An autonomous system for ocean acoustic tomography

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1. Introduction.

Vertical line arrays (VLA) are a widely used apparatus in underwater acoustics with applications in sonar prediction, underwater communications and acoustic tomography , among others. Recent developments in digital electronics and communications allow for "off the shelf" development of VLA systems, with a large number of embedded acoustic and non acoustic sensors able to fulfil application requirements, as opposed to single or few receiver configurations available until only a few years ago. Very often the flexibility in water column sampling is achieved by splitting the VLA into modules that can be assembled according to the application. Such systems can be deployed and recovered from small vessels with a shorthanded crew and makes it possible for research labs with reduced budgets and operational means (ships and manpower) to get control over the whole development process from data acquisition up to the data post-processing. SiPLAB, a signal-processing laboratory located at the University of Algarve, Portugal, has recently acquired such a system to support its research under the INTIMATE project [1]. This system, here below referred to as Ultra Light Vertical Array (ULVA), can be configured with up to 16 hydrophones operating in the band 10 -- 2200 Hz, and various non acoustic sensors such as thermistors, tiltmeters and pressure gauges. In its original configuration the acquired data is transmitted either by cable (near shore applications) or through a high speed radio link to a remote location - usually a research vessel - where it is stored and interfaced to a PC, for monitoring proposes and online processing. SiPLAB has successfully used the ULVA in a shallow water experiment devoted to shallow water acoustic tomography and communications (INTIFANTE'00 [2]). Although, the goals of the experiment were successfully achieved, some system drawbacks were identified during operation. The radio link was found to be the weak part of the system, since the directional antenna requires a fine tunning, often incompatible with ship movement, and interference free reception is only ensured within 2km range from the VLA radio buoy. Also, the power consumption of the transmitter on the array side reduces the system autonomy, which is a strong impairment for making long period ocean observations. This is particularly relevant since the procedure for changing the batteries are strongly sea state dependent and involve a high risk for the personnel and for the equipment.

In order to overcome the observed drawbacks of the ULVA, SiPLAB has decided to transform it into an autonomous acquisition system with local storage facilities, lower power consumption, capability of online remote quality control of the acquired data and positioning information. This new ULVA, named Remote Data Acquisition System (ULVA/RDAS) is based on "open technologies", which are cost effective, allow future upgrade and, offer a relatively easy integration into a tomography network system.

In the next sections, after an overview of the actual ULVA system, the architecture of the new ULVA/RDAS is presented. Follows the evaluation report of the new ULVA/RDAS at sea. Conclusions are drawn in a final remarks section.

2. The ULVA System.

The original ULVA system was developed by Co.l.mar, La Spezia, Italy. It can be deployed and recovered from a small vessel as for example the 30 m long hydrographic research ship used during the engineering test (see section 4). The ULVA system is formed by two main subsystems: a wet end subsystem composed of an array of acoustic and non-acoustic sensors, a telemetry unit and a radio buoy; and a dry end subsystem, on board ship, where data is monitored and recorded. A layout of the ULVA system is presented on figure 1a. Low frequency acoustic signals are acquired by a 16-hydrophone array. The array is also instrumented with a number of non-acoustic sensors: 2 pressure gauges and 2 biaxial tiltmeters for the recovery of the array geometry, and 20 thermistors for the measurement of in situ temperature profiles. The array is split in 3 modules that can be assembled to obtain various configurations. The acquired analogue signals are digitalized in the telemetry unit, multiplexed and sent to the radio buoy. The data stream is sent to the dry end of the system through a radio link operating at 1.28 GHz with a bit rate of 2.5Mb/s. The receiver block at the dry end of the system demodulates the data stream, marks the acoustic data with a synchronization pulse derived from a GPS pulse and makes the data available in a RS422 port to interface to a DAT recorder. The demultiplexed data are also available on a digital interface. A secondary radio link, working in the UHF band, is used to send simple DTMF coded control commands from the dry end to the radio buoy. With these simple commands it is, for instance, possible to switch the array ON and OFF, to control the array gain, etc. SiPLAB has developed a

PC based system (DAMS) that online monitors and stores the data collected from the digital interface [3].

3. The new ULVA/RDAS

The proposed objectives of the ULVA/RDAS were accomplished by introducing an embedded PC based system on the buoy: an "intelligent" system that allows wide stand alone operating capabilities. The acquired data is stored at wet end using industry standard hard disks. The remote data quality control and acquisition system status monitoring is possible by a newly introduced wireless LAN link. The system runs embedded NT (eNT), which is a convenient OS since a scalable kernel can be defined according to the needs, and is a "de facto" standard, so nearly all-peripheral boards can run under this OS. Embedded NT also provides a standard file system support for the disks, and communication facilities like a TCP/IP stack, that allows a high level of portability and upgradability.

a) Hardware

The ULVA/RDAS architecture is depicted in figure 1b. The strategy was to build an alternative radio buoy system, called RDAS buoy, that fulfils the requirements for the new system without intervention on the existing telemetry unit and sensor array. The core of the system is a single board PC with a low-power mobile Pentium 266 processor, as a compromise between performance and power consumption. The single board PC provides an Ethernet connection to interface the wireless LAN, EIDE controllers for the disks, parallel ports to control the power supply system and a USB and serial ports (not used at the moment). The chosen back plane holds PCI and ISA slots to interface to GPS/Timing and digital acquisition cards (DAC). The GPS/Timing card provides GPS information and accurate pulse signals to mark the acquired acoustic data within a microsecond precision, a must for tomographic applications. Two newly developed electronic cards accomplish the interfacing with the existing telemetry unit. Those cards transform the serial bit stream, coded in a biphase-like format received from the telemetry unit, into parallel TTL level signals and respective handshake suitable to the DAC card. The data throughput reached at the maximum sensors configuration required the selection of a DAC with DMA capability to avoid data loss and processor wasting. The acquired data is stored in two low power consumption 30 Gb mobile hard disks with high anti-shock characteristics. The OS and system control codes are installed on a 96 Mb chipdisk, to prevent the use of mechanical parts in this critical sub-system. A new power supply is designed to fulfil the requirements of the different electronic cards. The power supply is based on commercially available DC/DC regulators with a newly introduced switching board that can switch off , remotely or under buoy computer control, individual subsystem as required, thus increasing the system autonomy. The communications between the RDAS buoy and the remote monitor computer are supported by wireless technology, allowing the usage of a TCP/IP stack in a transparent fashion and future easy integration in a network of instruments.

b) Software

The improvement of the ULVA/RDAS against the original ULVA was, in a large scale, reached by introducing an "intelligent" PC architecture into the buoy that runs eNT OS and a customized application that controls the whole system. In fact the application is distributed over the ULVA/RDAS buoy and the remote monitor computer, using a client-server concept and takes advantage of multi-threading, windows messages and other advanced interprocess communication facilities provided by Windows NT. The application at the monitoring computer, using a graphical interface, allows the user to fully parameterize the data acquisition process as for example the time to start acquisition, file names, type of acquisition (continuous or paused) and other parameters. Also, a window with system status information, like ULVA/RDAS buoy localization and array depth is provided. Another important task performed at the monitoring side is the ability to visualize and listen to the data being acquired (figure 2). At the buoy the application acts as a server, controlling the acquisition process, which includes read and store the data, but also switch on/off selected subsystems to minimize power consumption, provide status information and acoustic data to the remote monitoring computer. This part of the application is designed to, after parameterization, be able to control the system in a stand-alone mode, without the need of a communication link established with the monitor computer, performing all the data checking and local hard disk storage. The communication with the monitor computer can be activated at any time by the remote computer. In this way the ULVA/RDAS can be deployed, configured, monitored and than left unattended while the research vessel is free to perform other tasks.

4. At sea test.

An engineering test took place in September 2002 at Espichel Cape, off Lisbon port, in Portugal. The test plan was designed to evaluate the different subsystems (UHF and wireless lan radio links, acquisition modes and monitorization). The wireless hardware was provided by YDI, while using a 12 dBi omnidirectional antenna installed 7 m above sea level, a rate of 11 Mb/s was achieved up to a range of 5 km, whereas at 9 km a link of 1 Mb/s could be obtained (see figure 3). Replacing the omnidirectional antenna with a 24 dBi directional antenna the distances increased to 7 and 15 km for 11 and 1Mb/s, respectively. In both cases the antenna at the buoy was an 8 dBi omnidirectional monopole mounted 2 m above the sea level. The system was left at sea only for a few hours, but an extrapolation based on the measured power consumption could allow us to estimate that the system autonomy in a communication state was at least doubled when compared to the original ULVA. In future operations with the system left standalone in a power saving mode, its autonomy can be increased accordingly. Direct data recording on the buoy allowed us to obtain a much higher data quality than that found in previous radio telemetered data sets.

5. Final remarks

The changes introduced into the original acquisition system, include various important improvements, namely: i) extended time of operation, ii) stand alone operation capabilities, iii) possibility of establishing communications at a longer range and iv) local storage and time stamping of acquired data eliminating noise and data dropouts induced by communication link hazards. These improvements fulfil the requirements for the sea trial to be performed under the ATOMS project during the summer 2004 [4]. One can remark that the new ULVA/RDAS system is based in "open technologies" that allow easy future upgrade and introduction of new functionalities like, for instance, further data reduction using the onboard available processing power. Also in the now world of internetworking this new system could be easily integrated in a network of instruments.

Acknowledgements

The authors acknowledge the support of the Instituto Hidrografico, for at sea facilities aboard the NRP ANDROMEDA research vessel during testing. The ULVA/RDAS system was developed under the ATOMS project (Contract PDCTM/P/MAR/15296/1999) supported by the Science and Technology Foundation, Portuguese Ministry for Science and Higher Education.

References

[1] Internal Tide Measurements with Acoustic Tomography (INTIMATE), 1996-2000, FCT, Portugal, (http://www.ualg.pt/siplab/proj/intimate/intimate.htm)

[2] JESUS S.M., COELHO E., ONOFRE J., PICCO P., SOARES C. and LOPES C., "The INTIFANTE'00 sea trial: preliminary source localization and ocean tomography data analysis", Proc. of MTS/IEEE Oceans 2001, pp 40-45, Hawaii, USA, November.

[3]C.Lopes and C.Soares, ``Data Acquisition and Monitoring System (DAMS)", Rep 01/00-SiPLAB, December, 2000.

[4] Acoustic Tomography System (ATOMS), 2000-2004, FCT, Portugal,

(http://www.ualg.pt/siplab/proj/atoms/atoms.html)

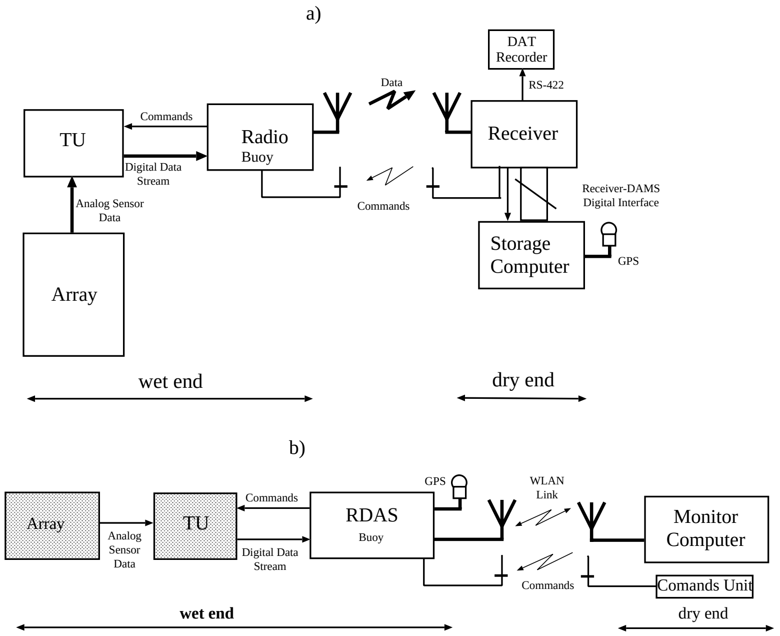

Figure 1: Block schema of the Ultra Light Vertical Array (ULVA) : original layout (a); modified ULVA with the remote data acquisition system (RDAS) (b), original blocks are shadowed.

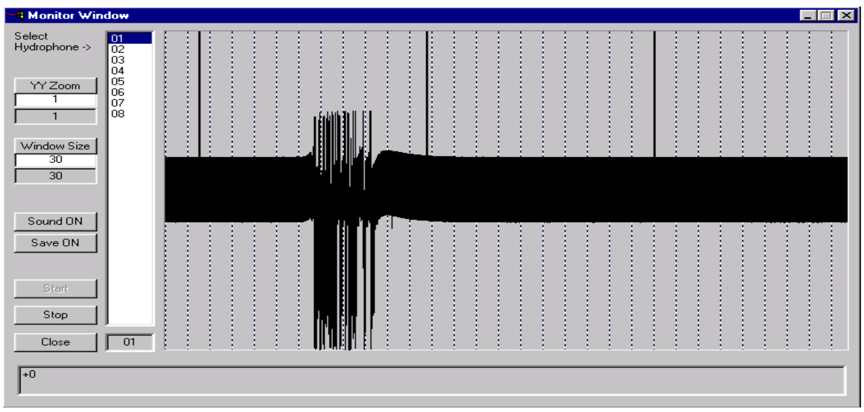

Figure 2: Monitor window to visualize the data being acquired at the remote buoy.

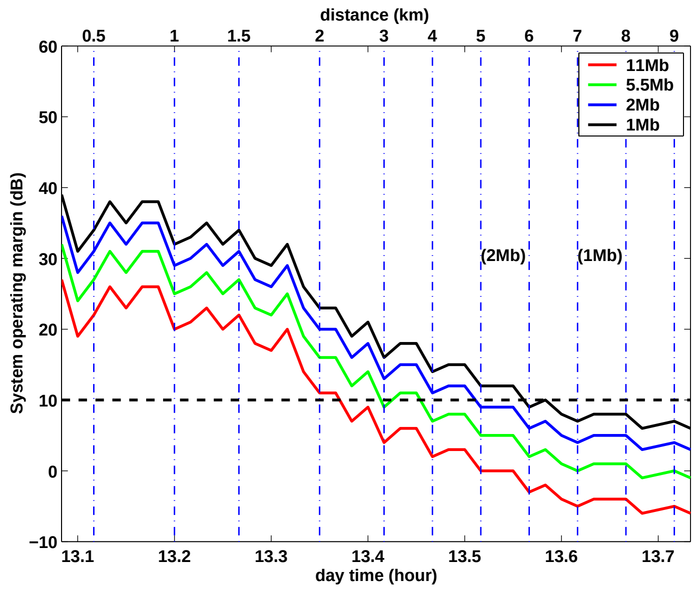

Figure 3: Measured system-operating margin of the wireless communication sub system between buoy and the ship during the sea trial test, with the omnidirectional antenna. Dashed line at 10 dB is the WLAN manufacturer requirements for a "good connection". Values within parenthesis are the real throughputs achieved at given time/distance (only worst case values represented).