An Underwater Camera for Security and Recreational Use

Robin Bradbeer, *Senior Member*, *IEEE*, K. K. Ku, L. F. Yeung, and K. Y Lam

Abstract - *The objective of this project was to design an underwater camera and instrumentation system that could be used to detect and follow moving objects, and be able to be deployed at a depth of up to 100 m for an extended period of time. This was achieved by using a pan, tilt and zoom high resolution camera connected to a base station via a powered fibre optic cable. The camera was successfully deployed for 100 days continuously, recording video on to a DVD recorder in real time.*[1].

Index Terms — Underwater camera, underwater fibre optic communications, underwater instrumentation.

I. Introduction

If a camera is to be used underwater for monitoring activity, either for security, scientific or recreational use, it must not only be robust, but also easily controllable. A high-resolution, remote powered and real-time controlled camera is necessary for this project. Using functions such as, zoom, pan and tilt will be needed, along with a real-time video capturing and recording system, which can capture real time pictures and store a large amount of video recording to PCs, or direct to DVD.

High quality imaging is supported by using an optical fibre cable to prevent loss of data and image. In the test situation, the video signal is sent directly over the powered cable to the shore station in the Marine Science and Engineering Laboratory in the Marine Park at Hoi Ha Wan, Hong Kong. This decreases distortion of video signal and at the same time increases the speed of transmission due to fibre optic. A block diagram of the system is shown in Figure 1.

The system also has external connectors that allow a controllable illumination from a single or array of lights, as well as a serial data interface so that external instrumentation can be interfaced to the communications system, thus allowing real time monitoring of the ambient surroundings. This is especially useful for marine biology work, or the monitoring of pollution levels.

The Marine Science and Engineering Laboratory at Hoi Ha Wan is the base for a number of experiments and developments in underwater communication, instrumentation and robotics. [1-4]

This paper will describe the various parts of the system, some of the design problems and how they were solved and then show some of the output from the camera and instrumentation system.

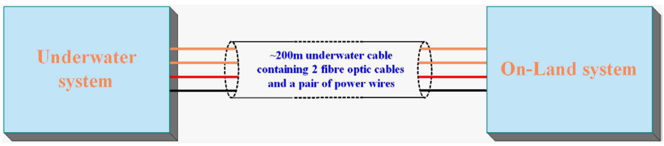

Figure 1 Block diagram of the system

II. The On-Shore System

The on-shore system diagram is shown in Figure 2. It consists of the following:

a) Data controlling Unit;

b) WDM filter;

c) Fibre-to-video converter;

d) Isolating transformer;

e) Video capturing hardware to PC

The whole system uses a bidirectional communication via the two optical fibre cables. Control commands in RS-232 format are sent from one of the PCs through PC's 'com port' to the underwater system. Those commands can be for camera control, lighting control or sensor control. The user can select one of two PCs to control the underwater system by using the switch. The RS-232 command signals are converted to optical signals and sent down one of the fibre optic cables to the underwater system. Once the underwater system has received the command signal, it sends back the sensor data and video signals to the on land system down the other fibre optic cable.

The optical signal sent back from underwater system is combination of both video (with wavelength 820nm) and sensor data (with wavelength 1300nm), a WDM filter is applied to split the signals. After the optical signals are

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Robin Bradbeer is an Associate Professor, Department of Electronic Engineering, City University of Hong Kong, Hong Kong. (email: eesbrad@cityu.edu.hk)

K. K. Ku is a Research Assistant, Department of Electronic Engineering, City University of Hong Kong, Hong Kong. (email: kkku@ee.cityu.edu.hk)

L. F. Yeung is an Associate Professor, Department of Electronic Engineering, City University of Hong Kong, Hong Kong. (email: eelyeung@cityu.edu.hk)

K. Y. Lam is a Research Fellow, Department of Biology and Chemistry, City University of Hong Kong, Hong Kong. (email: kkylam@cityu.edu.hk)

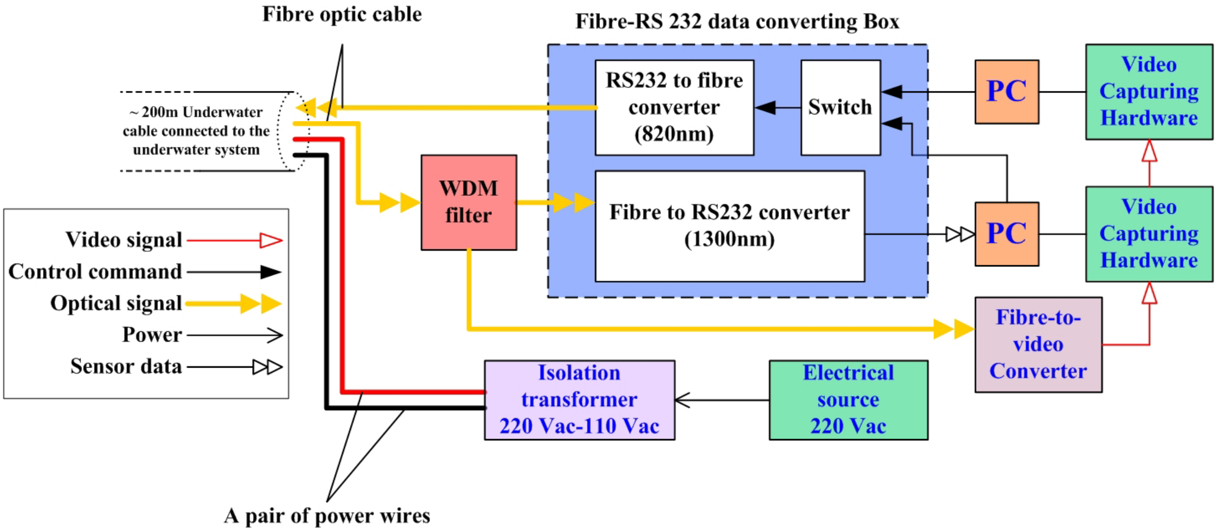

Figure 2 Block diagram of the on-shore system

separated, the two signals of different wavelengths are converted to a video signal and a data signal by the fibre-to video converter and the fibre-to-RS232 converter respectively. The data signal can then be sent back to the PC and the video is processed through video-capturing hardware and then displayed on the screens of two PCs. The main power to the underwater system is 110Vac stepped down from an isolation transformer from 220Vac electric source.

III. THE UNDERWATER CABLE

A specially designed cable was constructed for this project. It contained two multi-mode optical fibres and two twisted copper power cables. The cross-section is shown in Figure 3. The cable was coated with a PVC waterproof covering, with aramid yarn to prevent water leakage along the cable. Its diameter was 14mm, and the length 210m.

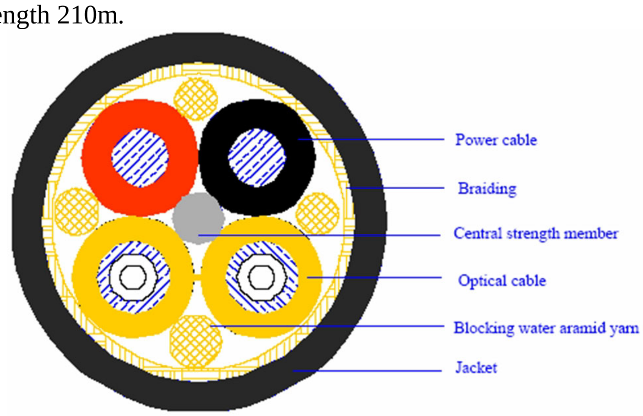

Figure 3 Cross-section of the powered fibre optic cable

IV. THE UNDERWATER SYSTEM

The Underwater system contains the following:

a) Toroidal transformer 115/230 a.c.;

b) Power supplying board;

c) Light;

d) Controlling board;

e) Video-to-fibre converter;

f) Sea-Bird interface board;

g) Optical coupler;

Once the optical signal is received by the underwater system (Figure 4), the control board converts it into different signal formats for the different components, e.g. RS232 for lighting brightness control, RS422 for camera moving control and RS232 for sensor control. As the video image is needed for real-time, the video signal is converted to optical one continuously. When the retrieving of sensor data from PC on-land is requested through correct command, the Seabird sends the data in RS232 format to the RS232-to fibre converter. The optical coupler combines the optically converted sensor data and converted video signal and sends back to the on-land-system to process. The power supply board regulates 110Vac to the proper power for different circuit boards and components.

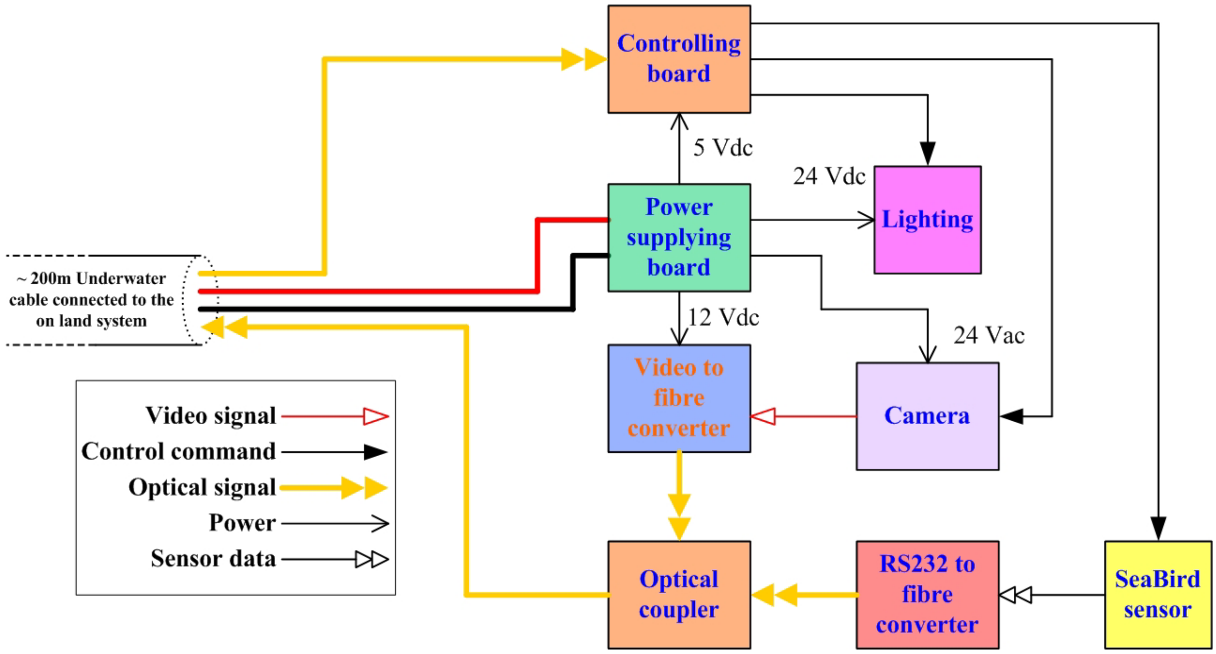

Figure 4 Block diagram of the underwater system

V. Communications and Control

The communications system was designed to control the camera pan, tilt and zoom, as well as sending command data to the LED light that was fixed externally to the camera. It was also decided to design the system such that any external sensors connected to the camera via the serial data port on the casing could be controlled, such as requesting data stored on the internal flash memory of the sensor unit, or to acquire data in real time.

The camera was based around a SpeedDome III unit. This has a resolution of 480 lines and the output was composite video 1Vpp NTSC format. The SpeedDome was chosen as it had the ability to track objects using built in software. The majority of the dome control commands use three byte packets that consist of Dome address, Command, and Checksum. Dome address range is from 1 to 0xFF depending on the type of control system used. The dome acknowledges a command with its address (one byte) within 25 msec. The control data speed was set to 4800 baud.

The commands sent to the camera unit included:

Home the camera	Start Pan Left
Start Pan Right	Start Iris open
Stop Pan	Start Iris close
Start Tilt up	Stop Iris
Start Tilt down	Stop all movement
Stop Tilting	Start Focus near
Start Focus far	Stop Focus
Start Zoom In	Start Zoom out
Stop Zoom	Start Pan Faster
Start Pan Fastest	Stop Pan Faster

VI. The Camera Housing

The housing is built to protect the camera and all electronics being put underwater. The material of the housing must be also considered for underwater usage. An underwater housing for this project includes an acrylic dome acting as a window of the camera shown in Figure 5, a main body to house the electronics and a sealed cover with the attached underwater cables. The acrylic dome is screwed on the top of main body with an O-ring seal. Even stainless steel is eroded easily if it is placed in seawater for long time due to the chemical reaction between screws and housing with salt water. Material other than stainless steel was considered for making the housing. Acrylic and Nylon is a better choice for anything being used underwater for three months.

VII. Final System Design

Figure 6 shows the system being assembled, with all the component boards inserted into the camera housing. The cable connected to the camera can also be seen clearly. It was decided to fix the cable permanently to the camera housing, as the cost of hybrid fibre-copper underwater connectors was excessive. This was possible as the camera was going to be used fairly close to the shore station. However, the design can accommodate such connectors if desired at a later stage.

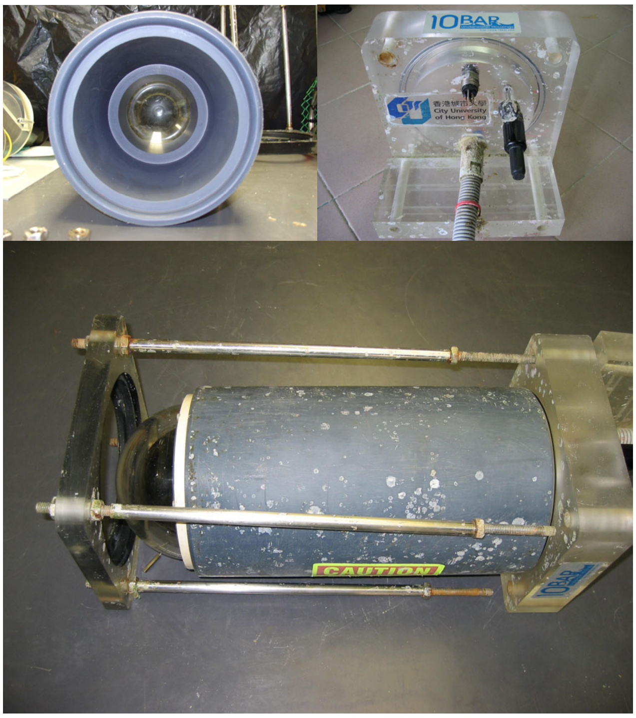

Figure 5 Camera housing

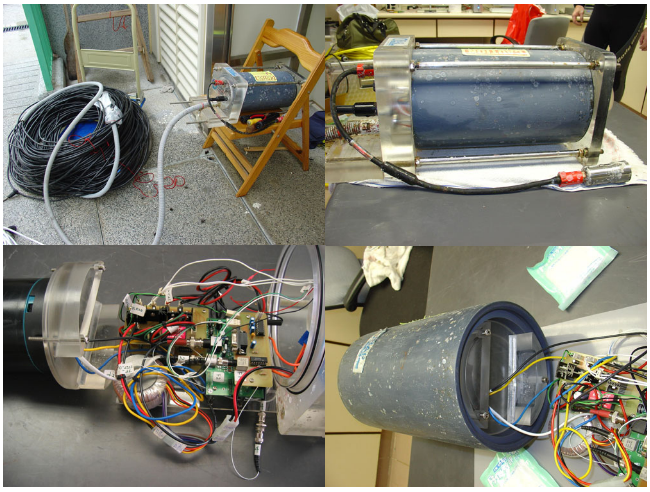

Figure 6 Assembling the camera electronics in the housing

VIII. Discussion

A number of problems had to be solved once the camera had been in the water for a few days. First, the was a problem with the focusing of the zoom lens. As the camera used in this project can pan and tilt, a hemispherical dome was used. However, when the camera is put underwater, the focus effect when zooming is worse than on land. The camera has lens with focal length 4 to 48mm in air, but when the camera stays underwater the camera cannot focus with a zoomed picture due to the distortion of the Dome window. By experiment, adding a correction lens has a positive effect of the zooming picture, and the camera can zoom on to object within 25cm long by adding a 3-dioptre-macro lens. This, of course, limits the usefulness of the current version, but can be overcome by use of different optics.

Secondly, the zoomed picture was not clear because of the condensed water vapour in the dome. When the camera is put underwater, the temperature difference between the about 20°C generates the fog on the doom. The fog can be removed by adding silicon gel to the electronics. The temperature of the electronics is also measured by a thermometer inserted in the housing, which can be read by divers through the acrylic face plate at the rear. This will be replaced by an electronic version connected to the data system in future models.

Thirdly, the use of an external light at night time attracts many marine organisms, and this blocks the light illuminating the objects being monitored. Initially, the light was put parallel to the camera pointing to the target object. However, too much light was either blocked or reflected, mainly by plankton, although crabs also took great delight in investigating what was going on! This situation was improved by putting the light in a position such that the light path is not parallel to the camera view, or off to one side, thus not blocking it. An alternative was to use lights some distance away from the camera dome, but this required a separate system with its own power supply. A 12 V system was deployed with good results later in the experiment.

Finally, there e was significant and fast marine growth on the acrylic dome. Thus it was necessary to use a diver to regularly clean the dome - around once a week.

IX. Results

This instrumentation system worked well for the 3 months continuous usage underwater, observing a coral bed at a depth of 3-4 metres. It even survived a typhoon! The system was fixed to the sea bed using rebars hammered into the hard sediment under the sand. The system was clamped to the rebars. The fibre optic/power cable was buried under a thin sand layer for protection.

After 3 months the system was raised and cleaned to clear away all the marine growth. It is now being used at another location.

Figure 7 shows the camera underwater, as well as some of the stills taken from the dvd recorder used to capture the video at the on-shore station. These were used to monitor the fish population on a diurnal basis. The system was set up at an established reef in the protected Marine Park. It was able to monitor activity on the reef, not only by fish and other aquatic creatures, but also monitored divers and their activity.

X. Conclusions

The project achieved the following:

- a high-resolution underwater camera that can Zoom, Pan and Tilt as well as being controlled remotely via optical fibre
- a fibre optic communication for underwater, especially for underwater cameras and instrumentation. In addition, the system can also communicate with a sensor system via the optical fibre, thus allowing real-time analysis of the underwater environment..
- an environmentally friendly system that is good for the marine environment with real-time underwater recording by remote control, rather than by diver. The image captured is stored directly to PC that the capacity of PC is much more than digital camera.
- a system that can be used for recreational and security use, as it can monitor the underwater environment on a 24 hour basis, for up to 3 months at a time.

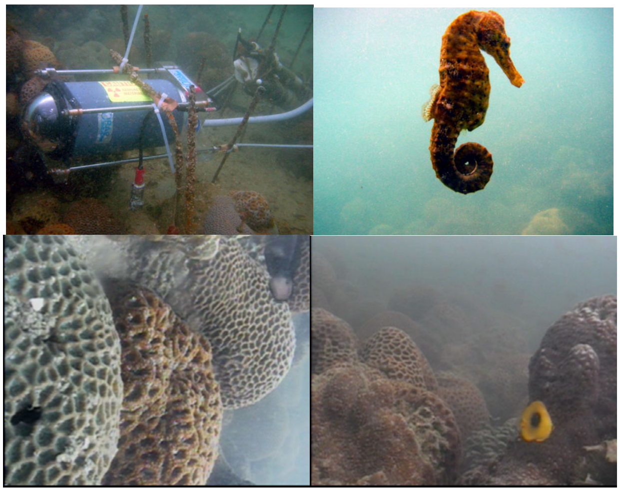

Figure 7 Camera in situ, and stills from video taken by camera

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Robin S Bradbeer, (M'90 - SM'93) is an Associate Professor in the Department of Electronic Engineering, City University of Hong Kong, Hong Kong. Her main research interests are underwater robotics, especially in conjunction with marine biologists. She is working on a number of projects to design instrumentation and remote operated vehicles to monitor reef activity. She has just completed a Doctorate in Education at University of Durham, UK, investigating studio-based methods for teaching mechatronic engineering. Robin is currently Chair, IEEE Hong Kong Section Consumer Electronics Chapter. She was 2nd Vice-President, International Affairs, IEEE Consumer Electronics Society AdCom in the 1990s.

Kenneth K K Ku is a Research Assistant in Department of Electronic Engineering, City University of Hong Kong, Hong Kong. He graduated with BEng in Mechatronic Engineering from City University of Hong Kong in 2003. He has been working on underwater systems in the Department of Electronic Engineering, City University of Hong Kong, Hong Kong since graduation.

Lam F Yeung is an Associate Professor in the Department of Electronic Engineering, City University of Hong Kong, Hong Kong. His current research interests are in developing robust multivariable control methods, large scale systems, adaptive control systems and autonomous guidance vehicles, real-time systems. He has published over 35 technical papers in journals and conference proceedings, and one monograph. He was also awarded the IEE *Heaviside Prize* for his paper in 1983.

Katherine K Y Lam is an accomplished marine biologist of who has studied many aspects of Hong Kong¡¦s marine environment. She received her PhD in 1999 and worked as a postdoc researcher at the Swire Institute of Marine Science at the University of Hong Kong. Now she is a research fellow of the Hoi Ha Wan Marine Laboratory, City University of Hong Kong. Current interests are studying spatial and temporal changes in coral communities using remote operated vehicle (rov) and real time underwater surveillance camera.