Acoustic Float for Marine Mammal Monitoring

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LONG-TERM GOALS

Our goal is to develop an inexpensive solution to the problem of near real-time monitoring of marine mammals. We are developing an acoustic monitoring system, the *QUEphone* (***Qu****asi-****E****ulerian* ***phone***), which is based on a commercial profiling float. By deploying a number of these inexpensive systems in advance of an operation, an area can be monitored for the presence of beaked whales and other species of concern.

OBJECTIVES

Acoustic methods are used increasingly often, in part because of some distinct advantages: the ability to detect animals underwater, to work at night and in poor weather, and to record the relevant signals and post-process them if necessary. Acoustic surveys have used two principal methods: Long-term recordings made using either cabled hydrophone arrays or moored long-term acoustic recorders to estimate the seasonal distribution of species, and hydrophone arrays towed behind a ship used to determine whether marine mammals are present at a given time. For real-time monitoring and mitigation, the towed array approach is most often used, but it suffers several drawbacks: Marine mammals are monitored in only one area -- close to the ship -- and ship time can be prohibitively expensive. Another alternative, currently under development by several teams, is to equip several ocean gliders with hydrophones and marine mammal call-detection software and send them out to

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14. ABSTRACT
Our goal is to develop an inexpensive solution to the problem of near real-time monitoring of marine mammals. We are developing an acoustic monitoring system, the QUEphone (Quasi-Eulerian phone), which is based on a commercial profiling float. By deploying a number of these inexpensive systems in advance of an operation, an area can be monitored for the presence of beaked whales and other species of concern.

15. SUBJECT TERMS

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monitor in real time, but again the gliders are relatively expensive, at upwards of $100,000 each [*Rogers et al.*, 2004].

We are taking advantage of existing vertical profiler float technology and the proven acoustic data logging and detection technologies to develop components and interfaces at Oregon State University (OSU) and the Applied Physics Lab of the University of Washington (APL-UW). We are making the *QUEphone* an acoustic platform capable of repeating many profiles up to 2000 m deep for a long period, with bi-directional communication capability and web data access for users. In normal operation, it can sink to the ocean floor, listen for calls of interest (in particular, from beaked whales), and when it detects these calls, rise to the surface to communicate this detection to shore (Fig. 1). The *QUEphone* can also be deployed to dive to a specified depth and drift with the current while performing acoustic monitoring.

APPROACH

Our approach is by taking advantage of the existing vertical float profiler and DSP data processing technologies and integrate into an inexpensive near real-time acoustic profiler system useful for the marine mammal research community. There are approximately 3,000 vertical profilers currently profiling the water column, sending the data (e.g., temperature, conductivity and depth) in near real-time while drifting the global oceans. This widespread profiler float, known as the Argo float, is a matured technology, and is manufactured mainly by two companies, Webb Research (APEX) and Martec (PROVOR). Our original acoustic float, the *QUEphone*, developed in 2006 [*Matsumoto, 2006*] was based on the Martec's PROVOR float platform design. However since the program began, we learned the recent reliability record of both floats [*Kobayashi et al.*, 2006], and it became apparent that the APEX was superior in survival rate to the PROVOR float (~75% vs. ~25% after 100 profiles). In addition to the reliability issue, we also learned that fewer than 10 PROVOR floats of the same model were left in stock. For these reasons we made a crucial decision to switch from PROVOR to APEX and redevelop the communication and control interface for a new float platform.

We have divided our task into seven phases as follows:

1. Develop communication protocol and web interface with the APEX (Matsumoto, OSU)
2. Develop software for beaked whale call detection (Mellinger, OSU)
3. Develop DSP hardware and software (Jones, UW)
4. System integration (Matsumoto, Jones)
5. Lake test (Matsumoto, Jones, Dziak)
6. Sea trial (Matsumoto, Jones, Dziak)
7. Data analysis (Matsumoto, Jones, Mellinger, Dziak)

To control the float and satellite communication and to pass on the float status information to the DSP board, rather than adding another microprocessor inside the float as originally planned, we have reprogrammed the APEX float processor board itself (apf9) by changing the C source code that was provided by Webb Research Corporation. It is a simpler design and instead of another processer interfacing the DSP and the float microprocessor, the APEX controller board directly feeds the float status information including the external pressure and battery voltage to the DSP board so that it knows when to start and stop logging/processing the acoustic data. When the DSP detects beaked whale calls, it sends detection parameters to the APEX controller board. The parameters to be transferred include the time of detection, signal strength, signal ratios, average click intervals and other related statistics.

When the float comes back to the surface, it transmits the detection file of up to 50kB of size. The scheme is much simpler than adding another processor and also saves on power consumption.

Currently we are using NOAA's (National Oceanic Atmospheric and Administration) buoy web data interface to access the data and to send a new mission profile to each float. The advantage of NOAA's web site allows the user to retrieve the past float data stored in the web server as well as to transmit a new mission profile to each float. The data base is maintained by Pacific Environmental Lab., of NOAA. This data transmission protocol can be changed to suit other web sites that use the same Rudics interface if required.

WORK COMPLETED

A. Redesigned *QUEphone* interface (OSU)

1. Pre-amp design and fabrication
2. Redesign of bi-directional satellite communication protocol through Rudics server and design of web interface

A new wide-band (1kHz to 40kHz) differential-in and differential-out pre-amp with a maximum gain of 60dB was designed and built (Fig. 3). The APEX float controller source code was modified, and we are now capable of receiving and sending ASCII files through the secure NOAA/PMEL Rudics web interface for near real-time monitoring.

B. Detection software development (OSU)

The detection stage for the *QUEphone* has been implemented in the APL-UW DSP board and is operational. The ***E**nergy **R**atio **M**apping **A**lgorithm (**ERMA**)* was developed at OSU to reduce the number of false positive detections while keeping computational cost low, as is needed for long-term real-time operation on the acoustic platforms including *QuePhone* (*Klinck and Mellinger, 2009*). ERMA analyzes clicks produced by all odontocete species occurring in an area (geographic species mix) and evaluates the best-performing energy ratio for a target species. For beaked whales the energy ratio between 37 kHz and 10.6 kHz is used for detection (see Figure 1). On the second stage, the energy ratios are used to configure a noise-dependent threshold detector based on a Teager-Kaiser energy operator (e.g. Kandia and Stylianou, 2006). The number of detected clicks, their inter-click intervals (ICIs) and detection amplitudes are also used to further reduce the number of false positive detections.

Yack *et al.* (2009) compared the performance of several state-of-the-art beaked whale detectors including the OSU ERMA detector (Fig. 2). The comparison showed that the OSU ERMA detector performed similarly to other more sophisticated detectors. ERMA detected all periods when beaked whales were acoustically present in the investigated data set. Furthermore Yack *et al.* (2009) conducted a test on a non-species data set containing Risso's dolphin echolocation clicks. The analysis revealed that by using ICI information, the ERMA detector was able to reduce the number of false positive detections to less than 20% - less than most other detectors.

C. DSP Hardware and Software Development (APL-UW)

The ERMA detection algorithm was successfully transported and implemented on the *Blackfin BF537E* based DPS board developed by C. Jones at APL-UW. Mellinger/Klinck (OSU) have assisted Jones in translating his program into C to make the code run efficiently both in time and power. DSP subsystem design and fabrication is complete. Hardware testing, software development, and system integration with the APEX float is underway.

Fig. 5 shows the DSP motherboard configured with a Blackfin BF537E processor. The DSP subsystem consists of a motherboard with 24-bit sigma-delta analog to digital conversion, power control, peripheral interfaces, and CF Card data storage (up to 64GB). A separate Bluetechnix Tinyboard Blackfin processor board (visible at the center of the board - CM-BF537E) processor is mounted to the motherboard. The size of the board is 2.5x3 inches. It is our plan to have the DSP record the signal continuously at 100 kHz sampling rate as well as run the detection algorithm simultaneously. It can run at maximum clock speed of 500MHz, but also is scalable down to 100MHz to save power if needed.

The system software uses the open source uCLinux operating system with code developed in C/C++ using standard Linux resources and open source DSP libraries. The processor will digitize a single hydrophone channel (128 kHz sampling rate), log the raw time series data to CF Card, and process the time series to detect echolocation clicks, then communicate to the float APF9 controller.

D. System integration (OSU/APL-UW) - In progress

Fig. 5 shows the assembled *QUEphone* which is still undergoing bench test. It is now capable of sending data files less than 50kB in size including the acoustic and engineering data of the float to the Iridium Rudics site. At this point only the transmitting the float engineering data has been tested. Test of serial handshaking between the float controller and DSP will be conducted in October. When the float surfaces and transmits the data files, the acoustic detection file will be attached at the end and will be posted on the NOAA buoy web site immediately at http://intranet.pmel.noaa.gov/rudics/ALL_RUDICS/ Any user with a proper login permission can retrieve the data and sends a new float mission file through the NOAA web interface. Our plan is to conduct a lake test and sea trial in Washington in November and December, 2009.

RESULTS

OSU completed the fabrication of the beaked whale pre-amp. APL-UW completed the DSP board fabrication and implemented beaked whale ERMA detection routine and tested on a bench. OSU has successfully modified the APEX float controller/communication program and developed data web interface to allow users to transmit and receive the files between the Iridium Rudics site and individual float. At present the acoustic profiler float is going through the system integration phase.

IMPACT/APPLICATIONS

America's environmental laws, including the Marine Mammal Protection Act, the Endangered Species Act, and the National Environmental Policy Act, as well as intense public concern, compel the Navy to minimize the impacts of its operations on marine mammals and to mitigate any adverse impacts those operations may have. Harm to marine mammals has been an especially prominent issue for midfrequency sonars and beaked whales, after some of these whales stranded and died at times and locations close to naval exercises [*Barlow et al*. 2006]. For these reasons, it has become important for the Navy to monitor the occurrence and behavior of marine mammals [*Macleod and D'Amic*o 2006]. The *QUEphone* under development will be a relatively inexpensive tool to allow the US Navy to acoustically monitor the exercise area for the beaked or other endangered species and give proper warning in a relatively short time frame when these animals are present.

RELATED PROJECTS

"Automatic Detection of Beaked Whales from Acoustic Seagliders", ONR grant # N00014-08-1-1082. This project is also using the ERMA detection method, configured differently because it will be operated with different species.

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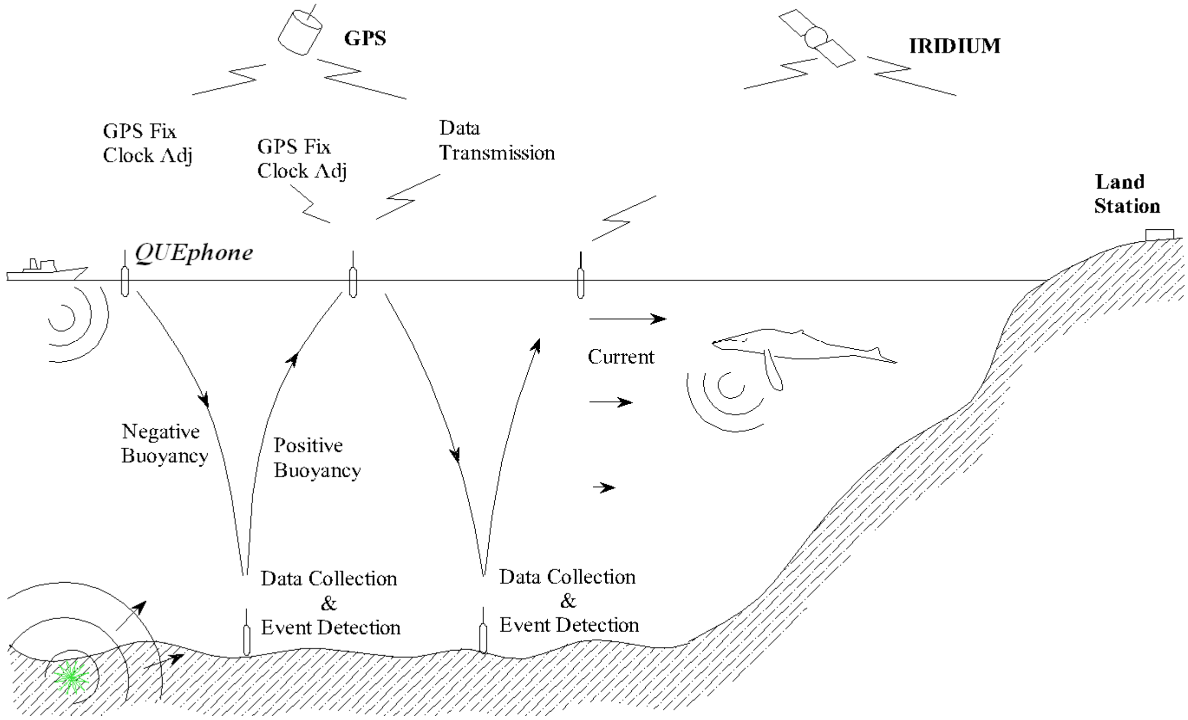


Fig. 1. Conceptual diagram of the QUEphone in operation.

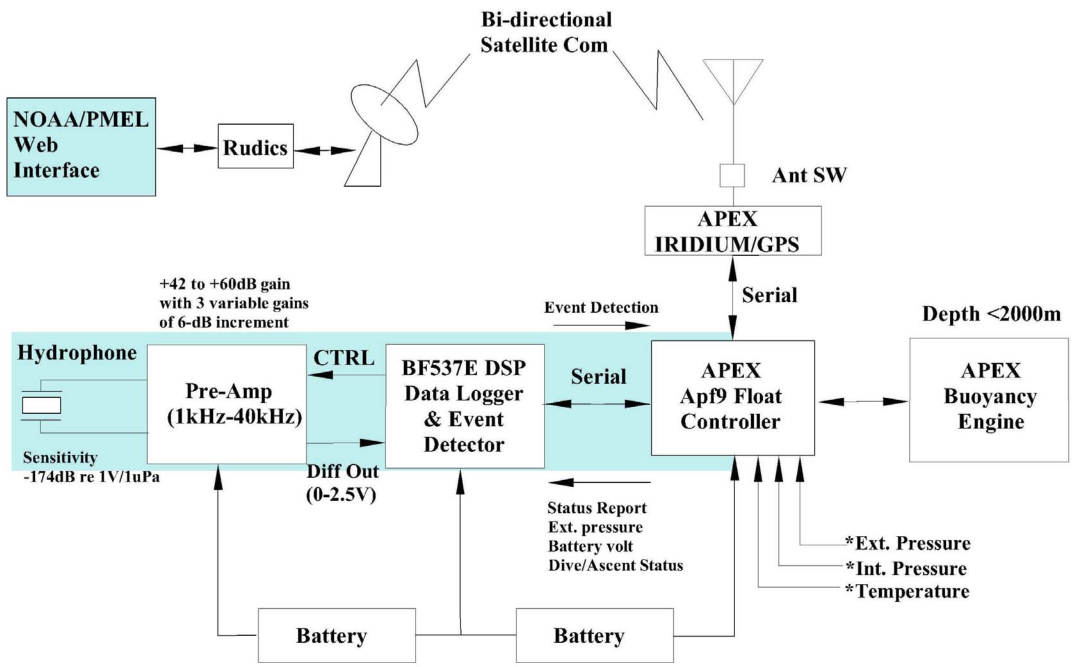


Fig. 2. Block diagram of the QUEphone Acoustic Float, including the pre-amp, Blackfin BF537E DSP, APEX float controller, buoyancy engine, and Iridium/GPS modem. The blue shaded area is the system to be developed and integrated by OSU and APL-UW.

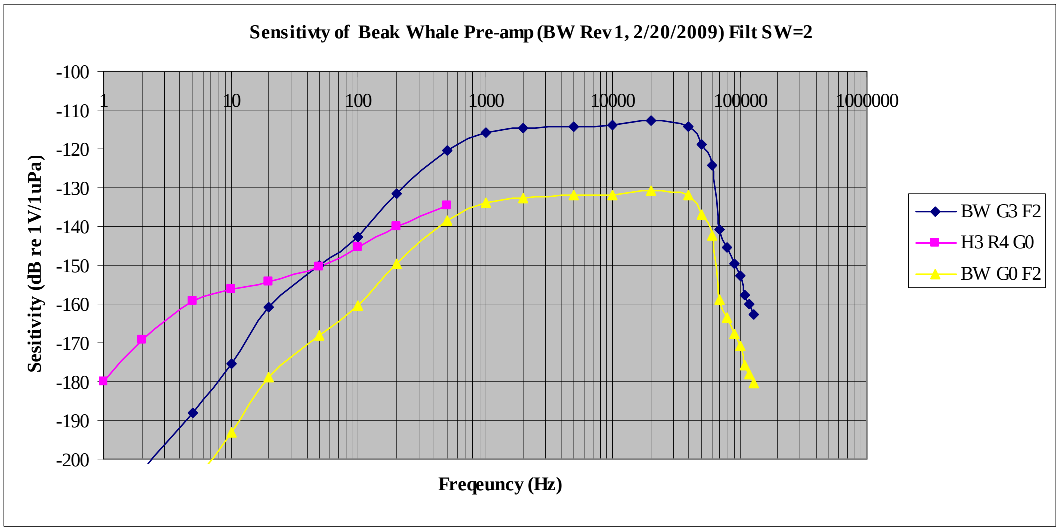


Fig. 3. Combined sensitivity of the hydrophone and the QUEphone. Dark blue line is the highest and yellow line is the lowest gain of the pre-amp with a 4-step programmable gain at +6-dB increments. For comparison, a sensitivity curve has been used for the past seismic monitoring is added (pink).

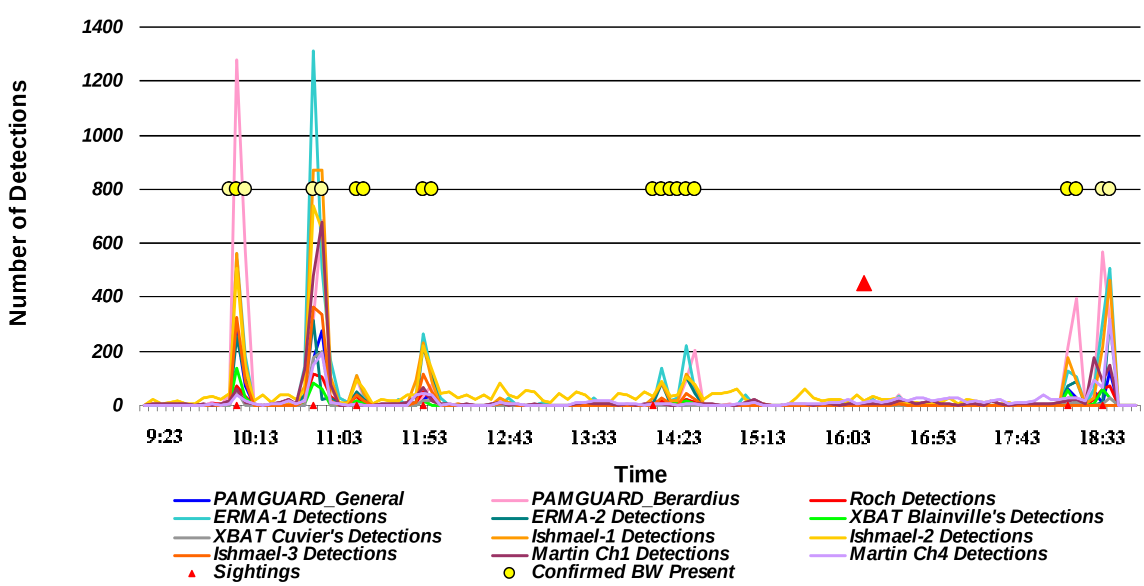
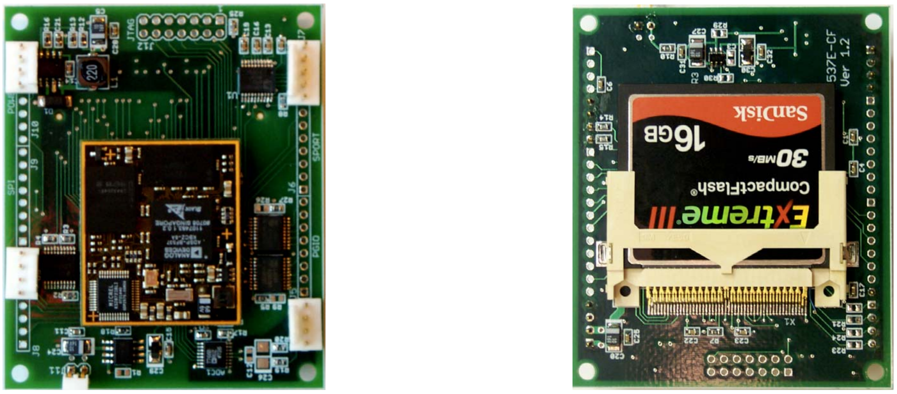


Fig. 4. Comparison of beaked whale detection algorithms. The yellow dots represent 5 minute intervals when beaked whales were acoustically present. Source: Yack et al., 2009.



Top Bottom

Fig. 5. APL-UW DSP board based on Blackfin BF537Ewith CF Card data storage.

Fig. 6. Assembled QUEphone acoustic float. Iridium/GPS antenna and hydrophone are mounted on the endcap. A plastic cage protects the hydrophone during the deployment recovery operation from a small boat.