AUTONOMOUS BUOYED ENVIRONMENTAL MEASUREMENT SYSTEM (ABES)

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LONG-TERM GOALS

Under joint sponsorship of ONR-321SS and ONR-322PO, ABES is developing a low-cost oceanographic sensor system which will gather current, conductivity, pressure, temperature and tide data on a vertical array for a period of days to weeks before releasing a buoy which will broadcast the data via RF telemetry to a receiver.

The intent of this device is to provide to the oceanographic community a low-cost system of sensors that affordably yields dense spatial sampling for shallow (depth < 200 m) applications. The system would not replace existing high-resolution oceanographic instrumentation, but fill the niche for a low-cost, lower-resolution system that would provide the end user with the ability to achieve higher spatial sampling. For maritime forces that must be prepared to deploy on short notice and operate in unfamiliar coastal waters, the system would be capable of providing near real-time environmental support, particularly in oceanographically complex littoral settings.

OBJECTIVES

The objective of this two-year project is to provide a prototype system that demonstrates approximately 13 temperature and conductivity sensors spanning 100 m in a vertical array. Data will be time-division multiplexed up to solid-state memory in a buoy, submerged until the data collection phase is complete. The buoy will then separate from the array, rise to the surface, and transfer data via RF. This prototype will serve as the backbone configuration that demonstrates a novel time division digital electrical multiplexing data collection technique that uses one low-cost (8 dollars) analog-to-digital converter per sensor.

APPROACH

Our hypothesis is that an array of lightweight expendable COTS sensors that utilize proven time division electrical multiplexing can provide a robust, affordable data collection apparatus for environmental sensing.

The prototype system will demonstrate approximately 13 temperature and conductivity sensors spanning 100 m in a vertical array. Data will be time-division multiplexed up to CMOS memory in a buoy, submerged until the data collection phase is complete. The buoy will then separate from the array, rise to the surface, and transfer data via RF. This prototype will serve as the backbone configuration and demonstrate the time division electrical multiplexing data collection technique. Other sensors can then be added as COTS refinements progress. The system will allow any variety of low-bandwidth (e.g., less than 100 Hz sampling frequency) sensors to input their output into the array backbone. Sensor electronics (e.g., preamplification, multiplexing, D/A) and mechanical issues (configuration, packaging, and sensor encapsulation) will be investigated on a case-by-case basis.

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Some characteristics of the design include:

(1) ABES does not rely on a buoy with surface expression.

(2) Two-wire time division digital multiplexing.

(3) Cost in production around two thousand dollars per unit.

(4) Spread spectrum RF LAN data relay architecture allows monitoring using a COTS RF modem in any PC located at the base station, or on the Internet. Data is also stored in flash memory in the buoy and can be retrieved if full EMCON is desired.

(5) User-selectable sensor suite of up to 20 sensors.

TASKS COMPLETED

The Autonomous Buoyed Environmental Measurement System is a two-year project that started 1 Jan 96. At the start of FY97, work had been in progress for 9 months. This report summarizes accomplishments between months 10 to 22, after sensors had been selected and some breadboarded.

During the second year, the sensors began transitioning to through-hole and surface-mount electronics packages that will be serially multiplexed in a prototype underwater system, with incremental testing en route toward a final system prototype demonstration in the ocean.

During a 21 Mar 97 bench test, an experimental conductivity sensor immersed in a beaker of seawater gathered water conductivity data under the control of the buoy processor, which stored the data and then relayed it over the RF link to the receiver connected to a standard laptop, which displayed the gathered data.

A preliminary ABES bench demo was conducted on 25 Mar 97. The demo included three sensors (miniaturized electromagnetic current sensor, tiltmeter, and depth sensor).

A Motorola Oncore GPS chipset was added to the instrument suite in the ABES buoy to add location information to the data stream in the event that the buoy needs to be recovered.

Two ABES strings will provide water-column measurements pertinent to underwater acoustics during the TTCP Rapidly Deployable Systems Experiment in the Timor Sea in October 98.

Sensor specifics

The ABES sensor list as of September 1997 includes 3 CTD (conductivity, temperature, pressure) modules, 5 temperature sensors, 1 tide height sensor, 1 tilt sensor, 1 current meter, and 1 accelerometer. With the advent of DC (direct current) response accelerometers, one of these may double as a tilt indicator. An optional acoustic ambient noise sensor is treated theoretically, but will not be implemented in hardware in the prototype.

(A) Pressure sensor

In the ABES prototype, pressure sensors will be incorporated as depth sensors at the seafloor and at the submerged buoy. We have breadboarded the IC Sensors model 1431 pressure sensor and verified through laboratory testing that it is suitable for the task. This sensor has a range of 0-2 MPa (a depth rating of about 300 m), good linearity, accepts potting well, 1 kPa accuracy, 70 Pa sensitivity, is consistent with 12 bit digitization, and costs about 20 dollars.

(B) Thermistor

Several thermistors throughout the water column would provide a temperature profile. The technology here is straightforward and has been demonstrated previously. A thermistor is included in each CTD module.

(C) Electromagnetic flowmeter

Building on an NRaD-patented design, testing is underway to determine if a coil-type electromagnetic flowmeter could be incorporated in the ABES anchor. This would require the measurement of extremely low voltage levels induced in coils of copper wire surrounding a pair of silver electrodes. Water current and direction could be obtained by installing this electromagnetic instrument in line or on the anchor without resorting to moving components. Several sensors distributed throughout the vertical array, together with the compass described below, would provide a water current profile to compare against the integrated current measurement derived from the tilt of the array.

(D) Tiltmeter

Modern solid-state accelerometers available from IC Sensors and Analog Devices, Inc. have DC response that allows them to be used as tilt sensors. These sensors have sine and cosine outputs that facilitate true tilt measurement and are inexpensive (about 10 dollars). Fluid-filled electrolytic tilt sensors made by The Frederics Co. and Spectrum, Inc. are other alternatives, but tend to cost more and require pressure protection for in-water use. Previous operational work in Arctic arrays has relied on the use of tilt measurements of vertical strings to verify acoustic element localization (active acoustic) schemes for pinpointing receiver elements. In these vertical arrays, a tiltmeter measures tilt at the bottom of the array. An averaged current through the water column is calculated based on the hydrodynamic characteristics of the array system.

Depending on the accuracy required, one may desire to populate the field with several electromagnetic flowmeters to determine necessary parameters. We have mathematically modeled the signal available for hypothetical array profiles at a range of current speeds.

(E) Compass

Located in each electromagnetic current meter package or with the tilt sensor, a compass would measure the current direction with respect to magnetic north. Three magnetometers would be used, two to measure the two horizontal components of the Earth's magnetic field, and one to correct for dip.

We have chosen a state-of-the-art magnetoresistive magnetometer for the compass in ABES, the Honeywell HMC1022. This two-axis device can easily sense the azimuth and dip of the Earth's magnetic field. It is a 3-V device, available in 16-pin small outline integrated circuit (SOIC) form factor. Cost is $4. Output is a differential voltage proportional to magnetic field strength. It is used in navigation and attitude reference systems in spacecraft. The range and resolution are far beyond adequate for underwater array orientation. This compass requires a reset current pulse to be provided occasionally, which requires some power penalty.

(F) Four-electrode conductivity cell

This sensor provides measurement of water conductivity, from which salinity is inferred knowing temperature and depth. This could be one or several sensors distributed through the water column. The output of one sensor would be monitored continuously during the initial descent to provide a profile. Afterward, a time series would be collected at a fixed depth. For the initial prototype, the CTD sensor will measure in static mode.

Three Ocean Sensors Inc. (San Diego, CA) conductivity, temperature, and depth modules will be used. These innovative sensors are included as an outcome of a Cooperative Research and Development Agreement (CRADA) between Ocean Sensors, Inc. and NRaD. They feature a range from 0.1 mS/cm to 100 mS/cm with a sensitivity of 0.05 mS/cm. They required 5 mA at 5 V during their measurement period, with 0.5 second warm-up time. The OS CTD sensor has been implemented in through-hole printed circuit card format, potted, and tested in the laboratory.

RF subsystem

The RF subsystem will use spread-spectrum wireless data transceivers that operate in the 902-928 MHz band. The subsystem is divided into two parts: (1) the buoy-mounted transceiver and (2) the base station. The base station could be land-based or located aboard a vessel or aircraft. Freewave Technologies DGR-115 series transceivers will be used. These have a small footprint (OEM board size is 62 mm by 129 mm), 19.2 kbaud transfer rate and low power requirements (180 mA at 12 V in transmit, output power 0.3 W). The cost of a transceiver is about 700 dollars.

Sensor Microcontrollers

Each ABES sensor will have associated with it a microcontroller, (Microchip, Inc. PC16C74), and a hardwire transceiver. This microcontroller will be the interface between the sensor analog-to-digital converter and the buoy-based microprocessor. The target controllers cost about 11 dollars and operate on 50 µA at 3 V. They are digitally addressed by the buoy-based microprocessor and respond by putting a digital voltage value on the data line. Each microcontroller has an associated 32 kHz crystal clock that provides timing to the sensor analog-to-digital converter. The 32 kHz clock for the microcontroller will be provided by a Harris HA7210 oscillator circuit.

System Microprocessor

The buoy-based microprocessor and memory is based on the combination of an Onset Model-8 Tattletale computer and a Persistor Flash Card. The system microprocessor will accept mission configuration parameters (e.g., which sensors will be sampled and when, at what rates, for how long, and when the anchor should break away). It will also accept calibration, through a graphical user interface (GUI), from the topside interface computer in the form of look-up tables to compensate for sensor transfer function nonlinearities. The system microprocessor can also perform auxiliary functions, e.g., averaging, conversions, or computing integrated current speed and direction from various sensor outputs.

The present topside interface computer is a SHARP PC-8900 laptop. This computer will allow the user to display the output of the sensors, and modify calibration coefficients, sampling rates, and sleep cycles.

GPS (Global Positioning System) Receiver

Once the ABES buoy reaches the sea surface at the end of its mission, it is desirable to be able to locate the buoy for recovery. A Motorola 8-channel GPS receiver mounted on a printed circuit card is housed in the buoy to provide positioning information as part of the broadcast data. The GPS receiver is only activated by the microprocessor upon anchor release, because this module consumes a hefty 1 W. Software written for the Onset Model 8 microcontroller allows the GPS serial data stream to be merged with the recorded sensor data and then broadcast as part of the RF feed.

Riser Cable

Three Surlyn-coated 28 AWG copper stranded electrical wires (power, ground, and signal) sewn together with a Tex 210 4-strand Kevlar thread strength member comprise the riser cable. This cable has an overall outside diameter of about 2 mm and a measured breaking strength of 10 N. The weight per 100 m is 4.5 N in air and 1.5 N in water. Resistance per 100 m is 20 Ohms. The riser has excellent hockle resistance when packaged in a random layup inside the deployment container.

IMPACT FOR SCIENCE and TRANSITION OPPORTUNITIES

Possible long-term applications for the outcome of this work are numerous, including monitoring of sewage outfalls, river estuaries, power plant discharge, mine reconnaissance and pre-surveillance for amphibious operations. There is commercial applicability as an alternative to the expensive and relatively cumbersome Norwegian Sea Watch system now being marketed to American customers.

The transition potential is to an expendable, inexpensive sensor suite that would be covertly installed at several candidate sites approximately one week prior to the deployment of a surveillance system.

In a fleet system, the instruments would collect environmental data and provide this information to the mission planners prior to array deployment, facilitating optimized placement of the surveillance system.

NATO SACLANT's METOC Office selected a suite of ABES arrays to use in "Rapid Response 98", the environmental support arm of NATO’s "Strong Resolve 98" maritime exercise. Two ABES arrays will be deployed during the exercise in Spring 98 to obtain in-situ data for NATO amphibious forces conducting simulated landings on a hostile beach.

Dr. Edward C. Whitman, Technical Director, Oceanographer of the Navy (N096T) indicated that there is an immediate need for a system like ABES to support NATO exercises (Rapid Response 98, Strong Resolve 98). CAPT Tom Pearson, SACLANT, is the point of contact for this possible transition path.

Small Business Technology Transfer (STTR) Topics were submitted to ONR 321 and forwarded as part of a higher-level package in July 96. There are three general areas that could benefit from technology transfer via an STTR. These could possibly be blended into one STTR, with technology transfer partners Ocean Sensors, Inc., Sparta, Inc., Scripps Institution of Oceanography Coastal Studies Center, and NRaD. Other partners that might be able to capitalize on the technology are Spartan and Sippican.

RELATED PROJECTS

XMOOR, PI Dr. Janice Boyd, NRLSSC

Autonomous Sensors Concepts RJ14K83, PI Mr. Gary Davis, NRaD

Pending or existing SBIRs pertinent to environmental monitoring systems, including:

(1) An "A" size buoyancy driven sampling package with STD sensors, GPS, and digital radio data transfer. (Kim McCoy from Ocean Sensors and Jim McEachern of NAWC). This is a derivative of the OS200 APV [McCoy, K., "Autonomous Profiling Vehicles", Sea Technology, Feb 96, 15-18];

(2) "Air-Deployable Expendable Multiparameter Environmental Probe". (T. Castaldi from Navmar Applied Sci Corp and Jim McEachern, NAWC).

(3) "Microsensors for Tactical Meteorology and Oceanography".

PUBLICATIONS and PATENTS

After one round of resubmission, the US Patent Office accepted all 14 claims under Navy Case Number 77247, a patent application entitled "A Buoyed Sensor Array Communication System", J. R. Olson, J. M. Stevenson, and B. J. Sotirin, that was filed May 96.

STATISTICAL INFORMATION

There are three students from San Diego State Univ. working on this project. One of them is a woman.

A 24-thousand-dollar contract to Scripps Institution of Oceanography was executed during FY 97.