

ELECTRIC AND NEAR-FIELD ACOUSTIC DETECTION, A MONOGRAPH

Ad. J. Kalmijn
Scripps Institution of Oceanography,
La Jolla, California
Phone (619) 534-4670
E-mail adjkalmijn@ucsd.edu

N00014-96-1-0435

LONG TERM GOALS

To complete and fully document my long-term ONR studies on the weak-electric sense of sharks and rays, and on the low-frequency acoustic sense of fish in general. My mathematical physics approach has led to several new lines of basic research concerning two major sensory systems. In the years to come, I wish to bring my ONR effort to its full potential and share the results with the Biology, Physics, and Engineering communities.

OBJECTIVES

To publish a monographic text on the electromagnetic and low-frequency acoustic sensory systems of aquatic animals. The text shall introduce the mathematical-physics and sensory-biology prerequisites needed, present my theories and their experimental verification, critically discuss the relevant literature, and spell out future lines of research. This work is supported by ONR Biological Oceanography and Biological Science & Technology.

APPROACH

The research approach consists in applying the exactitude of mathematical physics to sensory systems operating under biologically valid conditions. Weak electric and low-frequency acoustic fields are studied to identify and mathematically define their biologically relevant features. Behavioral and neurophysiological experiments are conducted under conditions ensuring that the results pertain to the normal functioning of the sensory systems.

The monograph addresses sensory biologists with an interest in physics as well as physicists and engineers with an interest in sensory biology. In my opinion, it is highly desirable for biologists to acquire a better physical understanding of the natural stimulus, and for physicists and engineers to acquire a better feel for biological systems. The monograph promotes the interaction between students and professionals of either background.

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 30 SEP 1997		2. REPORT TYPE		3. DATES COVERED 00-00-1997 to 00-00-1997	
4. TITLE AND SUBTITLE Electric and Near-field Acoustic Detection, A Monograph				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) University of California, San Diego, Scripps Institution of Oceanography, La Jolla, CA, 92093				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 4	19a. NAME OF RESPONSIBLE PERSON
a REPORT unclassified	b ABSTRACT unclassified	c THIS PAGE unclassified			

WORK COMPLETED

As agreed upon, original theories and new experimental findings must first be published in journal format. The first three articles resulting from the present endeavor have appeared, one as a publicly issued symposium paper, and two as regular journal articles. The manuscripts for two more journal articles are available for inspection and will be submitted soon.

Two of the interactive computer models to be included in the monograph are operational. One allows the user graphically to view the near fields of arbitrary electric and acoustic sources defined in terms of multipole series. The other demonstrates my approach algorithm guiding a predator to its prey using the electric sense or the inertial sense organs of the inner ear.

I have gathered and studied most of the material for the monograph, the journal literature of three centuries and the relevant biology and physics texts. Of the material that I worked through I have prepared abstracts on which the monograph will be based. As the journal versions had priority, writing the monograph will be the task for the coming two years.

RESULTS

The most significant result of the present endeavor is my finding that the common bioelectric fields of prey and the acoustic near fields of moving underwater objects are governed by the same mathematical equation. Thus, the electric sense of sharks and rays, and the inertial sense organs of the inner ear of fish in general may make use of the same salient field features and apply essentially the same approach algorithm.

As for the inertial sense organs of the inner ear, I furthermore discovered an important mode of excitation not yet considered. As acceleration sensors the predator's inertial organs detect not only the familiar temporal changes in the velocity field of the prey, but also the spatial changes in the velocity experienced over time as the predator moves through the field of the prey.

The approach algorithm guiding a predator to its prey, initially developed for the electric sense of sharks and rays, was proven to apply to the inertial sense organs of the inner ear as well, with the important difference that the electric sense relies on the rotation of the electric field with respect to the body axes, whereas the inertial sense may use the rotation of either or both the acceleration field and the spatial derivative of the prey's velocity field.

IMPACT

The results of my work are highly relevant to several Navy issues: (1) the electric and low-frequency acoustic detectability of submarines and other underwater vehicles, even when moving stealthily at a constant velocity with the engines shut off, (2) the method to be utilized for guided missiles seeking sources of galvanic and steady velocity fields, (3) fish bite and, in particular shark bite, at underwater cables, towed arrays, and other critical underwater equipment and gear, (4) the environmental impact of naval and industrial activities in the oceans. Of what I hear, present research on these issues is in dire need of the results forthcoming from my basic research.

TRANSITIONS

Because of my physics and engineering oriented approaches, all the results are expressed in a language rendering them directly available for naval and industrial implementation.

RELATED PROJECTS

The present project has not only yielded exciting new findings of its own, but by its nature also makes good use of all concurrent and earlier studies relevant to the monograph. In particular, my present studies on the electric sense of sharks and rays are highly relevant. The objective of those studies is to arrive at a model of the receptor system and to study how the animals can detect dc nV/cm electric fields given the inherent noise limitations.

REFERENCES

1. Kalmijn, A.J., 1994. Near-field acoustic detection: I. Principles and biological relevance. *Sensory Systems*, 8:202-219.
2. Kalmijn, A.J., 1995. Electric and near-field acoustic detection. In 1915-1995, 80 Years of Comparative Physiology, pp. 24-31. Tessel Offset, de Meern, Utrecht, the Netherlands.
3. Kalmijn, A.J., 1997. Electric and near-field acoustic detection, a comparative study. *Acta Physiol Scand*, 161, Suppl 638, pp. 25-38.

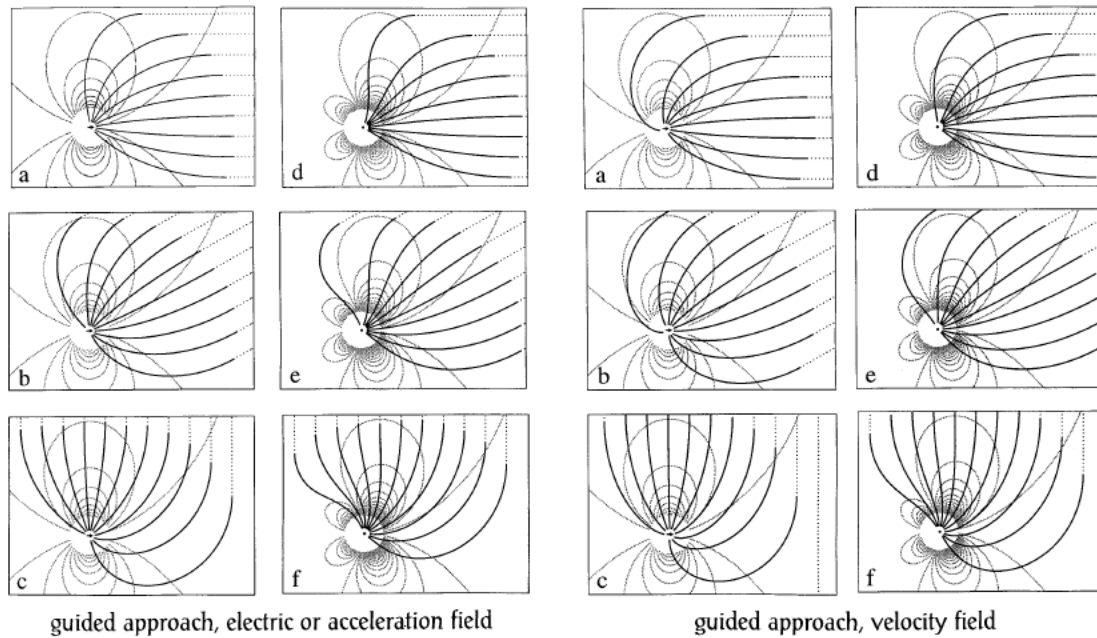


Figure 1

Examples of multipole fields and approach paths of predators guided by the electric, the acceleration, and or the velocity field of their prey, relying on the electric sense and the inertial sense organs of the inner ear respectively, made with the author's multipole and approach-algorithm programs. Box a, b, and c, dipole source; d, e, and f, combination of monopole, dipole and quadrupole source. Top, middle, and bottom rows, approaches from different directions. From Kalmijn, reference #3.