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TIVA A SELF CONTAINED IMAGE/DATA ACOUSTIC TRANSMISSION SYSTEM FOR UNDERWATER APPLICATION

B. LEDUC and G. AVELA*

IFREMER, Département DIT/ICA, BP. 70, F-29280 Plouzane, France

**ORCA Instrumentation, 38, Rue Jim Sevellec, F-29200 Brest, France*

Résumé :

L'image des fonds marins est un précieux support pour l'exploration et l'exploitation sous-marines. Jusqu'à présent, seuls des véhicules à câble permettaient d'acquérir ces images. L'augmentation des portées souhaitées a conduit l'IFREMER (Institut Français de Recherche pour l'Exploitation de la Mer) à développer un système de transmission d'images et de données

de grande capacité par voie acoustique : TIVA. Basée sur les technologies récentes de traitement du signal, la première génération de cet équipement a été utilisée avec succès au cours de la campagne d'exploration de l'épave du TITANIC (transmission d'images) et pendant des opérations scientifiques, pour vérifier le bon fonctionnement d'instruments tels que pénétromètres, scissomètres ... La seconde génération a été développée par ORCA Instrumentation. Les sous-ensembles FOND (caméra, électronique de gestion, de mémorisation, de compression,

chaîne acoustique, modulation, amplification) sont en liaison avec l'ensemble de surface (hydrophone, récepteur, filtrage, démodulation, restitution des images ...).

Il est maintenant possible de transmettre de grandes quantités d'informations, sans câble, par voie acoustique, depuis le fond des océans (6000 m) jusqu'en surface.

Abstract :

Underwater exploration and exploitation programs have early expressed the need for pictures and images. Still cameras and TV cameras have been used to take photographs and films of the sea bottom, of the living resources, of undersea man built equipments. Sophisticated instruments have recently been designed with enhanced characteristics (high definition and sensitivity, color, ...). Unfortunately, because of the needed bandwidth to transmit the signal, the only way to get real-time data was to use cables. This technique is however limited to a few hundred meters of water. Another mean to transmit image data over long distances was needed.

Within the framework of its programs related to underwater intervention, IFREMER (Institut Français de Recherche pour l'Exploitation de la Mer) and ORCA Instrumentation have designed a self-contained system to transmit images from the sea bottom to a surface vessel : TIVA. The use of acoustic waves enables the source to be completely separated from the receiver. This technique is bandwidth limited and the maximum baud rate is far beyond the ones which can be achieved in the labs. The quantity of information within an image is so large that a long time is needed to transmit the whole set of data. Compression algorithms have been studied and applied to actual data in order to decrease this transmission time. The modulation and the associated demodulation equipments were specifically designed for the application. The specific constraints of the equipment (self-contained instrument, memory, space, power limitations, ...) and the desire to process the data in a very short time before the transmission, led to a trade-off between the power of the compression algorithm and the other characteristics such as current consumption, memory size ... The equipment has been successfully used to send images in real time during the survey of the TITANIC's wreck. Scientific at-sea campaigns (penetrometry, shear vane meter deployment ...) have been optimized with the use of TIVA and its capacity to send images and data to the user at the surface.

The transmission of data gathered by different underwater instruments on control systems was first done by using electrical and/or electromechanical cables which linked the source to the receiver. However these technics are limited to a few hundred meters of water because of logistic problem and price.

Then, acoustic transmission is the only way to "break the material link" between the source (the camera or other instruments) and the receiver (the display) if long distances have to be reached.

IFREMER and ORCA Instrumentation have designed a self contained equipment which achieves the transmission of image data through more than 4000 meters of water over an acoustic data link.

THE CONSTRAINTS OF THE TRANSMISSION LINK AND OF THE ENVIRONMENT :

Before designing the hardware, studies have been made to take the constraints of the transmission channel into account :

- The frequency is the limiting factor as far as the range is concerned. The longer the range, the lower the frequency must be. A low frequency (26 KHz) has been chosen to solve the first applications.

- The data rate depends on the modulation scheme and on the bandwidth of the transmission system, including the transducer.

- Thermal and salinity gradients can influence the acoustic propagation and create multiple channels and the receiving cone may vary with the hydrologic conditions, the seasons and the depth.

- In fact an image is a "sensor" which requires a big quantity of informations, the number of images that can be transmitted per second depends on the efficiency of the algorithms which are used to reduce the data.
The harsh marine environment also gives its own constraints : pressure (6000 meters), corrosion.

A compact equipment with high autonomy has to be designed to fit the requirements of the underwater support : autonomy (low power consumption), volume and weight. It also has to transmit a big quantity of informations as fast as possible.

The system can be divided into two main parts : the underwater acquisition, processing and transmitting subsystem, and the receiving and decoding station aboard the vessel.

THE UNDERWATER EQUIPMENT :

Besides the battery pack and the light, the underwater equipment consists of a single housing :

diameter	150 mm	weight	20 kg
length	600 mm	net weight	5 kg
		the rated pressure is	600 bars

Figure 1 presents the block diagram of the equipment included :

- . a CCD camera and the associated circuits (493 lines x 390 points) ;
- . acquisition and processing circuits based on a MOTOROLA 68 000 CMOS microprocessor ;
- . fast processor for image compression ; - a modulator ;
- . a wide-band power amplifier ; and - power supplies.

The CCD camera

Manufactured by I2S (Bordeaux, France), the CCD camera has been designed to withstand a hard environment. The low-weight compact camera is a cylinder of length 80 mm and diameter 60 mm.

The CCD sensor is made by SONY (band W or color can be used), and gives a 493 lines x 390 points image. 1 printed circuit board is used to generate synchronization, control signals for the CCD sensor and digitize the video signal (6 bits per pixel) ; it also enable the direct memory access (DMA) to the microprocessor.

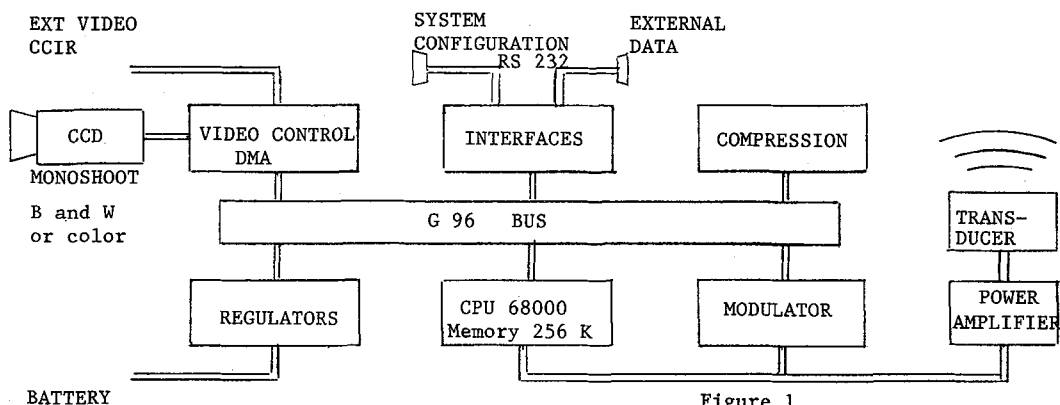


Figure 1

The acquisition and processing circuits

This subsystem consists of 3 printed circuit boards (see figure 1) which are all connected to a G 96 format bus : one CPU card based on the MOTOROLA 68 000 CMOS microprocessor (256 Kbytes RAM - serial and parallel ports - watch dog - real time clock...), one signal processing board (image compression, made by XCOM Grenoble, France), one serial interface board. This latter board enables the user to initialize the system ; many parameters are user selectable : frequency, baud rate, acoustic power, camera and video control and configuration...

Before being serially sent to the modulator, the data are formatted to a RS 232 C standard ; this allows easy lab testing.

The Modulator

This part has been studied in co-operation 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 (see table 1).

DEPTH/RANGE	0/2000	2000/6000
Fréquency/Bandwidth (khz)	50/10	25/5
Max data rate (bits/sec)	19200	9600
Low definition rate (sec/image) 250 x 190 pixels uncompressed/compressed	20/2	40/4
High definition rate (sec/image) 493 x 380 pixels uncompressed/compressed	80/8	160/16

Table 1

The Wide-band Amplifier

It 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.

The transducer

This has been studied by PONS (Aubagne, FRANCE) ; its Sv is 165 dB (re. Pa, 1 m, 1 V).

THE SURFACE EQUIPEMENT

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 reconstitute the other transmitted data. The equipment comprises (see Fig. 2) :

The hydrophone. It is manufactured by PONS and is associated to a low-noise pre-amplifier. Its Sh is -158 dB (re. Pa, V).

The amplifier and the filters. The acoustic signal is amplified and band-pass filtered ; the signal level is made compatible with the demodulator.

The demodulator. This detects the phase of the signal and transforms it into a numerical signal which will then be processed by the data processing unit.

The data processing unit. According to the transmitted picture, different algorithms are used to retrieve the original picture ; a standard AT - PC is used.

After testing the whole system in the laboratory and in the testing tank of the Centre de Brest, the underwater equipment was fitted on the Epaulard, the acoustically remote-controlled unmanned submersible.

The camera container was placed in the Epaulard, looking downward. The power supply was the same as that of the submersible and the flashing light was synchronized with the shot (see Fig. 3).

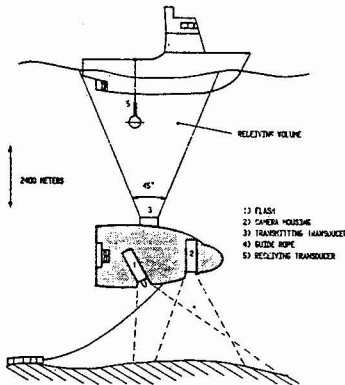


FIGURE 3

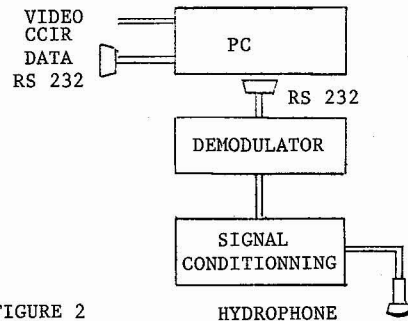


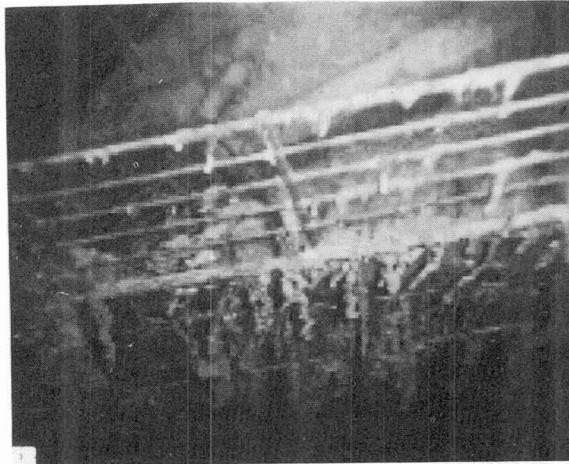
FIGURE 2

OPERATIONALS USES

Various at-sea campaigns have been made to test the whole equipment : several configurations were tested (PSK 2 and PSK 4 - various image compression algorithms).

The most prestigious campaign gave real time shots of the TITANIC's wreck in 1987. Images were continuously sent from the NAUTILE (a 3 men/6000 meters sub-marine) to its support vessel (N/O NADIR). A sample is presented in the paper with the main characteristics.

- low definition picture
250 x 150 pixels - 6 bits per pixel.
- range 4 000 meters.
- strong thermocline
- compatibility with other acoustic systems (navigation, sounders, underwater telephone...).
- receiving cône : 45°.
- error rate : 10^{-4} (in the cône).



Scientific use : several scientific campaigns already used TIVA. The scientists on the vessel received the images of the sea bottom in real time and were able to decide when to make measurements with their instruments (penetrometer - shear vane meter).

CONCLUSION

A powerful tool is now available. It can be simply adapted to almost any applications by choosing the right parameters. Use of compression algorithm gives high image transmission rate. Mixing of environmental data in the image is possible.

TIVA is in fact a MODEM which can be used to transmit any type of data which would require high transmission rate and long range (for example seismic, robotics...).