# An underwater camera and instrumentation system for monitoring the undersea environment


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**Abstract:** It is impossible to use human divers carrying underwater cameras, with limited battery and recording capacity, to monitor marine life and coral behaviour, and to record for 24 hours a day over 3 months. This is especially true in the coral spawning period. As a result, the use of an instrumentation platform, remotely controlling a deployed underwater camera systems and sensors, is an alternative approach that can provide long-time monitoring and image recording. This paper describes the design, implementation and results obtained from such a remotely operated system.



**Keywords:** Underwater camera, fibre optic communication, WDM, underwater instrumentation


## Introduction

The qualities and functions of a camera used underwater for monitoring are important when used to monitor coral behaviour such as spawning. A high-resolution, remote powered and real-time controlled camera is necessary for this project. In addition, this camera has functions, such as, zoom, pan and tilt so that a larger range be obtained. A real-time capturing and recording system, which can capture real time pictures and store a large amount of video recording to PCs, is indispensable.


Figure 1 Block diagram of the underwater system

To support high quality imaging, optical fibre cable is used to prevent loss of data and image. The video signal is sent directly over a fibre optic 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.

A 5-in-1 real-time remote control sensor, which can measure temperature, pressure, PAR, dissolved oxygen and salinity, is also used with the camera system to provide environmental analysis for this project.

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.

## Underwater cable

The configuration of the underwater cable is shown in Figure 2. The cable, which contains 2 copper wires and 2 multimode fibre optic cables [5], is about 210m long, and connected between the Marine Life Centre and the underwater system. The waterproof jacket is made of PVC. In addition,

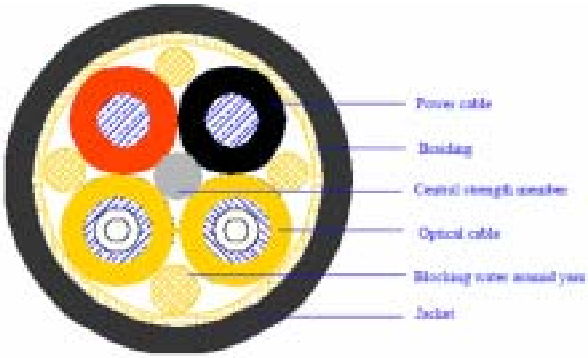

Figure 2 Configuration of the underwater cable

aramid yarn is put inside the jacket to prevent leakage of water. This cable was designed and manufactured specifically for this project

processes the received video signal and sensor data for analysing the marine environment.

As shown in Figure 3, the whole system uses a bi-directional communication via 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

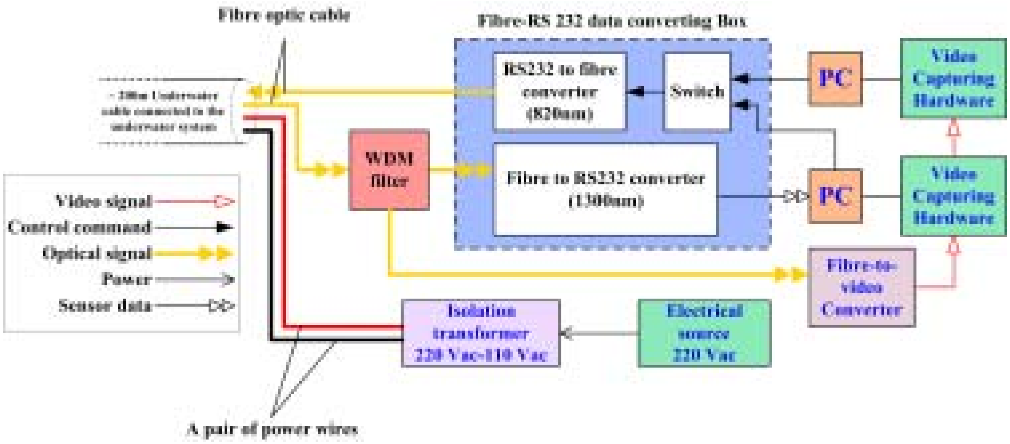


Figure 3 Block diagram of on-land system

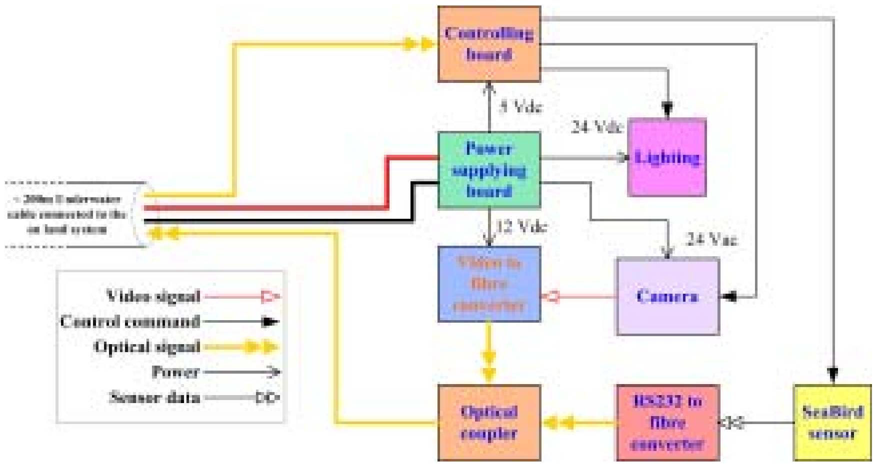


Figure 4 Block diagram of the underwater system

**On-land system**

The on-land system is placed at the Marine Life Centre to control the deployed underwater system including the camera and the environmental monitoring sensor. At the same time, this system

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 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.

**Underwater system**

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 Seabird 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 is regulates 110Vac to the proper power for different circuit boards and components.

**Prototype**

In this project, some common signal formats, e.g. RS232 and RS422, were used to control the camera and the Seabird sensor. To test each section, prototype circuits were built and then connected together to finalise the overall design. Once this had been proved in practice they were integrated into single system

*Sending RS232 signals from PC to PC via fibre*

An RS232-fibre transmitter and a fibre-RS232 receiver were built to test the effect of using fibre optic. The system set up is shown in Figure 5.

This system is set up to send RS232 characters from PC's 'com port' to another the PC's 'com port' through a 100m-long fibre optic cable. TTL signals are common for fibre optic transmission and it is easy to get a TTL optical transmitter and receiver to build the system. Figure 6 shows the compatible TTL transmitter and receiver circuit for optical fibre.

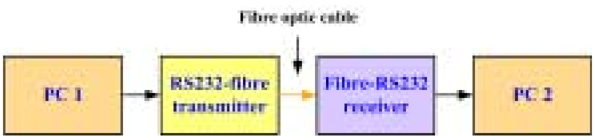


Figure 5 RS232 communications between PCs

To communicate with PC, RS232 line driver is also used to do conversion between RS232 and TTL signal for both of transmitter and receiver circuit [6].

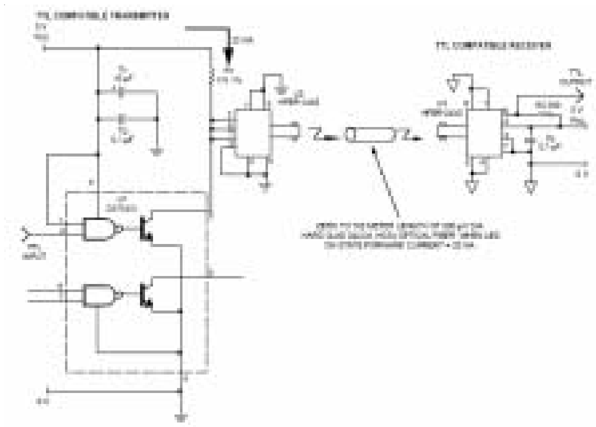

Figure 6 Compatible TTL transmitter and receiver circuit

*Sending RS422 commands to camera via fibre cable*

The prototype system for the camera control is shown in Figure 7. The camera can only read the commands in RS422 format. As an RS232-fibre transmitter has been built before, the main task is to convert optical signal back to RS422 for the camera to read. To keep it simple, only a TTL to RS422 converter circuit is considered when building this testing system. The rest of circuit is the same as the compatible TTL transmitter and receiver circuit shown in Figure 4 above.

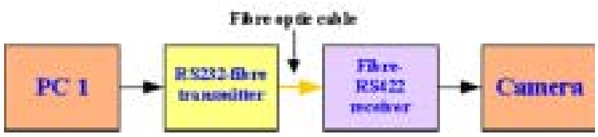


Figure 7 Testing system for Camera control

*Camera Control Protocol*

The camera used in this project is SpeedDome III camera dome [7] (Figure 8) which can communicate using RS422. The dome consists of a mounting base, and housing and rotating eyeball assembly. The dome camera uses RS-422 balanced line at

Figure 8 SpeedDome III camera

4800 Baud. The command set includes the following commands:

| | |
|---|---|
| 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 |

**Housing**

Figure 9 Acrylic Dome and O ring

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 9, 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.

*Nylon and Acrylic Main Body*

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. The main body contains three materials:

1) Nylon cylinder to house electronics shown in Figure 10a;
2) Two acrylic blocks (top and bottom shown in Figure 10c and 10d) to clamp the cylinder;
3) Stainless steel bars and nuts to screw all the parts together shown in Figure 10b.

Figure 10a Hollow Nylon cylinder

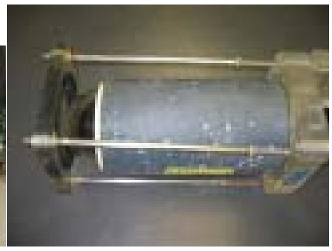

Figure 10b Whole housing

Figure 10c Top Acrylic block

Figure 10d Bottom Acrylic block

**Seabird sensor**

The Seabird sensor not only measures the data from five sensors, but also a data logger that can store the data in its flash memory. This SBE 16*plus* SEACAT [8] is designed to measure temperature, pressure, dissolved oxygen, salinity and PAR in marine environment. Through the software, the user can set the sampling interval by typing command on PC. The software can also do real-time graph plotting that allows user to analyse the data immediately.

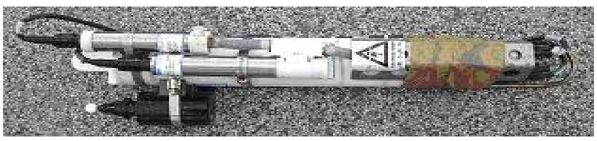

Figure 11 Seabird sensor

## Final system design

Figure 12 System photos

## Underwater photo captured by the system

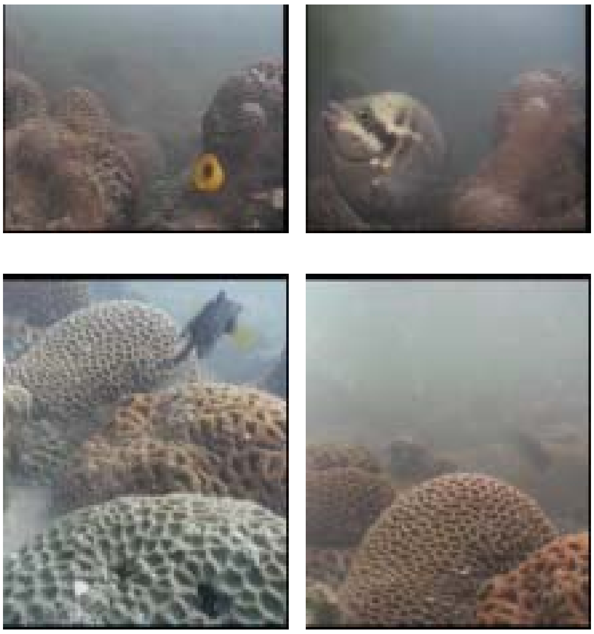

Figure 13 Underwater photos captured by the system

## Discussion

*Focusing underwater using the zoom lens*

As the camera used in this project can pan and tilt, to obtain a larger range of view for the camera, a hemispherical dome is 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.

*Water vapour in  the camera Dome*

Initially, the camera could not focus with a clear zoomed picture because of the condensed water vapour in the dome. When the camera is put underwater, the temperature difference between the running electronics at about 35°C and the water about 20°C generates the fog on the doom. The fog can be removed by adding silicon gel to the electronics.

*Marine organisms block the light*

Light can attract many marine organisms at night, 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.

*Marine growth on the acrylic dome*

There 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.

## Conclusion

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.

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 camera. In addition, the system can also communicate with the sensor system via optical fibre. Through the system, real-time analysis of the underwater environment is achieved.

* 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.


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