For the turbidity sensor WQ770 (TU sensor), the results are presented in Fig.3.

**Fig. 2. Calibration curve for WQ301 sensor at 25°C.**

**Fig. 3. The WQ770 turbidity sensor calibration curve for a set of 5 calibration formazine solutions**

5. Conclusion
The sensor calibration system presents a user-friendly interfaced based on a HMI touch screen that is connected to the Ethernet port of real time controller.
FPGA based implementation permits the different tasks (actions) associated with the calibration system to be performed in parallel mode, which implies shorter processing times and accurate. The FPGA core added to a real time controller permits the implementation of advanced processing techniques and data communication tasks not possible with conventional processing devices.
The water quality sensor calibration system has reduced power consumption due to the use of low power electrovalves and peristaltic pumps.
The results obtained show that the sensor test/calibration system is a good solution for water quality sensor field calibration procedures.

---

**A PRACTICAL APPROACH ON WATER QUALITY MONITORING BASED ON DISTRIBUTED MEASUREMENT SYSTEM AND INTELLIGENT SIGNAL PROCESSING**

O. Postolache (1,2), Helena Ramos (1), P. Girão1, M. Pereira (1,2)

1. Instituto de Telecomunicações, DEEC, IST, Av. Rovisco Pais, 1049-001 Lisboa, Portugal, phone: +351218417974, E-mail: poctav@mail.ist.utl.pt
2. Escola Superior de Tecnologia, Instituto Politécnico de Setúbal, 2910-508 Setúbal, Portugal

1. Introduction
This paper presents a set of distributed measurement systems for water quality (WQ) monitoring characterized by different communication protocols (e.g. IEEE802.11b/g, SDI-12). Special attention is granted to the advanced processing of the data acquired from the measurement channels in order to offer best metrology performances for a given hardware using intelligent processing architectures based on neural networks, adaptive neuro-fuzzy inference system and Kohonen maps.

2. Distributed Measuring System
Different distributed measuring systems for water quality monitoring were developed in order to assure higher flexibility, accuracy and mobility. Communication interfaces associated with IEEE802.3, IEEE803.11b/g or SDI-12 were included on the water quality monitoring nodes (RTP1, RTP2) that are connected to the advanced data processing and data logging units expressed by a host computer. Different architecture were designed and implemented on of them presented in Fig. 1.

**Figure 1. Distributed Measurement Systems for Water Quality Monitoring based on real-time processing unit and IEEE 802.3 and IEEE 802.1g communication protocols (AP-access point E WB-wireless bridge)**
3. Data Intelligent Processing

Intelligent data processing solutions expressed by neuronal network [1] and Fuzzy Neural Network – ANFIS type [2] were designed and implemented for the present applications. Figure 2 depicts the overall processing scheme that includes the NN or the FuNN processing block associated with WQ measuring channel inverse modeling [3] and the Kohonen Self organized Map (K-SOM) neural network [4] for global representation of the data received from the sensing nodes.

![Figure 2. Water Quality Intelligent Processing Scheme (WQ K-SOM – the water quality Kohonen map associated with j sensing node, IPB – intelligent processing block, NN- neural network algorithm, FuNN – Fuzzy neural Network Algorithm)](image)

4. Results and Discussions

With intelligent modeling of water quality measuring channels based on neural network (Multilayer Perceptron), the global modeling errors were lower than 1% (Table 1).

<table>
<thead>
<tr>
<th>RTPs</th>
<th>ε_T(%)</th>
<th>ε_pH(%)</th>
<th>ε_C(%)</th>
<th>ε_TU(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTP1</td>
<td>0.81</td>
<td>0.26</td>
<td>0.23</td>
<td>0.18</td>
</tr>
<tr>
<td>RTP2</td>
<td>0.73</td>
<td>0.31</td>
<td>0.28</td>
<td>0.15</td>
</tr>
</tbody>
</table>

Table 1. Percentage error of WQ parameters values for the data received from two RTPs after neural network processing.

Referring to the FuNN water quality measurement channel modeling a practical approach concerning the relation between the number of membership functions of FuNN mf layer the modeling errors is presented in Table 2. Best results are obtained up to three Gaussian mf.

<table>
<thead>
<tr>
<th>Nmf1, Nmf2</th>
<th>mf1, mf2 type</th>
<th>e_max</th>
<th>Hybrid</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>trimf</td>
<td>0.7962</td>
<td>0.0042</td>
</tr>
<tr>
<td></td>
<td>trapmf</td>
<td>0.7959</td>
<td>0.0043</td>
</tr>
<tr>
<td></td>
<td>gaussmf</td>
<td>0.7861</td>
<td>0.0041</td>
</tr>
<tr>
<td>3</td>
<td>trimf</td>
<td>0.7895</td>
<td>0.0047</td>
</tr>
<tr>
<td></td>
<td>trapmf</td>
<td>0.7894</td>
<td>0.0044</td>
</tr>
<tr>
<td></td>
<td>gaussmf</td>
<td>0.7834</td>
<td>0.0042</td>
</tr>
<tr>
<td>10</td>
<td>trimf</td>
<td>0.7964</td>
<td>0.0090</td>
</tr>
<tr>
<td></td>
<td>trapmf</td>
<td>0.7964</td>
<td>0.0011</td>
</tr>
<tr>
<td></td>
<td>gaussmf</td>
<td>0.7992</td>
<td>0.0010</td>
</tr>
</tbody>
</table>

Table 2. Accuracy of FuNNpH modelling versus FuNN's architecture and training type – FuNN testing phase.

Optimal FuNN training (no overfitting) were obtained for thirty training epoch (Nepoch=30). The evolution of computational load for higher modeling accuracy is expressed number of floating point operations and for the particular case gaussmf is presented in Figure 4.

![Figure 3. The evolution of modeling error for the associated to FuNNpH model](image)

Referring globally representation of the water quality (WQ) a Kohonen self organizing map (with 6X10 nodes) was designed (Figure 4). On the map can be observed three WQ zones, called K-SOM clusters that were defined such as very good WQ (VGood), good WQ (Good) and bad WQ (Bad).

Based on the designed map, the global evolution of WQ can be carried out. For example, for the particular case of WQ data, pH=6.8, C=5002S/cm, T=15.5°C, and TU=202NTU, the best matching unit cell (BMU) corresponds to Vgood cluster (K-SOMC42). To express the pH, C, TU and T data distribution on the K-SOM the multiple hit histogram representation was used. Thus highly concentration of data corresponds to K-SOMC31, K-SOMC62 of the “VGood” cluster, K-SOMC13 and K-SOMC35 of “Good” cluster and K-SOMC19 of the “Bad” cluster.

![Figure 4. The K-SOM associated to water quality classification in Tagus Estuary (WQ class1 – very good, WQ class2 – good, WQ class3 – bad) and the corresponding multiple hit histogram of WQ values.](image)

Referring to WQ K-SOM design quality, the quantization error, qe, is lower than 0.3 and the topology error, te, is lower than 0.1.

5. Conclusions

The proposed distributed multi-parameter measurement system to monitor water quality based on IEEE803.11g and SDI-12 protocol and on intelligent algorithms permits WQ accurate parameters measure-
ment over a wide water area. Multidimensional data representation of water quality measurement channels, using Kohonen self-organizing maps (K-SOM) to express the WQ class, permits a quick identification of pollution events and offers a global representation of the water quality in the assessed areas.

References

CONDUCTIVITY CELLS FOR WATER SALINITY MEASUREMENT

A. Lopes Ribeiro

Instituto de Telecomunicações, Instituto Superior Técnico, Av. Rovisco Pais, 1096-001 Lisboa, Portugal
Phone: +351 218418376 email: arturlr@ist.utl.pt

1. Introduction
The water electrical conductivity correlates with the content of solved salts. In the sea water the conductivity is essentially due to the ions of sodium chloride. In river estuaries the water conductivity also depends on the presence of other solved elements, namely those originated by undesirable pollutants.

In this article we present our work on the development of water conductivity cells to be displayed continuously under the environmental conditions, which impose constraints on robustness.

The electrical conductivity of liquids can be measured using cells with nude metallic electrodes. However these cells are not useful to work under environmental underwater conditions. The need for permanent operation of the measurement apparatus poses a maintenance problem related to the continuous growing of biological organisms and to the continuous deposition of other inorganic materials which foul the equipment and degrade the acquired data.

In our system, inductive conductivity cells will be used [1]. Figure 1 shows the structure of these cells. Their relevant characteristic consists on the complete electrical insulation of the active metallic conductors. To help the protection against environmental conditions, the cell is enclosed in a plastic container, provided with some holes to allow the access to the water stream.

Figure 1. Cell structure: two cores with windings inside a plastic container.

2. Electrical Measurements
The inductive cell may be considered as a double transformer. A sinusoidal voltage is applied to the primary winding of the first transformer. The secondary winding of the first transformer is the water circuit which, as represented in Fig.2, is considered as a single turn. The secondary transformer is a symmetric replication of the first

When a sinusoidal voltage is applied to the primary of the first transformer, an output voltage can be measured on the secondary of the second transformer. In our implementation, the output voltage is measured, separating the components in phase and in quadrature with the input. This is done by using integrated multipliers, as is shown in the measuring circuit represented in Fig.3. Being the water conductivity dependent on the temperature it is necessary to measure it as well. The three slow varying signals are fed into an integrated low-price processor which controls also the communication with a transceiver module.

Figure 3. Circuit block diagram

3. Results and Discussion
The cell was first tested in dry conditions. This is possible if the water circuit is replaced by an external variable resistor. In the next test the cell was immersed in a bath with controlled temperature [2] as shown in Fig.4. The operating conditions were varied in order to optimize the overall behaviour. The operating frequency f=50 Hz was chosen because it was found that the relation between applied and output signal amplitudes is good for the lower values of RW, and the second order effects, resulting from the high water dielectric permittivity or from the limited penetration depth of the varying field in salty water were negligible.

Figure 4. Water bath for test measurements.