IMAGES AND DATA TRANSMISSION OVER A HIGH BAUD RATE ACOUSTIC LINK FROM AN OCEAN BOTTOM STATION

G. AYELA (1), B. LEDUC (2)

(1) ORCA instrumentation, 5 rue Pierre Rivoallon, 29200 BREST, FRANCE
(2) IFREMER Centre de Brest, BP 70, 29280 PLOUZANE, FRANCE

1 ABSTRACT

ORCA instrumentation and **IFREMER**, the French Ocean Agency, have designed a self-contained system, called **TIVA**, to transmit very large quantity of data, at a high rate, from the sea-bottom to a surface vessel.

This powerful and flexible equipment has been successfully used during operational campains at-sea (TITANIC wreck survey, 4000 m deep ; Mediterraneen sea, 2600 m deep; Pacific Ocean, 2650 m deep...). **Images** (black and white, color) and data have actually been transmitted from a manned submarine, an autonomous fish and a self contained bottom station to the surface vessel, over an acoustic link, for scientific and operational purposes.

Color camera, new image compression algorithms have been implemented to increase the capabilities of the system. TIVA is now available and can be adapted to user's specifications (range, baud rate, type of data ...).

2 INTRODUCTION

The Scientific Community and Servicing companies have expressed the need to get data from underwater equipments, such as ocean bottom seismometers, bottom moored stations, oil well instruments, sensors. The specifications of the transmission system vary with the application. Real time is not always needed. The quantity of data varies from a few bytes (sensors) to several hundred of Kbytes (images, seismic data). Distance between the acquisition system and the user can be as low as a few hundred meters or less, to the full ocean depth.

Acoustic waves are the only realistic way to transmit data when the transmitter is located underwater. The use of acoustic waves enables the source (transmitter) to be completly separated from the receiver : no more costly cables and associated material. The surface team can, at last, see the same pictures as the ones seen by the crew of the submarine ; the scientist can receive the data stored in the underwater instrument without retrieving it.

IFREMER, the French Ocean Agency (Institut Français de Recherche pour l'Exploitation de la Mer) and **ORCA instrumentation**, a company specializing in Underwater Acoustics and Marine Instrumentation, have decided to design and to build a complete system **to transmit large quantity of data, over long ranges, at a "as high as possible" data rate.**

The system has been designed to be able to transmit any type of numerical data, including image, from TV camera.

3 DESCRIPTION OF THE SYSTEM

The system can be divided into two main parts:

- the underwater subsystem located near the "sensors", on an autonomous bottom moored station, in a manned or unmanned submarine;
- the surface unit receives, decodes, stores and displays the data.

3.1. The Underwater Equipment

Besides the battery pack, the light and the transducer, the underwater equipment is contained in a single housing (diameter : 150 mm ; length : 600 mm ; weight : 20 kg in air, 5 kg in water), rated at 600 bar.

Figure 1 shows the block diagram of the underwater unit.

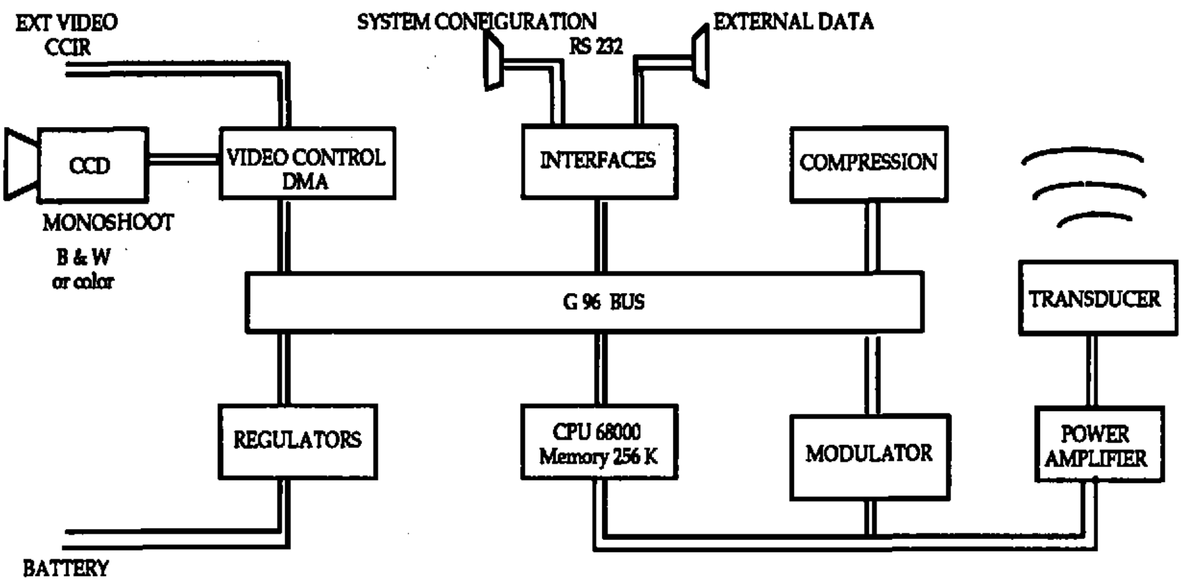


Figure 1: Underwater Unit

The camera manufactured by I2S (Bordeaux, France) uses a black and white or color CCD sensor (493 x 390 pixels). One board generates synchronisation and control signals and digitizes the video output (6 bits per pixel). One image is then stored in static memories with DMA process.

The acquisition and processing circuits consist in 3 boards : one CPU board based on MOTOROLA 68000 CMOS microprocessor (256 Kbytes RAM-serial and parallel ports - watch dog - real time clock ...), one signal processing board (image compression), one serial interface board. This last board enables the user to initialize the system; frequency, baud rate, acoustic power, camera control ... are user selectable parameters. The numerical data are sent to the modulator in a serial format. This makes lab testing very easy.

When image has to be sent, **compression algorithms** can be used to decrease the number of data. One board is dedicated to this task.

The modulator has been studied in cooperation with the Ecole Nationale Supérieure des Télécommunications de Bretagne (**ENSTB**). The "phase shift keying" modulation is used with a choice between PSK 2 and PSK 4. The data rate is programmable and depends on the carrier frequency.

Max. Range	2000 m	6000 m
Frequency	53 KHz	26 KHz
Bandwidth	10 KHz	5 KHz
Max baud rate	19200 bits/s	9600 bits/s

The frequency and the baud rate can be adapted to the user's specifications.

The wide-band Amplifier amplifies the carrier signal and drives the transducer. This element must have a good efficiency. The nominal electric power applied to the transducer is 50 W r.m.s. ; it is a programmable parameter (10, 25, 50 W).

The **transducer** has been studied by **PONS** (Aubagne, FRANCE) : its Sv is 165 dB (re.µPa, 1 m, 1 V).

3.2. The surface unit

The on-board equipment has to receive the acoustic wave, to demodulate it, to display the transmitted picture on a standard video screen and to restitute the other transmitted data.

The **hydrophone**, manufactured by **PONS**, is associated with a low-noise pre-amplifier.

The Sh is - 158 dB (ref. µPa, m, V). The acoustic signal is amplified and band-pass filtered and its level is made compatible with the **demodulator**. This one detects the phase of the signal and transforms it into a numerical signal which will then be processed by the **data processing unit**.

According to the transmitted picture, different algorithms are used to retrieve the original picture : a standard PC/AT is used.

Besides the acoustic part, the demodulator and data processing unit are very important. They have to detect low signal level in the noise. Up to date technics have been used to ensure that the "lowest" error rate is obtained : 10 E-5 is a typical error rate.

The surface unit is contained in a **standard 19" cabinet**. It is connected to the hydrophone and to the microcomputer.

A video screen displays the received images and the environmental and other data are displayed on the PC screen.

4 ACTUAL USES AND RESULTS

TIVA has been intensively used in various environments and aboard different supports such as manned submarine (**NAUTILE**), autonomous fish (**EPAULARD**), self-contained oceanographic equipment (geotechnic instrument) and autonomous bottom moored stations. **Frequencies were adapted to the desired range : 26 KHz** to go down to **4000 meters and 53 KHz for a 2000 meter range.** Thanks to the high flexibility of the equipment, the best trade off can be found to optimize the application.

The most prestigious campain gave real time shots of the **TITANIC's wreck**. Images were continuously sent from the NAUTILE (3 man, 6000 meter rated submarine) to its support vessel (R/V NADIR); see figure 2.

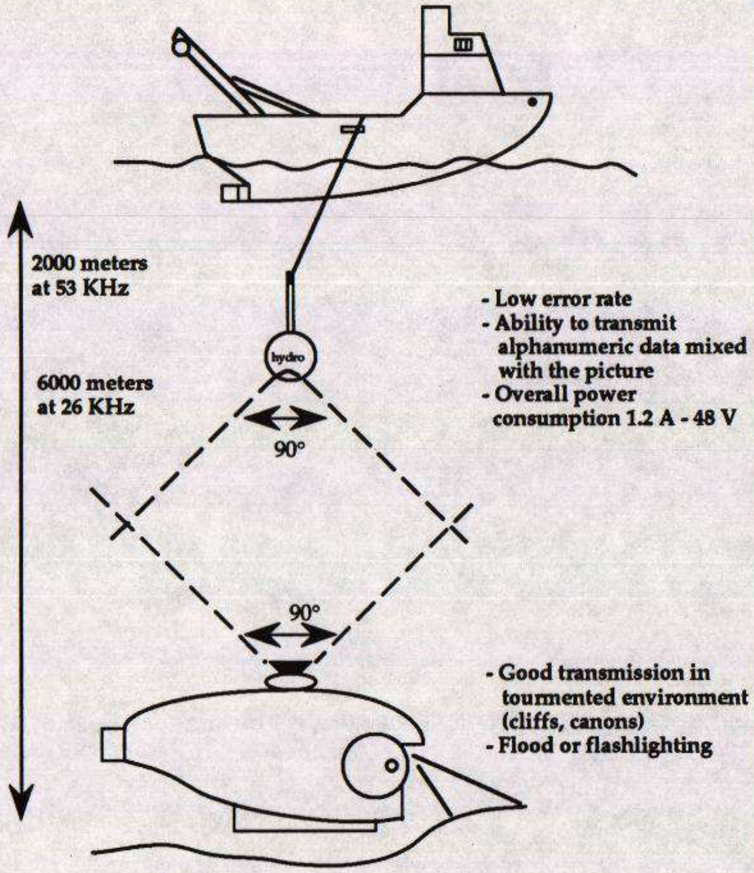


FIGURE 2: TIVA and NAUTILE SUBMARINE

Operational campains at-sea have also been made : ship's wreck survey and scientific instrument monitoring. A sample is presented on Figure 3 : view of an oil tanker wreck at a depth of 2600 meters in the Mediterranean Sea.

The people aboard the surface ship can now be active and decide what to do after the reception of images and data. They can change the strategy of their measurements according to the received information ; they can also exchange messages with the crew of the manned submarine to optimize the underwater work.

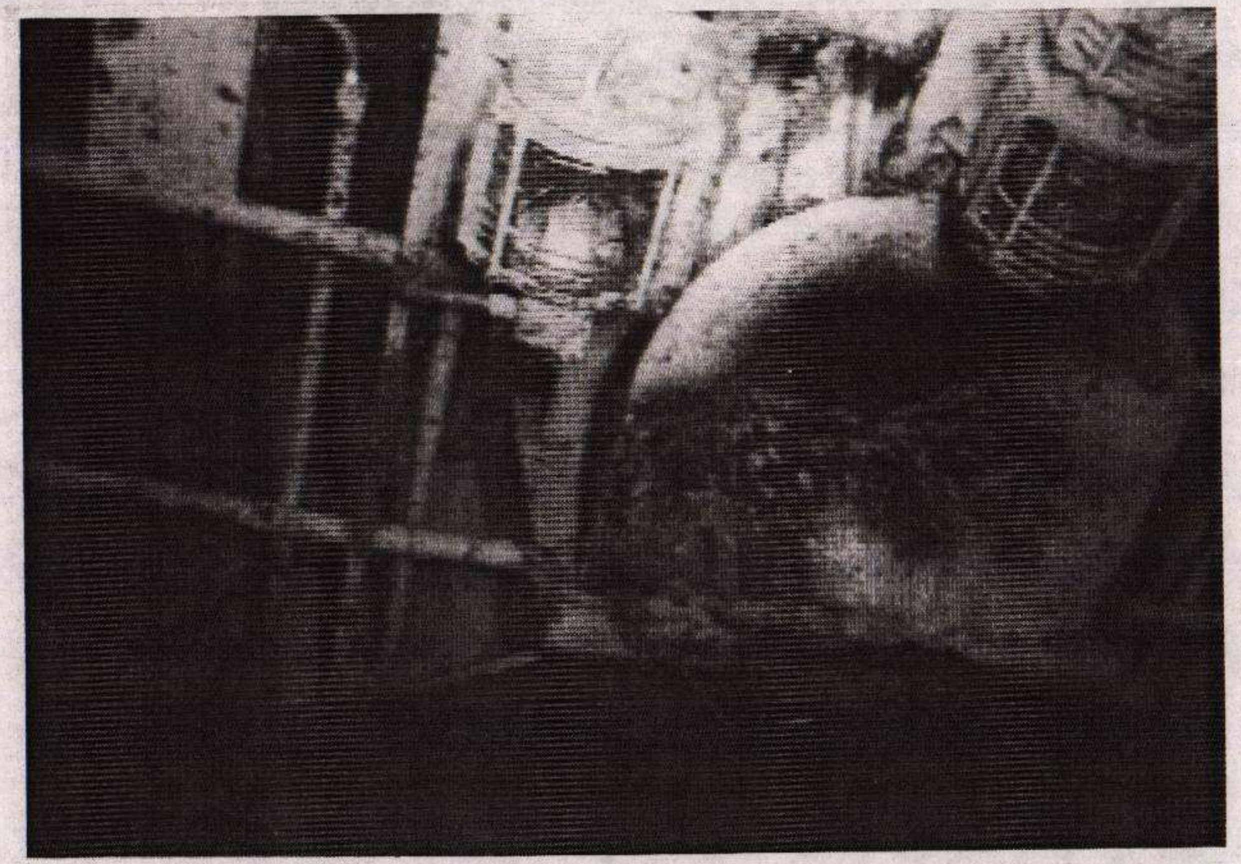


FIGURE3: WRECK OF AN OIL TANKER (2650m, Mediterranean Sea; 26 KHz; 8800 bits/s)

New compression algorithms have been implemented to decrease the time to transmit one image.

Figure 4 shows the time to transmit one image at various aud rates, with and without compression.

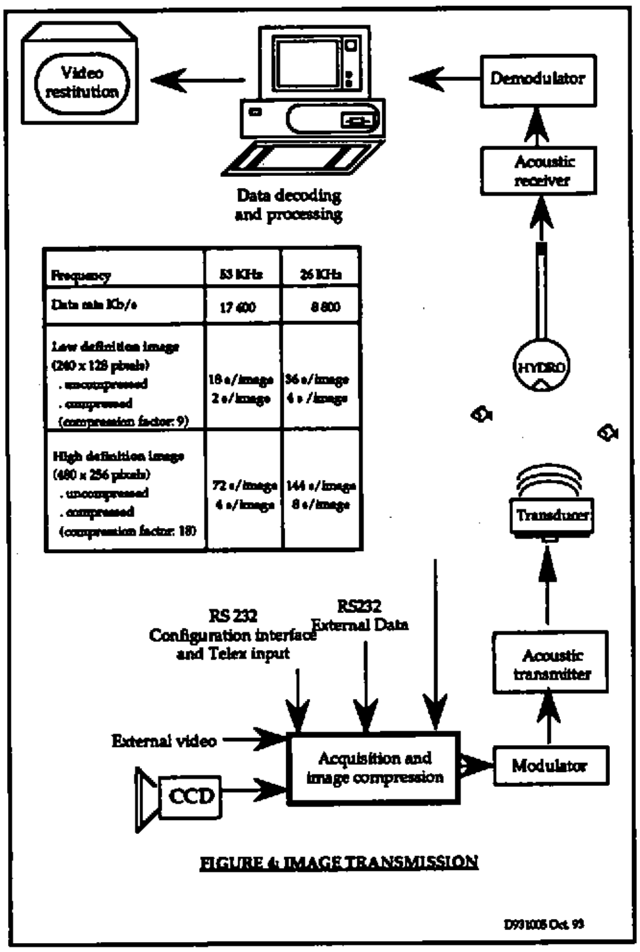
5 "SAMO" : UNDERWATER STATION

The system has also been used in the Pacific Ocean, at a depth of 2650 m, to monitor life around hydrothermal vents: fishes, crabs, giant tube worms (Riftia) have been shot by the color TV camera and images have been transmitted in real time.

This self-contained underwater bottom moored station is called SAMO (see figure 5). The main subsystems of the station are the TIVA system (acoustic link), flashlight, pressure balanced batteries, acoustic down-link, sensors... Figure 6 is an artist view of SAMO.

HIGH DATA RATE ACOUSTIC LINK

After NAUTILE has installed SAMO at the spot of interest, the station acquires and stores the environmental data. The ship comes back every one or two days and interrogates SAMO via the acoustic down-link. Environmental and housekeeping data are sent via TIVA, the up-link, and displayed on the PC screen as time series.



Frequency	53 KHz	26 KHz
Data rate Kb/s	17 400	8 800
Low definition image (240 x 128 pixels) . uncompressed . compressed (compression factor: 9)	18 s/image 2 s/image	36 s/image 4 s /image
High definition image (480 x 256 pixels) . uncompressed . compressed (compression factor: 18)	72 s/image 4 s/image	144 s/image 8 s/image

FIGURE 4: IMAGE TRANSMISSION

Another command is then sent to ask for color images which are transmitted, stored and displayed on a video screen.

SAMO has been successfully used and enabled biologists to study the evolution of hydrothermal vents, in almost real time, from the surface. Three Megabytes of environmental data and 200 Mbytes of images were transmitted with almost no error.

Images were also transmitted to Brest (France) from the sea bottom to the surface vessel via the acoustic link and from the vessel to Brest via satellite.

This experiment shows that future underwater stations may be interrogated from shore and can report data via acoustic and radio links if a relay buoy is set near the bottom moored station.

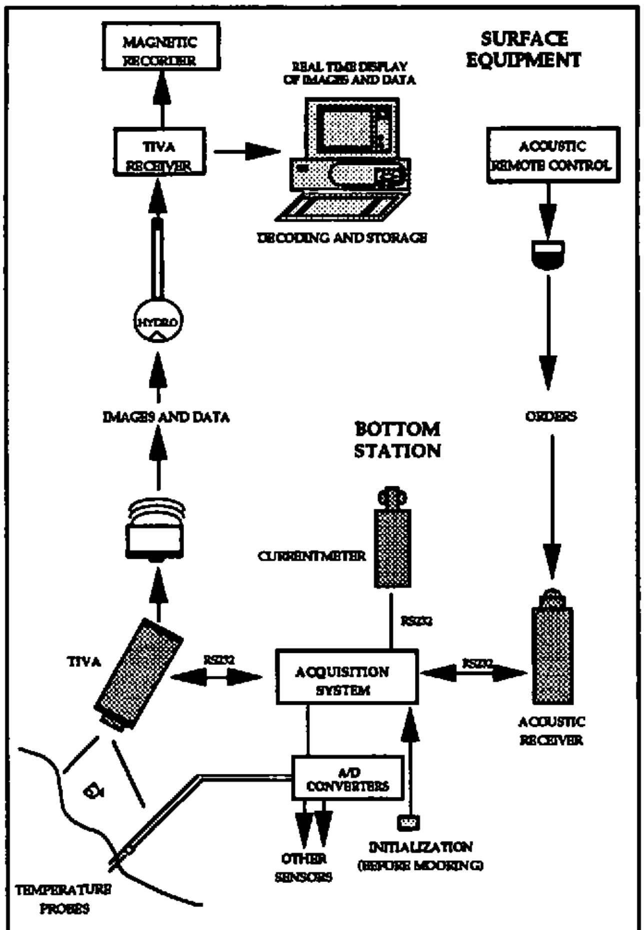


FIGURE 5: SAMO BLOCK DIAGRAM

6 PRESENT DEVELOPMENTS - CONCLUSION

ORCA instrumentation and IFREMER are presently improving the high capacity acoustic link TIVA, and are also working on other types of acoustic links to be used in other applications which need, for example, transmission of data over horizontal links. New types of modulations are used. Tests have been performed at sea and results are very promising.

These studies will soon lead to the installation of underwater networks with a central station and auxiliary stations. Horizontal acoustic links will allow the transmission of commands from the central station to interrogate the smaller units and data acquired by these stations will be reported to the central station. Vertical acoustic links will enable the user to retrieve large quantity of data, including images, from the surface.

Technical checks can be made and scientific or operational data are transmitted without retrieving the whole system.

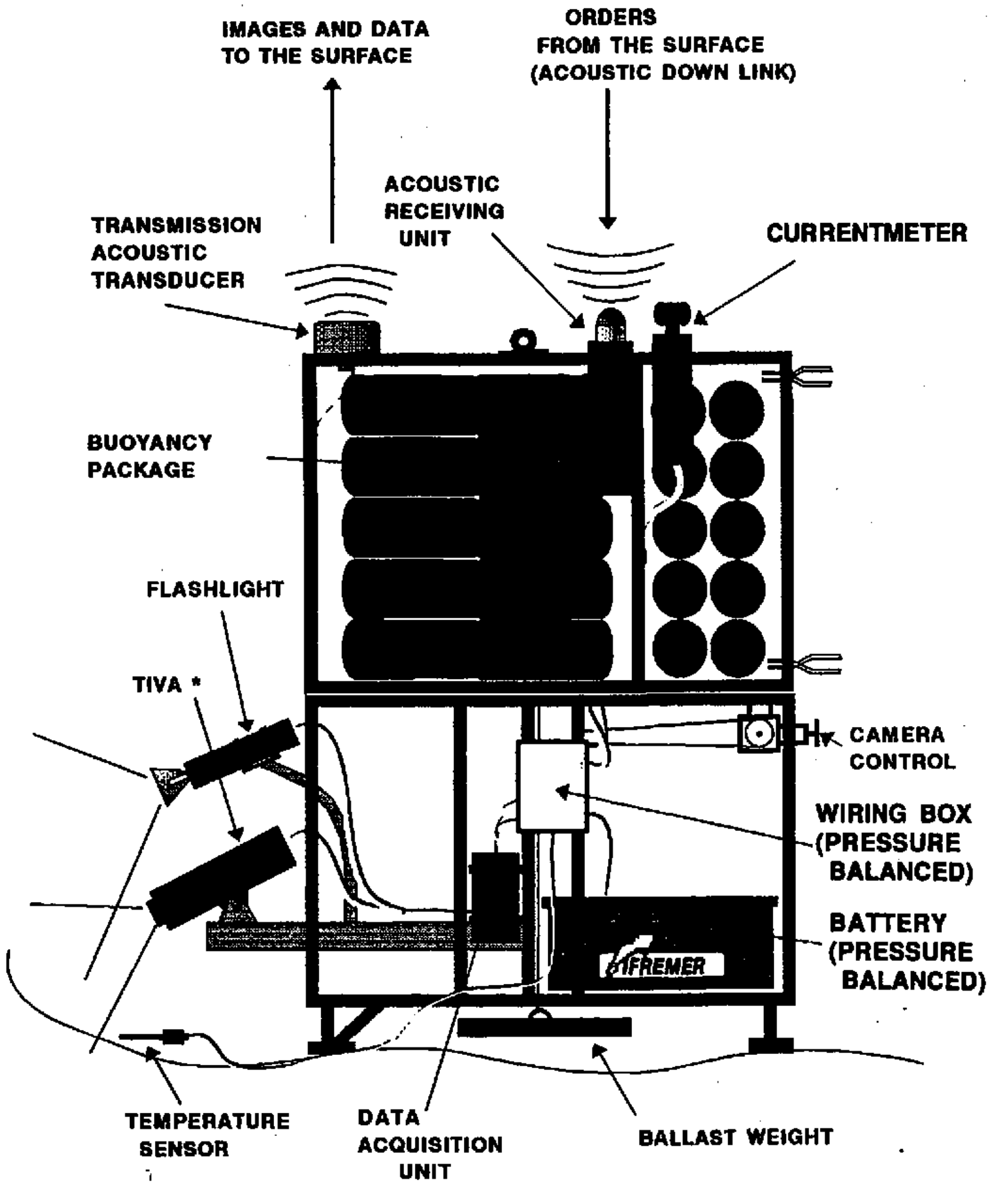


FIGURE 6: SCHEMATIC OF SAMO STATION
THE UNDERWATER SYSTEM