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Advanced Engineering Laboratory Project Summaries – 1990

Edited by

Daniel E. Frye

May 1991

Technical Report

Funding was provided by the Woods Hole Oceanographic Institution.

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Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543

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Approved for Distribution:

Albert J. Williams 3rd

Albert J. Williams 3rd, Chairman
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.

TABLE OF CONTENTS

Acoustic Current Meter
Neil L. Brown 5

Inductive Telemetry Modem
N. L. Brown, E. L. Hobart and A. J. Fougere 6

BEEP Fish-Tracking and Data Collection Project
Frank Carey, Robin Singer and Dick Koehler 9

Analysis of High-Frequency Multitone Transmissions
Propagated in the Marginal Ice Zone
Josko A. Catipovic and Arthur B. Baggeroer 11

Bandwidth-Efficient Trellis-Coded Modulation for
Phase Random Rayleigh Fading Channels
Josko A. Catipovic 12

Compact Digital Signal Processing Enhances Acoustic Data Telemetry
Josko A. Catipovic, Daniel E. Frye, and David Porta 13

High Data Rate Acoustic Telemetry for Moving ROVs
in a Fading Multipath Shallow Water Environment
Josko A. Catipovic and Lee E. Freitag 20

Performance Limitations in Underwater Acoustic Telemetry
Josko A. Catipovic 21

Spatial Diversity Processing for Underwater Acoustic Telemetry
Josko A. Catipovic and Lee E. Freitag 22

Specifications and Applications for an Advanced Acoustic Telemetry System
Josko A. Catipovic, Daniel E. Frye, and David Porta 23

Algorithms for Joint Channel Estimation and Data Recovery - Application
to Equalization in Underwater Communications
Meir Feder and Josko A. Catipovic 24

A Long-Term, Deep-Water Acoustic Telemetry Experiment
Lee Freitag, Steve Merriam, Dan Frye and Josko Catipovic 25

TABLE OF CONTENTS - continued

Telemetry of Ocean Current Data from Fieberling Guyot
Daniel E. Frye 26

Increased Data Rate for Control of Deep Ocean Robotics
Edward Hobart 36

Data Direct from the Ocean Bottom to Your Desk
Richard Koehler 38

A 5 MHz Sonar for Detection of Suspended Sediment
Richard Koehler 40

Modifications to the Schmitt-Toole High Resolution Profiler
Richard Koehler and Ellyn Montgomery 41

Power Supply Design for a Cable Based Acoustic Source
Stephen P. Liberatore 42

SAIL Compatible Three Channel Acoustic Navigation Interrogator
Stephen P. Liberatore 51

North Atlantic Tracer Release Experiment
Ann Martin 52

WHOI DSP32C Based Acoustic Telemetry Modem
John S. Merriam 54

Piezoelectric Rain Sensor
Robin Singer and Robert Weller 70

The Autonomous Benthic Explorer (ABE): A Deep Ocean AUV
for Scientific Seafloor Survey
Dana R. Yoerger, Albert M. Bradley and Barrie B. Walden 79

Acoustic Fish Tag
Jia Q. Zhang, Albert M. Bradley, Stephen P. Liberatore, Neil Brown
Alan Duester, Lee Freitag and Frank Carey 80

ACOUSTIC CURRENT METER

Neil L. Brown

Abstract

Design and breadboarding of the electronics for a low power, low cost acoustic velocity sensor have been completed and initial tests have been performed on a single axis prototype. The electronics are simple and are intended to accommodate a 4 axis sensor head design. The design is a continuous wave type that determines current velocity along each axis by measuring the difference in total phase shift for signals traveling in opposite directions. The essential differences between this and earlier designs are as follows:

1. Transmission takes place in one direction at a time.

2. There is only one receiver which is used to measure the total phase shift in each direction.

3. The phase shift is measured at the 1 mHz carrier frequency. Earlier designs measured the phase shift difference at a low frequency obtained by heterodyning the carrier frequency with a local oscillator.

This approach has a number of advantages. First, only one receiver is required. Secondly, uncertainties in receiver phase shift do not matter since current velocity is a function of the phase difference. The only requirement is that the receiver has a cosine response to the total phase shift including its own. Since phase measurement is performed at the carrier frequency, no heterodyning oscillator is required.

The result is that the prototype current sensor has a zero offset of less than 0.25 cm/s. The power consumption is 2.1 milliwatts which is independent of the number of axes. It is expected that the magnetometer compass and tilt sensor also being developed will consume about 5 milliwatts and the microprocessor will consume 1 to 2 milliwatts on average making a total of less than 10 milliwatts.

Funding was provided by the Office of Naval Research under contract N00014-86-0751.

INDUCTIVE TELEMETRY MODEM

N.L. Brown, E.L. Hobart, A.J. Fougere

Abstract

During the last 12 months, members of AEL have developed a power efficient Inductively Coupled Modem (ICM). A prototype set of modems have been built which allow for 1200 baud data transfer between a number of remote units and a single master. The inductive modem uses standard, plastic-jacketed mooring cable as the data transmission channel. The surrounding sea-water is used to form the return electrical circuit. This results in a system where data is transmitted directly on the mooring cable supporting the instrumentation, eliminating the need for expensive multi-conductor cables and terminations. Industry standard modem hardware is used, operating in a half-duplex transmission mode.

Signals are coupled to the mooring wire using a split core transformer which is clamped around the mooring wire. The mooring wire and sea water return are electrically configured as a one turn winding around the split core transformer. Through the use of efficient signal modulation, low noise signal reception, and low power digital electronics, the ICM underwater unit consumes only 350 mW while transmitting or receiving and only 1.5 mW at idle. The underwater water unit continuously cycles "on" and "off" testing the line for carrier signal from the master. If carrier is detected, the underwater unit stays "on" and determines if the data sent from the master is addressed to it. Units not addressed return to power "on/off" cycling while the addressed device passes information to the master. Remotes can also initiate direct data transmission to the master. As a result, the ICM system is configured as a serial data interface between the user and his instrument, requiring little in special protocol to successfully achieve data transmission. Figures 1 and 2 show the ICM system and modem block diagram, respectively.

Dock testing of the ICM has begun which is expected to continue into early 1991. A full sea trial of the ICM is expected to occur during summer 1991. AEL is also working to transfer the ICM technology to industry making it readily available to the scientific community.

Funding was provided by the Office of Naval Research under Contract Number N00014-86-0751.

To be published in Proceedings MTS 91, New Orleans, November 1991.

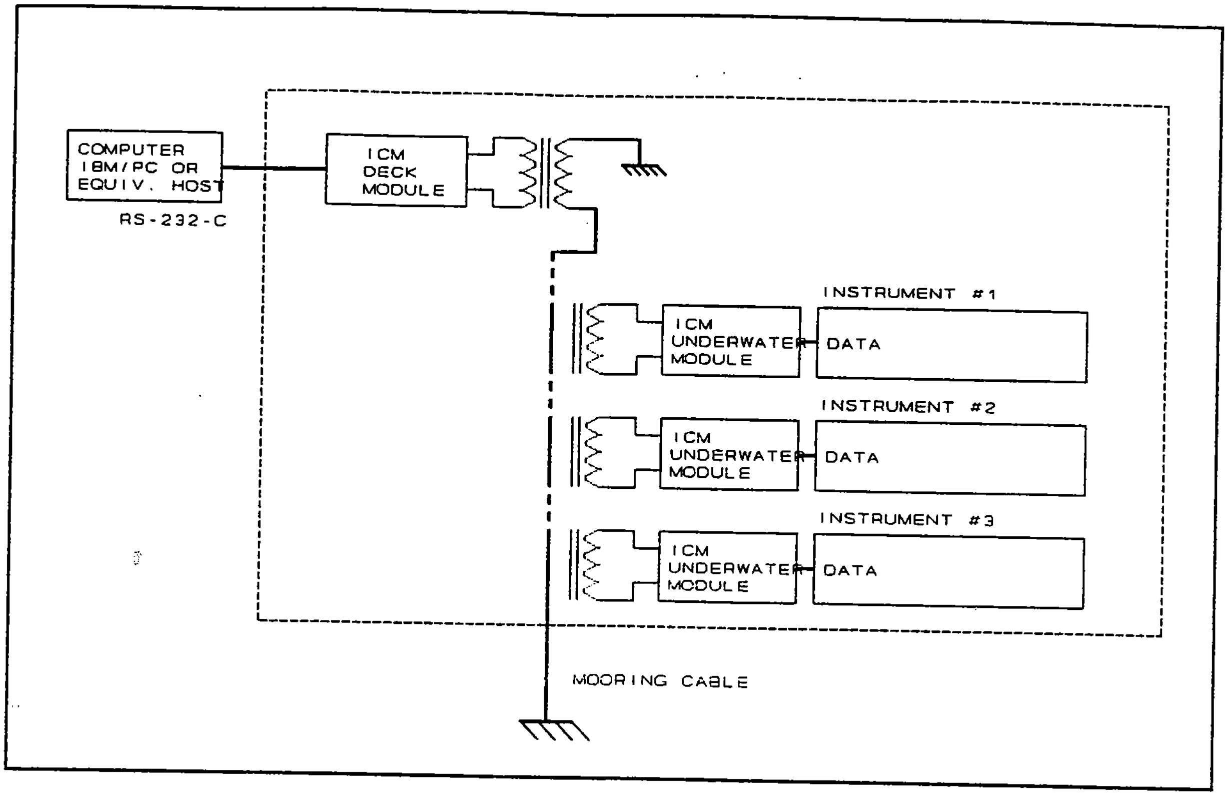


Figure 1: The ICM System

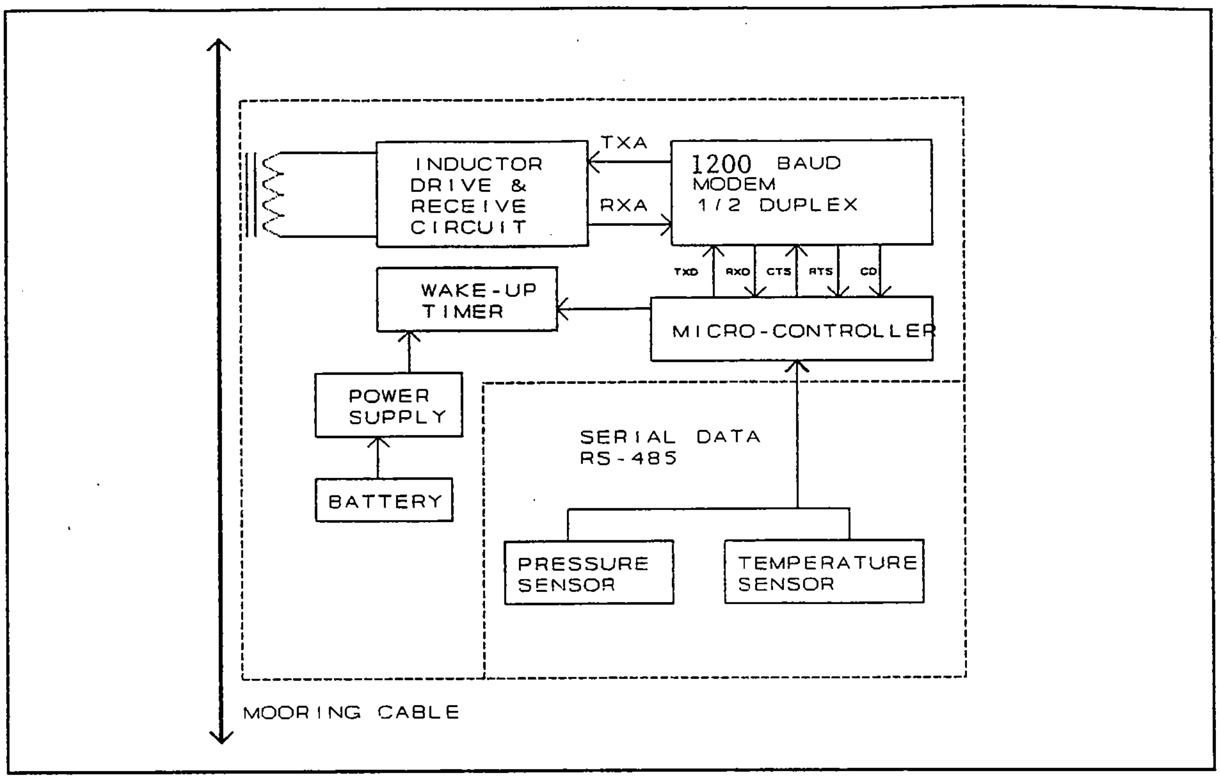


Figure 2a: Inductive Modem Underwater Unit
with Temperature and Pressure Sensors

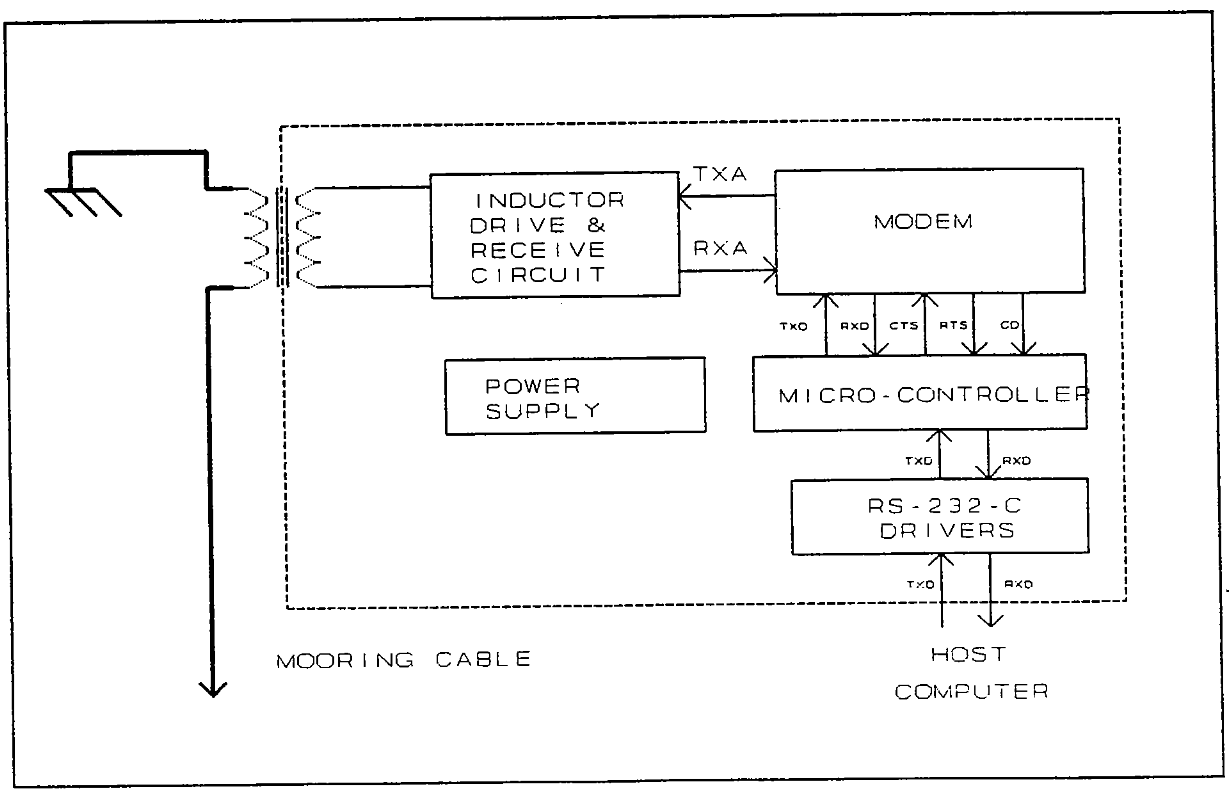


Figure 2b: Inductive Modem Master

BEEP FISH TRACKING AND DATA COLLECTION PROJECT

Frank Carey, Robin Singer and Dick Koehler

Introduction

In the BEEP program, information about fish physiology and behavior has been collected through implantation of sensors and acoustic transmitters in a variety of fish species. In particular, biologists have collected pressure(depth), water temperature, body temperature, swimming speed, and heart rate data from squid, large pelagic fish, and sharks. BEEP data has provided insight on environmentally motivated swimming patterns and the strategies fish use in coping with the large temperature gradients in the ocean.

Hardware

Transmitter

Sensor information is transmitted acoustically by a piezoelectric ceramic transducer at a crystal controlled frequency in the 30 to 50 kHz. range. Multiple channels of pulse rate modulated sensor data are time multiplexed, with periods on the order of a minute. The multiplexer clock is driven by the same crystal which controls the carrier frequency.

Receiver

The receiver consists of 4 broadly directional hydrophones and an electronics package to amplify, modulate, and decode the tones for data acquisition and processing by an IBM PC compatible computer. The hydrophones are arranged in a square pattern under a tow body that is suspended on a conductive cable over the side of a boat. Direction to the strongest signal is determined by switching between hydrophones, and the boat is turned in the direction of the maximum signal in order to follow the transmitting fish. The signals detected by the hydrophone pass through a broadly tuned preamplifier and are amplified, filtered and demodulated by a heterodyne receiver. The audible tones are converted to logic levels by a tone decoder which consists of a phase-locked loop, a phase detector, and a voltage comparator.

Computer Interface

A Metrabyte DASH-8 board, which resides on the PC bus, demodulates the sensor data. It has an 8254 timer/counter, analog and digital I/O channels, and an A/D converter which is used as an additional digital input. The digital circuit associated with the DASH-8 card converts the pulses from the tone decoder to 8254 gate and control signals. The software reads the timer/counters to determine pulse intervals. The DASH-8 digital inputs are used for sensor channel information and counter status signals and a digital output is used for counter control.

Synchronization

The receiver has a clock circuit, identical to the one on the transmitter, to determine which of the multiplexed sensor channels is current. Synchronization is maintained by the researchers who reset the receiver clock manually using the distinct changes in pulse rate which can be heard when the sensor channels change.

Software

The data acquisition program uses the channel information to apply the appropriate calibration factor to the pulse interval data and convert it to engineering units. It presents the data as a time series graph on the PC screen and writes it to disk each hour, with time and date stamps. The screen is dumped to the printer every 10 minutes to provide a paper record that is useful for following the course of an experiment. Analysis programs are used to remove errors and reveal the patterns of fish behavior.

Conclusion

The BEEP system is an inexpensive but effective program for the study of fish in their own habitat. By incorporating a variety of sensors, biologists can examine in great detail the responses of fish to environmental stimuli.

Funding for the project was provided under NSF contract No. OCE-88-11421.

ANALYSIS OF HIGH-FREQUENCY MULTITONE TRANSMISSIONS PROPAGATED IN THE MARGINAL ICE ZONE

Josko A. Catipovic and Arthur B. Baggeroer

Abstract

This work presents estimates of frequency and time coherence functions of acoustic transmissions centered at 50 kHz over a 1-km horizontal under-ice path in the marginal ice zone (MIZ). The data were collected during the MIZEX '84 experiment as part of a feasibility study for an underwater acoustic telemetry link. It is shown that the acoustic fluctuations are dominated by a 10-Hz process conjectured to be due to the turbulent under-ice layer. Significant energy in the 0.1-Hz band was also observed. The two processes differ in frequency coherence characteristics. An underwater telemetry system designed for this channel will be dominated by the high-frequency fluctuations, but the slower process is capable of causing disastrous data losses unless its effects are anticipated.

Funding was provided by the Office of Naval Research.

Published in Journal Acoustic Society of America 88 (1), July 1990.

BANDWIDTH-EFFICIENT TRELLIS-CODED MODULATION FOR PHASE RANDOM RAYLEIGH FADING CHANNELS

Josko Catipovic

Abstract

A bandwidth efficient modulation method for the incoherently demodulated Rayleigh fading channel is analyzed and implementation results reported. The method is based on partitioning binary expurgated modulation (BEXPERM) codes into subsets with desirable minimum Hamming distance properties. The subsets are comparable to signal constellation subsets used for trellis coded modulation (TCM) over phase coherent channels. A convolutional code is used to generate a subset mapping rule; its free distance is chosen to match the Hamming distance distribution within a subset to produce an overall code with error correcting capabilities comparable to those of a single BEXPERM subset. The resulting modulation method is more bandwidth efficient than MFSK while exhibiting significant coding gain. BEXPERM allows 14 kbit/sec data rates over the 2 - 10 km shallow water fully saturated ocean acoustic channel. This data rate represents a 40% increase over that currently achievable for these conditions.

Funding was provided by the Office of Naval Research under Contract N00014-86-K-0751.

Submitted for publication: IEEE Journal of Oceanic Engineering

COMPACT DIGITAL SIGNAL PROCESSING ENHANCES ACOUSTIC DATA TELEMETRY

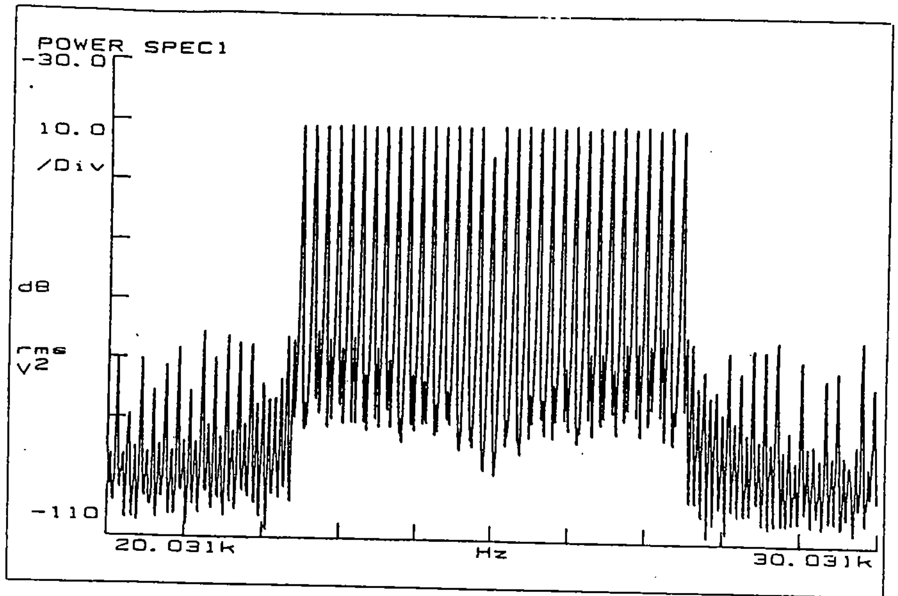
New Power-Efficient Systems Provide Means for Remote Command Control, and Communication Between Two Underwater Locations

Josko A. Catipovic and Daniel E. Frye
Woods Hole Oceanographic Institution
David Porta, Datasonics, Inc.

Acoustic data telemetry has been used ever since it was discovered that the ocean could support signal transmission. Past applications have ranged from low-baud-rate command and control systems for ocean equipment such as sea floor valves and backup acoustic blowout preventer (BOP) control in the offshore industry to acoustic releases for oceanographic moorings. These systems typically operate at tens-of-bits per second. A few higher rate systems have been developed, but these have shown high sensitivity to ocean channel features such as multipath and doppler, and are generally useful only for vertical transmission from sea bottom instruments to surface ships.

Recently, the processing capabilities of compact digital signal processing (DSP) components have encouraged computationally intensive acoustic telemetry implementations capable of overcoming many of the channel-caused problems which limited data rates in the past. The new generation systems are compact, power efficient, and contain most of the essential communication features in software.

One of the more difficult problems in achieving high data rate transmission is channel multipath, encountered particularly when communicating over the horizontal channel. The multipath arises from surface and bottom reverberation; geometric reflections from nearby objects such as piers and ships; and in-water turbulence, thermal gradients, and other environmental effects. The factor dominating system performance is the rate of change of the multipath, rather than the multipath duration or the number of reflections. If the multipath were stationary, classical techniques could track and mitigate the multipath effects. As the multipath becomes more dynamic, tracking becomes difficult and system performance degrades. For this reason, communication over the shallow water horizontal channel, particularly in enclosed bodies such as bays and harbors, is the difficult aspect of acoustic telemetry. Applications in deeper water, or where the data transmission path is more nearly vertical, are easier to address because of the reduced multipath environment. Our strategy has been to design the telemetry system for the most demanding channels of interest, namely shallow water environments, but to design the system hardware to operate over more benign channels with appropriate software modifications.



The ATM-840 transmission spectrum.

Figure 1

Hardware Designs

A general purpose acoustic telemetry system has been designed at Woods Hole Oceanographic Institution and is being manufactured by Datasonics, Inc. under licence. The bulk of the system's complexity is in the software, particularly the channel tracking and adaptation algorithms. The development process began with extensive software simulations on a work-station network. With this technique, a propective algorithm is benchmarked against other techniques with Monte-Carlo system simulations over Rayleigh fading multipath channels. The final step is to migrate the selected algorithms onto space - and power - efficient hardware implementations.

Two hardware designs have been developed:

1. The ATM-840 is a low power acoustic telemetry modem centered around a Motorola 68HC11 microcontroller. The modem consists of a data transmitter capable of coded multiple frequency shift keying(MFSK) transmission at data rates up to 1,200 bits per second, and a data/command receiver with a 300 bit per second capability.

2. The ATM-850 is based on AT&T DSP32C processors. This modem allows transmit and receive functions at rates up to 5,000 bits per second over worst-case acoustic channels. The ATM-850 can use larger signalling alphabets and can implement advanced decoding, adaptive equalization, and synchronization algorithms required to support higher data rates.

The ATM-840 system is envisioned as a modem for subsurface instrumentation. It is compact, and transmit efficiencies approach 1,000 bits/joule/kilometer. The included command receiver and a packet transmission protocol allow implementing a local area network between many subsurface instruments and a central data collection point. It is ideally suited for applications where many subsurface instruments need to be interfaced to a single satellite or fiber-optic link to shore. The system employs MFSK transmission with up to 16 tones which allows representation of two bits with each tone transmission, thus transmitting 32 data bits with each transmission frame. Typically, a synchronization frame is inserted periodically into the data sequence. The data is double sideband (DSB) modulated onto a software-controlled carrier. For this example, 16 tones are transmitted in the 22.5 to 27.5 kHz bandwidth. The actual data rate is 1,200 bits per second exclusive of synchronization overhead. For most applications, the data band utilized is 15 to 20 kHz, although the ATM-840 is designed to accept a variety of acoustic transducers, and the modulation frequency is software controllable from 1 kHz to 100 kHz.

The ATM-840 data receiver uses an incoherent FSK demodulator. Passive filters are used for FSK demodulation, resulting in minimal power drain. The system employs a wakeup receiver which initiates processing of a possible incoming data packet. Packet validity is confirmed by software, and an invalid data sequence (or false alarm) is rejected.

SPECIFICATION SUMMARY

Specifications	ATM-840	ATM-850
Frequency	15-20 kHz (typical) 12-13 kHz (command)	15-20 kHz (typical) 13-14 kHz (command)
Modulation	16 tone MFSK (data) FSK (command)	up to 256 tone MFSK (data) FSK (command)
Data Rate	up to 1200 bps (data) up to 300 bps (command)	up to 5000 bps (data) up to 300 bps (command)
Range	5000 m	5000 m
Acoustic Source Level	186dB	186dB

The Capable Modem

The ATM-850 is a much more capable modem, with a 5,000 bits per second half duplex bidirectional data link. The unit incorporates a DSP-32C digital signal processing system, as well as a 68HC11 microprocessor. The 68HC11 provides simple interfacing to a wide variety of data sources or instruments requiring control and also performs a number of watchdog functions. In long-term operation, the DSP-32C system is powered down; the 68HC11 detects incoming acoustic data packets or an instrument requiring data transmission and wakes up the DSP. This allows long-term remote deployments and reasonable data transfer efficiency. The processing power drain for the DSP is 1 - 3 watts, largely dependent on the amount of fast RAM required by the system.

The ATM-850 is packaged identically to the ATM-840, but because of its increased power requirements and intended application on underwater vehicles and surface buoys, power supplies are external. This results in a compact 4-inch OD by 8-inch cylindrical instrument interfaced to an external transducer. The module consists of an analog input board with an A/D converter, an analog output board with a D/A interface and power amplifier, and DSP processing components. A single DSP-32C is capable of performing up to 25 million floating operations per second at its full rate of 50 MHz. In practice, the slowest clock speed that will allow the desired set of processing algorithms to be implemented is selected. This keeps receiver power consumption at a minimum. Programmable read-only memory contains the software for the receiver, and storage for raw data and intermediate results is provided by fast static RAM. Because long-term deployments usually operate on a low duty cycle, provision was made for powering down the processor when it is not actively receiving or transmitting data. This makes for efficient operation under circumstances where the system is operating intermittently.

The ATM-850 implements a front-end FFT demodulator, aided by a maximum likelihood equalizer and synchronizer. The input data is processed to extract the synchronization data, and this is used by the synchronizer to determine optimal data frame boundaries. This information enables the FFT demodulator to be properly aligned on the incoming frames and to recover the incoming tones representing the digital data. The synchronization sequence also minimizes the resultant equalizer workload. The equalized FFT output is used by a soft-decision Viterbi decoder which greatly reduces data transmission errors.

Operating in a 'Sleep Mode'

Both the ATM-840 and the ATM-850 are equipped with extremely low power command feedback systems which allow the modems to operate in a sleep mode between telemetry operations. One use of this feature is to poll a remote unit which is in sleep mode. The poll includes a system wakeup ID, which, if it is recognized by the modem, powers the microprocessor and initiates a transmission sequence. This allows a number of remote units to be controlled by a single master station and allows each remote to conserve battery power.

The heart of the acoustic modems is the real-time software. The units were designed with future performance and application upgrades in mind. For example, the DSP-32C processors can be connected in a serial pipeline if several processor cards are included in the receiver. This allows augmenting the processing capability for future higher data rate applications or more computationally intensive software components.

On a system level, a local area network (LAN) protocol is under development. The LAN will allow real-time access to and data telemetry from any of a number of instruments deployed within a few kilometers of a hard-wired or satellite link. The central receiver, implemented with an ATM-850 system, has interfaces for a number of satellite systems, such as Argos and Geostar. This software package is targeted at efficient real time data telemetry from large numbers of ocean bottom sensors to the laboratory.

Planned Applications

The ATM-840 acoustic telemetry modem, with 1,200 baud transmitter and 300 bits per second command receiver, should find a wide range of applications for remote recovery of data from subsea instruments where the total data transfer requirements are not too demanding. This would include data acquisition from current meters, tide gauges, and other instruments where periodic samples of several hundred bits per sample need to be reliably transmitted to a surface buoy, platform or other gathering location.

This system is currently under evaluation by the University of New Hampshire for use in a project to monitor an offshore dumping site for the U.S. Army Corps of Engineers. In this case, several subsea modems are to be connected with sea bed monitoring instruments located around a site which is about 3 kilometers x 3 kilometers. A centrally located buoy contains the surface acoustic modem which is interfaced with a packet radio RF telemetry link to a shore laboratory. The subsea instruments can report data on a programmed, or unpolled basis, or can be addressed on command from the shore laboratory. In this application, data will be acoustically transmitted at a 300 baud rate.

Several experiments have been planned utilizing the DSP-based ATM-850. An experiment planned for deployment in the fall of 1990 off the coast of California involves the use of two acoustic telemetry systems to transfer data from bottom current sensors to a pair of surface buoys with line of sight telemetry links. In this experiment, high frequency current fluctuations measured near the bottom are relayed at 1,200 baud to a shore based operator. Because the current fluctuations are of most interest during storms, the sytem is being designed to operate during heavy seas and high winds.

Another planned application will utilize two DSP-based modems to transfer data and downlink commands from a SOFAR moored listening station to a surface buoy 500 meters above it. In this application, data requests will be initiated by the surface buoy controller and the instrument at 500 meters.

An application presently under discussion involves interfacing an internally recording CTD to a 1,200-baud, low power ATM-840 equipped with a highly directional transmit transducer. This system will be designed to collect and transmit CTD data continuously at 1,200 baud. Reception will be at the surface using a directional receive hydrophone and an acoustic receiver interfaced to shipboard computers. The critical design problem in this application is to obtain 6,000-meter range while extracting only 10 watts from the CTD's onboard power supply.

The acoustic telemetry modems undergoing development by engineers at Woods Hole Oceanographic Institution and Datasonics, Inc. represent a significant breakthrough in the art of underwater acoustic data telemetry. Acoustic telemetry has previously been restricted to data rates generally below 100 bits per second, especially in a shallow water high multipath environment. The new telemetry modems allow the use of a transparent medium for transfer of data between underwater locations. The technology will allow periodic acquisition of data from deployed instruments, control and communication with autonomous underwater vehicles, and in general will offer the means for remote command, control and communication between two underwater locations.

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Funding was provided by the Office of Naval Research under Contract N00014-86-K-0751.

Published in Sea Technology, pp. 10-15, May 1990.

HIGH DATA RATE ACOUSTIC TELEMETRY FOR MOVING ROVS IN A FADING MULTIPATH SHALLOW WATER ENVIRONMENT

Josko A. Catipovic and Lee E. Freitag

Abstract

A compact telemetry system for digital data telemetry at rates up to 10 kbits/sec over 1 to 10 km is presented. The system is designed for worst case ocean acoustic channel conditions, and operates in the presence of source/receiver motion, fading and multipath. In addition, the system incorporates spatial diversity by utilizing multiple hydrophones and data processing subsystems. This allows much more reliable operation under realistic circumstances where noise events and transducer masking are unavoidable. The result is a system specifically geared toward use at sea with an ROV. Preliminary dockside test results are presented to demonstrate the effectiveness of this multichannel system.

Funding was provided by the Office of Naval Research under Contract N00014-86-K-0751.

Published in: IEEE Proceedings, Sixth Annual ROV Conference, June 1990.

PERFORMANCE LIMITATIONS IN UNDERWATER ACOUSTIC TELEMETRY

Josko A. Catipovic

Abstract

This work addresses current performance limitations in digital underwater acoustic telemetry. Recent increases in computational capabilities have led to a number of complex but practical solutions aimed at increasing the reliability of acoustic data links. These solutions span the problem from the ocean-basin scale data telemetry to video image transmission at a few hundred yards' range. A common fact is the opportunity to implement highly complex tasks in real time on modest hardware. The data rates range from 1 to 500 kb/s and are much slower than, say, satellite channels, while acceptable system complexity is higher than virtually any other channel with comparable data throughput.

The basic performance bounds are currently the channel phase stability, available bandwidth, and the channel impulse response fluctuation rate. Phase stability is of particular concern for long-range telemetry, channel fluctuation characteristics drive equalizer, and synchronizer design, and the bandwidth limitation is a direct constraint on data rate for a given signaling method.

Funding was provided by the Office of Naval Research under Contract N00014-86-K-0751.

Published in IEEE Journal of Oceanic Engineering, Vol. 15, No. 3, July 1990.

SPATIAL DIVERSITY PROCESSING FOR UNDERWATER ACOUSTIC TELEMETRY

Josko A. Catipovic and Lee E. Freitag

Abstract

A large increase in the reliability of shipboard or stationary underwater acoustic telemetry systems is achievable by using spatially distributed receivers with aperture sizes from 0.35 to 20m. Output from each receiver is assigned a quality measure based on the estimated error rate, and the data, weighted by the quality measure, is combined and decoded. The quality measure is derived from a Viterbi error-correction decoder operating on each receiver and is shown to perform reliably in a variety of non-Gaussian noise and jamming environments and reduce to the traditional optimal diversity system in a Gaussian environment. The dynamics of the quality estimator allow operation in the presence of high-power impulsive interference by exploiting the signal and noise differential travel times to individual sensors.

The spatial coherence structure of the shallow-water acoustic channel shows relatively low signal coherence at separations as short as 0.35 m. Increasing receiver spacing beyond 5 m offers additional benefits in the presence of impulsive noise and larger scale inhomogeneities in the acoustic field.

A number of data transmission experiments were carried out in Woods Hole Harbor to demonstrate system performance in realistic underwater environments where the acoustic telemetry system is expected to operate. Diversity combining, even with only two receivers, can lower uncoded error rates by up to several orders of magnitude while providing immunity to transducer jamming or failure. The performance improvement is achieved at no increase in bandwidth or transmitted power.

Funding was provided by the Office of Naval Research under Contract N00014-86-K-0751.

Published in IEEE Journal of Oceanic Engineering, Vol. 16, No. 1, January 1991.

SPECIFICATIONS AND APPLICATIONS FOR AN ADVANCED ACOUSTIC TELEMETRY SYSTEM

Josko Catipovic and Daniel E. Frye,
Woods Hole Oceanographic Institution
David Porta, Datasonics, Inc.

Abstract

An acoustic telemetry system capable of reliable operation at data rates up to 5,000 bits per second has been developed at the Woods Hole Oceanographic Institution and is being produced by Datasonics, Inc. of Cataumet, Massachusetts. This paper describes the telemetry system, summarizes results of recent at-sea tests, and discusses several upcoming operational applications of the equipment.

The telemetry technique makes use of MFSK acoustic data transmission where many tones are transmitted simultaneously and modulation and demodulation are done digitally with FFT's. Receiver software has been implemented on a digital signal processing chip, the AT&T DSP-32C.

Tests of prototype hardware have been performed in shallow water over path lengths of 800 to 2500 meters with baud rates up to 5000 bits per second. Vertical transmission tests in depths to 3000 meters have also been performed using low power transmitters operating at 600 to 1200 bits per second. Tests have been performed for both coded and uncoded data and acceptably low error rates have been achieved. Several upcoming deployments of the advanced acoustic telemetry system are described including a deep water moored array application, a bottom to surface link in shallow water, and a profiling application.

Funding was provided by the Office of Naval Research under Contract N00014-86-K-0751.

Published in Oceanology International Proceedings, Brighton, England, March 1990.

ALGORITHMS FOR JOINT CHANNEL ESTIMATION AND DATA RECOVERY - APPLICATION TO EQUALIZATION IN UNDERWATER COMMUNICATIONS

Meir Feder and Josko Catipovic

Abstract

One of the main obstacles to reliable underwater acoustic communications is the relatively complex and unstable behavior of the ocean channel. The channel equalization method, that one can estimate and track this complex and rapidly varying ocean response, may lead to reliable data communications at high rates which utilize fully the available bandwidth. Unfortunately, standardized equalization techniques fail in this environment. In this paper we derive methods for joint ocean-channel estimation and data recovery, using optimal, Maximum Likelihood (ML) estimation criterion. The resulting ML problems may be complex; thus we will use iterative algorithms; e.g., the Expectation - Maximization (EM) algorithm. The different methods correspond to different assumptions about the ocean channel. The theoretical derivation of these methods as well as preliminary results on simulated ocean data experiments are presented.

Funded in part by the Office of Naval Research under contract Number N00014-86-K-0751.

Published in IEEE Journal of Oceanic Engineering, Vol. 16, No. 1, January 1991.

A LONG-TERM, DEEP WATER ACOUSTIC TELEMETRY EXPERIMENT

Lee Freitag, Steve Merriam, Dan Frye and Josko Catipovic

Abstract

Between April and November of 1990 an acoustic telemetry system was deployed on a surface mooring twelve miles south of Bermuda in approximately 3000 meters of water. The purpose of the experiment was to perform a long-term test of a low-power data link which can be used to collect data from a number of subsurface instruments, forward it acoustically to a surface buoy and then via satellite to shore. Data was transmitted to the surface buoy at 600 bits per second from acoustic modems placed on the mooring cable at 300, 1500 and 2900 meters below the surface. The modems were equipped with command receivers and were polled by the surface unit several times per hour with a request for data. They were also programmed to transmit data in response to an internal interrupt once each hour. The received information was processed at the surface by a compact, low-power DSP-based receiver, then passed to an oceanographic instrumentation computer for processing and forwarding to shore using the ARGOS data collection system. Operation of the telemetry system was monitored remotely in near real-time over the course of the experiment. The modem at 1500 meters provided data for six months, the entire period the mooring was in place. Twenty million bits were received from this unit, at an average bit error rate of $1.45\text{x}10^{-3}$ for the 180 day experiment.

The system as deployed is discussed in detail and performance results are presented. Additional work on the system which has resulted in improvements in reliability and data rate are also presented.

Funding was provided by the Office of Naval Research, under Contract N00014-86-K-0751.

To be published in Proceedings, Oceans 91, Hawaii, October, 1991.