The Bioacoustic Probe: A Miniature Acoustic Recording Tag

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NEED

Ship-shock trial of the Winston S. Churchill (DDG 81), May 2001

Seismic vessel in the Beaufort Sea, Alaska, August 1999

Law requires monitoring and mitigation of acoustic impacts on protected species, including all marine mammals. Activities affected include:

- *Oceanographic research*
- *Live-fire exercises*
- *Ship-shock trials*
- *Test ranges*
- *Experimental and operational sonar*
- *Seismic geophysical surveys*

Mitigation approaches include:

- *Rescheduling operations*
- *Relocating operations*
- *Reducing or canceling operations*

BUT for many protected species, acoustic mitigation by be too conservative, or not conservative enough!

- *Acoustic sensitivities known only for a few species*
- *Most data from captive — not free-ranging — subjects*

So it is imperative that we better understand the acoustic sensitivities of a WIDE RANGE of marine species, including critical protected species such as blue, fin, humpback, right, sperm, and beaked whales.

SCIENTIFIC APPROACH

To understand an individual's acoustic sensitivity we must measure BOTH the acoustic stimuli AND any response.

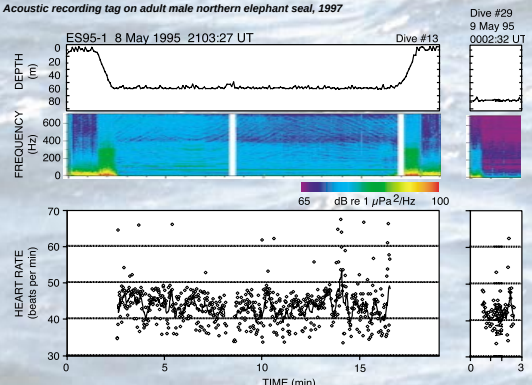
The most accurate way to measure these data is AT THE SUBJECT.

Thus we need a FLEXIBLE ACOUSTIC RECORDING TAG for attachment to a WIDE RANGE OF MARINE SPECIES by DIVERSE RESEARCH GROUPS under HARSH FIELD CONDITIONS.

SCIENTIFIC BACKGROUND

Acoustic recording tag on adult male northern elephant seal, 1997

Initial tests of the acoustic-recording-tag concept took place in the spring of 1995 on northern elephant seals (*Mirounga angustirostris*), under an ONR-sponsored program led by B.J. Le Boeuf (PI) and D.P. Costa (co-PI) of UC Santa Cruz, and P.L. Tyack (co-PI) of WHOI. See Fletcher et al. (1996) and Burgess et al. (1998).



Acoustic recording tag observations from a juvenile female elephant seal near Monterey Harbor. *The panels at left (Dive #13) show a dive during which the subject encountered vessel noise. The short panels at right (Dive #29) show a quiet period during a later dive. The curvilinear spectral patterns indicate passage of a motor vessel, with the minimum occurring at the time of the closest point of approach. The absence of flow noise during much of the record indicates swim slowing or cessation, unusual behavior for elephant seals in shallow shelf waters. A nine-point moving average of heart rate (lower panels, solid line), obtained from the acoustic data with a matched filter, indicates no obvious change in heart rate during passage of the vessels; neither does the heart rate in the presence of vessel noise differ significantly from that in its absence. While this example must be interpreted with care, it nevertheless demonstrates the capacity of acoustic recording tags to address questions of noise impact.*

ABSTRACT

Recent research has demonstrated the utility of acoustic recording tags to assess the exposure and response of marine mammals to sound [*e.g. Burgess et al., 1998*]. Such recorders have proved capable of acquiring acoustic, behavioral, and physiological data simultaneously, allowing deeper investigation of sound impact on wildlife than is possible with visual methods alone. The experimental nature of existing tags, however, has limited their adoption by the wider bioacoustical community. To enable broader use of the technology, a new general-purpose acoustic recording tag is being developed. Miniaturization to a cylinder approximately 3 cm in diameter by 20 cm in length, including the hydrophone and battery, will allow application with a variety of species and attachment methods. Initial versions of the device will sample acoustics with 16-bit resolution at bandwidths up to 14 kHz, as well as temperature and depth with 12-bit resolution. Longevity will depend on the choice of sampling schedule; constant acoustic sampling at 2 kHz will fill the 288-MB solid-state flash disk in 21 hours, but this lifetime can be extended by reducing resolution or by recording only during times of interest. Low-power three-volt electronics are used throughout the design, allowing a single half-AA-size lithium battery to power the entire tag. In March 2001, the tags were deployed as autonomous seafloor recorders off Maui to measure the song of humpback whales (*Megaptera novaeangliae*). Initial test deployments on free-ranging marine mammals and sea turtles are expected by fall 2001. [Work supported by ONR.]

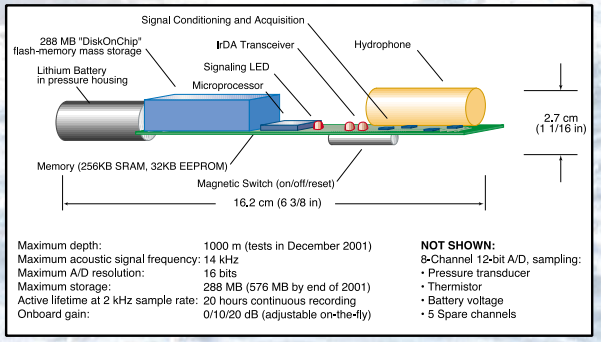
TECHNICAL OBJECTIVES

To be applicable to a WIDE RANGE OF SPECIES by DIVERSE RESEARCH GROUPS requires a tag that is:

- SMALL
- LOW-POWER
- RELIABLE
- FLEXIBLE
- SIMPLE AND EASY TO USE IN FIELD
- MANUFACTURABLE

TECHNICAL APPROACH

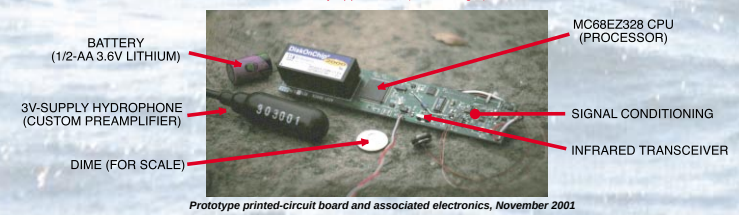
TO REDUCE BULK	ENCAPSULATE IN RESIN
TO REDUCE POWER	USE 3V, LOW-POWER ELECTRONICS
TO MAKE RELIABLE	ONLY OPTICAL, NO ELECTRICAL CONNECTORS
TO MAKE FLEXIBLE	ADJUSTABLE SAMPLING PARAMETERS
TO MAKE EASY TO USE	COMMAND WITH PALM PDA
TO MAKE MANUFACTURABLE	SINGLE-BOARD CONSTRUCTION



Maximum depth:	1000 m (tests in December 2001)	**NOT SHOWN:**
Maximum acoustic signal frequency:	14 kHz	8-Channel 12-bit A/D, sampling:
Maximum A/D resolution:	16 bits	• Pressure transducer
Maximum storage:	288 MB (576 MB by end of 2001)	• Thermistor
Active lifetime at 2 kHz sample rate:	20 hours continuous recording	• Battery voltage
Onboard gain:	0/10/20 dB (adjustable on-the-fly)	• 5 Spare channels

STATUS, NOVEMBER 2001

- 3-Volt-Supply hydrophone designed (detail at upper right)
- Eight prototype tags constructed
- One demonstration unit encapsulated in resin
- Single 1/2 AA lithium cell provides power to fill 288-MB storage
- Infrared commanding operates from Palm PDA (detail at upper right)
- Preliminary applications (detail at right)



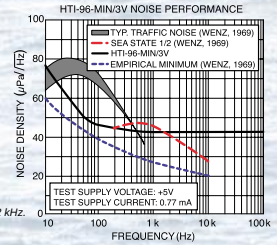
Prototype printed-circuit board and associated electronics, November 2001

REDUCING POWER CONSUMPTION: 3-VOLT-SUPPLY HYDROPHONE

No 3V-supply preamplified hydrophone could be found to provide optimal sensitivity. So a 3V-compatible, low-power hydrophone preamplifier was designed.

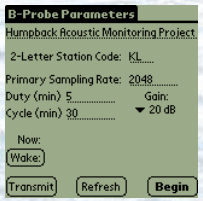
The preamplifier design was provided to High-Tech, Inc. (Gulfport, Mississippi) for inclusion in its HTI-96-MIN miniature cylindrical hydrophone series.

The resulting HTI-96-MIN/3V is now commercially available from HTI. It provides a sensitivity of -172 dB re 1 V/μPa while drawing 0.75 mA (typical).



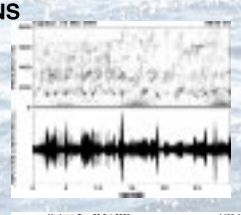
Noise performance of custom 3V hydrophone preamplifier. *Self-noise falls below typical ambient noise between 10 Hz and 2 kHz.*

EASE OF USE: INFRARED COMMANDING USING PALM PERSONAL DIGITAL ASSISTANT

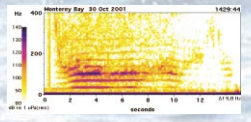


Screen shot of Palm PDA software for commanding the tag. *In this example the user has asked for 5 out of every 30 minutes to be recorded, at a sampling rate of 2048 Hz and with additional gain of 20 dB. The wake-up time has not been set yet.*

APPLICATIONS



Humpback call monitoring from fixed positions off Maui, March 2001. *Tags were used as seafloor acoustic recorders to monitor humpback whale vocalizations at several sites during the breeding season (Au et al. 2000).*



Attachment to blue whales off California, August and October 2001. *Test deployments of a tag (inside a pressure housing) led to design refinements. Deployments took place in collaboration with John Calambokidis (Cascadia Research) and John Hildebrand (Scripps). This case shows a blue whale 'B' call recorded shortly after the tag released from a subject. It is not clear in this particular case that the call originated from the subject.*

FUTURE

A prototype unit was encapsulated in resin for the first time in November 2001. Tests will occupy the following weeks to assess the ability of the unit to handle pressure and shock.

In early 2002, the electronic design will be revised and additional behavioral sensors will be added. Among the sensors likely to be added are acceleration, orientation, and light level.

Throughout 2002 the prototype tags will be applied in partnership with separately-supported field biology programs, for example with blue whales (John Calambokidis, Cascadia Research).

REFERENCES

Au, W.W.L., J. Mobley, W.C. Burgess, M.O. Lammers and P.E. Nachtigall (2000). Seasonal and diurnal trends of chorusing humpback whales wintering in waters off Western Maui. Marine Mammal Science 16(3), 530-544.

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Fletcher, S., B.J. Le Boeuf, D.P. Costa, P.L. Tyack, S.B. Blackwell (1996). Onboard acoustic recording from diving northern elephant seals. Journal of the Acoustical Society of America 100, 2531-2539.