONS OF THE CALCULATIONS

5.1 Mooring

The main idea of any kind of mooring deployment is to keep the mooring on the location it was placed and to get accurate measurements from the instruments aligned with it. The main components which are involved in Moorings are as follows [3]:

1. Anchors: Pile/Drag/Plate/Deadweight
2. Weights
3. Lines: Wire/Rope/Chain
4. Buoys: Surface / Subsurface

A few common mooring configurations [4]:

Mooring Types	*Depth*	*Scope*
All chain	5-40 m	2-4
Semi-taut	40-300m	1.5-2.5
Inverse Catenary	>2500m	1.1-1.3

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Taut	Uses pre-stretched nylon rope for the entire line	0.98
Elastic	Used or shallow water mooring as other mooring types fail due to abrasion	Not defined

Table 2

The surface-moorings when deployed can be defined as successful depending on two major factors i.e.

1. Its ability to accurately measure and determine all the range of conditions the mooring might encounter.
   Its design and structure which support and make the mooring capable to survive in all the determined conditions.

Proposed specifications of the final product	
Battery Life	1.5 years
Weight – without sensors (in air)	10 kg
Weight – without sensors (in water)	6.5 kg
Load	500 kg
Battery Type	Lithium ion
Frequency of communication	17-35 kHz
Actuation	Fusible link
Construction	Steel, coated with erosion safe paint
Tilt Indicator	--
Battery Type	Rechargeable
Link Type	Nickle chromium, Replaceable
Depth	25 m

Table 3

5.2 SONAR

SONAR equations tell us if the SONAR signal is strong enough with respect to the background noise for the system which is in use. The equations will give us a value which will give us the probability of detection of the initial signal [5].

Parameters like the strength of the input signal, Transmission Loss (TL)-the signal strength which is attenuated or dispersed due to various factors when the sound travels from source to destination are taken into consideration for the sonar equations. Factors like the signal strength at the receiver which is also known as target strength (TS), noise levels (NL) which depend on the sea level at which the sonar system is placed, the type, amount of marine life and the power gain of initial signal which is increased by increasing the number of transmitter/receiver antennas known as array gain which in turn have a major impact on the working of the SONAR system.

6 Product Specifications

6.1 Hardware Specifications

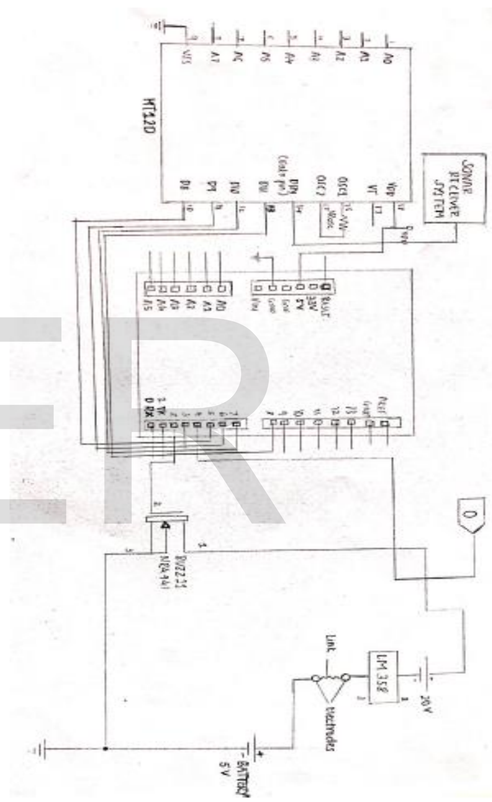

Figure 4

6.2.1 The Microcontroller

Arduino Uno [6] is the most standard board available and its flexibility is one of the main reasons for its selection. It offers a variety of digital and analog inputs and serial interface, required for the transmitting and receiving of data. Second being inexpensive, Arduino boards are relatively less expensive as compared to other micro controllers. As Arduino is based on Atmel's ATMEGA8 micro controllers, they are open source and have extensible hardware. It provides circuit designers to make their own version of the module thereby being able to extend and

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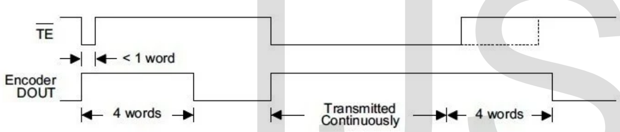
improve it. The software of the Arduino is compatible with all kinds of operation systems like Linux, Windows and Macintosh, etc. Arduino also comes with an open software system with an ability to merge with prevailing programming libraries and may be extended and changed.

6.2.2 The Encoders

The requirement for an encoder and decoder is justified by the need to maintain the integrity and strength of the signal and also to make sure that the signal is caught and used by the right module. The HT12E Encoder [7] and HT12D Decoder[8] IC's are suitable for the operation as they are commonly used for remote control systems and radio frequency applications and are also cost-effective. This encoder-decoder pair is used to transmit and receive 12 Bit data serially.

It converts 12 Bit parallel data into a serial output using an RF transmission medium. They are capable of encoding N bit information as address and 12-N bit as data and belong to the CMOS LSI's series. Its operating voltage is 2.4 V ~ 12 V and has high noise immunity technology at low power consumption. It requires minimal external components for its operation and can provide minimum 4-word transmission.



Transmission timing for the HT12E

Figure 5

HT12D also belongs to the CMOS LSI's series and shares the same basic features as HT12E. It works in a pair with the encoder for proper operation. (12) The decoders receive serial addresses and data from a programmed HT12E series of encoders and they compare the serial input data three times continuously with their local addresses. The input data codes are decoded and then transferred to the output pins if no error or unmatched codes are found. The VT pin also goes high to indicate a valid transmission otherwise it always indicates LOW.

6.2.3 The SONAR Transponder

The SONAR transducer that we have used is JSN-SR0T4-2.0[9]. It provides an accuracy of up to 2mm and detects a signal over the distance of up to 6m which is permissible for a proof of concept at the moment. The module includes the transceiver of an integrated ultrasonic sensor and control circuit.

The advantages of using this transducer are that it is small and very easy to integrate. It has a low voltage rating and a very low power consumption. It has strong anti-interference protocols and high precision measurement. The probe of this hardware is made for usage in wet and rough environments.

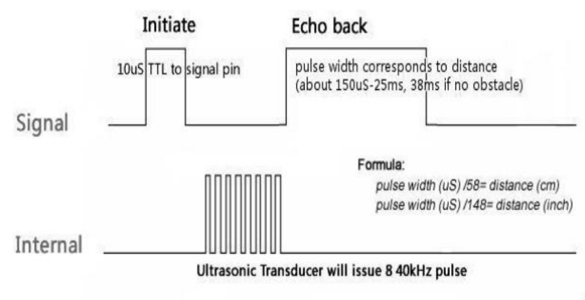


Figure 6

The working of the transducer can be explained by the timing diagram. First a time cycle has to be established which is done by a specific process. A short pulse, at time zero, is transmitted which is received by the transducer on the other end. After the echo of the first pulse fades, the next one is transmitted. According to the specifications, a cycle period of a minimum 50ns needs to be used. Once a stable channel is established, the data can be transmitted.

6.2.4 The circuit specifications

Power loss takes place between the battery and fusible link which is proportional to the distance between these two components. To overcome this loss we need to use an amplifier. The amplifier used in our circuit is LM358 [10], which is an operational amplifier and provides a gain of 100dB. This gain provides amplification of the input circuit which compensates for the power loss between the battery and fusible link. LM358 has an input voltage range of 3V to 32V and the amplified voltage is not supply voltage dependent.

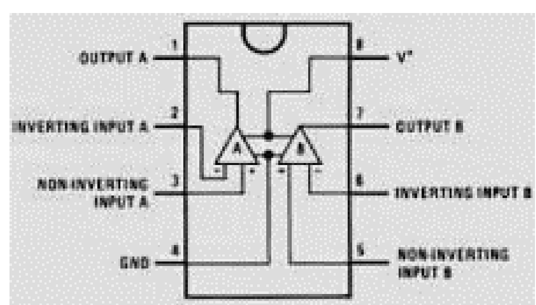


Figure 7

Two electrodes are used at the ends of the fusible link, which are used to provide the necessary voltage to the fusible link by connecting the fusible link to the circuit. Graphite electrodes are used in the circuit as they are robust and have a low thermal coefficient.

The MOSFET used in the circuit is BUZ11-

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NR4941. This is an N-Channel Enhancement Type MOSFET. This MOSFET can be used for high power applications which and also have a low threshold voltage which can be provided by an Arduino microcontroller which is used in our circuit. Its minimum Drain to Source Threshold voltage (BVDSS) is 50V. The minimum and maximum gate threshold voltages (VGS) are 2.1V and 4V respectively and it has a typical value of 3V. Gate source Drain current (IDSS) has a typical value of 20uA and its maximum value is 250uA. Gate Source Leakage Current (IGSS) has a typical value of 10uA and its maximum value is 100uA. Rise Time (tr) has a typical value of 70ns and its maximum value is 110 ns. Turn ON Delay Time (tON) has a typical value of 30ns and its maximum value is 45 ns.

The Battery which we used in our circuit is LBXR20. It is a 20V Lithium-Ion Battery. The weight of the battery is 12 grams and its dimensions are 6.69 x 3.19 x 4.5 inches. This battery can withstand harsh environments and has a high battery life which are the required features for the battery used in our circuit.

6.2.5 The lever mechanism

The shown figure consists of a hinged lever arm held by a fusible link which in turn holds a secondary link. A lever is a rigid body which works on a simple mechanism and can rotate around itself. It can be classified according to the relative positions of the effort, resistance (load) and the fulcrum. The hinged lever in our system is based on the Class 3 lever mechanism.

In the Class 3 mechanism, the effort lies between the fulcrum and the resistance.

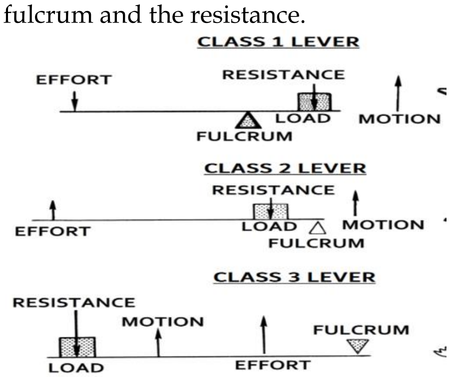

Figure 8

The hinged lever arm can be made of low friction, self-lubricating, lightweight and non-corrosive materials like plastics such as PVC, nylon, derlin etc. which can be supported by the fusible link. The hinged lever arm should work smoothly experiencing minimum friction. This is a considerable idea due to its quick releasing capabilities once the fusible link is heated, thus releasing the secondary link with minimum time delay.

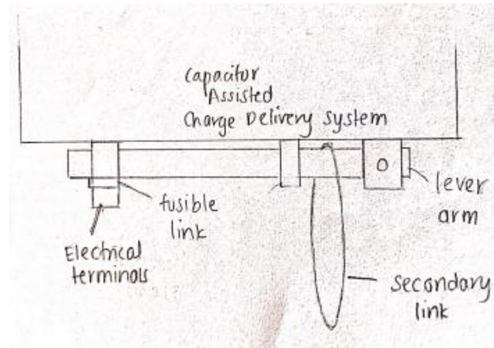

Figure 9

6.3 Software Specifications

6.3.1 The Mooring Simulation

To obtain the mooring values and simulate our fusible link buoyancy mechanism we used MD&D [11] toolbox of MATLAB application. This toolbox is used to simulate mooring underwater and the effect of time dependent current and wind on this design.

Mooring Design and Dynamics is a set of routines that are used to test the feasibility of moorings. It uses a set of equations to simulate the body. It can evaluate towed body apparatus, single point oceanographic moorings and mooring data.

The package solves a set of static force balance equations to determine the dynamics of moorings in the ocean under the influence of three dimensional time dependent currents. It also helps in evaluating the spatial position and tension of each mooring element based on the relative position of the anchor.

After using the MD&D programs, when a mooring is constructed, the position of each mooring element is calculated by solving the balance of forces acting on it within a time dependent three dimensional current.

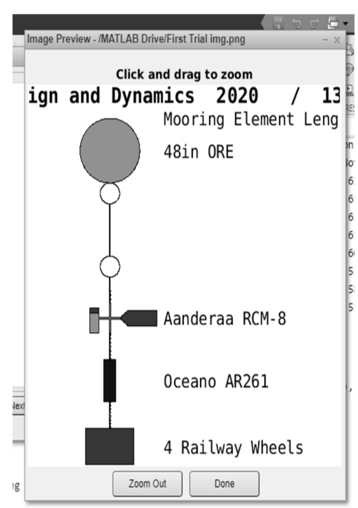

Figure 10

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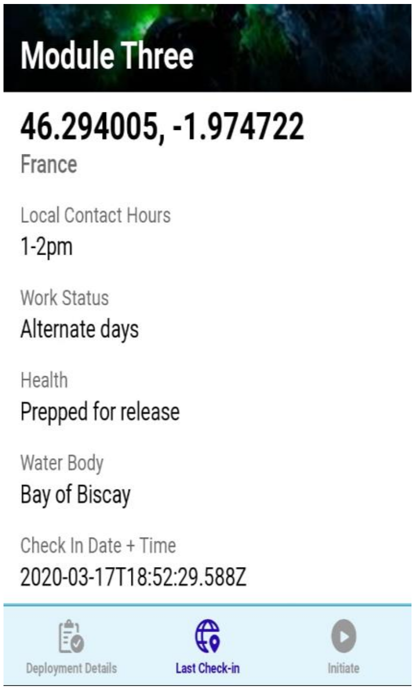

Figure 11

6.3.2 The Software Application

We have built a sample software application that can be run on a browser or even a cellular advice. It is used to send a remote signal to trigger the acoustic release.

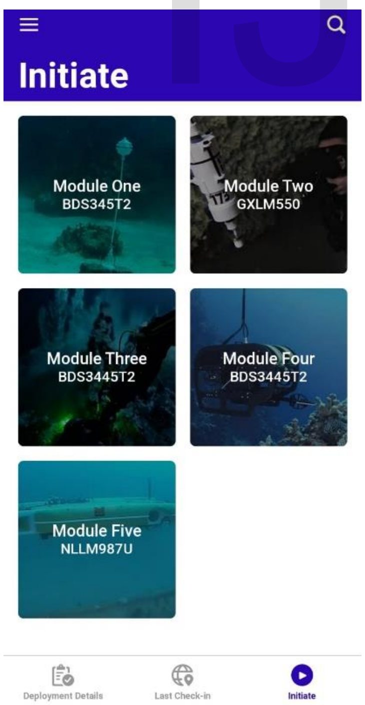

Figure 12

It can also be used to keep track of the health and location of the deployed mooring in future developments. A sample mock-up of such a functionality can be seen in the attached image.

7 Applications

Acoustic Release is a system which is used for instrument recovery from the ocean floor. This system can be used in varied fields their intent of use depending on the type instrument to be recovered [12].

7.1 Commercial

An arrangement of sensors deployed in the ocean floor by ocean experts can be recovered using an Acoustic Release mechanism. Data is collected from these sensors such as the different type of ocean floor movements which can be useful to give an insight about different types of phenomena like tsunamis, shifting of the ocean floor which can give rise to an increase or decrease in the ocean water levels.

7.2 Military

The acoustic release can be used to recover a group of sensors which is used by marine scientists to monitor flora and fauna at deep sea levels. It can let them know about any changes in the climate at these levels and its effect on the ocean settlements. It can also be used by them to identify different external elements which can cause changes in the ocean flora and fauna and this will help them in taking necessary precautions to control these changes.

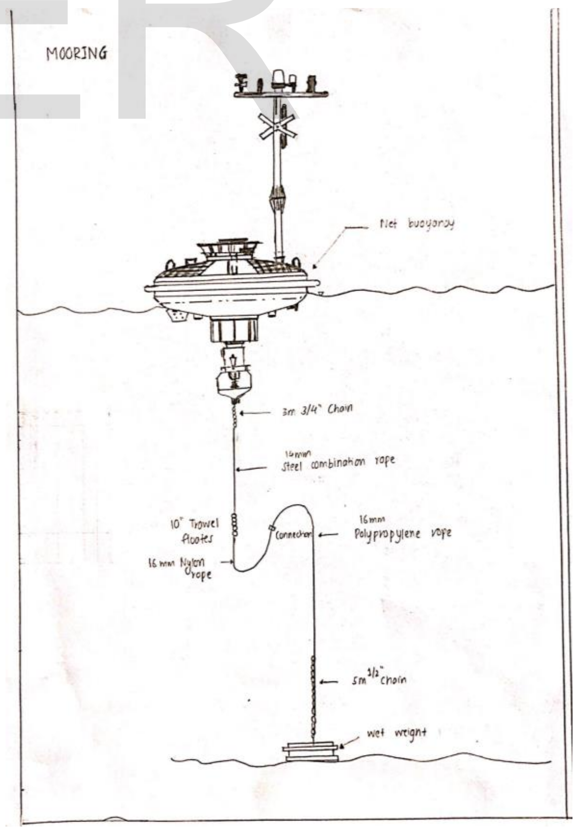

Figure 13

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8 CONCLUSION

Acoustic release is an oceanographic device used for the deployment and subsequent recovery of instrumentation from the sea floor in which the deployment and recovery is triggered by an acoustic command signal used by oceanographic researchers, navy and fishermen. Typically, acoustic releases have a motor release mechanism, but was aimed on implementing the release mechanism using the fusible link. Acoustic releases based on the motor release mechanism are bulky, expensive and can undergo failure due to environmental degradation, electrolytic corrosion. The acoustic release using the fusible link provides greater advantages over the motor based system as it does not require thermal insulation, less affected by marine bio fouling, rapid release of anchor and requires less battery power.

9 FUTURE SCOPE

Based on the work that has been completed till now, the deliverables for the product include – a fusible link acoustic release, a health monitor, a transponder for the user to the communicate with a dashboard and a mobile application which would store the log files for each of the modules for easy fact checking.

The constraints that the product has included the fact that the fusible link has to be replaced after each operation. The other factor being that the load on anchor ends has to be limited.

After further research and development, we would also like to include a surface to underwater and an air to surface combined communication channel. This would enable a continuous data transmission and a higher security.

10 END SECTIONS

ACKNOWLEDGMENT

This project, the research behind it and the paper that we have successfully finished has been a labor of love which would not have been possible without many of the stoic supporters that we have had from the conception of the project idea.

Our Head of Department, Dr. Prachi Mukherji helped us out every single time that we needed it by taking precious time out of her busy schedule and made sure that we got the right support, guidance and valuable suggestions.

We would like to thank CWPRS for presenting us with the opportunity to working with them and for the resources provided through the duration of the project. We would further like to express our gratitude to G.V.Ramanrao, Scientist-D at CWPRS for his expertise which helped assist us with our project and this research paper and his constant encouragement throughout. We would also like to express our appreciation to Vivek Saxena, Research Assistant at CWPRS for his technical guidance and constructive recommendations.

None of this would have been even remotely possible without the staff members of our Electronics and Telecommunication department and we would like to take this opportunity to express our sincere thanks to them, especially to Prof Kishori Rajwade. They made sure that we had all the support and infrastructure that we needed as and when the research required for it.

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