The Acoustic Oceanographic Buoy Telemetry System

An 'advanced' sonobuoy that meets acoustic rapid environmental assessment requirements

{A. Silva, F. Zabel, C. Martins}

In the past few years Rapid Environmental Assessment (REA), applied to shallow waters, has become one of the most challenging topics in ocean acoustics. The REA concept evolved after the cold war when the outset of regional conflicts shifted the potential operational areas from open ocean towards littoral areas, and has been identified by NATO as a new warfare requirement. REA must provide detailed and accurate information, in near real time, in order to prepare the maritime forces deployment into highly variable coastal waters that are not well known. More recently REA has become a promising technique for civil and scientific environment monitoring. Such an interest arises because the coastal transition zone is a region of significant fishing effort and of intense ship traffic. The rapid knowledge of the dynamics and structure of coastal zones would assume strong importance in the case of natural or man made hazards. Because of the short time required for REA applications, the main topics of REA have been identified as rapid data collection, data synthesis and assessment, and dissemination of assessed products to action groups [1].

In the context of REA, the data synthesis and assessment requires the use of dynamic models for nowcast and forecast [2] that are fed with data acquired by the recording equipment. Data collection can be attained by using space/airborne sensors e.g. for marine wind, large scale currents and shallow water bathymetry; traditional oceanographic sensors like CTDs, wave height and ADCPs; passive and/or active acoustic e.g. for submarine localization, mine detection, tomography and bottom inversion. Acoustic means also provide the necessary framework for a fast and easy deployment of an underwater communication network where the underwater nodes (e.g.: oceanographic sensors, autonomous underwater vehicles, benthic labs, telemetry buoys) communicate with each other by using acoustic modems and consequently no cables are required. The use of acoustic equipment is usually termed as Acoustic REA (AREA), it provides an unmanned and inexpensive manner of doing high-resolution surveys, and allows for remote data collection in a large area.

Currently one of the most promising AREA concepts is the use of a field of air-dropped 'advanced' sonobuoys, as an interface between an underwater wireless Acoustic Network (AcN), and an air Radio Network (RaN). The underwater AcN nodes are responsible for data collection. The air RaN nodes (satellites, aircrafts, vessels ...) are responsible for the raw data storage and relay over local or world distributed data processing groups, for near real-time data synthesis and assessment. The 'advanced' sonobuoy field is responsible for the upload (from the AcN to the air RaN) of the acquired data; and for the download (from air RaN to the underwater AcN) of control and operation instructions. The 'advanced' sonobuoy field integrates simultaneously the air RaN and the underwater AcN, and that results in a single seamless network. Moreover, the 'advanced' sonobuoys can be used as an intermediate step for acquired data pre-processing and data fusion, through which data reduction can be attained. Such data reduction implies shorter data uploading, an important requisite for REA operations in a hostile area where the long time presence of air RaN nodes can compromise the mission success. Hostile area operations suggest that the 'advanced' sonobuoy field must integrate a network where nodes can be added or suppressed at any time, performing reduced operations even with a single 'advanced' sonobuoy.

The Acoustic Oceanographic Buoy (AOB) telemetry system wants to meet the 'advanced' sonobuoy characteristics. It integrates the air RaN by using a standard 'IEEE 802.11' WLAN configuration, and the underwater AcN by using a hydrophone array and an acoustic source. The first AOB prototype was tested during the Maritime Rapid Environmental Assessment sea trials in 2003 [3], and in 2004 [4]. The present version of the AOB was tested, from 15th of September to 2nd of October 2005, during the MakaiEx sea trial off Kauai Island, Hawaii, USA, in the context of the High Frequency Initiative promoted by HLS Research Inc, San Diego, USA.

In the following, the AOB design will be described, the main system features will be addressed, the MakayEx AOB engineering test will be presented and future developments will be pointed out.

System design

The physical characteristics of the AOB, in terms of height (1.2m), diameter (16cm), weight (40kg) and autonomy (12 hours) tend to those of a standard sonobuoy. However, the AOB presents advanced capabilities, which include: stand-alone or network operation; local data storage; dedicated signal-processing; GPS timing and localization; real-time data transmission and relaying. In this section the AOB hardware and software is briefly presented and the main characteristics of the 'base station', an air RaN node, will be given.

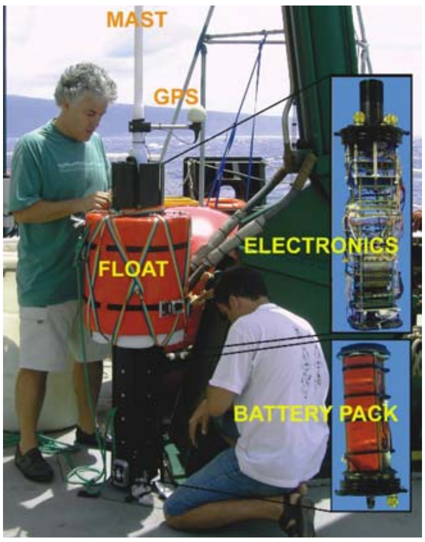

Figure 1: “AOB pre-deployment set-up, during Makai Ex. sea trial”

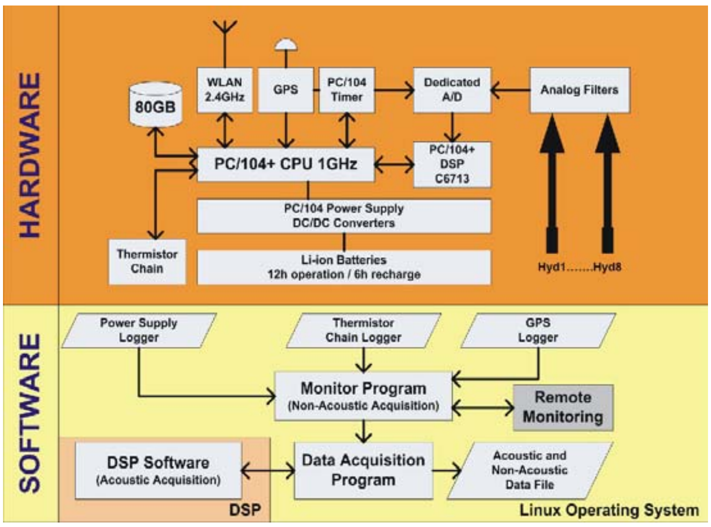

Figure 2: “AOB overview”

The hardware system is contained within a PC/104 computer/electronics stack with standard purchased and inhouse developed boards. The core is a fan-less CPU board which takes care of all the system management. A 120 Gbytes hard drive allows for *in situ* data storage. Due to its standard WLAN transceiver the AOB is easily integrable with other similar systems to form a flexible network, and to perform online high speed data transmissions. A GPS receiver is responsible for timing and positioning information. An external data logger with 16 thermistors is responsible for the water column temperature sampling. The acoustic data acquisition system includes 8 hydrophones, 42dB pre-amplifiers, 15kHz anti-aliasing filters, signal conditioning circuitry and a dedicated acquisition board. A real time GPS synchronized timer provides the acquisition board with an accurate clock sampling signal and absolute time marking, a must for tomographic applications. The TMS320C6713 DSP board gives the AOB strong signal processing capabilities that allow for *in situ* data processing tasks.

All software applications were specifically developed for the AOB which runs the Linux operating system. The software is divided into various modules each running independently. Modules include: GPS position logging; power supply control and monitoring; thermistors chain non-acoustic data acquisition; real-time remote monitoring; and the main acoustic data acquisition program which configures acquisition and stores data on the local disk. The modules exchange information through the use of TCP/IP network sockets which also allows real-time remote monitoring of buoy position and acquired data.

The 'base station' that monitors the AOBs and manages the AOB WLAN network is portable and is comprised of a notebook and one external antenna, allowing for a reliable connection up to 10 km. The user is presented with a visual output of the 'base station' and AOB trajectories on-top of a bathymetric map, the state of the various equipments inside the buoy and the display of acquired signals. When deployed, operation requirements can be remotely modified, changes can be performed at any time and include parameters such as data acquisition rate, begin and end time for each acquisition cycle, and other options.

AOB main features

The AOB is a reusable system with reduced maintenance. Aboard, only two maintenance operations have to be performed: recharging batteries and downloading acquired data. Both are done by simply unplugging one connector, and plugging two connectors: one for recharging the batteries, and the other for external power supply and a fast ethernet link. The AOB is light enough in order to be deployed by hand from a ship, and robust enough to be deployed by air from an aircraft or to operate under rough sea conditions. At sea, the AOB is a salt-water-plug and play system designed to operate in free drifting mode, self time synchronized and locatable with great precision at all times.

Due to its DSP facility, the AOB is suitable for performing distributed digital signal processing tasks. When used in Matched Field Tomography (MFT), in the frequency domain, the AOB can pre-process the acoustic data. This can be performed by computing Fourier transforms of the acquired raw data, compute cross-covariance matrices estimates, and then just send to the base station the data concerning the frequencies of interest for posterior MFT operation. Such a distributed processing technique is advantageous when the propagated signals are either broadband or tones, in particular for the latter since only few frequency bins contain useful information. When used in non-coherent underwater acoustic data communications the DSP processing capabilities allow for the implementation of a full demodulation system. It is also suitable for the implementation of simple array processing passive localization algorithms.

Engineering test

The first engineering test of the present AOB version, in its stand-alone mode, took place during the MakaiEx sea trial [4]. Three deployments were initially planed but six were done since it was realized that the AOB was an easy system to deploy and recover. The AOB was in a free drifting configuration during five of the deploys; remote monitoring of the buoy was useful to know the status in terms of positioning, and battery supply. There was one deployment where the AOB was tethered to the ship. This was not the initial planned setup and the rough sea conditions at the time showed that the AOB construction was robust and functional even when under strain. During the MakaiEx the AOB participated in a wide spectrum of scientific experiments. In the first five deploys, 8-14 kHz acoustic transmissions where acquired with the main objectives of high-resolution tomography and understanding of the acoustic-environment interaction at high frequency and its influence on underwater communications. In the last deploy acoustic transmissions ranging from 500 Hz to 14 kHz where acquired in order to performs field calibration using inversion algorithms at high and low frequency.

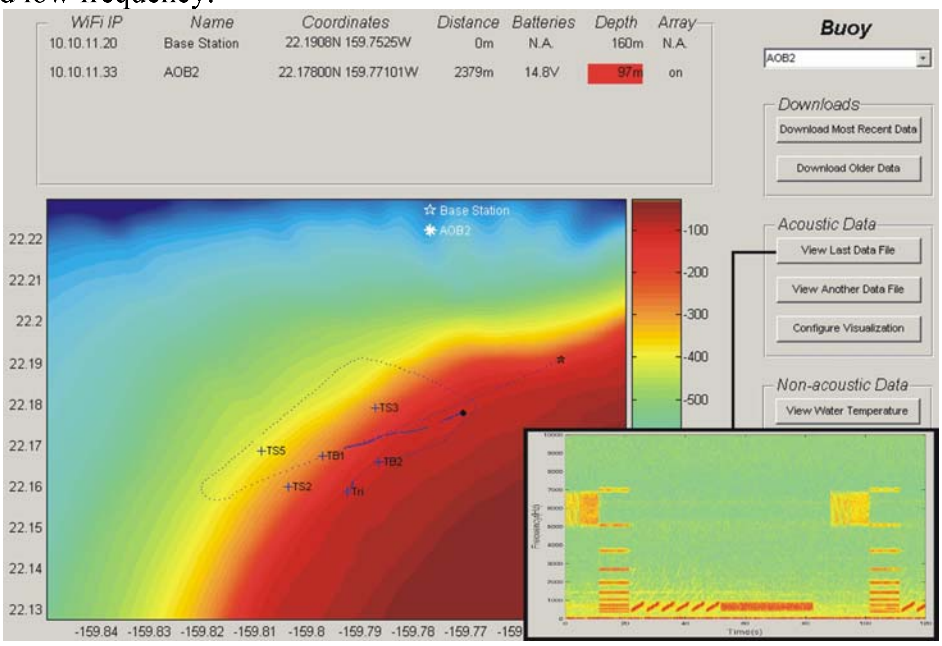

Figure 3: "Base Station monitor interface, with received acoustic data during the Makai Ex. sea trial"

Future developments

The AOB is now fully operational in its stand-alone mode, and the developing team is looking to future developments. A current project is the replacement of the sensor array by a robust and light array with 16 hydrophones, thermistors, pressure and other user defined sensors; and an acoustic source for control/communication operations over the underwater nodes.

An AOB network-mode engineering test, with 3 AOBs, is now under preparation and is scheduled to take place in October 2006. After that, as well as supporting the University of Algarve Signal Processing Laboratory (SiPLAB) research activities, the AOB's will be operated as a service to the international underwater research community.

Acknowledgements

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