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PORFIDO:
OCEANOGRAPHIC DATA SENSOR FOR THE NEMO PHASE 2 TOWER

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Abstract

PORFIDO (Physical Oceanography by RFID Outreach) is a system designed to gather oceanographic data in parallel with underwater Čerenkov neutrino experiments, without interfering with the main setup. A sensor is glued to the outside of an Optical Module, in contact with seawater, and a reader is placed inside, facing the sensor. Data are collected by the sensor and transmitted to the reader through the glass by RFID. The sensor gathers power from the radio frequency, thus eliminating the need for batteries or connectors through the glass.
In the framework of KM3Net, we plan to deploy several PORFIDO probes with the NEMO Phase 2 tower in 2011[1)].
We have performed several tests to prove the functionality of the system and the absence of any interaction with the NEMO electronics.

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1 – INTRODUCTION

Typical oceanographic data are collected by deploying self contained instruments anchored to the bottom of the sea, and recovering them after a period of weeks or months, when the batteries have died, to collect the acquired data. In contrast, a neutrino telescope installation offers to the oceanographic community the possibility to gather data continuously and in real time, since an essential part of the installation is an underwater electro optical cable which carries power to the telescope and data from it to shore. A very small fraction of both the power and of the bandwidth available even to a small telescope is sufficient to collect relevant oceanographic data.

The problem is to interfere as little as possible with the neutrino detector, which means using small detectors and avoiding the need of connectors or penetrators, that are very expensive and that offer low reliability.

We have built such a system, PORFIDO[2)], using the well established technique of RFID to gather data through the glass spheres of the Optical Modules and to supply power to the sensors with the RF itself.

PORFIDO is made up of two elements: the sensor, which is glued to the outside of the Optical Module (OM), and gathers data from the sea water. The Reader, which sits on the inside of the OM, reads the measured data through the glass using RFID, and communicates with the NEMO electronics to send the data to shore.

2 – RFID

Radio Frequency Identification (RFID) is a technology that has been developed for access control, and is spreading widely in this and other fields.

In the standard setup, a Reader emits an RF beam, and the responding unit (Tag) answers with its own identity code, deriving power from the RF itself and thus eliminating the need for batteries. Recent developments have focused on adding to the Tag the possibility to take measurements in the environment and transmit them to the Reader together with its ID code. The EPC C1GEN2[3)] protocol, developed by EPCglobal, includes the possibility of sensors in RFID tags.

3 – THE RFID TAG – WISP

We have used as an RFID Tag the WISP, developed at the Intel Research center in Seattle[4)]. It is passive (no batteries), has a thermometer and an accelerometer on board, and is designed with an open architecture to include new sensors. Software for the integration is available from the designers.

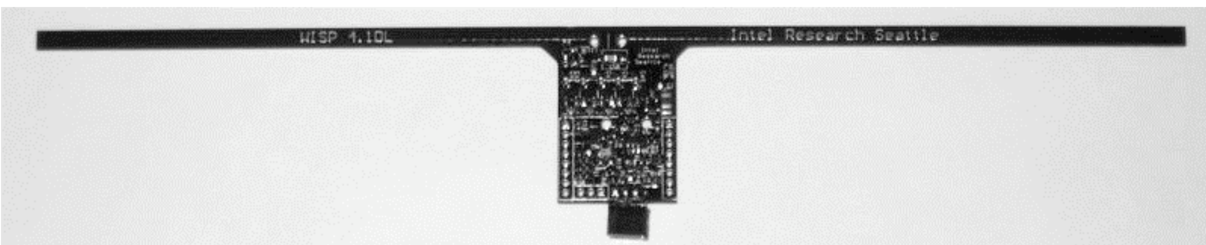

Figure 1 – The WISP.

4 – THE RFID READER

The RFID Reader to be installed inside the optical modules has to be small, does not need a lot of RF power and must be cheap. Several firms offer such instruments, and we have chosen the ThingMagic[5)] M5e-compact reader for its small footprint and good performance with the WISP.

5 – TESTS

We ran a long series of tests to verify the feasibility of the system and the absence of interaction with the electronics of NEMO.

5.1 – Sea Water Test

Since we need the tag to work at 4000 m depth, the WISP was potted in a shell of two component epoxy one cm thick, and glued on the outside of the glass sphere housing the optical module.

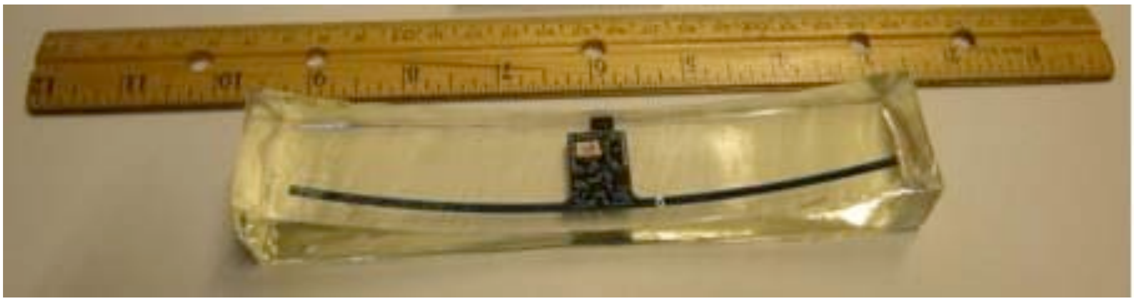

Figure 2 – The WISP potted in epoxy.

Figure 3 – The WISP glued to the sphere.

To test the performance in sea water, the WISP glued to the sphere was immersed in salt water simulating the sea. Using an RFID Reader we were able to read the WISP at a rate higher than one per second, which is more than enough compared to the intrinsic time constant of oceanographic data. The immersion in salt water did not have any effect on the performance.

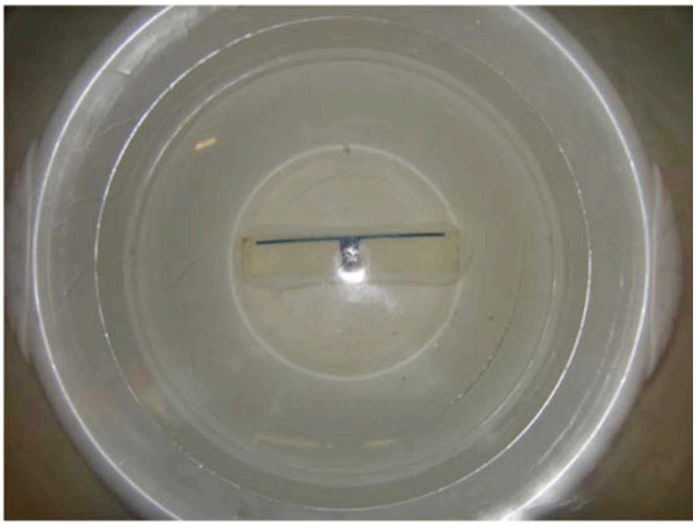

Figure 4 – The WISP in seawater.

5.2 – Pressure Tests

To simulate the working conditions of the experiment, the complete system was installed inside/outside a glass sphere and sealed off.

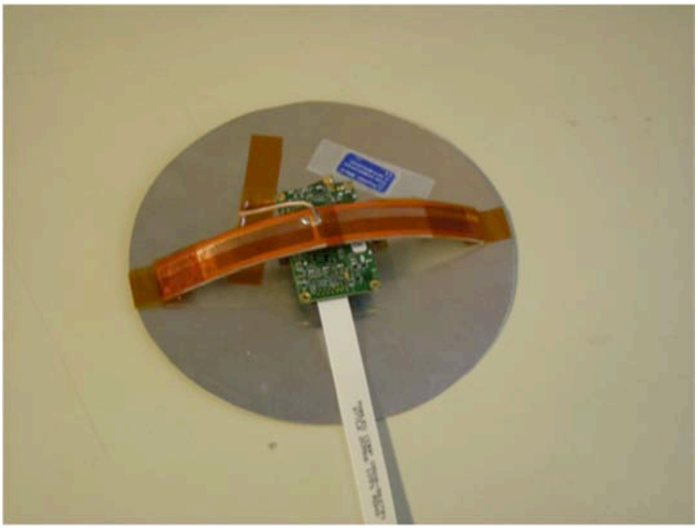

Figure 5 – The pressure test assembly.

It consisted of the Reader, the Antenna and an Aluminum shield on the back to protect the Photomultiplier Tube (PMT) and the electronic data acquisition board from RF interference.

To collect data we built a battery powered data logger unit and installed it inside the sphere, with a magnetic switch to control the power.

Using the Catania-INFN pressure test chamber we pressurized the sphere to 40 MPa, equivalent of 4000m depth in water, and kept it working for 20 hours.

Figure 6 – The pressure test.

The system recorded data correctly for the whole period from two WISPs, one measuring temperatures and the other reading a three-axis inclinometer.

5.3 – RF Interference Tests

We wanted to prove that the RF field generated by the reader does not interfere with the PM tube and with the electronic boards inside the Optical Module.

We built a black box and installed in it a working Optical Module and the PORFIDO system. First of all we looked directly at the PMT signals, disconnecting the base from the readout board (FEM, Front End Module). We used a LED pulser generating single photon pulses on the PMT. The RF signal interference generated by the reader was of about 3 mV, to be compared with the LED signals that were greater than 50 mV

Finally, to test the interference with the electronic boards, we reconnected the PMT signal to the FEM and we measured the FEM signal rate with different threshold settings, turning on and off the LED pulser operating at 1MHz frequency. No false events were recorded.

No RF shield was used in the tests.

6 – THE ANTENNA

The dipole antennas that we used for the tests proved adequate but difficult to handle, being very sensitive to the presence of conductive materials in the vicinity of the reader.

At this point we realized that our setup, with an emitter and a receiver placed at a distance of only 12 mm and with glass in between, was more similar to a capacitor than to a transmitter - receiver pair.

Therefore we discarded the 147 mm dipoles and built two capacitors using square copper pads, 25x25 mm^2, facing each other on the two sides of the glass. See Fig. 7.

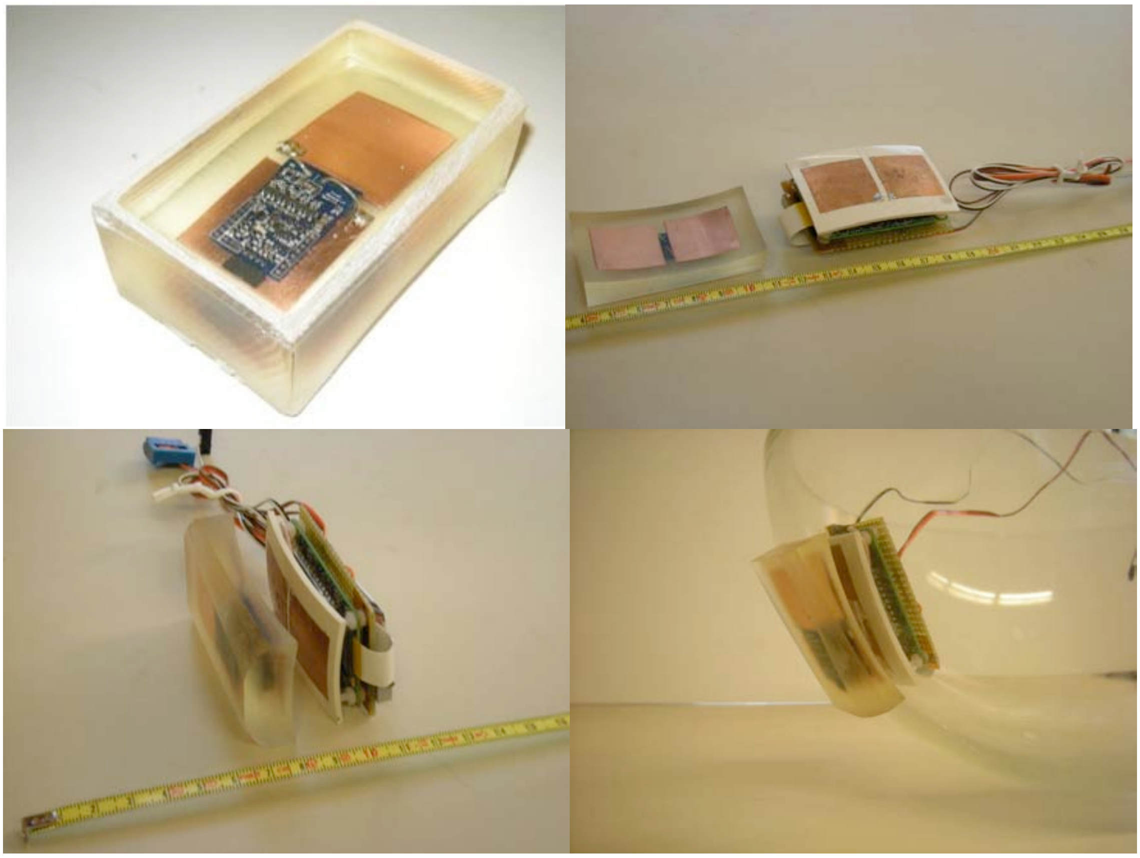

Figure 7 – The external and internal sections of PORFIDO in the lab and mounted on the Optical Module.

The results were excellent. The system was much more stable and immune to the presence of metal in the surrounding space, we were able to decrease the reader RF power by a factor of 10, and the interference decreased accordingly.

We repeated the interference tests and the test we had done previously, putting the WISP and the copper pads, potted in resin, into salt water. No negative effects were recorded.

One more advantage of this new design is that the dimensions of PORFIDO decreased to the size of the reader alone, 70x40 mm. This will make it much easier to incorporate the system in any new designs for the Optical Modules.

7 – POWER

We have strict restrictions on the power available for PORFIDO. Since the Reader draws about 0.5 A @5V for 200 ms, we have installed a 1 F capacitor to store the necessary power. The capacitor recharges slowly while the reader is inactive.

Commands to the reader are sent transparently on a simulated serial connection in the optical fiber link of NEMO.

8 – CONCLUSIONS

The NEMO group has approved the installation of 4 PORFIDO probes on the Phase II tower that will be deployed in 2011 in the Capo Passero site, and we are now working to integrate it in the system.

Several different kinds of sensors can be implemented to work with the WISP, and we are starting to work on a salinity sensor and on a dissolved oxygen monitor.

We believe that the oceanographic community could greatly benefit by the use of this kind of instrument, that can efficiently parasite the Čerenkov neutrino telescopes which will be built in the future.

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(2) Marco Cordelli et al.: PORFIDO: Oceanographic Data for Neutrino Telescopes, LNF–10/02 (P), February 4, 2010 and Nucl. Instr. & Meth. **A 626-627** (2011) S109-S110.

(3) EPCglobal UHF Class 1 Generation 2 (*EPC C1Gen2*) Protocol specification [EPC07].

(4) http://wisp.wikispaces.com/

(5) ThingMagic, Inc., One Cambridge Center, 11th floor, Cambridge, MA 02142, USA.