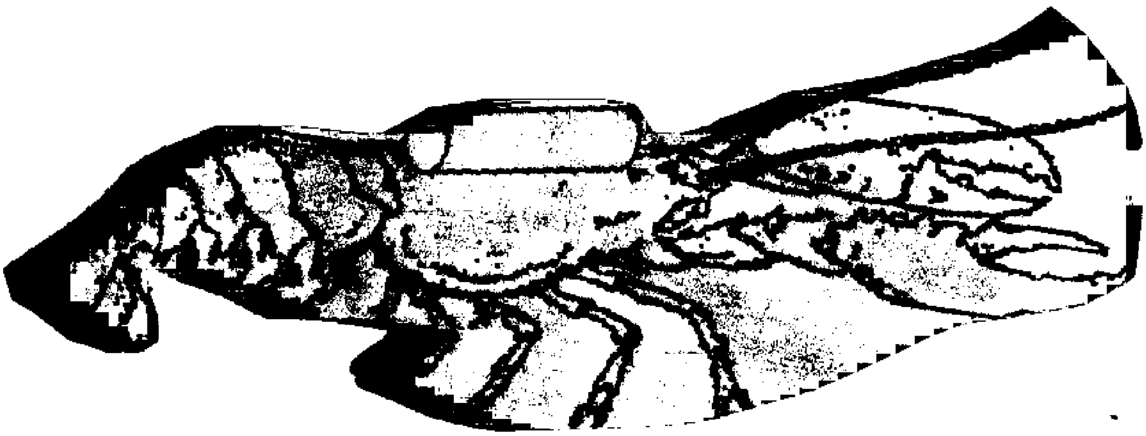
NHU-T-90-002

C R U S - S T A T I O N

COMPUTERIZED REMOTE UNDERWATER SCANNING STATION



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UNHMP-AR-SG-90-7

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1.0 INTRODUCTION

"To understand the biology of an animal species, we must know where the individuals go, what they do, and how they do it. We always prefer to collect data from individuals that are ranging as freely as possible. But rudimentary technique has often limited our work." [1]

This preceding quote tends to sum up the reasons for this Ocean Project. The problem of tracking lobsters is of immediate interest to several marine biologists at UNH. They are attempting to understand the behavior of lobsters in the Great Bay Estuary. The goal of this project was to address the "where do they go" portion of this research.

Until recently (the past 15 years), the ability to appreciate the capabilities of freely behaving animals has been highly restricted, because biologists have had to work within the abnormal confines of their laboratory. Instrumentation could not be brought to the field, animals did not behave normally in laboratory situations and biologists could not observe how organisms reacted within their environment.

> "To visualize how this limits our appreciation of the whole animal, imagine studying the human being from physiology alone. No amount of probing in the operating room can get us very close to the experience of a chess player or a concert violinist." [2]

At the present time, UNH researchers are attempting to understand the movements of lobsters in the Great Bay Estuary using two methods. The first is capturing lobsters, tagging them with sphyrion tags, and then releasing them. Then every time a lobster is recaptured by a lobsterman, the time and place of the capture are recorded. The distance moved can be calculated knowing the sites of release and recapture. This method is inexpensive and can tell researchers about general movements over long periods of time. The problem is determining the lobsters' movements between the time they are released and the time they are recaptured.

Direct field observation is not a very practical method of study, especially in an estuary with reduced visibility. Animals tend to be elusive; often producing more frustration than results. Therefore, in recent years, a new method of study, biotelemetry, has been developed. Biotelemetry uses an implanted sonar transmitter to track the movements of a marine animal in its natural habitat. The transmission consists of a series of sonar "pings" at a preset frequency. The transmitter of each lobster has a specific 3 number code, such as 3,4,5. This series of "pings" is delivered approximately every 10 seconds. The researchers detect these signals by use of a hand-held hydrophone and receiver. Three days a week, they go out in a boat and search for lobsters. When a lobster is located, the time and position are recorded. This method has proven to be useful in determining weekly movements, since most of the tagged lobsters are found at least once a week. The drawbacks of this method of detection are the amount of time needed to do the locating, the intermitant nature of the data, and the lack of precision.

Ideally, researchers need remote tracking system which would give researchers continuous and more precise information about the movements of lobsters in the estuary. The system should make use of the sonar emitters already available. Furthermore, it should scan for sonar signals from the lobsters at short time intervals, identify the lobsters found, and determine their position. It should then transmit the data back to a central receiving station where it can be analyzed. Since the sonar emitters have a limited range, a number of receiving units would have to be installed strategically throughout the estuary to complete the system and make accurate tracking possible. It was the goal of this project to build one of these receiving stations, within the constraints of a budget, and to show the feasibility of the entire system.

2.0 DESCRIPTION OF POSSIBLE SOLUTIONS

If three biologists were each in a different location in the estuary, they could simultaneously track a single target and find its location using triangulation. If each biologist was replaced with an automated tracking station, and a central base station was located within transmitting distance of the tracking stations, information from each station could be collected at the base station and the tracking of the target could be accomplished. The information transmitted from each station would include time and angular position relative to the station itself. With this information, the base station computer would be able to determine exact location of the animal in question. It was decided that the aim of this project would be to design and build one of these direction finding stations to prove the feasibility of an entire system. (See figure 2.0-1)

Three overall design solutions were considered. The first consisted of a rotating directional hydrophone mounted on top of a pressure vessel located on the ocean floor. The pressure vessel would contain electronics for receiving purposes as well as a microcomputer and backup power supply. The pressure vessel would be connected to a buoy on the surface, which would contain a transmitter and the main power supply. The hydrophone would rotate once every fifteen minutes and sample to detect signals and their directions. The actual direction would be determined by use of a computer algorithm which would record the direction when the signal was the strongest.

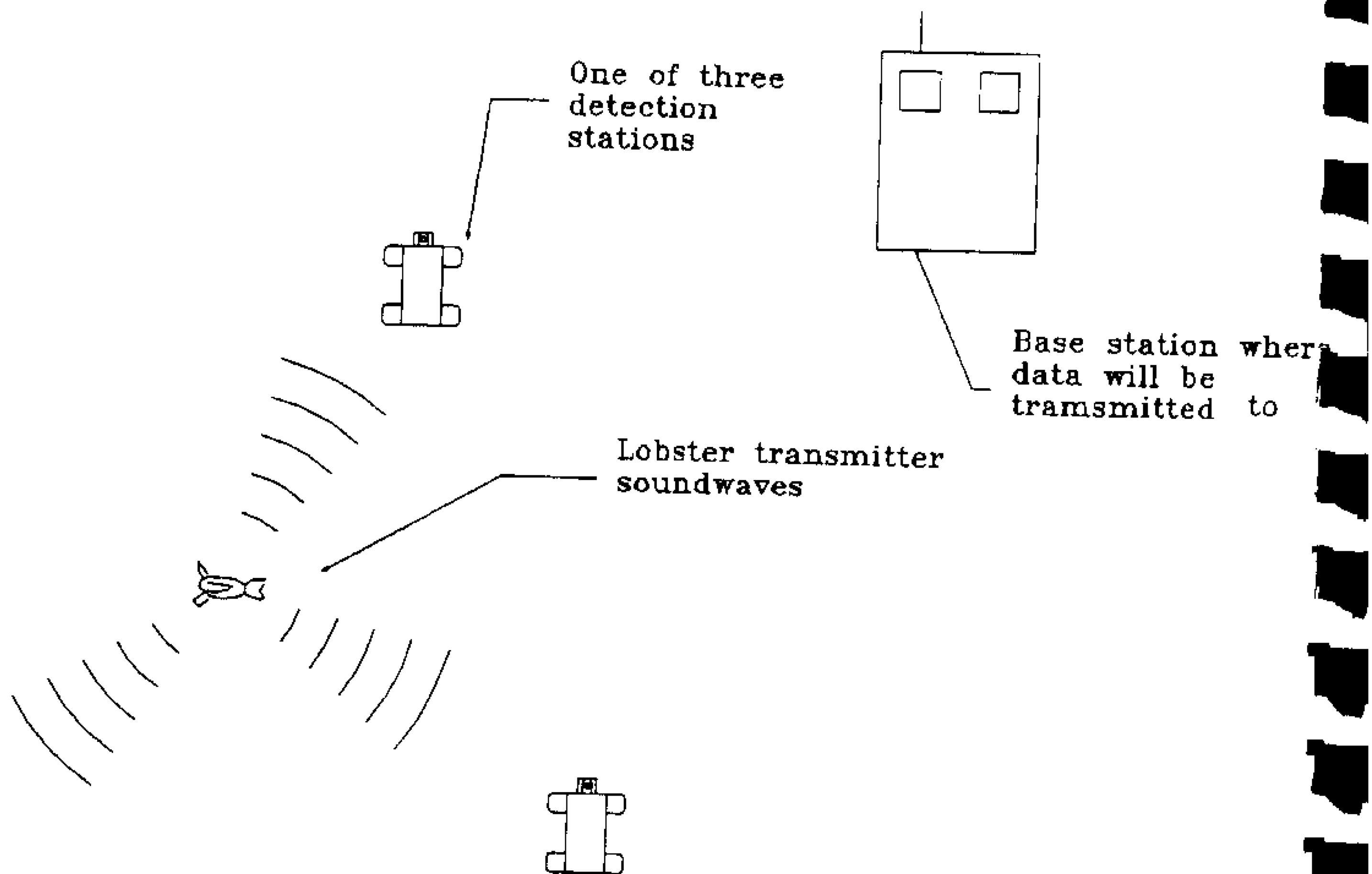


Fig. 2.0-1 System Overview Incorporating Triangulation

The second solution utilized a pulse detection method. It consisted of several stationary pressure transducers mounted a precise distance apart. The time delay between the response of the two transducers to an incoming signal would then be used to determine the angle from which that signal came. For this solution, there was also a pressure vessel containing electronics for receiving and processing of information; it also would be connected to the surface.

The third solution considered was the phase detection system. The phase detection system consisted of several transducers mounted within half a wavelength of each other, on center. Depending on the angle from which the signal came, there would be a difference in phase between the signal "seen" by one transducer and the signal "seen" by another. Signals would be received from several transducers and processed to determine directions.

The solution chosen was the phase detection method. The rotating hydrophone method was eliminated from consideration for the following reasons. First, the phase and pulse detection methods had no moving parts which increased their reliability in a marine environment and reduced the probability that they would require extensive maintenance . In contrast, it was also clear that a rotating shaft protruding from a pressure vessel, as required for the rotating hydrophone model, would make it difficult to completely seal the vessel and adequately protect the electronics. Second, the rotating hydrophone model required a significant amount of programming for the microprocessor which would have had to control a stepper motor to rotate the hydrophone. Third, a great deal more power would have been needed to drive the stepper motor and the associated electronics than was anticipated for the phase detection or pulse detection methods. Fourth, after analyzing data in the field, it was determined that amplitude detection would be difficult due to the random variation in the amplitude of sonar signals.

Having eliminated the rotating hydrophone, the choice between pulse detection and phase detection was then considered. The main problem with pulse detection was that it required detecting the leading edge of a 25 millisecond pulse. With a signal pulse traveling at 1500m/sec, it would be necessary to mount the transducers very far apart to achieve any accuracy. This necessitated a large rigid underwater structure. Furthermore, if the transducers were mounted far apart, the signal would have to travel through different mediums, which would change the speed and add error to the calculations. The size of the structure necessary and the error introduced when moving the transducers apart made the system less practical. The phase detection system was then chosen since it had no moving parts, required less programming, was compact, and promised a higher degree of accuracy than the pulse detection system.

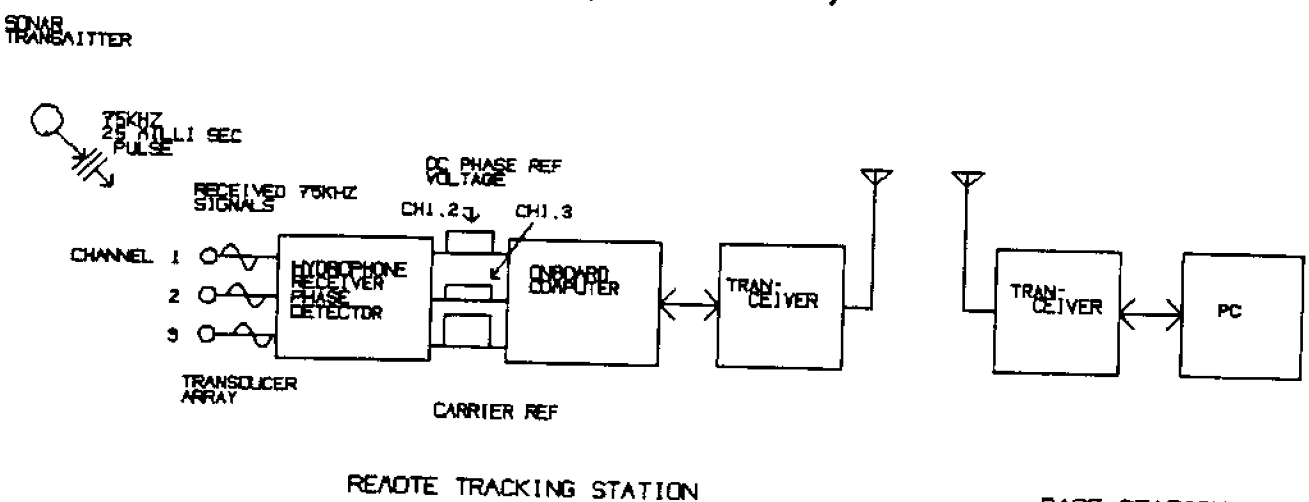


Fig. 2.0-2 Signal Block Diagram

An overview of the phase detection system is summarized as follows and shown in figures 2.0-2 and 2.0-3. An incoming signal will be received by an array of three transducers. The hydrophone receiver and phase detector located in an underwater pressure vessel will produce a DC voltage proportional to the difference in phase of the signals received at each transducer. The on board microcomputer will then make calculations to determine the direction of the incoming signal and record this direction along with the time. This information will then be transmitted to a modem in a surface buoy via a wire datalink. The modem will connect to a transceiver, which will transmit the information back to a base station. This information could later be used to time log position of a target.

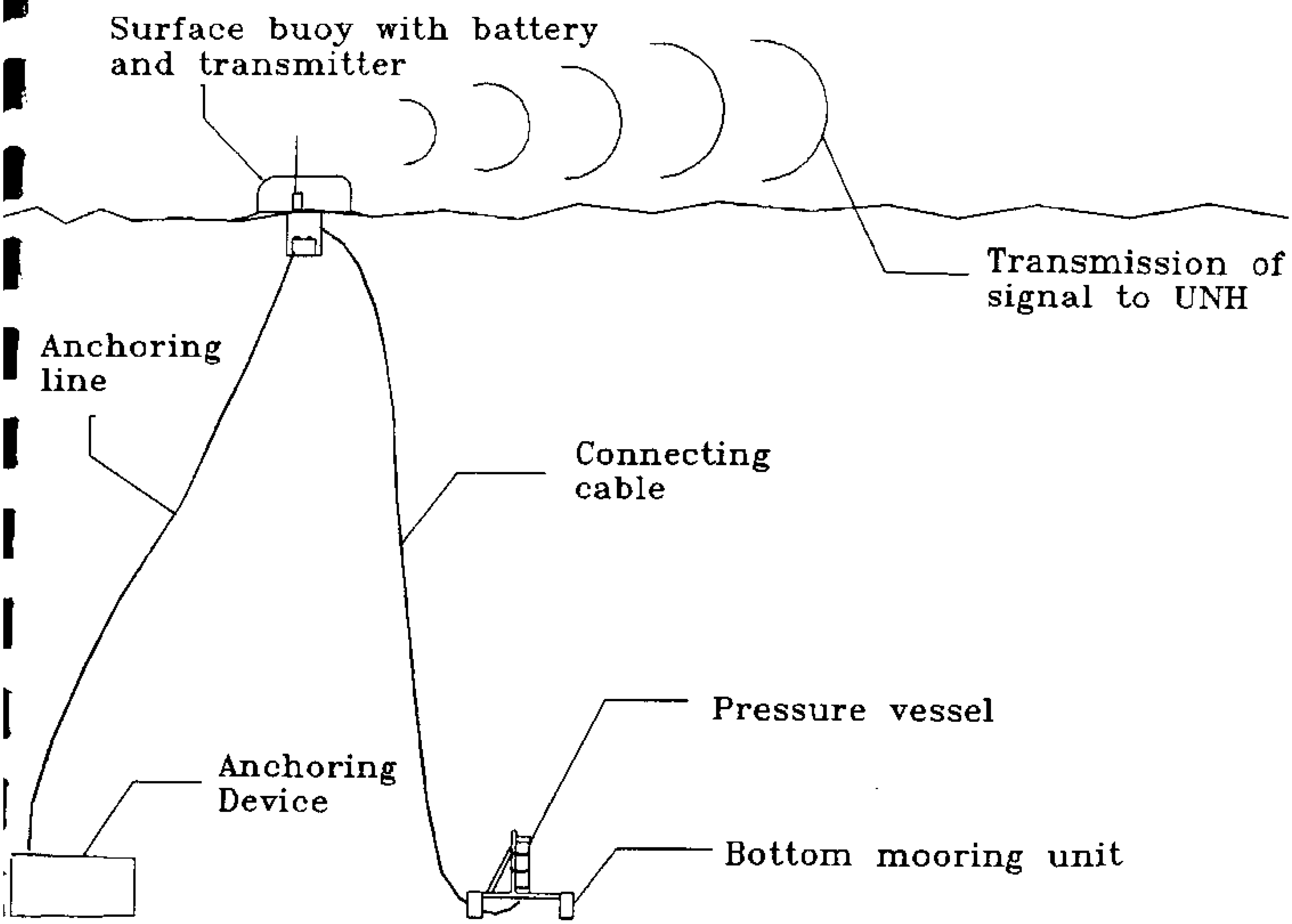


Fig. 2.0-3 Remote Tracking Station Overview

3.0 DESIGN GOALS

1) Three Channel Hydrophone Signal Phase Design (3.1)

2) Hydrophone Design (3.2)

3) Microcomputer - Data Acquisition and Storage (3.3)

4) Power Distribution (3.4)

5) PC - Level Data Retrieval and Computation (3.5)

6) Bottom Pressure Vessel Housing (3.6)

7) Pressure Vessel Mooring Device (3.7)

8) Surface Buoy Design and Components (3.8)

3.1 THREE CHANNEL HYDROPHONE SIGNAL PHASE DETECTOR

The positioning scheme is based on using phase detection of two separate hydrophone outputs receiving the same incoming signal pulse. The actual phase detection will be accomplished by using a well established signal processing technique.

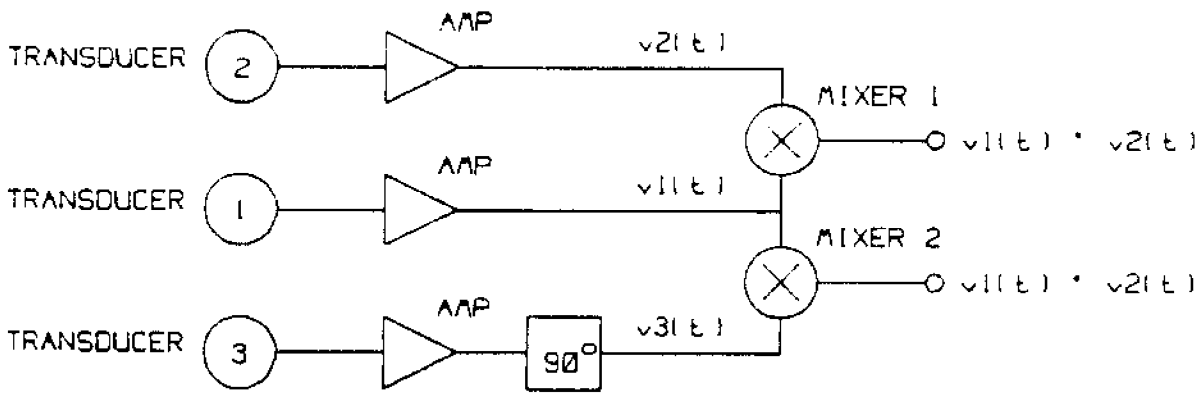


Fig. 3.1-1 Block Diagram of Phase Detection Process

As seen in Figure 3.1-1, the design has three transducers, which are the devices used to receive the incoming signal. Two transducers limit the vision to ninety degrees; the design calls for one hundred eighty degrees of vision. A third transducer, with a ninety degree phase shift, was added to solve this problem. To understand the basis of the design, a few communication system principles need to be discussed.

If two signals are applied to a mixer, the output is the product of the two signals. In this case, the two signals can be defined as

$$v_1(t) = A \cos(\omega t + \phi_1) \text{ and } v_2(t) = A \cos(\omega t + \phi_2).$$

Taking the product,

$$v_1(t) \cdot v_2(t) = A/2 \cos(\phi_1 - \phi_2) + A/2 \cos(2\omega t + \phi_1 - \phi_2).$$

Note the first component of the product gives a DC voltage relevant to the phase difference of $v_1(t)$ and $v_2(t)$. This is the heart of the design.

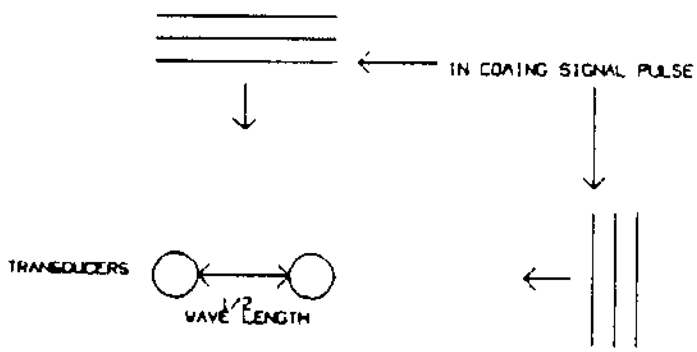


Fig. 3.1-2 Two Transducers Receiving an Incoming Signal

From this, a better understanding of the design's field of vision can be discussed. Taking two transducers and an incoming signal perpendicular to the transducers' axis, as seen in Fig. 3.1-2, the phase difference between the two signals would be zero degrees. Likewise, if the incoming signal was to the right or left, the phase difference would be one hundred eighty degrees, noting that the distance of separation of the two transducers is one half of the wavelength of the transmitted signal.

The problem is knowing on which side of the perpendicular is the incoming signal being received. Remember the equation to the solution is :

$$ARG\ 1 = A/2 \cos(\phi_1 - \phi_2).$$

If A = 2, the ARG 1 could be any value between 1 and -1, inclusive. Determining quadrants can be accomplished by using a second signal that is ninety degrees out of phase with the first.

$$ARG\ 2 = A/2 \cos(\phi_1 - \phi_2 - 90).$$

If the sign values of ARG 1 and ARG 2 are compared, the 180 degrees of vision can be divided up into four areas. Figure 3.1-3 shows how the signs reflect upon the position of the incoming signal throughout one hundred eighty degrees of vision.

To review, an incoming signal will pass by the three transducers. Three signals will be generated, each having a different phase in time with respect to the center transducer. The phase difference is determined by the angle of the incoming signal with respect to the axis of the transducer array. The signals will then be mixed to generate DC voltages relevant to the phase difference. From this information, the angle of the incoming signal can be determined. The information will then be averaged and stored by the microcomputer, to be downloaded into a PC for angle computation later.

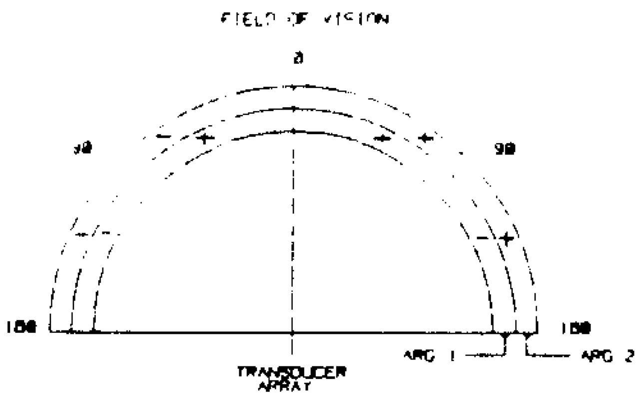


Fig. 3.1-3 Sign Changes in Field of Vision

The first step in the phase detector design is to take the very low voltage signal from the transducers and amplify it for signal processing. Starting at the left in Figure 3.1-4, the buffer isolates the transducer from the circuit and then the signal is amplified for signal processing. In the next stage, a second order Sallen and Key bandpass filter was incorporated into the design to filter out unwanted noise. Note that the third channel of the design has a differentiator to shift the signal by ninety degrees. As mentioned previously, this is necessary to obtain a field of vision of one hundred eighty degrees. A final amplification stage is used before mixing. The output of the mixer is the input into a second order Sallen and Key lowpass filter, which passes only the DC voltage containing the desired information. The signal, at this point, is a low DC voltage with positive and negative sign values. Next, the DC voltage is amplified and put through a summing circuit to shift the voltage, so that it is within the 0 to +5 volt range required for input to the Analog to Digital converters of the microcomputer.

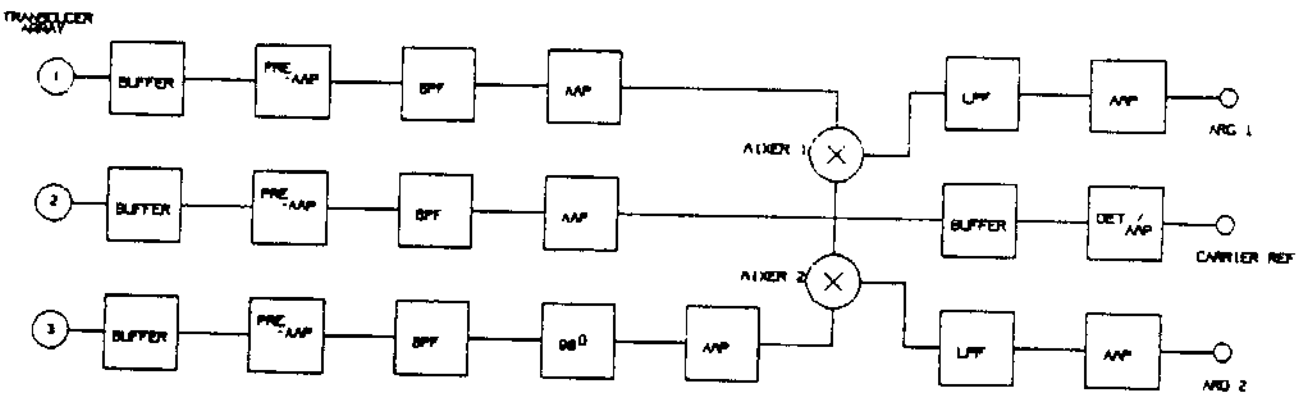


Fig. 3.1-4 Block Diagram of Three Channel Hydrophone Phase Detector

The final part of the design is the detector circuit. This circuit will take the processed signal and give a DC reference voltage proportional to the carrier amplitude. This is needed to divide out the variable **A** in the equations, thus making the information independent of the signal strength.

This completes the three channel hydrophone signal phase detector design.

3.2 HYDROPHONE DESIGN

The hydrophone, used to receive the incoming signal, plays a critical part in the overall system design. The goal of the hydrophone is to receive the incoming signal and generate a phase difference determined by the angle of the incoming signal with respect to the transducer array axis.

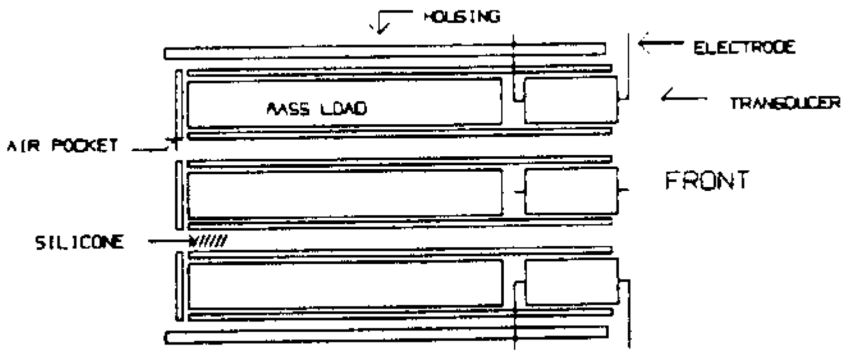


Fig. 3.2-1 Hydrophone Design

A critical part of the design was that the transducers needed to be one half of a wavelength, of the carrier signal of the transmitter, apart on center. Being limited to a seventy five kilohertz transmitting frequency, this led to the need to mount the transducers a centimeter apart, on center. Therefore, the diameter of the transducers needed to be less than a centimeter .

A mass loading scheme was the method used for the mounting of the three transducers. When a signal hits a transducer, the transducer expands generating an electromagnetic signal. The mass load, which is heavier than the transducer, channels the energy into the expansion of the transducer, rather than moving it. To isolate the transducers from each other, an air pocket surrounds each element. The final step in the design will be to protect the transducers from the surrounding water.

3.3 MICROCOMPUTER - DATA ACQUISITION AND STORAGE

3.3.a MICROCOMPUTER SELECTION AND FEATURES

The following criteria were needed in the microcomputer for collecting and storing data:

-Low Power Consumption

-RAM Size Must be Large Enough for Data Collection

-4 - 8 bit Analog to Digital Converters to Input Data

-RS-232C Compatible I/O Ports to Transmit Data to a PC

-Speed of Processor Must be at least a 2 Megahertz Bus Cycle

-Must be Affordable

Many microcomputers exist on the present market. They have a multitude of different features: memory size, ease of programming, available support, speed of processor, and other features.

The Micro-Computer chosen was the Motorola M68HC11 Evaluation Board (EVB), see figure 3.3-1. The EVB provides a low cost tool for proving the feasibility of the tracking system.

M68HC11 Evaluation Board Features:

-8-8 bit Analog to Digital Converter

-8 Megahertz CPU Clock with 2 Megahertz Bus Cycle

-8 Kilobytes of RAM

-512 Byte On Board EEPROM

-Socket for 8 x 8 Kilobyte EPROM

-2- RS232C Compatible I/O Ports

-C-MOS Technology for Low Power Consumption

-On Board Buffalo Debugger

-MC6850 Asynchronous Communications Interface Adapter I/O Port

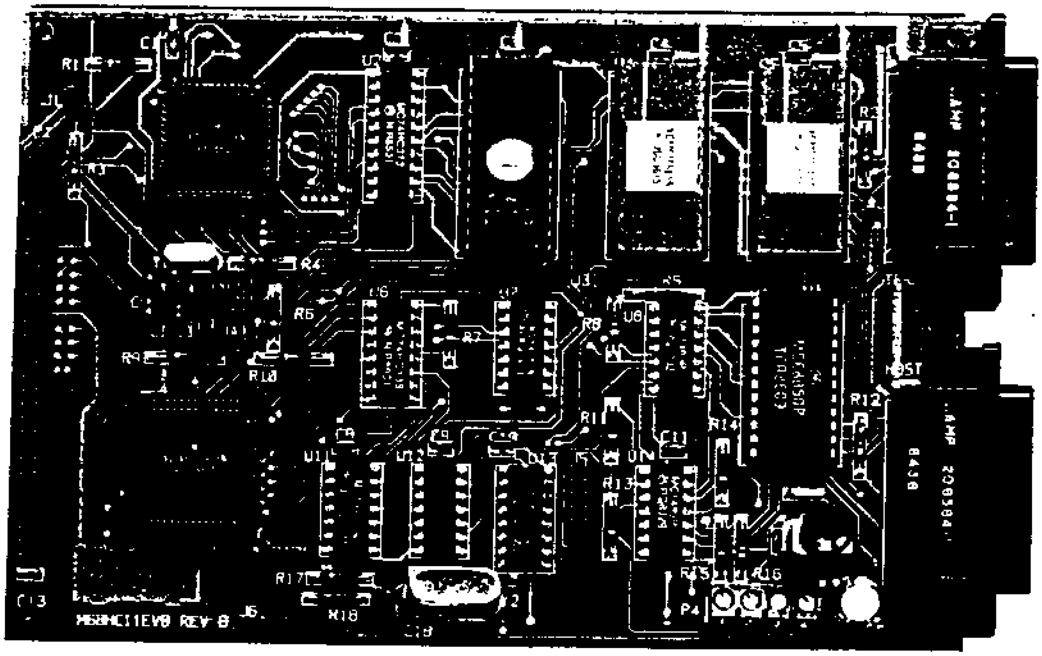


Fig. 3.3-1 Motorola 68HC11 Evaluation Board

The EVB was easily programmed, by writing the assembler code and assembling the code on a DOS based PC. The assembled code was downloaded into the RAM of the EVB, by connecting the serial communications port of the PC to the Serial Communications Interface on the EVB. With the program in RAM, the Buffalo Program, the on-board debugger, was used to debug the code.

At present, the code is being loaded into RAM and run directly from RAM. Due to program length, the available EEPROM is not large enough to store the code. Therefore an EPROM will be used as permanent storage of the code, preventing the loss of code each time power is lost to the system.

3.3.b PROGRAM DESCRIPTION

The purpose of the EVB is to interface with the electronic phase detection hardware. See Figure 3.3-2 for a flowchart description of the program.

Four voltages, which represent two phase shifts, a reference voltage and a ready to transmit voltage, are the inputs to the Analog to Digital converters on the EVB. The first three voltages are the outputs of the detection hardware, where the fourth is a signal to tell the processor to send data through its RS232C compatible port to the PC.

The computer is idle until it detects a reference voltage, that signifies a pulse is present, or the ready to transmit voltage high. If it is not transmitting and there is space in the RAM, the reference voltage is compared to a constant, which is determined by the noise level. When the reference voltage is above the noise level, a pulse is present. The transmitter on the lobster sends out a 25 millisecond pulse every second. Thus, the phase shift voltages are scanned by the Analog to Digital converter on the M68HC11 Microcomputer at one second intervals. The A/D collects 30 samples from each pulse. The data is averaged and stored in

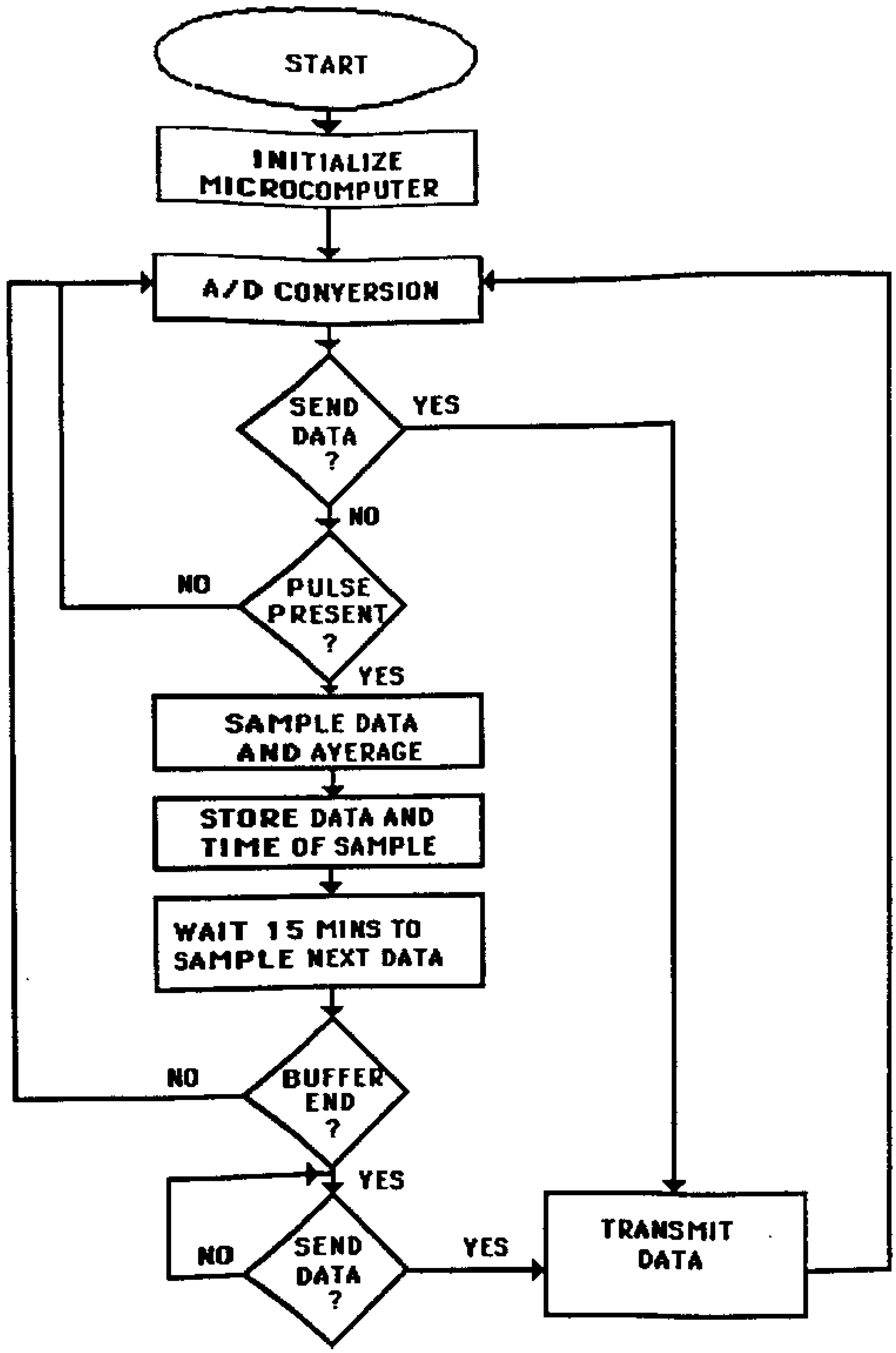


Fig. 3.2-1 Flowchart of Software for M68HC11 EVB

memory along with time of detection. After 30 seconds of collecting and averaging data, the computer waits fifteen minutes to start collecting data again. This is done until the memory buffer is full or a transmit high is detected by the fourth channel of the A/D.

When the microcomputer is signaled to transmit data, it sends each byte stored in memory. The PC that receives the data and must store it in hexadecimal form in a file. Since most programs convert the individual bytes received from the communications port into ASCII format, it was necessary to write a C program that would do this. The program transfers one byte at a time to the file while there is data being transmitted. From this file, the information can be processed to determine the angle of location of the lobster.

There are two possible methods of downloading the information to the PC. One method, is by a direct link to the microprocessor's RS232C compatible port from the cable in the upper buoy. The other method is using a modem and transmitter in the upper buoy to link to the microprocessor. With the buoy transmitter, with a PC and transmitter, at UNH or any other location within transmission range, the buoy can be called and the data can be transferred as radio signal. This is the most desirable method of data collection from the microcomputer.

3.4 POWER DISTRIBUTION SYSTEM

The following criteria had to be taken into consideration when designing the power distribution system:

-Long Lifetime Expectancy Needed

-Need +/- 12 Volts and +5 Volts

-Size Limitations Exist

-Leak Proof Batteries

-Rechargeable Batterie

-Access for Recharging Must be Convenient

With these necessary specifications, it was decided that the best solution would to use a main power supply and a back up power supply. The main power supply, located in the upper buoy, supplies long term power to the system. While the backup power, located in the lower units pressure vessel, provides power only when the main power supply needs to be recharged or when being charged. This ensures, that the computer does not lose power. If power is lost to the computer, all data will be lost from the RAM.

There were many different batteries that were available. With size and money limitations, the batteries were chosen based on life expectancy versus cost for the size needed.

The battery chosen for the main power supply was a 12 volt marine battery that was attained for less than dealer cost. Therefore the battery, while meeting our specifications, was also affordable. The location of the main power supply, allowed for a large, heavy duty battery, while also being easily accessible for recharging. The backup power supply had extra size requirements added to the specifications, because of the six inch inside diameter of the pressure vessel. Instead of using a single larger battery, we chose to use two smaller 12 volt batteries.

The electronics and the microcomputer require +/- 12 volts power supply. The microcomputer also requires a +5 volts power supply. With the use of voltage regulators, -12 volts and +5 volts are attained. Two LM7912CT negative voltage regulators make it possible to provide -12 volts. An LM340T5 voltage regulator makes it possible to convert from +12 volts to +5 volts.

3.5 PC LEVEL- DATA RETRIEVAL AND COMPUTATION

With a PC, the data needs to be downloaded form the microcomputer and calculate the angular position of the target. After having retrieved the data from the microcomputer, the first step in determining angular position is to take the given data and scale it. The data received from the microcomputer is in the form of integers ranging from 0 to 255. These numbers represent voltages of 0 to +5 volts. The data first must be coverted to the 0 to + 5 volt range by multiplying by 5/256. Recall from section 3.1, that ARG 1 and ARG 2 were shifted to be within the input range of the A/D converters using hardware. Thus the data the must be shifted back down by 2.5 volts due to the shift up done for A/D conversion.

Recall from section 3.1 that the DC carrier reference voltage is used to generate solutions that are independent of the signal strengths and that the desired information is in the form,

$$v(t) = A \cos (\phi_1 - \phi_2),$$

where v(t) is a DC voltage related to the phase difference of two signals, $v_1(t)$ and $v_2(t)$. The variable **A** is equal to one half of the incoming signal's peak amplitude. With the DC carrier reference voltage, the amplitude can be divided out, resulting in the equation:

$$v(t)' = \cos (\phi_1 - \phi_2).$$

This makes the equation independent of the signal carrier, eliminating the problems associated with random signal strengths. The next step is to reverse the mixing process. Taking the inverse cosine of the processed data, ARG 1 and ARG 2, generates the phase difference of the two original signals $v_1(t)$ and $v_2(t)$, see section 3.1.

As mentioned in section 4.1, a phase error is associated with the hydrophone circuit stages. To solve this, a final scaling will be incorporated to adjust the phase angle maximum, so that it occurs at zero degrees. The target's angular position, from the normal of the transducer array axis, is equal to one half of the phase difference. For example, if the incoming signal was traveling in from the far right of the field of vision, the phase difference generated by the signals would be one hundred eighty degrees. Thus corresponding to the targets location, would ninety degrees in a clockwise direction from the normal of the array axis.

To improve the degree of accuracy, the ARG with the least magnitude would be used to determine the angle, since this is where the voltage variance is greatest for small changes in angular position. The quadrant of the angle can be determined by comparing ARG 1 and ARG 2 also.

3.6 BOTTOM PRESSURE VESSEL HOUSING

It was necessary to store the receiver and phase detection electronics in close proximity to the hydrophone to reduce noise on incoming signals (see section 3.2). Therefore, it became necessary to design and build a pressure vessel for this purpose. The criteria on the pressure vessel were determined to be the following:

1) Vessel had to be safe at a depth of fifty feet.
2) Vessel had to have a life of at least 2 years.
3) Vessel had to house receiving electronics,microprocessor, and backup power supply.
4) Vessel had to have electrical connectors to provide connections for 6 wires from Pressure Vessel to Surface.
5) Vessel had to have a mounting bracket for the hydrophone.
6) Vessel had to have a safe connection for the passing of 6 wires from hydrophone to receiver.
7) Vessel had to be easily deployable.

Figure 3.6-1 shows the pressure vessel design. The chosen material from which to make the pressure vessel was Polyvinylchloride plastic. Other materials considered were aluminum, steel, and other plastics. Polyvinylchloride, 6in. PVC sewage pipe, was chosen because it was inexpensive, readily available, and best fulfilled the aforementioned requirements. Calculations, shown in the appendix, showed that the

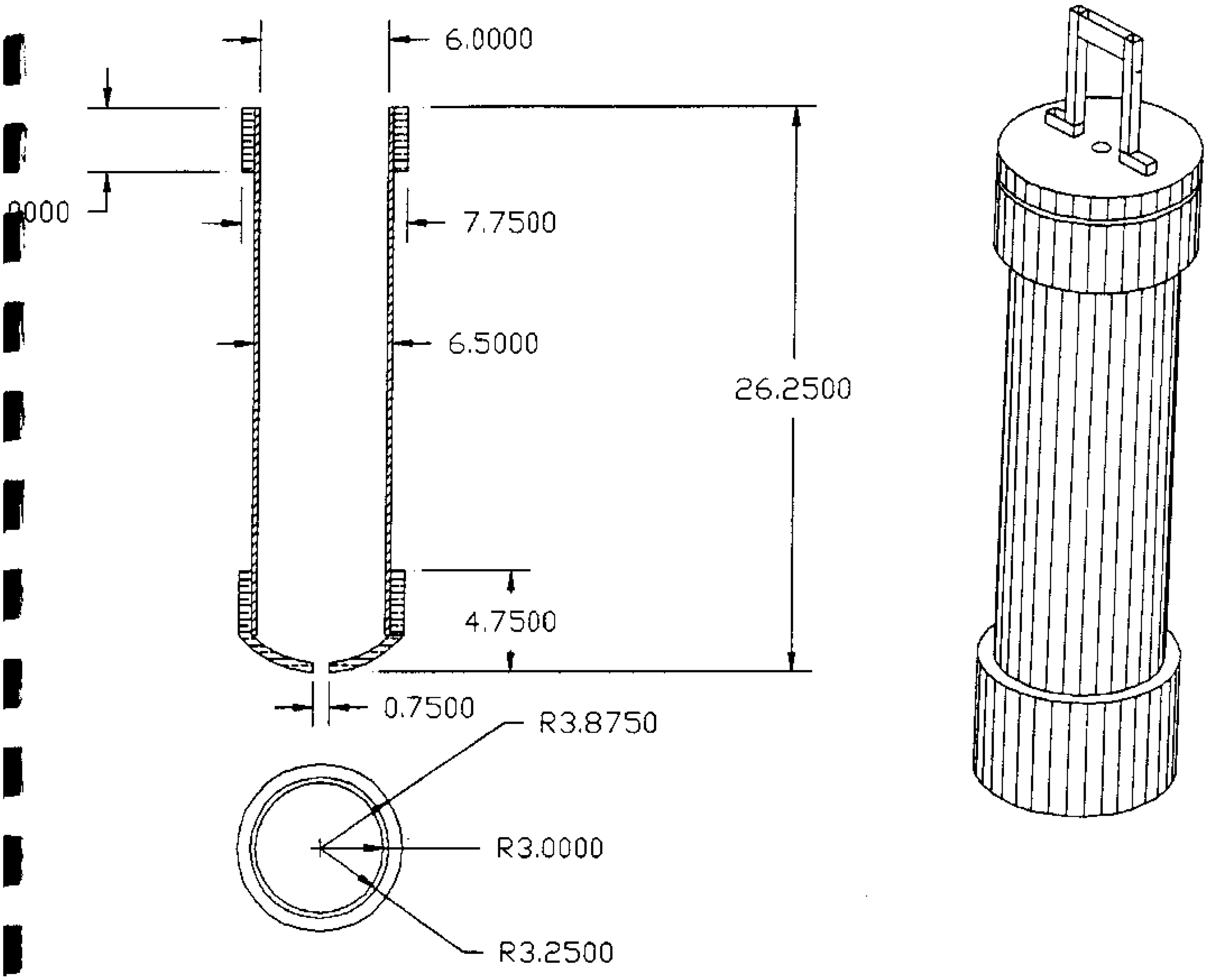


Fig. 3.6-1 Design of the Pressure Vessel (Dimensions in inches)

pressure vessel would fail due to yielding before buckling. The yielding calculations showed that our pressure vessel has a factor of safety of 5 at a depth of 50 feet. The bottom end of the pressure vessel was permanently sealed by means of an end cap and PVC cement. The top end is a lid machined out of a solid plate of PVC. The lid can be seen in Figure 3.6-2.

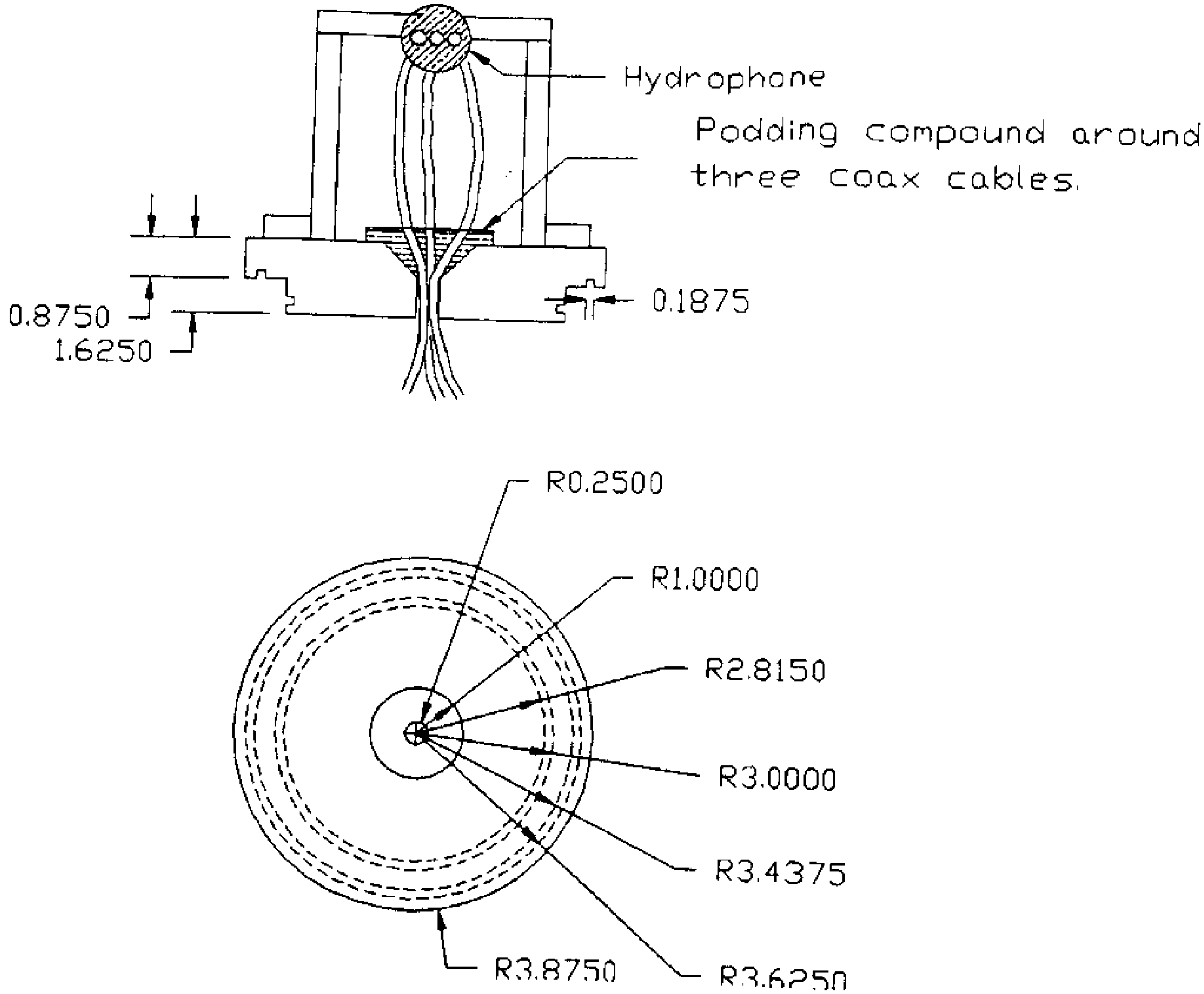


Fig. 3.6-2 Pressure Vessel Lid with Mounted Hydrophone (Dimensions in Inches)

The lid was sealed against leakage by means of two O-Rings. One ring formed a face seal and the other formed a piston seal. The face seal

was expected to form a perfect seal, but the piston seal was used for added protection. In order to make a large enough surface for a good face seal, a thicker ring of plastic was added to the end of the pressure vessel. This extra plastic ring was manufactured by machining a standard 6in. PVC endcap. The extra thickness also provided a firm mounting for the stainless steel latches which were used to hold the lid firmly in place.
The six wires from the hydrophone (section 3.1) penetrated the pressure vessel through the lid. This was accomplished by drilling a hole just big enough to put the wires through and using a podding compound to seal the hole. To improve the seal, two countersinks were drilled on either side of the initial hole to form reservoirs for the podding compound.

The hydrophone was mounted on top of the lid by use of two brackets manufactured from PVC and cemented to the lid. The reason for using plastic here was to stay away from any material which could corrode in sea-water. As a result the only metal parts on the pressure vessel exposed to the water were the stainless steel latches and the stainless steel connector on the bottom.

The aforementioned connector was necessary to facilitate penetration of six wires linking the pressure vessel to the surface. These wires were necessary for power supply and data transmission. Both the electrical connector and the cable were donated to the team by DG O'Brien Inc.

A rack on which to mount the electronic components was made out of sheet metal and threaded rod. The design can be seen in Figure 3.6-3. The reason threaded rod was used was because it was readily available and allowed the designer to make size adjustments at later dates. Flexibility of this sort is important for a prototype design.

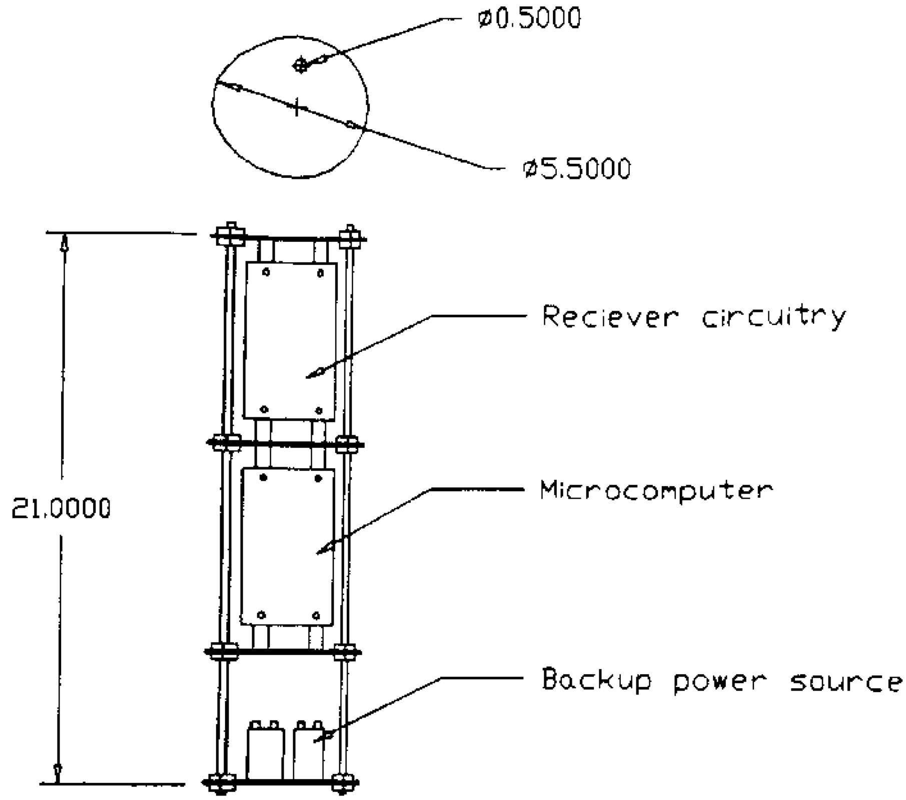


Fig. 3.6-3 Circuitry Rack Assembly (Dimensions in Inches)

3.7 PRESSURE VESSEL MOORING DEVICE

The mooring device was built as a bottom platform on which to mount the pressure vessel and hydrophone. It was decided that this should be a separate unit so that it could be deployed from a boat and firmly mounted on the bottom of the estuary before risking deployment of the pressure vessel with its hydrophone and electronics. It was envisioned that the mooring device would be lowered to the bottom from a boat by use of a winch. The strength cable used to lower the mooring would then be attached to the surface buoy (section 3.8). The wire connections for data communications and power supply would be made between the buoy and pressure vessel. A diver would then take the pressure vessel and dive down to the mooring. Using a dive compass, the diver would then orient the pressure vessel and attach it to the mooring. Thus, it became apparent what the design criteria would be and they are listed as follows:

1) Mooring should be heavy enough to remain stationary on bottom.
2) Mooring should be corrosion resistant.
3) Pressure vessel should be easily attachable to the mooring and readily rotated.
4) Mooring should be easily deployable by a boat with a winch.

The design of the Mooring can be seen in figure 3.7-1. It was made of 2 inch and 6 inch PVC plastic pipe because it was inexpensive, available,

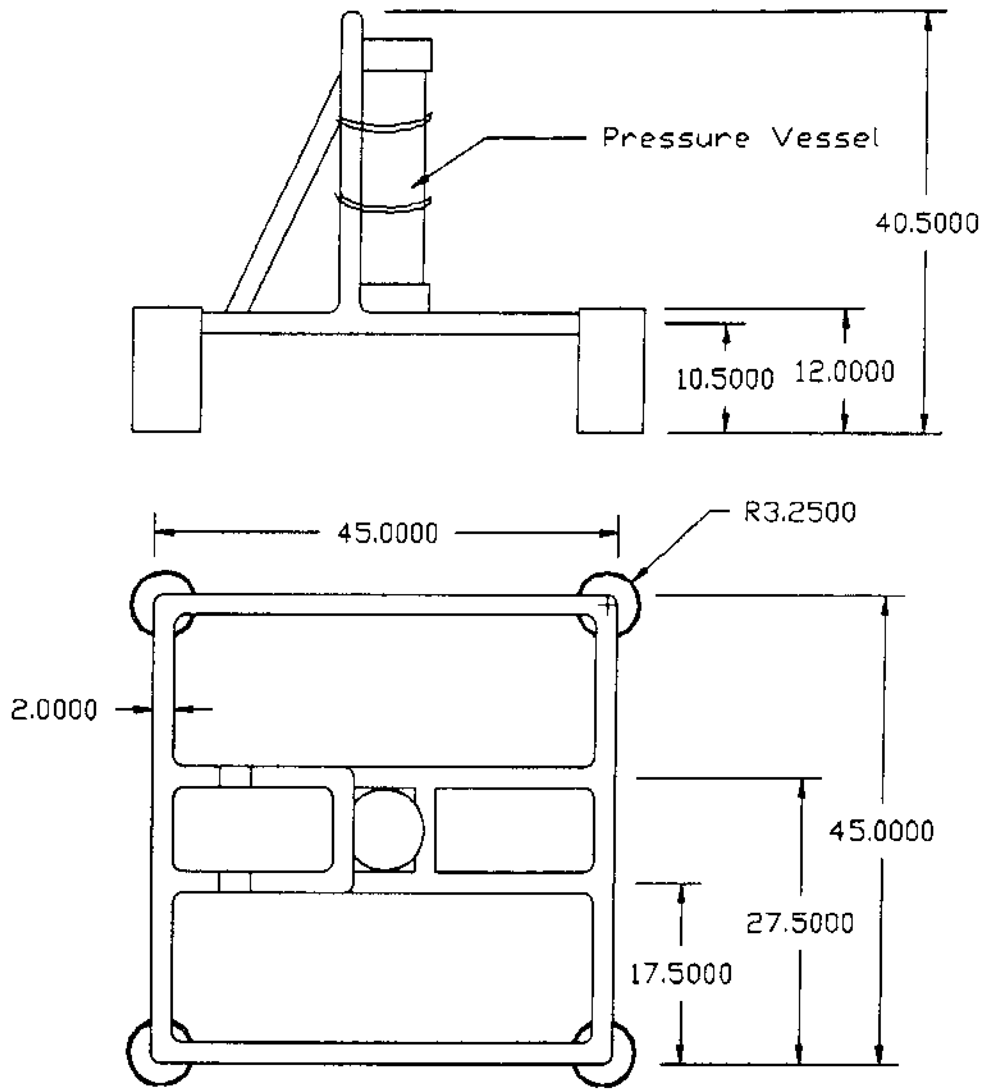


Fig. 3.7-1 Bottom Mooring Design with Pressure Vessel Attached (Dimensions in Inches)

corrosion resistant, and strong. The "feet" or 6 inch sections shown were used to keep the bottom of the pressure vessel (where the electrical connector was located) off the ocean floor and were filled with concrete to give the mooring an overall weight of 610 lb. When compared to the weight of the water displaced, this gave a negative buoyancy of 265 lb. The remaining pipe which could not be filled with concrete was allowed to flood with water to remain negatively buoyant. The pressure vessel was attached to the mounting by use of two rubber cords. In order to make the mooring easier to handle on land, the "feet" were designed to be detachable. The entire structure was cemented with PVC cement. The cement causes glued surfaces to melt and actually fuse together effectively making the entire structure one piece.

3.8 Surface Buoy Design

In order to provide a communication link as well as a physical link between the tracking station (located on the bottom of the estuary) and the surface, a buoy was necessary. It was decided that the buoy would contain the power source for the tracking station in the form of a 12 volt Marine battery. This allowed researchers to replace the power supply without raising the bottom unit which meant that research could be carried out over a longer period of time with less time spent on maintenance of the system. The other purpose of the buoy was to transmit information from the microprocessor (located in the pressure vessel) to a base station. This was to be accomplished by means of an ICOM micro 2AT (hand held transceiver) and a modem located in the buoy. Processed data would be transmitted from the microcomputer to the surface via a wire link (refer section 3.6) where it would go into a modem. The modem would alter the form of the data so that it could be transmitted by the transceiver. The base station would receive the signal with an identical transceiver and the information would then go through a modem once again and into a personal computer. To provide for these tasks, the following criteria were necessary for the buoy:

1) Buoy should float and be reliable.
2) Buoy should be waterproof.
2) Buoy should have a mounting platform for a 12 V Marine battery.

3) Buoy should have mounting brackets for both the transceiver and the modem.

4) Buoy should have a waterproof electrical connector for the wire data link from the bottom.

5) Buoy should have an eyehook on which the strength cable can be attached.

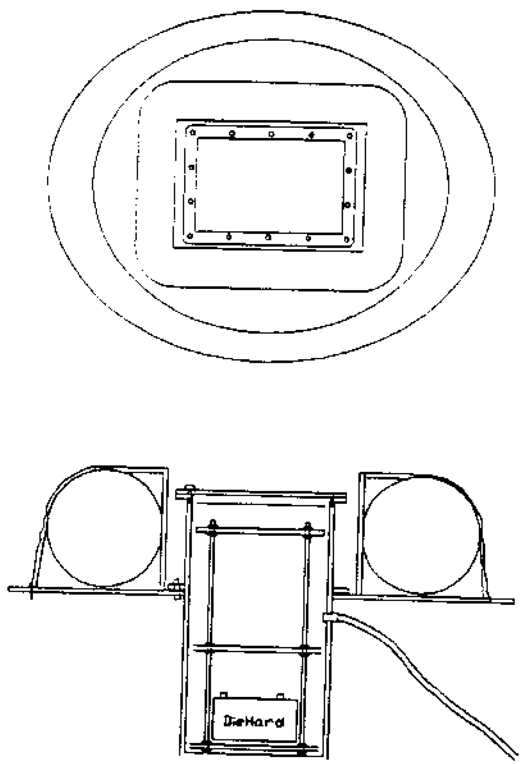


Fig. 3.8-1 Surface Buoy, Top and Side View

Figure 3.8-1 shows the design of the surface buoy. The watertight chamber was borrowed from an earlier project and consisted of a plexiglass box with a lid which was sealed with an O-Ring. The battery was mounted in the bottom of the chamber and the transceiver and modem in the top. This helped to protect the electronics should the battery leak acid. The floatation device for the buoy was manufactured from wood, an inner tube, and fiberglass. The wood frame was designed to fit snugly around the watertight chamber and to hold the inner tube in place. The frame was bolted to the chamber and the inner tube blown up around it. The entire floatation unit was then covered with fiberglass. It was intended that the fiberglass coating be watertight so that the inner tube was not necessary to the integrity of the buoy. Upon completion, the buoy was painted and tested.

4.1 HYDROPHONE RECEIVER & PHASE DETECTOR

The hydrophone receiver and phase detector circuit has been successfully assembled and tested.

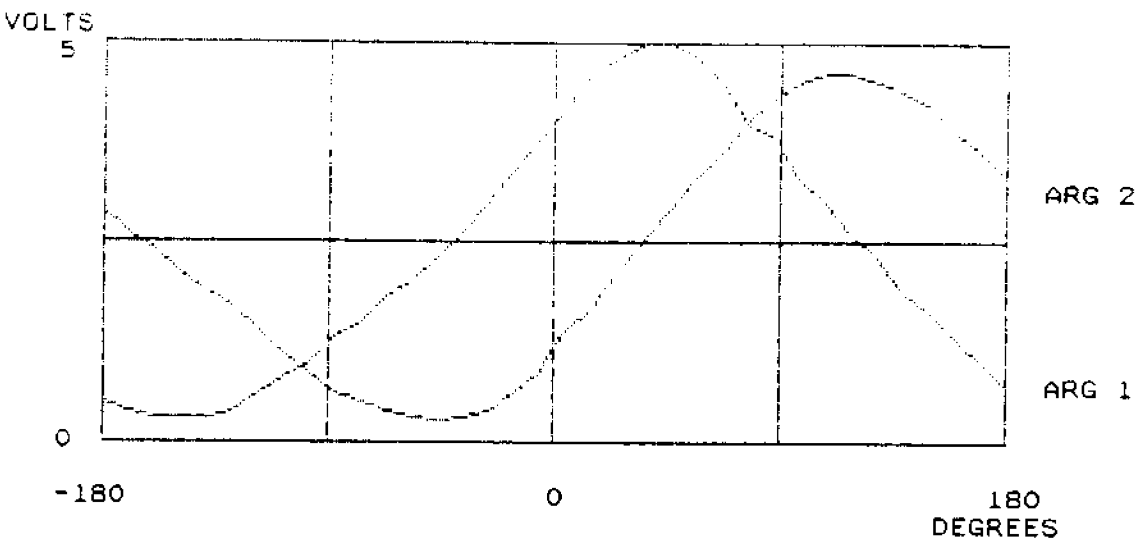


Fig. 4.1-1 Test Results of Hydrophone Receiver and Phase Detector

To test the hydrophone circuit, the input to the receiver was simulated in the lab using a phase shift oscillator. As seen in Figure 4.1-1, the maximum does not occur at the expected zero degree point. This can be attributed to the phase shifting of the circuit stages and can be easily compensated for in the final data computation. Recall from section 3.1, the desired information was in the form of a cosine function; figure 4.1-1 clearly shows ARG 1 and ARG 2 in this form.

The detector circuit, used to generate a DC carrier reference, has also been successfully tested.

As in any prototype design, there is room for improvement. The first problem found was in the actual construction of the circuit. To assemble the components, wire wrapping was used. This technique proved to be reliable but resulted in crosstalk. There are two solutions to the problem. First, a printed circuit board could be constructed. Second, if wire wrapping is used, the three channels should be put on separate boards. In the case of this circuit, crosstalk was reduced to a minimum by reducing amplifier gains. Other possible improvements include using higher order filters, improving impedance matching between transducers and circuit, and using low noise operational amplifiers.

4.2 HYDROPHONE DESIGN

Recall from section 3.2 that the goal of the hydrophone is to generate three signals with a phase difference, determined by the angle of the incoming signal with respect to the transducer array axis. Realizing that the hydrophone was the foundation of the design, a leading hydrophone manufacturer was contacted to price the design needs. It was quickly realized that the price for a professionally built hydrophone was beyond the project's budget. This led to the design in figure 3.2-1.

The construction of the hydrophone is finished, but a full test has not been completed at this time. The incoming signal generated at the target location is a twenty five millisecond, seventy five kilohertz pulse. Due to the small pulse width, the aid of a microcomputer and the hydrophone receiver and the phase detector circuit is required for testing.

The prototype hydrophone design will clearly affect the overall system's range and accuracy. The solution to this problem can be solved by having a professional manufacture the hydrophone.

4.3 MICROCOMPUTER - DATA ACQUISITION AND STORAGE

The program has been written for the M68HC11 Evaluation Board. It has been verified that it is working correctly with constant voltages and that it pauses .5 seconds between samples. At this point, it has not been interfaced with the electronics. It will only be at that point that the system as a whole can be tested. This interfacing has been delayed due to problems faced in downloading of data onto the PC. It was unrecognized that the hex values, that do not pertain to printable ASCII characters, would not be written to a file with the use of most programs available. This is being remedied with a C program, that reads the port directly and stores the data in integer form in a file.

Due to this delay, the code has not been written so that the upper buoy can transmit the data to UNH. Transmitting from a buoy has been done by others on campus. This would be a valuable addition to the system.

At this time, the micro-computer only stores the phase shifts and time of data collection. Improvements to the system include being able to store the temperature and salinity of the water for every along with the time and phase shift information.

4.4 POWER DISTRIBUTION SYSTEM

At this point in time, the batteries have not been used since all testing has been done in laboratories with power supplies. The improvements that would be helpful are: a solar charging power supply. This improvements would allow the scientist to leave the buoy for longer periods of time due to the longer life of the power system.

4.6 PRESSURE VESSEL HOUSING

After testing the pressure vessel to a depth of ten feet, it was found that it did not leak or fail in any way. This was significant since it showed that the O-Ring seal was good. When O-Rings fail, they usually fail at low pressures since they rely on pressure to make the seal. The pressure vessel was expected to be safe to a depth of fifty feet. This has not yet been confirmed by experiment. Assuming the pressure vessel does not fail at fifty feet, the design and construction of the pressure vessel will be considered a success. On hindsight, the only change which may have been made for the pressure vessel would have been to use a connector to get the six hydrophone wires (section 3.2) through the lid instead of the podding process (section 3.6). This is because it would have made it easier to replace corroded wires. The present solution of replacing corroded wires requires drilling the old wires out and repodding the new ones. Overall the pressure vessel was a success and was ideally suited for this project.

4.7 BOTTOM MOORING DEVICE

The bottom mooring device was a success. It was easy to deploy, non-corrosive, and stationary once deployed. The only concern was that the buoy had to be anchored separately since it represented considerable drag in the strong estuary currents, thereby, applying too much force for the mooring device to remain stationary. Deployment procedures remained the same except an extra anchor was attached to the tension cable connecting the mooring to the buoy. No major changes need to be made to the Mooring design.

4.8 SURFACE BUOY RESULTS

The surface buoy was a success in that it was reliable and adequately protected the electronic components mounted inside it (Refer to section 3.8). However, if the project were to be redone, a different method of construction would probably be implemented. The fiberglassing process turned out to be messy and unattractive. There was a problem with air bubbles being trapped between layers of fiberglass since square pieces of fiberglass cloth were being applied to a round surface (refer to section 3.8). One different way to provide flotation would be to use a square surface on which to apply the fiberglass. Another approach would be to mount sealed PVC pipes to the sides of the chamber to provide flotation. Although the method used worked, it was found to be inferior to these other alternatives.

5.0 CONCLUSION

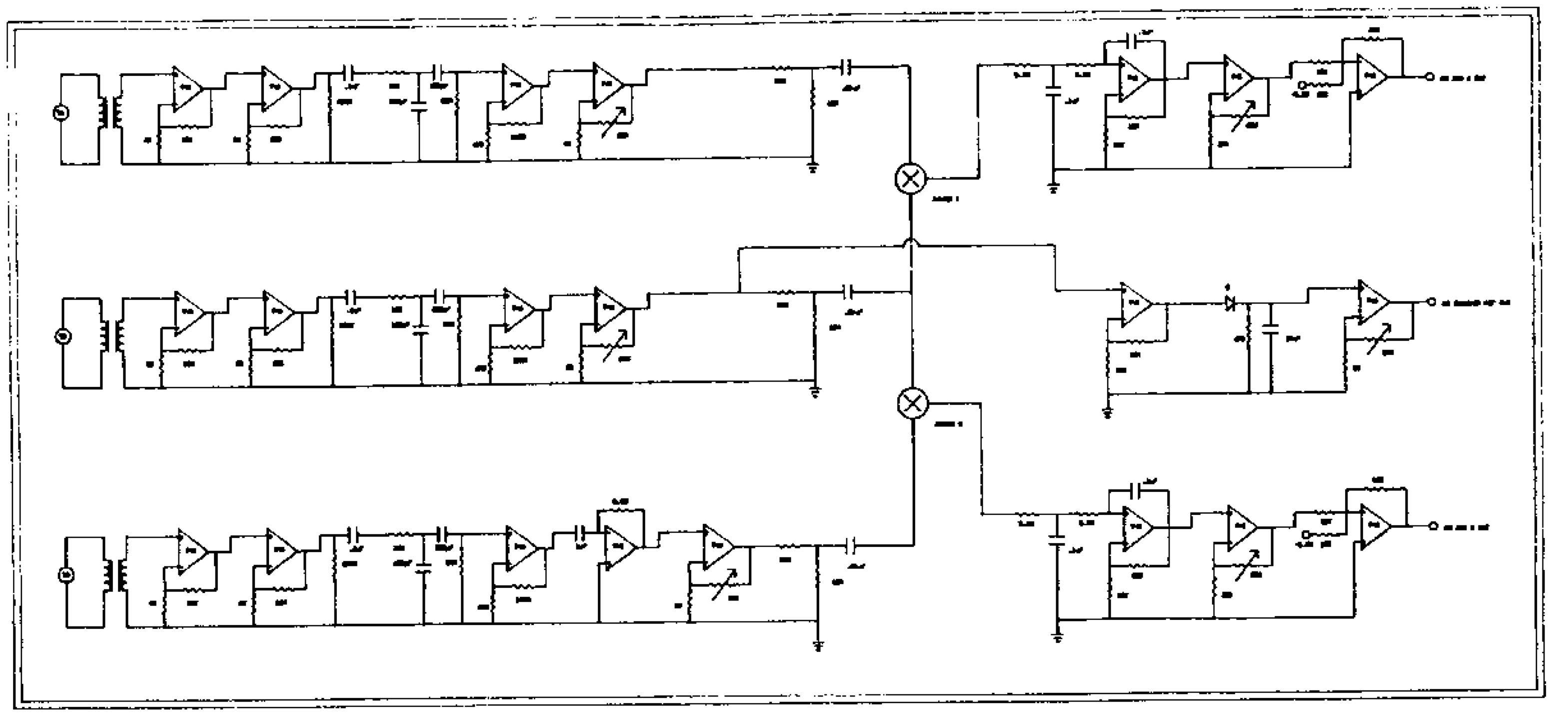
The overall goal of Project Crus-station was to prove the feasibility of a fully automated sonar tracking system. Although the proposed goal has not been completed, the engineering team is confident that the end results will be successful. The first successful completion of the project was the hydrophone receiver and phase detector. Test results proved this critical part of the design would meet design specifications. It can be concluded that given the proper input from the hydrophone, relative angular position of the target can be determined. Other goals successfully accomplished were the pressure vessel design, bottom mooring design, and surface buoy design. Although the pressure vessel and bottom mooring were designed for this project, they are certainly adaptable to any project operating under the same environmental conditions. With time running out on project Crus-station, all efforts were concentrated on collecting and processing raw data at the expense of time spent on the transmission of this data. However, transmission of this sort of data has already been proven to be feasible by various UNH projects. The hardware to successfully transmit has been acquired by this team and can be implemented in the future when this project is continued. It is clear to this team that success of the project relies on a functionally operating hydrophone. It should be noted that hydrophone testing is currently under way, but ,at this time, proper hydrophone operation has not been verified. The team is optimistic that the project will be successful if continued. Although this concludes the paper, by no means does it conclude the project. Yet to be completed are system integration, hydrophone testing, and field testing of the tracking station.

6.0 APPENDIX

THREE CHANNEL HYDROPHONE PHASE DETECTOR DESIGN

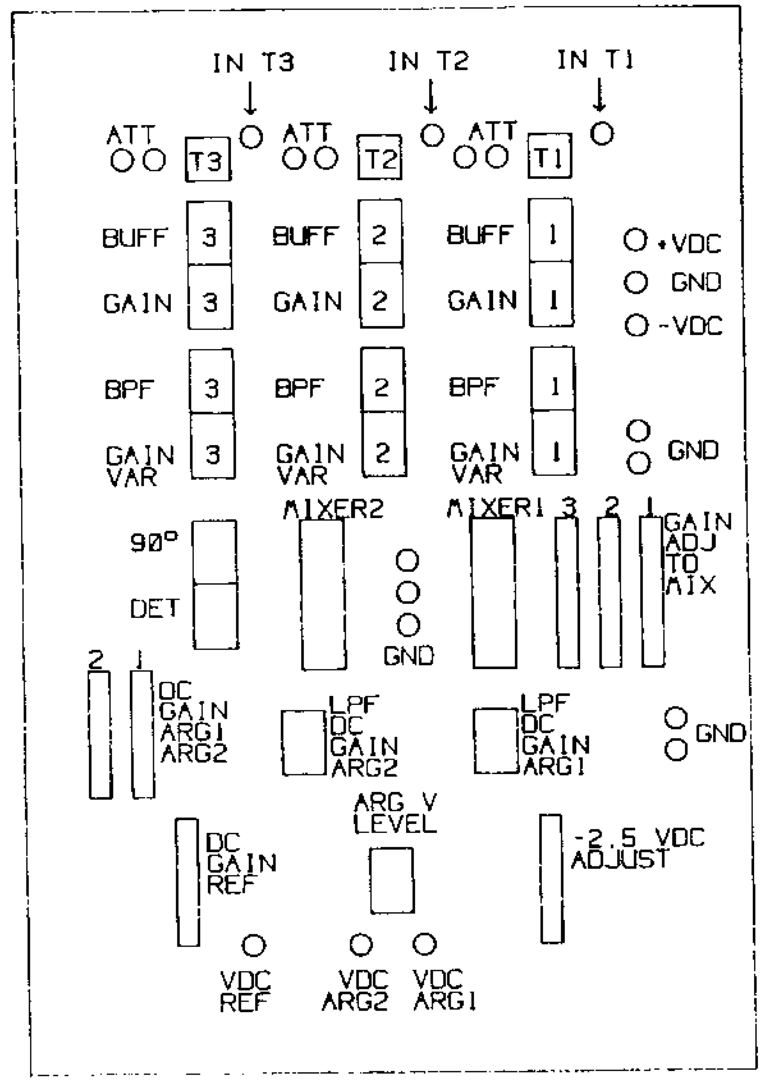
THREE CHANNEL 75 KILOHERTZ HYDROPHONE PHASE DETECTOR BOARD

CALCULATIONS



THREE CHANNEL HYDROPHONE PHASE DETECTOR
DESIGN BY DARRYL DIETZ

THREE CHANNEL 75 KHz HYDROPHONE PHASE DETECTOR BOARD.



Calculation to Determine Mode of Failure

If failure due to instability or buckling

$$P_{cr} = \frac{E\,h^3}{4(h-v^2)r^3}$$ Eq. 9-1 (ref. 6)

If faliure due to yielding

$$P_{cr} = \frac{\sigma_y\,h}{r}$$ Eq. 9-3 (ref. 6)

where:

E = Modulus of Elasticity
P_{cr} = critical pressure
h = cylinder wall thickness
r = average radius
σ_y = yield strength
v = Poisson's ratio

Specifacations for 6.5 in. dia. pressure vessel

E = 0.35 Mpsi
σ_y = 1500 psi
v = 0.2
r = 3.125 in.
h = 0.25 in.

Given these values:

$P_{cr\ yielding}$ = 213 psi $P_{cr\ instability}$ = 120 psi

Because $P_{cr\ yielding}$ is less than $P_{cr\ instability}$, the pressure vessel will fail due to yielding. (ref. 6)

Calculation of Pressure at a Depth of 50 ft.

$$P_{50\ ft} = P_{atm} + \rho g h$$

Eq. 2-4
(ref. 4)

where:

P_{atm} = 14.7 psi
ρ = 62.4 lb/ft^3
h = 50 ft.

Given these values:

$$P_{50\ ft} = 36.4 \text{ psi}$$

Calculation of Radial and Tangential Stresses at 50 ft.

$$\sigma_t = \frac{P_i r_i^2 - P_o r_o^2 - r_i^2 r_o^2 (P_o - P_i)/r^2}{r_o^2 - r_i^2}$$

Eq. 2-50
(ref. 8)

$$\sigma_r = \frac{P_i r_i^2 - P_o r_o^2 + r_i^2 r_o^2 (P_o - P_i)/r^2}{r_o^2 - r_i^2}$$

where:

σ_t = tangential stress
σ_r = radial stress
P_i = interior pressure
P_o = outside pressure
r_i = inside diameter
r_o = outside diameter
r = diameter stress calculation is desired

In this case

P_i = 14.7 psi
P_o = 36.4 psi
r_i = 3 in.
r_o = 3.25 in.

With these numbers:

σ_t (worst case) = 308 psi (compression)

σ_r = 36 psi (compression, same value as outside pressure)

Factor of Safety Calculation

$$\text{Safety Factor} = \frac{\sigma_y}{\sigma_{max}} \quad \text{(ref. 8)}$$

where:

σ_{max} = 308 psi
σ_y = yield strength = 1500 psi

Therefore we have an approximate safety factor of 5.

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