Some preliminary finite element modelling and the subsequent experimental tests allowed the determination of the cell constant $k_C=110\ m^{-1}$, which is the relation between the resistance R_W and the water conductivity σ_W:

$$R_W = \frac{k_C}{\sigma_W} \quad (1)$$

With the previous result it was possible to correlate the data from the dry experiments with those measured in the salty water bath where the conductivity was measured with a commercial instrument. The output voltages as a function of water resistance are displayed on Fig.5. From this graph it is clear that the cell sensitivity is rather low for low water conductivities. The measuring range was set in the interval $22<RW<440\Omega$ which corresponds to the conductivity range in the interval $0{,}25<\sigma w<5S/m$. This measuring range is appropriate to asses the water conductivity inside the estuary of the Tagus river near Lisbon. Fig. 6 shows the relation between our data and those obtained with the reference instrument.

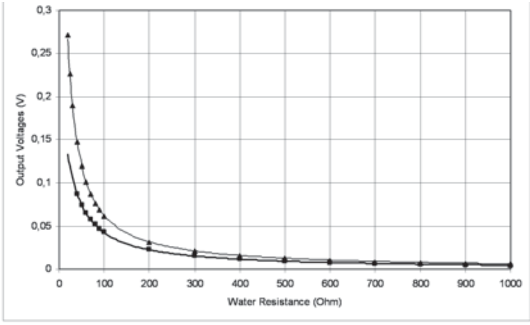

Figure 5. Output voltages as a function of water resistance R_W

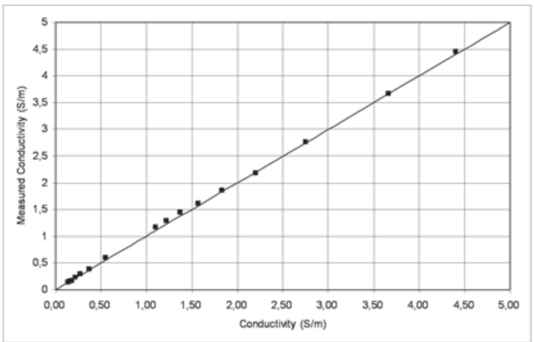

Figure 6. Water conductivity: Calibration experimental results.

4. Conclusions

An inductive conductivity cell to measure the electrical conductivity of the salty water was modeled, constructed and characterized in our laboratory. A number of these sensors will be placed in the river Tagus estuary near Lisbon. The array of sensors will work autonomously. Each sensor will be provided with a microprocessor to automate the measuring process and to control the transmission of data to a central point where the collected information will be processed.

5. References

[1] K. Striggow, R. Dankert, "The exact theory of inductive conductivity sensors for oceanographic applications", IEEE Journal of Oceanic Engineering, Vol. 10, N. 2, pp. 175-179, April 1985.

[2] H. Ramos, F. Assunção, A. L. Ribeiro, P. Ramos, "A Low-Cost Temperature Controlled System to Test and Characterize Sensors", Proceedings of the 10th IEEE Africon Conference, Vol. 01, pp. 57-60, Gaborone, Botswana, Sept. 2004.

ENVIRONMENTAL ASSESSMENT OFDOLPHIN' SADO ESTUARY BASED ON MULTI-PARAMETRIC PROBE, HYDROPHONE ARRAY AND GLOBAL POSITIONING SYSTEM

M. Crespo (1), J. Santos (1), A. Aleluia (3), O. Postolache (1)(2)

(1) ESTSetúbal-LabIM/IPS, Rua do Vale de Chaves, Estefanilha, 2910-761 Setúbal, Portugal
E-mails: postolache@est.ips.pt
(2) Instituto de Telecomunicações, Av. Rovisco Pais 1049-001, Lisboa, Portugal
(3) Gabinete de Sistemas de Informação Geográfica (CMSDURB), Câmara Municipal de Setúbal, Portugal

Abstract – The work presents a distributed measurement system for olphin live environment conditions, expressed in the water quality parameters and underwater acoustic noise. The design and implementation of an embedded turbidity sensor as well as the software of distributed measurement system for underwater acoustic source localization based on passive sonar techniques and GPS are included in the paper.

1. Introduction

The Bottlenose Dolphin, Tursiops truncates, community is unique in Portugal, and one of the few in Europe living permanently in an estuary or bay. In the 80's, the population of dolphins counted with more them forty individuals, but since then they've seen their numbers reduced, currently forming a family of twenty seven members. In this particular case of the Sado estuary dolphin population, industrial sound pollution and effluents in the inner region of the estuary have a negative impact over the community ability to orient and feed. In addition, intense harbour activity and high ship traffic affects dolphin's distribution and behaviour.

Therefore, the work reported here has implemented a collection of technologies in order to allow the study of this species in their natural environment, the levels of acoustic and water pollution, as well as pin-point the position of the dolphins sighted, mapping their activity within the estuary. The distributed measurement system can be framed under two entwined sections: a multi-parametric probe for water quality parameters measurements and underwater acoustic signal measurement component based on an array of three hydrophones. The system software performs multi-parametric probe remote control, underwater acoustic signal acquisition and includes an algorithm for sound source localization on a global position basis. The probe comprises several sensors to determine water quality parameters, such as temperature, level of pH, conductivity and turbidity. The array of hydrophones allows determining the source of sounds through a triangulation algorithm, as well as the quantification of acoustic pollution coming from nautical vessels and the surrounding industries in the Sado estuary region. Using a global positioning system (GPS), which provides the coordinates of the measurement location, and sound source relative position based on passive sonar technology the global position of the sound source can be determined.

2. Results and Discussion

The structure that supports the hydrophones (Sensor Technology, model SS03) is sustained by six buoys. Ordered in a line the hydrophones are place equally every 10 meters and connected to box containing pre-amplification circuits. Acoustic signals are then combined in an acquisition board (NI DAQCard-6024E) and sent to a computer aboard a ship. Software developed in LabVIEW performs low frequency filtering, clearing underwater noise existing in the environment. The type of structure and the number of hydrophones allows to simplify the underwater acoustic source localization algorithm.

The multi-parametric probe, also sustained by a buoy, is composed of several sensors, united in a single module.Temperature, pH and conductivity sensor measures are directly sent to the computer after a previous amplification and conditioning circuit. On the other hand, the turbidity sensor is managed by a microcontroller (PIC16F877). The programmed microcontroller controls the turbidity sensing unit, particularly the four IR beams architecture [1] as well as mathematical calculations associated with this configuration. In the developed turbidity sensor case, the microcontroller is in charge of adjusting the measurement range of the sensor. The program inserted in the PIC microcontroller verifies if the infra-red emitter power source is adjusted to the level of suspended particles in the water. According to the intensity of the beam measured in the IR receptor, the microcontroller will adjust the voltage applied to the emitters, through PWM port of the PIC. By regulating the turbidity measure range the sensor can adjust itself to the water conditions, allowing improved precision. In order to transform the relative position coordinates, determined by the system of hydrophones described on [2] and the implemented triangulation algorithm described on [3], into absolute position coordinates is necessary to transform the GPS information (obtained from Garmin GPSMAP76) into a cartographic representation system. The mapping scale used to represent the acquired data is of 1/25000. This decision took into account the fact that the GPS used is not professional and, therefore, some system corrections to enhance precision are not available. The conversion from one representation to another can be expressed in three steps: Molodensky Three-dimensional Transformation, Gauss-Krüger Projection System and, finally, Absolute Positioning. All steps, equations and considerations implied, are put into practice through an algorithm, developed in MatLab.

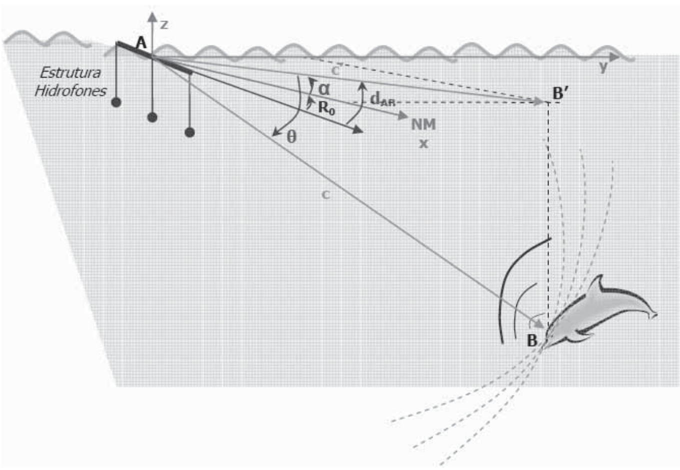

Figure 1. Schematic for the determination of the underwater acoustic sound source position .

In the last step of absolute positioning from polar coordinates to cartesian coordinates, is considered that the water surface is perfectly horizontal, referencing the "xoy" plane. However, to define the direction of X axis is necessary to resort to an electronic compass.The electronic compass allows to determine an angle, designated Zero Heading, which will orient our local referential. Compass outputs are sent to the computer, through acquisition board, where an application, developed in LabVIEW, handles the values and incorporates this information into the positioning algorithm.

Table 1 represents the evolution of uncertainty in the estimate of the position, associated with the minimum unit that can be defined in the electronic compass and the horizontal distances to which we need to register the position of the sound source. In this evaluation the 500 meter mark was not crossed.

Dist.(m) Unit (º)	10	50	100	150	300	500
0.25	0.04	0.22	0.44	0.65	1.31	2.18
0.5	0.09	0.44	0.87	1.31	2.62	4.36
1	0.17	0.87	1.75	2.62	5.24	8.73
2.5	0.44	2.18	4.36	6.54	13.09	21.81
5	0.87	4.36	8.72	13.07	26.15	43.58
10	1.74	8.68	17.36	26.05	52.09	86.82

Table I. Potential errors depending on precision of Zero heading calculation.

As it was verified, in order to obtain the desired precision, characteristic of a 1/25000 scale representation, the resolution in the Zero Heading acquisition angle for distances greater then 500m cannot be greater then ½ degree.

3. Conclusions

The paper presents a distributed system designed for water quality measurement and tracking of the dolphin community in Sado estuary. An important part of the work was dedicated to design and implement the embedded turbidity sensor, yielding an adjustable measurement scale, as well as in the implementation of the algorithm, which allows the cartographic representation of the underwater sound source. Simulation and field measurements underlines accurate measurement results of water quality parameters and underwater acoustic source detection and localizations.

4. References

[1] Postolache, O.; P.M. Girão; J. M. Dias Pereira; H. G. Ramos; " An IR Turbidity Sensor:Design and Application ", Proc IEEE Instrumentation and Measurement Technology Conf. , Anchorage , United States , Vol. Vol 1 , pp. 535 - 539 , May , 2002 .

[2] Postolache, O.; P.M. Girão; J. M. Dias Pereira; " Distributed Passive Sonar System for Performance Evaluation of Low Depth ", Proc Conf. on Telecommunications - ConfTele , Peniche , Portugal , Vol. I , pp. 251 - 254 , May , 2007 .

[3] Y. Chan, K. Ho, "A Simple and Efficient Estimator for Hyperbolic Location", IEEE Transactions on Signal Processing, Vol.42, No. 8, Aug. 1994, pp. 1905-1915