An Automated RFID and GPS Fixed Gear Identification System for Onboard Real-time Data Collection

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Executive Summary

The overall goal of the project was to develop an innovative automatic system, comprised of a radio frequency identification (RFID) scheme using microchip technology and a global positioning system (GPS) to monitor fixed gear end lines. The scheme would offer real-time fixed gear and line identification, haul back time and location information, as well as fishing effort monitoring capacity. The anticipated benefit of this approach is a passive system that will provide information that will increase our understanding and monitoring capacity of large whale and fixed gear interactions.

The concept development followed a three phase approach. Each stage on it's own provides a level of fixed gear identification beginning at visual line identification (Phase I), visual and RFID line identification (Phase 2) and automated RFID/GPS fixed gear identification with onboard real-time data collection (Phase 3). An embedded process was developed that allows microchips to be placed within twisted line, hold position and withstand the forces applied when set at depth (>4000ft), as well as hauled through the block system of both lobster and gill-net vessels. The embedding process allows for color schemes to be applied to visually indicate fishing method used or line position (i.e. bridle, up and down lines etc.). Each micro-chip with it's unique numeric code has a limitless number of descriptive field associations (i.e. fishing vessel, vessel owner, fishery, license number, etc.). Software capacity was developed to geocode (latitude/longitude) position with the unique microchip identifier as gear is hauled back.

The results from this pilot-scale project indicate that the microchip technology is a feasible method to identify fixed gear line and/or gear. More investigation is necessary to build a self-contained unit for deployment on commercial fishing gears as well as determine optimum antenna configuration.

Introduction and Scope

The overall goal of the project was to develop a new automatic system, comprised of a radio frequency identification (RFID) scheme and global positioning system (GPS), for real-time fixed gear and line identification, haul back location, and fishing effort monitoring. This project utilized previous research results that assessed the feasibility of using microchip technologies for fixed line identification. These initial results were used to improve component durability, information technology and data management. To accomplish the project goals the following tasks were conducted;

I. RFID durability and refinement of line tag design,
II. Evaluation of RFID sensitivity,
III. Automated GPS/identification system and Control Program Development, and
IV. At-sea Prototype Testing

Methods and Results

Refinement of Line Tag Design

On June 28, 2004 The National Fish and Wildlife Foundation contracted Benjamin Brickett and Dr. Scott Moffatt of Blue Water Concepts, to adapt microchip technology to the identification of fishing lines. Commercially available microchips were embedded into ropes along with a colored fiber for visual location within the line. Experimental field trials validated the ability for glass encapsulated microchips to withstand hydrostatic pressures in excess of 1,000 lbs corresponding to depths of up to 300 fathoms. The fragile nature of the glass covered chip was not able to withstand travel through a commercial hauler or bending over any type of radius when placed within fishing line. Experimentation concerning the bore diameter of the pellet, soft adhesives, and the flexural strength of the microchip eventually yielded an isolastic embedding process which has operated successfully during initial sea trials.

The objective of the current project was to refine line tag design to allow secure positioning within the marine rope and provide easy visual identification. An improved line tag design was developed that would allow secure positioning within the lay of the line (Figure 1).

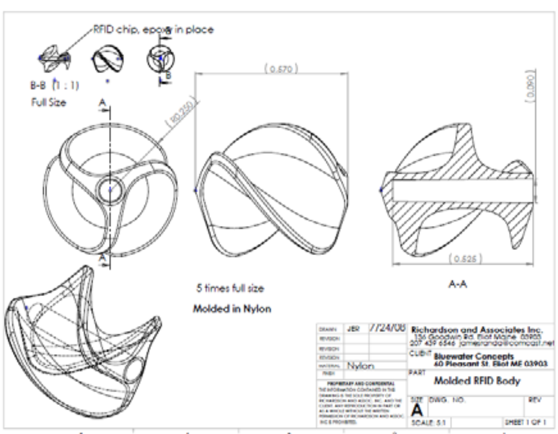

Figure 1. Line tag design for microchip

This tri-sparred design allows color coding, microchip protection from hauling and pressure forces as well as secure positioning within the lay of the line. Color coding could be applied for line identification (ground line, buoy line, anchor line etc.).

RFID Durability Testing

How does the implementation of a microchip effect the overall lifespan on the rope? Does the presence of a microchip disproportionately increase the rate of wear on the rope where it is embedded?

A series of simulated line cycles were run to test the effect of the presence of a microchip in 3-strand fishing rope. The line cycling apparatus was designed to cycle the test rope at an accelerated rate, allowing for quicker and more controlled results. The device consists of an electric motor that drives a commercial 12 inch hydroslave pinch-type hauler. It utilized a 4” hauler block and a 2” load block. The 2” load block held the rope in an

Figure 2. Example of rope wear patterns following simulation trials.

abrasive mixture, and could be used to adjust the tension on the test rope. Lines of two different sizes and material were short-spliced to themselves to form circles. One of the lines was 7/16”polypropylene/polyester mix. The other was ½”polysteel. Each of the test ropes contained 3 embedded microchips of working status with known reading codes. The simulation apparatus cycled the test ropes at 10 cycles per minute. Testing occurred with temperature conditions ranging from 25 degrees to 40 degrees Fahrenheit. Using the 2” load block, each line had 75 lbs. of continuous tension placed on it. Each rope was run through the hauler for 13 hours, for a total of 7800 cycles per rope. These cycles represent an estimated 40 years of hauling. During testing, the lower 2” load block was submerged in a container filled with salt water, mud, and rocks. With each revolution the line passed through this abrasive mixture, simulating the chafing and wear that may be encountered in real world conditions. Over the course of testing, chafing was evident throughout the rope. The chafing was most significant around the microchips (See figure 2). Despite this, the integrity of the rope remained strong.

Hydrostatic Pressure Testing

The microchip embedding material was evaluated by Teledyne Instruments, Inc., Seabrook, NH, for their ability to withstand the forces applied when set at depth. Three pressures (500psi, 1500psi, 2000psi) corresponding to depths of 1100ft, 3400ft and 4600ft were evaluated. In a hyperbaric chamber embedded microchips were slowly brought to test depths/pressures and returned to start values (Figure 3). At the end of each trial for each simulated depth all embedded chips functioned and were successfully read by the RFID scanner.

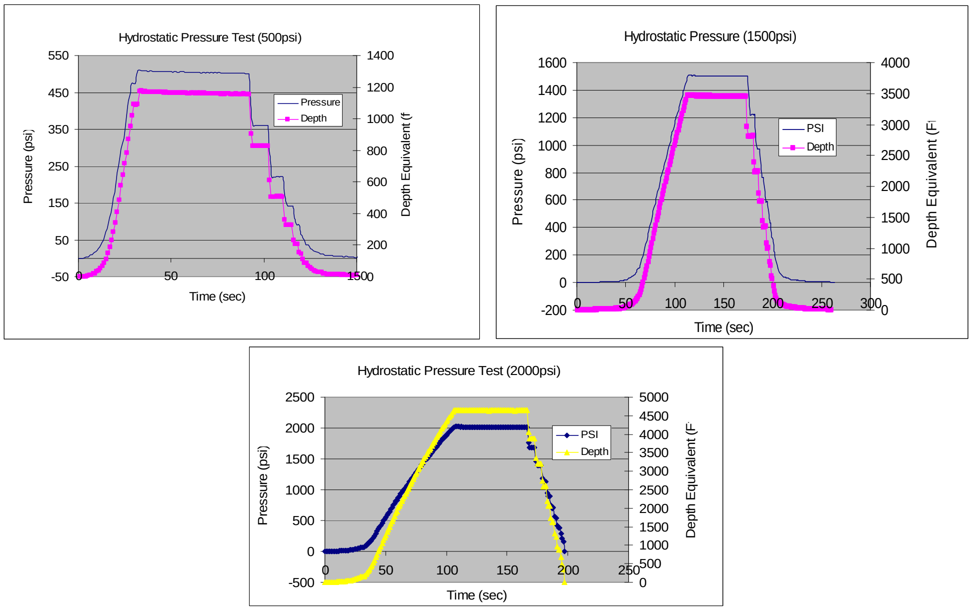

Figure 3. Hydrostatic pressure test curves.

Breaking Strength

Following the durability testing, the rope was pulled beyond its breaking strength with the microchips still embedded. This process was conducted in order to determine where the line would part, and if the functionality of the microchips would be adversely affected. Over these tests, the rope repeatedly broke in the area around the microchips. At the end of each trial, the microchips functionality was tested. All of the microchips proved to be operational. We were unable to quantify the breaking strength due to the absence of proper testing equipment. Future research should quantify the strength loss of microchip embedded line following extensive hauling.

RFID and Reader Selection

The key component of the technology is the RFID system that is composed of the RFID tag and the RFID reader. The RFID reader is a device that is used to "ping" the RFID tag for information. The RFID reader is composed of an antenna or scanner, that emits radio waves that enhance the communication distance from the tag and a reader/writer. The reader/writer allows RFID tags to be uniquely coded with identification information.

The prototype RFID and reader was selected for cost, durability and weather resistance. In this study, considering the fact that the RFID system will be utilized at sea, a communication frequency of 13.56 MHz and powered by electromagnetic induction was used. In this method electric power is transmitted inductively from the reader antenna passively to the chip. This power scheme and frequency has a moderate communication distance, communication directivity and resistance to moisture. Subsequent objectives were to evaluate the communication distance as well as impact common vessel materials would have on scanner sensitivity.

Evaluation of RFID Sensitivity and Communication Distance

To determine the effect RFID embedding material, fishing line and seawater exposure would have on the ability of the reader to detect the microchip signal a reference point for the microchip alone was estimated. To establish a **reference maximum communication distance** a naked RFID tag, or microchip, was placed at increasing distances from the antenna, or reader/scanner, beginning at 11.7cm until chips could no longer be reliably read (< 50% scanner sensitivity). The microchip alone had a maximum read distance of 20.3cm (8") with a corresponding scanner sensitivity of 62%. Scanner sensitivity was calculated as the average of the individual microchip sensitivities for the trial. It is important to note that scanner sensitivity and thus maximum read distance is largely dependent on the size, style and sensitivity of the antennae. More powerful antennas have specifications of up to 1 meter read distances. For the case of these experiments we were most concerned with determining the impacts of common vessel materials on read sensitivity, with the assumption that any observed impact would occur regardless of the sensitivity of the antenna. Material interference will be critical for determining where and on what materials to mount the reader/antenna.

A. Effect of embedding material, line encoding and seawater exposure on reader antenna performance

Following a similar procedure as above, five embedded microchips were repeatedly read by passing the antennae over the chip beginning at 11.7cm up to the reference maximum communication distance of 20.3cm. This process was replicated ten times and the sensitivity of each chip was calculated. Individual microchip sensitivity was calculated as the ratio of successful chip detections to the total number of scans. The maximum communication distance for the embedded chip was 13.7cm at 76% scanner sensitivity. Above 13.7cm the scanner was unable to detect the embedded chip. Overall the embedding material resulted in a 32% drop in maximum communication distance. The same procedure was conducted for embedded chips encoded in line and line encoded chips exposed to seawater (Figure 4). Embedded chips that were placed (encoded) in twisted fishing line had a maximum communication distance similar to that of the embedded chip alone, 13.7cm, indicating that the line material did not effect the transmitted signal. The conductivity of seawater appeared to increase communication distance with an observed maximum of 15.2cm at 75% scanner sensitivity and only a 25% drop in communication distance.

B. Effect of vessel construction material on reader antenna performance

Metal may affect the signal relay from the RFID to the reader. To determine the impact of metal as well as other common vessel materials may have on signal relay, a reader and antennae assembly was mounted to High Density Polyethylene, aluminum, stainless steel and wood.. The maximum communication distance of 13.7cm recorded by the line encoded and embedded chip alone was used for these comparisons. High density polyethylene and wood materials did not reduce the communication distance, with scanner sensitivities of 98% and 92% respectively. Both metal alloys (aluminum and stainless steel), interfered with the message relay from chip to antenna, resulting in zero successful readings.

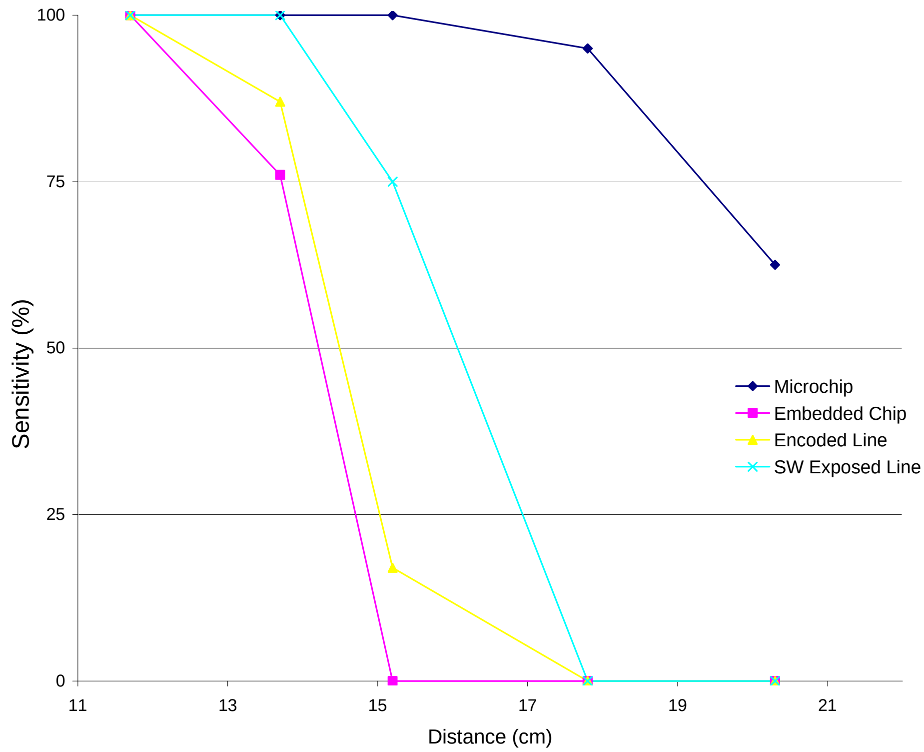

Figure 4. Effect of embedding material, line encoding and seawater exposure on antenna performance.

Automated GPS/identification system and Control Program Development

The role of GPS is to determine position and time. It's positioning accuracy is about 10 m root mean square (RMS), which is sufficient to measure the location and time of haul back of fixed gear fisheries. Ten meters RMS indicates that the measured position is within 10 m of the true position with a probability of 68%.

In this system, a laptop PC was used as a control device and for data storage. An RFID reader and GPS antenna are connected to the laptop via USB or serial connections. The control software, developed using Advanced NMEA Data Logger from AGGSoftware, receives a constant stream of GPS readings and periodic RFID readings. The RFID reader is positioned next to incoming line with embedded RFID chips. When the PC receives a signal with the ID number from the RFID reader, it simultaneously obtains location and time data from a GPS receiver. The time/date and location information is then correlated and stored locally in a comma separated value (CSV) file. The CSV file is then uploaded to a web application which converts it to a KML file for viewing using Google Earth© or Google Maps. Associated with the unique microchip ID number will be vessel information and the type of fishery now combined with area fished.

Figure 5. La Valley and Moffat collecting microchip position and ID data from inshore lobster vessel.

At-Sea Prototype Testing

Field testing began in September, 2008. Microchips were placed in both an inshore (20 microchips) and offshore (16) lobster vessel as well as a gillnet vessel (17 microchips). Following field tests chips were are collected from fishermen participants to evaluate their functionality and to assess their durability.

Offshore Lobster Vessel

Sixteen (16) microchips were embedded in ½" nylon rope at approximately 5 fathom intervals. The rope was an overall length of approximately 420 feet. This line was then used as an end line for an offshore 40 - trap trawl. The trawl utilized 900 lb. steel anchors on each end. These traps were fished on the Grand Banks, at depths up to 180 fathoms by the F/V Amy Philbrick. Latitude was 42*22'N, 67*25'W. The trawl was deployed twice, first set from June until September 2008. It was redeployed from September 2008 to February 2009.

The Table 1, below summarizes the results of the off-shore deployment.

Microchips Location In Line*	**Microchip Type**	**Did it Read?**	**If Not, Why?**	**Other notes**
#1		N/A		Missing. Rope Shows wear – Evident of recent ejection
#2	Nylon #6	Yes		
#3	Nylon #6	Yes		
#4	Nylon #6	No	Possible Hole in Seal	
#5	Nylon #6	Yes		
#6	Nylon #6	No	Possible Hole in Seal	
#7		N/A		Missing. Rope shows no wear – Evident of distant ejection
#8	Nylon #6	No	Possible Hole in Seal	
#9	Nylon #6-Cuffed Ears	Yes		
#10	Nylon #6 - Thin Ears	No	Hole in Seal	Not centered in rope
#11	Nylon #6	Yes		

#12	Rigid Polycarbonate- Small Ears	No	Poor Epoxy cure	Not Centered in rope - Early prototype
#13	Nylon #6- Radiused Ears			
#14	Nylon #6- Radiused Ears	Yes		Not Centered in Rope
#15	Nylon #6-Old-Style	Yes		
#16	Nylon #6	No	Hole in Seal	

Table 1. Off-shore lobster vessel trial summary.

Of the 16 microchips that were originally installed in the rope, 2 were lost at sea. Of the 14 that returned, 6 of the microchips were not functional. Analysis of the non-functional microchips revealed possible holes in the embedded material seals that separated the internal microchip from the salt water.

In-shore Gillnet Vessel

Seventeen (17) microchips were installed on October 7, 2008. Two chips were placed on each of the two end-lines of a gillnet string. On each end-line one chip was placed 5 fathoms from the top buoy and one 5 fathoms from the ocean floor connected to the net. The remaining chips were dispersed on twelve (12) gillnets along the string. They were placed on the float line and spread out so that each net had a chip approximately in the middle with the remaining chips being located near a bridle (where two nets are tied together). The gillnets were 6.5" mesh with 14 gauge monofilament. Each of the twelve nets in the string were 300 feet long and 14 feet deep. Gillnets were typically fished at a depth of 35 fathoms. Following field trials all retrieved (15) microchips functioned and were successfully detected by the RFID reader. Two chips that had been placed in braided style rope were lost. Since, the current embedding design is made for twisted line we were not surprised that these chips were lost. In total the encoded gillnet string was set and hauled (38) times from October 8th to December 18th, 2008.

In-shore Lobster Vessel

In-shore lobster fishery testing began in October, 2008 and continued through October, 2009. Of the twenty (20) microchips that were placed in the buoy lines and between traps within a ten trap trawl, eighteen (18) were recovered. All recovered microchips successfully registered their ID number. This initial results indicate that the embedding material can withstand repeated hauling and the microchips are not subjected to serious pressure or forces that interfere with their functioning.

Figure 6. Example of inshore lobster trawl map. Push-pins indicate a microchip placed within the ten trap trawl. Piscataqua River, ME.