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WHOI-96-04

Woods Hole Oceanographic Institution

Advanced Engineering Laboratory Project Summaries 1994

by

Daniel E. Frye

April 1996

Technical Report

Funding was provided by the Department of Applied Ocean Physics and Engineering of the Woods Hole Oceanographic Institution.

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Woods Hole, Massachusetts 02543

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Technical Report

Funding was provided by the Department of Applied Ocean Physics and Engineering of the Woods Hole Oceanographic Institution.

Approved for Distribution:

George V. Frisk

George V. Frisk, Chair
Department of Applied Ocean Physics and Engineering

ABSTRACT

The Advanced Engineering Laboratory of the Woods Hole Oceanographic Institution is a development laboratory within the Applied Ocean Physics and Engineering Department. Its function is the development of oceanographic instrumentation to test developing theories in oceanography and to enhance current research projects in other disciplines within the community. This report summarizes recent and ongoing projects performed by members of this laboratory.

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THE EFFECT OF SHORT-SCALE WIND VARIATIONS ON SHELF CURRENTS

K. H. Brink, J. H. LaCasce and J. D. Irish

ABSTRACT

Most existing models of shelf currents (such as coastal-trapped wave models) usually disagree with observations, in that the cross-shelf currents are weaker than observed and that the predicted coherence length scales of cross-shelf currents are much longer. We seek to test the hypothesis that these inconsistencies can be resolved by including in the forcing, more realistic wind variations with alongshore length scales down to about 10 km. We use the Coastal Ocean Dynamics Experiment (CODE) Northern California, 1982, wind observations to drive a linear, stratified stochastic ocean model which includes bottom friction. The model results are expressed as statistics of the flow field which can be checked against observations. CODE aircraft winds from 1982 low-level alongshore flight tracks were converted to stresses and then subjected to wave number spectral analysis. Results show about 1 order of magnitude more energy at wavelengths shorter than 50-100 km than would be expected from the extrapolation of larger-scale spectral estimates based on buoy wind time series. Thus, for the CODE region, the forcing is energetic at relatively short length scales. The model results for cross-shelf velocity support our hypothesis, in that the modeled alongshore coherence length scales are indeed much shorter than those from a large-scale-only model. For example, at a 7-day period, the present calculations predict a coherence squared of 0.3 at a 35 km separation, while the large-scale-only model predicts 0.3 at 250 km. The observations show a 35-50 km scale for 0.3 coherence squared. However, while cross-shelf current variances are increased, they are still about a factor of 5 or more smaller than the CODE shelf observations over the shelf.

Funding provided by National Science Foundation under Contract OCE89-22648, the Office of Naval Research under Contract N00014-92-J-1643, and Woods Hole Oceanographic Institution under Proposal #8375.

Journal Geophysical Research, Vol. 99, No. C2, p. 3305-3315, February 15, 1994.

A HIGH PERFORMANCE MICRO-POWER CTD SENSOR

Neil L. Brown

ABSTRACT

This paper describes a small, light-weight, precision CTD system using simple, low cost power electronics. The analog circuitry consumes 7 milliWatts, and the microprocessor consumes 20 milliWatts. Microprocessors currently under development are expected to consume significantly less power and will be used in future implementations of this concept.

High accuracy is achieved in two ways. The basic electronics described below are linear and reasonably stable. They are calibrated once every 1.5 seconds against precision resistance reference networks which simulate the outputs of the sensor bridges for three precisely known values at approximately 0, 50 and 100% of full scale of each of the measured parameters. The known values are accurately determined at the time of laboratory calibration. At each "calibration" of the electronics, simple polynomials expressing the relationship between the digital outputs and each parameter are recalculated, thus correcting for any drift in the electronics. Thus, accuracy depends only on the relationship between the outputs of the sensors and the calibration network and is independent of the stability of the electronics.

The extreme simplicity of the hardware was achieved by the use of a simple switching circuit (chopper) to precisely convert a DC output voltage to a square wave voltage exactly equal to the sensor or calibration circuit. This DC voltage is then digitized using an inexpensive commercially available A/D converter. This technique (which has been patented) is inherently linear and stable.

Funded by The Naval Research Laboratory under Contract N00014-92-C-6028.

***Oceans 94 Conference Proceedings*, Vol. 1, September 13-16, 1994, Brest, France, p. I385-I390.**

NOISE CANCELLING PERFORMANCE OF AN ADAPTIVE RECEIVER FOR UNDERWATER COMMUNICATIONS

Josko Catipovic, Mark Johnson, and Dennis Adams

ABSTRACT

Acoustic communication with autonomous underwater vehicles (AUVs) is complicated by the vehicles' self-noise, particularly on AUVs with on-board active acoustic systems. Fortunately, active emissions generated on-board the AUV provide a convenient reference signal characterizing the self-noise. This paper addresses the use of such reference signals to improve the performance of acoustic communication systems.

To this end, two methods of noise cancellation are examined both theoretically and experimentally. The first, called the cascade method, makes use of a conventional adaptive noise cancellation algorithm followed by a receiver with adaptive equalization. The second noise cancellation method involves a recently-proposed multi-channel adaptive receiver algorithm.

It is shown that the multi-channel receiver can operate reliably in a signal-to-noise ratio of -3dB or worse, a gain of about 10dB over a conventional receiver for the codes and data-rates used. The cascade method, however, has a performance inferior to that of the multi-channel receiver due to adaptation noise.

Funding provided by Advanced Research Projects Agency under Contract MDA972-91-J-1004 and by the LORAL Corporation.

***Proceedings Symposium on Autonomous Underwater Vehicle Technology Conference,* Cambridge, MA., July 1994, p. 171-178.**

LOW FREQUENCY ACOUSTIC MONITORING EXPERIMENT

Lee Freitag and Daniel Frye

ABSTRACT

A Surface Suspended Acoustic Receiver (SSAR) was modified to detect and store acoustic signals generated by underwater explosions. The SSAR was deployed east of West Palm Beach, Florida in October 1994 and a total of six SUS charges were dropped at ranges of 60 and 120 miles from the buoy. Acoustic signatures for the charges were recorded to disk from six hydrophones sampled at 300 Hz. Summary data for each charge are presented in the report along with details concerning the field activities and the SSAR hardware systems.

Funding provided by Advanced Research Projects Agency under Contract MDA972-93-1-0004.

***Preliminary Data Report*, Submitted to Ralph Alewine, Advanced Research Projects Agency, Arlington, VA., November 10, 1994.**

SURFACE SUSPENDED ACOUSTIC RECEIVER (SSAR) FOR MAPPING OCEAN

Lee Freitag, Daniel Frye, Walter Paul, and John Spiesberger

ABSTRACT

A free-drifting acoustic receiver capable of measuring acoustic travel times across ocean basins is being developed as part of the Advanced Research Projects Agency's (ARPA) Acoustic Monitoring of Global Ocean Climate program. This program is a multi-institutional effort to develop techniques to measure and analyze changes in the heat content of the ocean. The SSAR is a sophisticated and sensitive receiver which will provide an economical and geographically flexible alternative to fixed receiver arrays which are cabled to shore. The receiver combines a multi-element hydrophone array suspended in the sound channel with in situ data processing, acoustic and satellite navigation and near real-time data telemetry. The first ten operational units will be deployed in the North Pacific in Summer 1994 and will receive acoustic signals from sources deployed offshore Hawaii and California. SSAR lifetimes are designed for one to two years' operation with the potential for retrieval and refurbishment depending on their drift tracks.

The SSAR mechanical design is a unique configuration utilizing a small surface buoy to support satellite antennas and an 80 meter long reinforced rubber stretch hose which allows a protected low stress path for the signal conductors in the wave zone, and provides compliance to minimize wave frequency excitation of the suspended acoustic array.

The SSAR electrical design has two elements; the lower system consisting of a 6-element acoustic array, acoustic receiver, A/D converter, processor (a 286-based, low power computer), and an acoustic navigation system. The acoustic navigation system locates the array with respect to the surface buoy, which is located using a GPS receiver. The upper electronics system (in the surface buoy) consists of the GPS receiver, an Argos transmitter with multiple IDs, computer, and an acoustic responder. Communication between the two electronic systems is via RS-485 using 3 conductors which run through the elastic hose and the electromechanical cable.

Funding provided by Advanced Research Projects Agency under Contract Number MDA-972-93-1-0004.

***Proceedings, Oceanology International Symposium,* Brighton, England, March 8-11, 1994.**

A COMPACT UNDERWATER ACOUSTIC MODEM

David Herold and Mark Johnson

ABSTRACT

A major focus of the Acoustic Telemetry Group at Woods Hole Oceanographic Institution has been the development of adaptive algorithms for use in underwater acoustic communications, particularly in shallow water applications and in acoustic local area networks. As the current generation of commercial telemetry devices do not meet the computational requirements of such algorithms, a new compact signal-processing module has been developed. The key specifications for this unit were that it be able to provide data processing rates of at least 80Mflops (million floating-point operations per second) while being sufficiently compact for hand deployment and having low quiescent power consumption for long-term deployment. This paper presents details of the modem hardware and software architecture together with preliminary results from the first deployment using the new system.

Funding provided by Office of Naval Research Contract N00014-03-1-0988.

***Symposium on Autonomous Underwater Vehicle Technology Conference Proceedings,* Cambridge, MA, July 1994.**

UNDERWATER IMAGE COMPRESSION USING THE WAVELET TRANSFORM

David F. Hoag, Vinay K. Ingle, John G. Proakis, and Josko Catipovic

ABSTRACT

Autonomous Underwater Vehicles (AUV) have gained considerable attention over the years for exploration of the ocean environment. They cost far less than manned submersibles, are safer and can stay down for much longer periods of time. Tethered AUV's equipped with a video camera and onboard processing hardware are capable of transmitting video information to a surface ship over a fiber optic link. Of course the range of exploration of these AUV's is limited by the tether. Recently an idea has been proposed to remove the tether from the AUV and transmit the data in real-time to a remote site via an underwater acoustic channel. To accommodate this application, massive compression of the video data must take place onboard the vehicle prior to transmission. For example, the transmission of broadcast television quality monochrome video across a vertical underwater acoustic path would require a compression ratio on the order of 1250:1.

Approaches to video compression commonly combine still image coding techniques with simple motion estimation and compensation algorithms. This work focuses on the compression of still underwater images, which tend to exhibit low contrast and detail due to the poor lighting in a deep ocean environment. Underwater image compression algorithms should therefore be geared toward exploiting this feature of such images. The Joint Photographic Expert's Group (JPEG) algorithm is a standard approach to image compression which relies on the excellent energy compaction of the Discrete Cosine Transform (DCT). The algorithm achieves high rates of compression yet produces an undesirable "blocky" effect in the reconstructed data.

A separable 2D wavelet transform provides a means of decomposing an image into detail subbands which highlight horizontal, vertical, and diagonal spatial orientations. The Human Visual System (HVS) has maximum sensitivity toward horizontal and vertical contrast and minimum sensitivity toward diagonal contrast. A compression algorithm which employs a wavelet decomposition can then account for these characteristics of the HVS and weight the wavelet coefficients of various subbands

accordingly. Due to the nature of underwater images, a majority of the quantitative (VQ), whereby individual subcodebooks are generated for each of the subbands. This approach has advantages over conventional VQ techniques since the subcodebooks are smaller, implying faster convergence and fewer computations. Also this algorithm accounts for the HVS, which most VQ techniques ignore. Results demonstrate that the wavelet-based approach yields compression rates comparable to JPEQ, with better visual quality in the reconstructed underwater images.

Funding provided by Office of Naval Research Student AASERT Program under Contract N0001-14-92-J-1661.

***Proceedings Oceans '94,* Vol 2, Brest, France, September 13-16, 1994, p. 533- 537.**

THE DESIGN AND PERFORMANCE OF A COMPACT UNDERWATER ACOUSTIC NETWORK NODE

Mark Johnson, David Herold, and Josko Catipovic

ABSTRACT

A major focus of the Acoustic Telemetry Group at Woods Hole Oceanographic Institution (WHOI) has been the development of underwater acoustic communication networks. Similar to a cellular telephone network, an acoustic network consists of a number of nodes or modems which adaptively route digital data packets between scientific sensors and a data collection or viewing point.

A significant milestone in the development of such a network has been the recent demonstration of a multichannel adaptive receiver for coherent underwater communications. As the current generation of commercial telemetry devices do not meet the computational requirements of this algorithm, a new compact, high-performance modem has been developed at WHOI. This unit has a processing capacity of more than 80Mflops (million floating-point operations per second) and contains a full-featured personal computer.

In this paper, the capabilities of the new modem are reviewed together with preliminary results from two deployments of a network of six modems. The results highlight the ability of the new modem to autonomously monitor network configuration and channel quality.

Funding by Office of Naval Research under Contract No. N000-14-93-1-0988 and Advanced Research Projects Agency under Contract No. MDA972-93-1-0019.

***Proceedings, Ocean '94,* Brest, France, 1994, September 13-16, 1994, p. 467-471.**

REDUCED-COMPLEXITY RLS ESTIMATION FOR SHALLOW-WATER CHANNELS

Marko Kocic, David Brady, and Steven Merriam

ABSTRACT

An adjustable complexity, recursive least squares (RLS) estimation algorithm is presented which is suitable for adaptive equalization and source localization in shallow water acoustic channels. The algorithm adjusts its computational complexity, measured in FLOPS per update, in a decreasing fashion with the relative signal strength, by ignoring "insignificant" dimensions of the channel. The algorithm reverts to the well-known fast RLS algorithms when the signal quality is weak and may be combined with reduced period updating techniques. Examples illustrate computational savings in excess of one order of magnitude, permitting a tripling of the maximum data rate through these complexity - limited communication channels.

Funding provided by Advanced Research Projects Agency under Contract Number MDA972-93-1-0019.

***Proceedings of the 1994 Symposium on Autonomous Underwater Vehicle Technology,* Cambridge, MA., July 19-20, 1994, p. 165-169.**

DETERMINING SUSPENDED SEDIMENT PARTICLE SIZE INFORMATION FROM ACOUSTICAL AND OPTICAL BACKSCATTER MEASUREMENTS DURING STRESS

J.F. Lynch, J. D. Irish, C. R. Sherwood, and Y. C. Agrawal

ABSTRACT

During the winter of 1990-91 an Acoustic BackScatter System (ABSS), five Optical Backscatterance Sensors (OBSs) and a Laser In-Situ Settling Tube (LISST) were deployed in 90 meters of water off the California coast for three months as part of the Sediment Transport Events on Shelves and Slopes (STRESS) experiment. By looking at sediment transport events with both optical (OBS) and acoustic (ABSS) sensors, one obtains information about the size of the particles transported as well as their concentration. Specifically, we employ two different methods of estimating "average particle size." First, we use vertical scattering intensity profile slopes (acoustical and optical) to infer average particle size using a Rouse profile model of the boundary layer and a Stokes law fall velocity assumption. Secondly, we use a combination of optics and acoustics to form a multifrequency (two frequency) inverse for the average particle size. These results are compared to independent observations from the LISST instrument, which measures the particle size spectrum in-situ using laser diffraction techniques. Rouse profile based inversions for particle size are found to be in good agreement with the LISST results except during periods of transport event initiation, when the Rouse profile is not expected to be valid. The two frequency inverse, which is boundary layer model independent, worked reasonably during all periods, with average particle sizes correlating well with the LISST estimates.

In order to further corroborate the particle size inverses from the acoustical and optical instruments, we also examined size spectra obtained from in-situ sediment grab samples and water column samples (suspended sediments), as well as laboratory tank experiments using STRESS sediment. Again, good agreement is noted. The laboratory tank experiment also allowed us to study the acoustical and optical scattering law characteristics of the STRESS sediments. It is seen that, for optics, using the cross sectional area of an equivalent sphere is a very good first approximation, whereas for acoustics, which is most sensitive in the region ka $\sim$ 1, the particle volume itself is best sensed.

In concluding, we briefly interpret the history of some STRESS transport events in light of the size distribution and other information available. For one of the events "anomalous" suspended particle size distributions are noted; i.e., larger particles are seen suspended before finer ones. Speculative hypotheses for why this signature is observed are presented.

Funding provided by Office of Naval Research Code 1125G under Contract N000-14- 89-J-1049.

***Continental Shelf Research,* Vol. 14, No.10/11, p. 1193-1165,1994.**

FIRST SCIENTIFIC USE OF THE FAST HYDROGRAPHIC PROFILER

Ray G. Peterson, Teresa K. Chereskin, and Albert M. Bradley

ABSTRACT

Obtaining high-quality full-depth profiles of ocean temperature and salinity has been limited for more than a century by the need for a suitable winch, by the speeds at which instruments can be safely lowered and retrieved, and by the time needed for probes to adjust to changing environments. The desire to make the operation more time-efficient and (ideally) independent of winches has been around just as long. Although significant progress has been made in measuring the upper ocean with expendable probes, they are unlikely to provide WOCE-quality measurements in the deep ocean within the foreseeable future. However, in the early planning stages of WOCE it was realized that recent advances in technology could be used to develop an autonomous, highspeed, reusable instrument package that would return quality data from great depths.

In response to that need, the Fast Hydrographic Profiler (FHP) has been developed by Albert M. Bradley, Joshua K. Hoyt, Alan R. Duester and Stephen P. Liberatore at the Woods Hole Oceanographic Institution's Advanced Engineering Laboratory. The design considerations included accuracy and precision of the measured data, the sampling rate, buoyancy and hydrodynamic drag of the instrument platform, ease and safety of use, and the system's durability and on-deck turn-around time .

Funding by National Science Foundation under Grant No. OCE-93-01411.

***WOCE Notes,* Vol. 6, No. 3, October 1994, p. 10-15.**

ELECTROMAGNETIC FIELD INSTRUMENT FOR THE CONTINENTAL SHELF

Robert A. Petitt, Jr., Alan D. Chave, Jean H. Filloux, and Helmut H. Moeller

ABSTRACT

While electromagnetic field measurements in the deep ocean have been used extensively for geophysics and oceanography, comparatively few data are available from shallow water, defined here as the continental shelves of depths less than 1,000 meters. This discrepancy has not been due to lack of interesting topics to study, but more to the problem of making difficult electromagnetic (EM) measurements in this active and noisy environment. However, in recent years interest in shallow water EM measurements has grown and the techniques for collecting and removing noise from EM data have been refined.

We have developed and constructed a set of instruments for operation in shallow water. They are capable of measuring the two horizontal components of the electric field, the three vector components of the magnetic field, pressure, temperature, and two components of tilt at a sample rate of 1 Hz/month.

Funding provided by National Science Foundation Grant No. EAR-92-06820.

***Sea Technology,* September, 1994, p. 10-13.**

ADAPTIVE EQUALIZATION ALGORITHMS FOR HIGH RATE UNDERWATER ACOUSTIC COMMUNICATIONS

John G. Proakis, Milica Stojanovic, and Josko Catipovic

ABSTRACT

This paper is concerned with the design of high data rate acoustic communication systems that employ adaptive equalization to overcome the effects of intersymbol interference and fading. Our treatment is focused on the use of nonlinear decision-feedback equalization that is appropriate for high-speed, phase coherent digital communications on long range, deep water horizontal paths and medium range shallow water paths. The performance characteristics, limitations, and implementation complexities of adaptive equalization algorithms are also considered.

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***Symposium on Autonomous Underwater Vehicle Technology Proceedings,* Cambridge, Ma, July 19-20, 1994, p. 157-164.**

IN-SITU DATA PROCESSING MODULE FOR TELEMETRY

Robin Singer

ABSTRACT

Ice Ocean Environmental Buoys, deployed in April 1992 at two ice-camps in the Arctic Ocean, sent large amounts of ADCP data to physical oceanographers at W.H.O.I., using the Data Processing Module (DPM) telemetry link developed at A.E.L. The DPM, originally developed to provide in-situ processing, data reduction, and telemetry of Narrow Band ADCP data, was revised during a JAMSTEC-WHOI collaboration, to process and offload BroadBand ADCP data from remote sites via ARGOS. The planned nine month duration of the velocity profiles from the Beaufort Sea were provided to Dr. Al Plueddemann over the satellite link for a year and a half. Another buoy deployed 115 miles from the North Pole, in the center of the Transpolar Drift sea-ice current, sent ADCP data for 3 months before the link failed due to a PTT malfunction. The motivation for the DPM development was the desire for real time data in light of the difficulties of recovering data stored in instruments, in rugged, remote environments such as the Arctic.

Funding provided by Office of Naval Research Contract N00014-89-J-1288. Funding to construct the IOEB that was deployed in the Beaufort Sea was provided by Japan Marine Science and Technology Center (JAMSTEC), Yokosuka, Japan.

***Sea Technology*, Vol. 35, No. 2, February 1994, p. 45-49.**

PHASE COHERENT DIGITAL COMMUNICATION FOR UNDERWATER ACOUSTIC CHANNELS

M. Stojanovic, J. Catipovic, and J. G. Proakis

ABSTRACT

High speed phase coherent communications in the ocean channel are made difficult by the combined effects of large DOPPLER fluctuations and extended, time varying multipath. In order to accommodate for both of these phenomena, we considered a receiver which performs jointly optimal phase synchronization and channel equalization. Since the intersymbol interference on some underwater acoustic channels spans several tens of symbol intervals, making the optimal, maximum likelihood receiver unacceptably complex, we use a suboptimal, but low complexity decision feedback equalizer. The mean squared error multiparameter optimization results in an adaptive algorithm which is a combination of recursive least squares and second order digital phase and delay locked loops. The use of a fractionally spaced equalizer eliminates the need for explicit symbol delay tracking.

The proposed algorithm is applied to experimental data from three types of UWA channels: long range deep water, long range shallow water, and short range shallow water channels. The modulation techniques used are 4 and 8 PSK. The results obtained indicate the feasibility of achieving power efficient communication in these channels and demonstrate the ability to coherently combine multiple arrivals, thus exploiting diversity inherent in multipath propagation.

Funding provided by Advanced Research Projects Agency under Contract MDA972-91-J-1004.

***IEEE Journal of Oceanic Engineering*, Vol. 19, No. 1, January 1994, p. 100-111.**

ADAPTIVE SPATIAL/TEMPORAL MULTIUSER RECEIVERS FOR TIME-VARYING CHANNELS WITH SEVERE ISI

M. Stojanovic and Z. Zvonar

ABSTRACT

Multisensor processing for multiuser communications in highly dispersive time-varying channels is addressed. While greatly reducing intersymbol and multiple-access interference, spatial diversity implies a high increase in the complexity of an adaptive multiuser receiver. To reduce the complexity of the optimal combiner, the spatial structure of multipath is exploited. The complexity of resulting adaptive multichannel multiuser equalizers is reduced at no cost in performance. Performance of a decentralized multichannel receiver is demonstrated in the experimental underwater acoustic network scenario, showing results superior to those of a single-channel centralized receiver.

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Proceedings of the 28th Annual Conference on Information Sciences and Systems, **Princeton, NJ, March 1994, p. 127-132.**

SPATIAL PROCESSING OF BROADBAND UNDERWATER ACOUSTIC COMMUNICATION SIGNALS IN THE PRESENCE OF CO-CHANNEL INTERFERENCE

Milica Stojanovic, Zoran Zvonar, Josko A. Catipovic, and John G. Proakis

ABSTRACT

High throughput multiple-access communication networks are being considered for use in underwater acoustic channels. Bandwidth limitations of underwater acoustic channels require receivers to process broadband signals in the presence of several active users. To deal with the resulting multiple-access interference in addition to high intersymbol interference, spatial variability of ocean multipath is exploited in a multichannel, multiuser receiver. Two configurations of such a receiver, a centralized and a decentralized one, are presented in fully adaptive modes of operations. Results of their performance in an experimental shallow water channel demonstrate superior performance of spatial signal combining. The use of multiple input channels is shown to provide high level of tolerance for the near-far effect in both centralized and decentralized receivers.

Funding provided by Advanced Research Projects Agency under Contract MDA-972-91-J-1004.

***Oceans 94 Conference Proceedings,* September 13-16, 1994, Brest, France, Vol. 1, p. I286-I291.**

TIME SERIES TECHNOLOGY FOR MEASUREMENTS OF MICROBIAL RATE PROCESSES AND CHEMICAL STATUS IN THE OCEANIC ENVIRONMENT

Craig D. Taylor and Kenneth W. Doherty

ABSTRACT

Variables within the physical and bio-optical sciences have by-and-large been most successfully applied to long term, high resolution time series studies of the oceanic environment, but data often provide only an indirect measure of chemical status and biological activity. Unfortunately, most of the directly measured chemical and biological variables that one may wish to correlate with the physical world, such as primary production and inorganic nutrient concentration, are not typically measured at a temporal resolution sufficient to permit cause and effect to be effectively deduced. Chemical and biological measurements tend to be controlled as much by the logistical capabilities of the investigator as by any consideration of the temporal and spatial scales of the environmental changes that may actually be occurring.

Our laboratory has endeavored to reduce this temporal disparity between key chemical and biological measurements, and correlative high resolution physical and biophysical measurements. To this end we have been working on two lines of autonomous technology. The first, a Time Series - Submersible Incubation Device (TS-SID), an automated instrument for performing multiple in situ primary production or other incubation experiments. Incubations are performed under conditions that accurately simulate the environment and require no involvement of the investigator other than the analysis of samples at the end of the deployment. The second technical development has been an *in situ*, auto-calibrating continuous flow chemical analyzer (TS-CFA) for the time series measurement of 3 chemical species (initial emphasis, inorganic nutrients). The device is completely autonomous when deployed and is amenable to near real-time data telemetry. Because most of the labor intensive manipulations have been automated in both of these instruments, it is possible to greatly

increase the frequency of measurement in biological and chemical time series studies (up to several measurement per day). The instruments may also be deployed for extended periods (months) to provide time series measurements on seasonal time scales.

Funding provided by Dept. of Energy under Grant DE-FG02-92-ERG1426 and National Science Foundation Grant OCE-90-00112.

Presented at Office of Naval Research seminar on WHOI instrumentation development, July 25-26, 1994.

SYSTEM TESTING OF THE AUTONOMOUS BENTHIC EXPLORER

Dana R. Yoerger, Albert M. Bradley, and Barrie Walden

ABSTRACT

This paper describes the first shallow water closed-loop positioning tests of the Autonomous Benthic Explorer (ABE), an AUV designed to perform long-term surveys of the deep sea floor. We first present the background of the ABE program and discuss some of its potential missions. We then present the ABE design, with emphasis on those areas where it differs from "mainstream" AUVs. Finally, we present the results of our testing program to date, including navigation system performance, closed-loop hover, and automatic docking and undocking.

Funding provided by the National Science Foundation Grant No. OCE-88-20227 and OCE-92-16775.

***Proceedings of The IARP 2nd Workshop on "Mobile Robots For Subsea Environments",* May 3-6, 1994, Monterey, California, p. 159-168.**

A 16 BIT DUAL MEMORY BUFFER

Jia Qin Zhang and Jim Varnum

A 16 bit dual memory buffer was designed to meet the need for an acoustic signal data recording system. A dual buffering capability was required to handle the large data throughput and transfer to hard disk for storage. This buffer has two memory resources with 128K word capacities. The structure of this buffer also includes an address counter for source data writing access. The counter is designed to control both sides of the memory and can be set to a certain value by software, so the source data can be stored in any location and the size of the data block can be controlled. The main flexible feature is the size of data block to feed to a buffer. From the size of data frame the cpu assigns the counter location for the next data frame while the current data frame is continuously fed in. When the source side reaches the last data frame, the cpu reloads the counter address to the beginning of the buffer for the next frame.

When the buffer block is completed, the cpu switches the data route to another buffer before the next data frame is started. The source issues an interrupt to inform the cpu that the new data frame follows.

When a buffer is fully written with data, the source data is directed to a second buffer which is empty (all data is transferred to disk by the cpu). The filled buffer is controlled and accessed directly by the cpu, all the data from this buffer will be written to hard disk as a data block. An important feature of this device is that while the source is continuously writing data to one side of the buffer, the data flow is never interrupted, as long as the data rate for disk writing is larger than the source rate (160K bytes per second).

The buffer is transparent to both the data source and the cpu sides. The source only needs to provide a single address line, put in a data word, and then assert a write pulse.

The cpu can read/write both sides of the data buffer. Whenever the new data frame begins, the cpu has to write a data header at the location of the data frame, which includes the date, time, longitude, latitude, length of the frame, frame number, etc.

Arbitration is done by cpu. The cpu is busy writing data to disk as long as there is data in the buffer. It is interrupted by the source when a new data frame is started. Inside the interrupt routine the cpu does one simple job; to decide and to precondition the arbitration logic. This greatly

saves time for the source side since the source is free to write data as soon as a data word is ready.

The redirection of the counter, the reorientation of the two buffers and all other logic swaps are performed and activated by the interrupt pulse itself. Hardware swap logic makes the resource reorientation very fast and reliable. It includes a flag switch, a set of flip-flops, an enable control and associated logic. The original design used two separate counters to perform the task for address access and for address reload. Changes have been made to lower the hardware count. In the present design only one counter is employed with newly designed control logic to the tasks.

The data reading hardware for the address counter has also been removed. To save time, we removed the reset procedure for the address counter and used a simple hardware device to perform this function using an interrupt pulse.

Three PLD devices (Altera parts) are programmed to interface and decode the 16 bit signal. A Megatel product (a modified PC-104 computer) is used as the system controller and a SCSI disk is used to record the data. Laboratory tests confirmed the expected data rate of 160K bytes per second.

ACKNOWLEDGMENTS:

The system design was prepared by Mr. Jim Varnum who also designed the acoustic source hardware. Software was written by Mr. Bob Eastwood. Mr. Steve Lerner contributed to the software. Dr. Ken Stewart was the project supervisor.

Funding provided by Office of Naval Research Contract No. N000-14-93-I-0181 and Naval Undersea Warfare Center Contract N000-14-0-90-D-1979.

AN ADAPTIVE LINEAR MULTIUSER RECEIVER FOR DEEP WATER ACOUSTIC LOCAL AREA NETWORKS

Zoran Zvonar, David Brady, and Josko Catipovic

ABSTRACT

The Acoustic Local Area Network (ALAN) is designed for multipoint-to-point telemetry between ocean bottom sensors and a surface receiver in deep water areas. The main obstacle for coherent communications in this channel is strong multiple-access interference from co-channel signals, which affects a common narrowband request channel. Throughput and packet delay in this network depends on the capability of the receiver to resolve collisions between request packets. In this paper we propose an adaptive multiuser receiver for joint parameter estimation and multiple-access interference cancellation. It extends pervious work on adaptive multiuser detectors to the more realistic communication scenario by estimating signal parameters rather than assuming that they are known. The adaptive approach is different from the one used in centralized multiuser receivers in that no knowledge of the signature sequences of any of the active users is required.

Funding provided by Advanced Research Projects Agency Contract No. MDA-972-93-1-0019.

Proceedings 1994 International Conference on Acoustic, Speech and Signal Processing, Vol 2, Adelaide, Australia, April 1994, p. 389-392.

ADAPTIVE MULTIUSER RECEIVERS WITH DIVERSITY RECEPTION FOR NONSELECTIVE RAYLEIGH FADING SYNCHRONOUS CDMA CHANNELS

Zoran Zvonar and David Brady

ABSTRACT

We investigate the performance of low-complexity decorrelating multiuser receivers with diversity reception in frequency-nonselective Rayleigh fading synchronous CDMA channels. The impact of fading dynamics on the differentially coherent receiver with equal-gain combining is quantified. We also analyze an adaptive coherent multiuser receiver utilizing decision-directed carrier recovery and maximal ratio combining, and bound its error probability showing the impact of imperfect channel estimates and multiple-access interference. Both multiuser receivers have superior performance compared to their conventional counterparts. The comparison of two receiver structures indicates that the coherent decorrelating detector with diversity reception is preferable in nonselective fading CDMA channels with memory.

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Proceedings MILCOM '94, Fort Monmouth, NJ, October 1994, p. 982-986.

ADAPTIVE PROCESSING OF COMMUNICATION SIGNALS IN SHALLOW WATER ACOUSTIC TELEMETRY NETWORKS

Zoran Zvonar, Milica Stojanovic, and James B. Bowlin

ABSTRACT

Underwater acoustic communications have received much attention in recent years leading to the development of powerful and reliable receiver algorithms for signal processing in a variety of ocean environments. With the feasibility of high-speed coherent underwater communications established, the focus of current research is shifting to more demanding communication scenarios, as encountered in underwater acoustic networks.

We address the problem of signal detection in highly variant shallow water environments, in the presence of strong co-channel interference from other acoustic modems in the network. The signals of different users occupy the same bandwidth, making the respective channel responses and the underlying data symbol sequences the only distinction among distorted replicas observed at the receiver. We compare the performance of a single-sensor decision-feedback equalizer (DFE) against a centralized multiuser receiver which jointly performs adaptive equalization and interference cancellation, and against a decentralized multi-sensor DFE which performs spatial signal combining and multichannel equalization.

Performance of different receiver structures was tested on real data collected at a one-mile range in the Woods Hole harbor, from two closely separated sources. Excellent results were obtained at signal-to-interference ratios as low as -10 dB, showing the performance improvement of proposed techniques over DFE in a network scenario.

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The Advanced Engineering Laboratory of the Woods Hole Oceanographic Institution is a development laboratory within the Applied Ocean Physics and Engineering Department. Its function is the development of oceanographic instrumentation to test developing theories in oceanography and to enhance current research projects in other disciplines within the community. This report summarizes recent and ongoing projects performed by members of this laboratory.

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