Acquisition and Data Logging for the ANTARES Project

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Abstract

The goal of the ANTARES R&D project (Astronomy with a Neutrino Telescope and Abyss environmental RESearch) is to study the feasibility of the deployment and operation of a very large deep sea high energy cosmic neutrino detector. This program has begun in 1996 in the Mediterranean sea along the French coast at depth down to 2500 m. Several lines have been deployed repeatedly for site parameter measurements such as optical background, bacteria and sediment fouling, undersea currents.

These lines include a small autonomous intelligent controller which performs the acquisition and the storage of environment parameters, the interfacing with photomultiplier tubes and the control of some specific devices (acoustic modem, current meter, compass, motor).

This paper presents these tests and the different configurations of the controller used to drive them. The controller has to work autonomously with limited resources and with high reliability. The technical options chosen to meet these stringent requirements are described.

The next step of the program is presented. It will consist in the deployment of a complex mooring line including 8 photo-multiplier tubes and several instrumentation subsystems. This line will be connected to the shore by a 40 km electro-optical cable which will bring the power and allow data acquisition and supervision. The same controller as above will be used for slow control data concentration in a WorldFIP fieldbus architecture.

1 Introduction

The detection of high energy neutrinos offers unique opportunities for astrophysical investigations. A neutrino detector detects the neutrino by its interaction products. High energy neutrinos coming from astrophysical point sources will occasionally interact with matter and create a muon. At energies above 1TeV the angle between the interacting neutrino and the produced muon is very small. Therefore, the direction of the parent neutrino is well determined. In the water, the muon emits Cerenkov light which can be detected by photomultipliers tubes (PMTs).

The principle of the detector is based on an arrangement of PMTs in a 3-dimensional array. As the expected events rate is low, a volume of 1 km^3 is needed. The PMT and its electronics is enclosed in a pressure resistant glass sphere : the Optical Module (OM). The OMs are attached to a mechanical structure made of flexible and rigid elements which ensure their relative position in the water.

2 R & D Program of ANTARES

One goal of the ANTARES program [1] is to measure several crucial site parameters such as optical background (natural ^{40}K radioactivity and bioluminescence emitted by a wide range of sea animal species), bio-fouling (sediments deposit), water transparency and sea currents.

These measurements were begun in spring 1996 along the French Mediterranean coast at the depth of 2500 m. The site was chosen about 30 km off-shore from La Seyne-sur-Mer where we can profit from a good infrastructure.

Several types of mooring lines have been launched in order to carry out these measurements. They all include, from top to bottom : an ARGOS beacon, several buoys, the measurement instrumentation, a remote controlled release and a ballast. The instrumentation set-up is the following :

- 1 or 3 OMs for optical background measurement,
- several captors on the inside surface of an OM facing an LED for bio-fouling measurement,
- an OM facing an LED mobile along a rigid structure for water transparency measurement.

The usual length of a line is 200 to 300 m. The line descent or ascent takes 20 to 30 minutes at a depth of 2500m. During the first year of tests (from June 96 to July 97), a total number of 20 missions, either for deployment or recovery, have been made.

The acquisition system which has to be used must work autonomously without any connection to the shore or to a boat. Furthermore, the containers able to sustain high pressure from -2500 to -4000 m have a price which increases rapidly with their volume. So the stringent requirements the system has to meet are : high reliability, low power consumption and compactness.

3 The MBX micro-controller system for ANTARES

3.1 Hardware overview

The points listed above are well fulfilled by the off-the-shelf micro-controller system MBX from the firm MII. It is based on the MC68306 micro-controller, a CMOS device of the 68000 family. The system is composed of several boards connected together by a simple bus. The main board contains the micro-controller, 512 KB of EPROM and 1 to 2 MB of battery back-up RAM. The micro-controller supports 2 serial lines and timers, a dedicated chip is provided for real-time clock and calendar. An I /O board comes with the CPU board and has 8 analog inputs, 4 analog outputs, 16 digital inputs/outputs. An extension board may double the number of input/output channels. For specific purposes, a custom board is available. The overall power consumption of the system is 6 W (250 mA / 24 Volts). The space occupied by the 3 superimposed boards is 22 cm x 12 cm x 10 cm. The system is powered by external lithium batteries.

Another strong point for using the MBX is the extensive experience we acquired with it during the development of the CABTF program (Low Temperature Acquisition

System with a FIP connection). For this application, the MBX includes a standard WorldFIP fieldbus interface from MII and a custom board for cryogenic temperature acquisition. WorldFIP is used to interconnect the acquisition satellites to PLCs and supervision PCs [2]. An important decision was to use the vxWorks real-time operation system from Wind River System on this platform. For this purpose, a porting of the standard 68306 vxWorks support package was done. The FIP library, already available on the MBX but in a different OS environment, was adapted for vxWorks. This system is now used on several cryogenics installations at Saclay and CERN.

3.2 Hardware configurations

For all the configurations, the MBX is interfaced to a common set of signals (temperature, battery voltages...) which are periodically logged. A binary input is used which notifies the system of an imminent power failure. Then, the software can smoothly stopped the activity of the system. The specific features for each underwater type of site measurement are described in the following paragraphs.

3.2.1 Optical background measurement

The MBX is equipped with a Saclay designed board for interfacing PMTs. This board consists of :

- a front end logic building fast coincidences (510^{-9} sec resolution) and the pulse shaping of the incoming signals.
- Four 50 MHz 24 bits counters.
- The interface with the MBX extension bus.

To have some qualitative information on bio-luminescence, a first serie of tests was done with a single PMT. To study coincidences and then to make a good discrimination between the different origins of light, 3 PMTs are now interfaced to the system. A current meter is linked to the MBX via one serial line and gives information about velocity and direction of current, pressure etc... The system is powered 1 or 2 times each day for a duration of 1 or 2 hours. During this period, a predefined sequence of measurements is carried out. A typical deployment lasts from 2 weeks to 1 month.

3.2.2 Bio-fouling measurement

The MBX is equipped with a standard extension I/O board. An upper glass sphere includes a LED and its electronics. The lower glass sphere includes the batteries, the MBX and 9 photo-diodes used to measure the light received on different spots of the sphere. The system is powered twice a day for a duration of a measurement which is about 2 minutes. The line has to stay deployed for several months to appreciate the slow degradation of the light signals due to bio-fouling. The phenomenon is strongly correlated to the strength of the currents. Thus, a current meter is interfaced to the MBX to record simultaneously variation in bio-fouling and sea current. To be able to check periodically the system on site, an acoustic modem is also connected to the MBX. With this system, it is possible from the surface, to power the MBX and to establish a communication with it, for checking of the system and recovery of stored data. Typical transmission rates are 600 Baud from the bottom to the surface and 16 Baud from the surface to the bottom.

3.2.3 Water quality measurement

The MBX is interfaced to a PMT and, via standard I/O channels, to a motor. The goal is to move a trolley in a 35m long rigid structure. This trolley is equipped with a LED controlled by a DAC. A PMT and the MBX are located on top of the structure (see Fig. 1). The trolley is stopped on predefined locations and measurements of the transmitted light between the LED and the PMT are made.

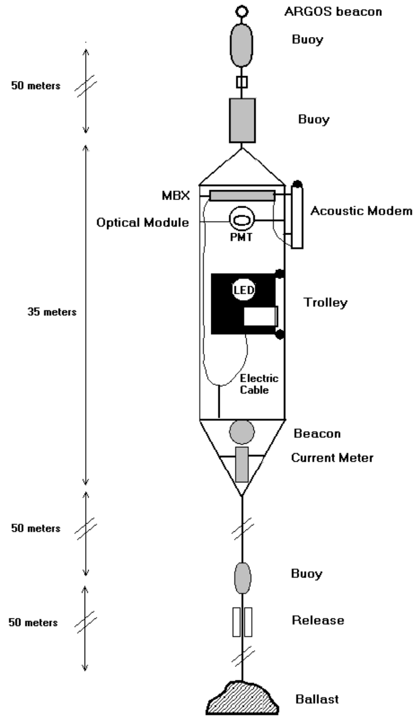

Fig. 1. Diagram of the Mooring Line for Water Quality Measurements

The time used to make a return trip along the complete length of the structure and to make 25 measurements is 90 minutes. The system is powered on the boat and the measurement procedure occurs automatically 2 hours later. An acoustic modem is also available, providing interaction with the system either to read data or, if required, at the end of the automatic procedure, to make <<manual>> trolley displacements and light transmission measurements.

3.3 Software overview

The software (RTOS + Application) is stored on the 512K PROMS of the MBX. The particular conditions in which this system is used have also strong implications on the software. The container of the MBX is usually closed several days before the deployment for high pressure tests. From this moment until the recovery of the system, the system must work without human intervention. The first rule was to build a software as simple as possible with all necessary run-time checks made and with possibilities of degraded operation. All the return parameters of the system calls are tested, all the important events and the errors are logged for analysis. Despite the concern to make the software as simple as possible, the battery back-up RAM is handled as a RAMdisk with a DOS compatible file system. The evolution of the different tests have proved the validity of this choice, as more and more data of different type is stored in several files. To insure the highest level of data security but with a penalty on the performance, a special <<auto-sync>> mode is used. With this mode the data is immediately written on the <<disk>> without waiting a flush of the buffer. For the long duration bioluminescence measurements several hundreds of files are created, each of them identified by the time of creation and the type of measurement (calibration, coincidence, selected PMTs...). The format for the data files is SDDS compliant [3] and the data are usually stored in binary format. The storage resources of the MBX are scarce, so a compression algorithm is planned to be used, enabling a compression factor of 2 or 3. For the future, a development for an additional 20 to 80 MB flash EPROM board is under study.

For development and debugging purpose, one serial port of the MBX is connected to a SUN workstation and is used with SLIP (Serial Line Internet Protocol). This link is also used after a deployment to retrieve the data with ftp.

The reliability is a key feature for this system. To date, we have only 2 partial failures to deplore : one was caused by a risky on-site transmission rate reconfiguration of the acoustic modem. Although the system was still working, the dialog from the surface became very difficult and eventually impossible. The second one was a saturation of the file system which occurred after the creation of roughly 110 files. This problem caused the loss of 2 weeks of data over a total of 4 weeks. The tests done in the laboratory have been limited to a few tens of files and then, were not able to indicate the possible problem.

4 Use of the MBX for the prototype detector

Besides the deployments of autonomous mooring lines for site quality measurements, a first element of a neutrino detector will be deployed in 1998. This line will be equipped with 30 OMs containing only 8 PMTs but with all the cables and containers needed for normal operation. The line will be connected to the shore by a 40 km electro-optical cable. This cable will bring the power to the line and will transmit the information from the 8 PMTs and the slow control data and commands.

The main constraints for the slow control system are : reliability, possibility of extensions (addition of new sensors) and distributed architecture (several satellites far from each other). To fulfill these requirements, an architecture based on the WorldFIP fieldbus technology was chosen [4]. The redundancy (physical medium and bus arbitration), the good data transfer rate (1 Mb/s over a 1 km long twisted pair), the on-line reconfigurability are some of the vital features of this fieldbus for its use in this context. The MBX controller equipped with its WorldFIP interface will act as data concentrators.

5 Conclusion

The ANTARES collaboration is involved in an ambitious program. A successful deep-sea deployment is the combination of many complicated processes. The micro-controller has obviously an important role in the success or failure of a deployment. The use of the MBX, an industrial product, enabled the fast development of a very reliable solution for deep-sea autonomous acquisition and data logging and is retained for future remotely controlled operation.

References

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