Design and Development of Intelligent Buoy System for Coastal Zone Monitoring Application



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Buoy

- Cardinal Buoy
- Cautionary Buoy
- Anchorage Buoy
- Mooring Buoy
- Control Buoy
- Hazard Buoy
- Information Buoy
- Swimming Buoy
- Diving Buoy
- Keep Out Buoy
- Scientific Buoys (O.D.A.S.)
- Fairway Buoy
- Isolated Danger Buoy

1.0 INTRODUCTION

According to the Oxford Dictionary, buoy is defined as navigation aids with floating object, fastened to the bottom of the sea or a river, that indicates reefs or other hazards, or for mooring [1]. Usually, they indicate shoals, obstruction, dangers and mark channels. Each types of buoy have their own specifications, with different sizes, colour, shape, top mark, number and light colour/ characteristics.

A special IALA mark is used to indicate special areas which include:

1. Ocean Data Acquisition System (ODAS) Buoys
2. Traffic separation marks
3. Spoil ground marks
4. Military exercise zone marks
5. Cable or pipeline marks
6. Recreation zone

An existing ocean or coastal observation/monitoring system features a stationary single or multiple measurement points with built-in data logger. Multiple data obtained (conductivity, tide/depth, temperature variation, dissolve oxygen, acoustic noise, etc.) is stored inside the data logger. Measurements of surface parameters require sensors that are mounted on an anchored buoy while the measurements of the bottom parameters require anchor-mounted sensing modules. The latter still requires a buoy as a marker or at least an anchored point whose coordinate is locked. The contributions of all these observations and measurement method have been proved for several decades by providing us with significant amount of oceanographic data.

However, there is still plenty of room for improvement for increasing the efficiency of the system. Existing monitoring and observation systems are passive systems, whereby periodic data collections are required for further processing and interpretations. For time-sensitive data, daily or weekly data collections have become standard operating procedures. Such a passive monitoring and observation approach can be replaced by the active method.

Recently, an active monitoring and observations system was implemented for early tsunami warning and underwater seismic monitoring observations. The enabling technology is satellite communications/remote sensing. Up to date, remote sensing is not a cost effective solution for coastal area monitoring and observations (less than 10 nautical miles from the shores). Passive observations system is exposed to several conceptual and technical disadvantages.

In this article, we will focus on design and development of scientific buoys, also known as Ocean Data Acquisition System (ODAS) Buoys. Generally, ODAS buoys are smaller in size and are bright orange or yellow in colour with vertical stripes on moored buoys and horizontal bands on free-floating buoys. They are also equipped with strobe lights for night visibility. Figure 1 shows some examples of existing ODAS buoy.

2.0 DESIGN CONSIDERATION OF AN ODAS BUOY

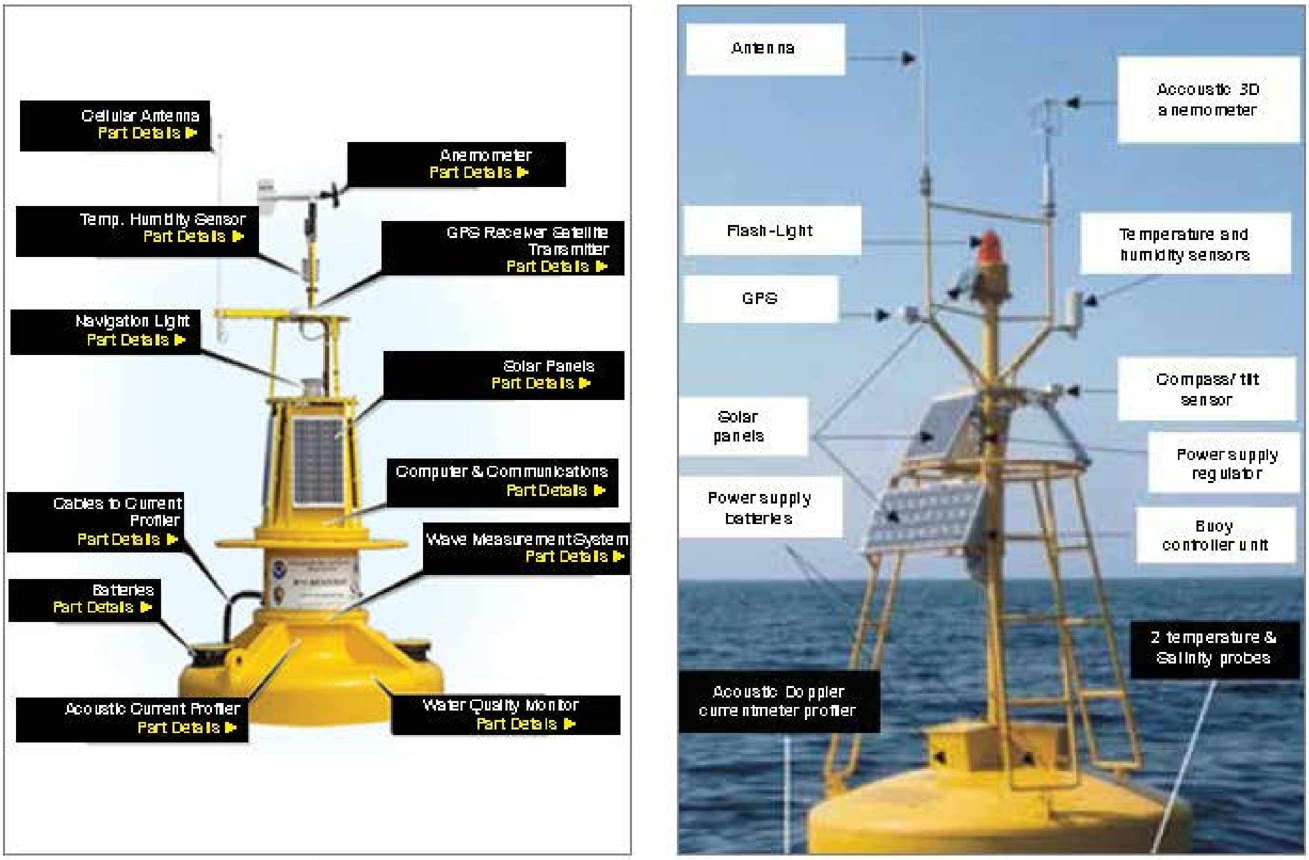
There are many factors to consider when designing an ODAS buoy, to ensure it serves the intended purpose for the intended duration of time.

Sensor

The first step when designing an ODAS buoy, is to decide on the types of parameters to be collect and how they will be collected. Common parameters collected from an ODAS buoy are sea surface temperature, air temperature and humidity, barometric pressure, wave height and direction, wave period and tide, current speed and direction, wind speed, wind direction and gust, and salinity. Some buoys have visual, audio observation equipment and several specialised sensors. For example, the Coral Reef Monitoring manual for the Caribbean and Western Atlantic [8] included temperature, dissolved oxygen, salinity, pH, light transmission, sedimentation, nutrients and current speed and direction in the list of parameters that may affect

(a) (b) (c) (d) (e) (f)

Figure 1: Examples of O.D.A.S Buoy (a) ODAS [2] (b) Integrated Ocean Observing System (IOOS) [3] (c) Wave Buoy [4] (d) Monterey Ocean Observing System [5] (e) NARACOOS Buoy [6] (f) Integrated Marine Observing System (IMOS) [7]



(a) (b)

Figure 2: Sensor placements on (a) CBIBS Buoy and (b) Oceanographic buoy by Sirio d.o.o. Koper

the growth and survival of reef organisms, and therefore should be monitored. Figure 2 shows placements of various sensors on CBIBS buoy and oceanographic buoy by Sirio d.o.o. Koper respectively.

Telemetry

The next consideration in designing an ODAS buoy will be the type of telemetry used. The choice of telemetry will depend on whether the data needs to be communicated in real time, the bandwidth requirement, the distance between the buoy and the ground station, and the operating cost. Communication through electrical or optical cable can be reliable and unlimited in terms of the bandwidth, which is ideal for real time data communication. However, installation of undersea cabling can be very expensive and requires various environmental and other considerations. Satellite communication is among the most popular choice of telemetry for weather or ODAS buoys owing to the widest coverage. The downside however, is the limited and high cost of bandwidth. Table 1 compares data size and cost for different satellite telemetries.

In an area which receives cellular network coverage, cellular communication may well be an option. The bandwidth and cost may vary, depending on the data plan and service provider. Another good telemetry option for coastal buoy is RF communication, which is free of charge and can provide a bandwidth higher than that provided by satellite communication.

Table 1: Data size and cost comparison of satellite telemetries [9]

System	Message size	Airtime cost	Monthly price, 1 message/day	Monthly price, 1 message/hour	Terminal power consumption (during transmission)
Iridium SBD	<340 bytes	$13/ mo+ $0.0015/byte [10]	$14.24 (30 bytes)	$31.48 (30 bytes – bulk tariff)	1.8W
IsatM2M	25 bytes	$0.06 for 10 bytes or $0.120 for 25 bytes	$5 (25 bytes – minimum spend)	$89.28 (25 bytes)	9W
ARGOS	32 bytes	$21/mo + $3.50/6hr slot[11]	$124	$437	<1W
DCP	650 chars (roughly 400 bytes)	Free	$0	$0	50-100W
Orbcomm	<2000 bytes?	Unlimited for $60/mo	$60	$60	24W
Globalstar simplex	<36 bytes	$30/mo for 100 9-byte message	$30 (9 bytes)	$165 (36 bytes-bulk tariff)	5W

Power

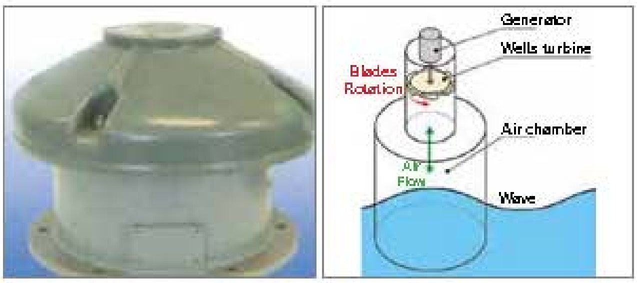
Power requirement for the buoy depends largely on the number and types of sensors used, sampling frequency, type of telemetry and frequency of communications. There are several options for generating power on a buoy system, the most popular of which are batteries, solar panels, diesel generators, wind turbine, and wave-activated generators (WAG). In regions that receive a large amount of sunlight, such the tropical region, solar panels provide access to free energy. However, buoys in other regions which don't have the luxury of sunlight, may opt for diesel generators or other sources of renewable energy such as wave-activated generators (WAG). Figure 4 shows an example of a WAG and the working principal. Some low-power buoys can even operate on batteries for several years.

(a) (b)

Figure 3: Satellite transceiver for (a) Iridium satellite and (b) Inmarsat D+ satellite

Mechanical Structure

All the telemetry, sensors, controller unit, and power generation equipment constitute the payload of the buoy that must be taken into consideration when designing its mechanical structure. The mechanical structure should include the mountings for the telemetry unit, sensors and power generation equipment such as solar panels as well as safe compartments for the controller boards and batteries. Another aspect of the mechanical design of the buoy is the mooring, i.e. how it will be fixed to the seabed. There are



(a) (b)

Figure 4: (a) Wave-activated generators (WAG) by Ryokuseisha Corporation (b) Principal of operation

several types of moorings which, according to American National Weather Service, depend on the hull type of the buoy, the location and the water depth. Figure 5 illustrates four types of mooring for buoy by the American National Weather Service.

A moorinsg system consists of a mooring line, anchor and connectors. The mooring line can be made of synthetic fibre rope, wire and chain or a combination of the three. An anchor attaches the mooring line to the seabed and can be of several types, namely a mushroom anchor, deadweight anchor, or screw-type anchor. The choice depends on the condition of the seabed. The overall mechanical structure design of the buoy should provide the buoyancy to hold the total weight of the structure, the payloads, and the weight of the mooring structure, while maintaining the required stability under various sea conditions.

3.0 DEVELOPMENT OF AN INTELLIGENT ODAS BUOY

Our Intelligent Buoy is a type of ODAS buoy that provides an intelligent observation of various oceanographic and meteorological parameters and which can integrate with other underwater, surface, and aerial platforms to form a larger and comprehensive integrated ocean observation system. Its target deployment area is a coastal marine park.

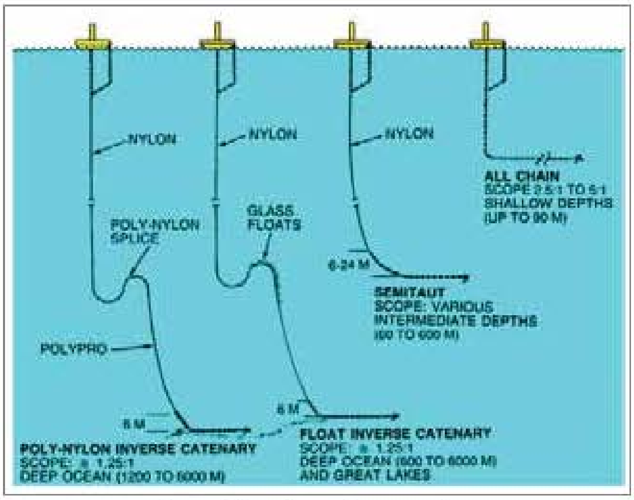


Figure 5: Four types of buoy moorings

It is called an Intelligent Buoy because, apart from collecting various scientific data, it can relay data from other platforms to the ground station and, at the same time, act as a beacon to help with localisation of some other mobile platforms.

Sensors

Listed in Table 2 are the various types of sensors installed on the Intelligent Buoy to measure oceanographic and meteorological parameters. In addition to some common sensors, the buoy is also equipped with a hydrophone, an underwater camera, and an omni-directional surface camera to capture audio and visual information from the marine environment. This hydrophone and camera can be configured to automatically respond to certain trigger to initiate the recording and capturing. Time information provided by on-board GPS is used to update the system real-time clock, hence keeping it from drifting.

Table 2: List of sensor on Intelligent Buoy

Sensor	Parameter
Anemometer	Wind speed and direction
Vapor Pressure, Temperature and Relative Humidity Sensor	Air temperature, humidity and vapor pressure
CTD sensor	Water salinity and sea surface temperature
Depth and temperature transducer	Water depth
Hydrophone	Underwater sound
Underwater camera	Underwater image
Sea surface omni-directional camera	Sea surface surveillance
Inclinometer	Sea surface roughness
Compass	Used in combination with anemometer for wind direction
GPS	Positioning and real-time clock update

Telemetry

Data acquired from the sensors are transferred to the ground station through wireless communication in a timely manner which eliminates the need to personally collect data from the buoy except for large audio and visual data which cannot be supported by the communication bandwidth. In addition to sending data from the buoy to the ground station, the wireless communication will also be used to remotely configure the buoy from the ground station. This is done with the use of a bidirectional radio frequency communication module, which is capable of reaching up to 3 kms of communication range using a high gain antenna mounted 2 metres above the sea surface. Furthermore, the communication system uses a mesh topology, which allows the message to hop from buoy to buoy in order to reach the ground station in the event that the distance between the buoy (originating the message) and the ground station is more than 3 kms.

Data Acquisition, Processing and Control

All sensors, communication module and other equipment on the buoy are controlled by a main controller located on the controller module. The whole electronics of the buoy takes a modular design approach, which allows for easier future expansion of the system. In this approach the main controller module board consists of a low power controller which performs basic controls of storage, GPS and communication module, and provides generous I/O ports to control the power module and other sensor modules located on different boards as shown in Figure 6. Sensors that require heavy computation such as camera and sound recorder, will have their own controller which will be managed by the main controller. The main storage consists of an SD card located on the main controller board. SDHC card is selected for this system because of the high capacity and low price.

Power

A lithium-ion battery with a suitable capacity is selected to power the whole system, and this battery will be recharged by solar panels to ensure continuous operation without the need to replace the battery. The capacity of the battery and solar panels are selected based on the power consumption of the system, estimating various sensors sampling rates and frequencies, and the duration and intensity of the sunlight throughout the year. The power for the buoy is managed by a power module which is responsible for converting the battery voltage to 3.3v, 5v, and 12v supply as required by the various instruments on the buoy.

4.0 CONCLUSION AND FUTURE PLAN

The UCRG Intelligent Buoy is currently being finalised and will be tested in the near future for real ocean application. It will be an excellent test-bed for future near-shore inspection, monitoring and marine mitigation activities. Certainly, further research is needed to study the performance of the buoy in various environmental conditions and other related issues. The design and development of the Intelligent Buoy was initiated by the UCRG team based in Universiti

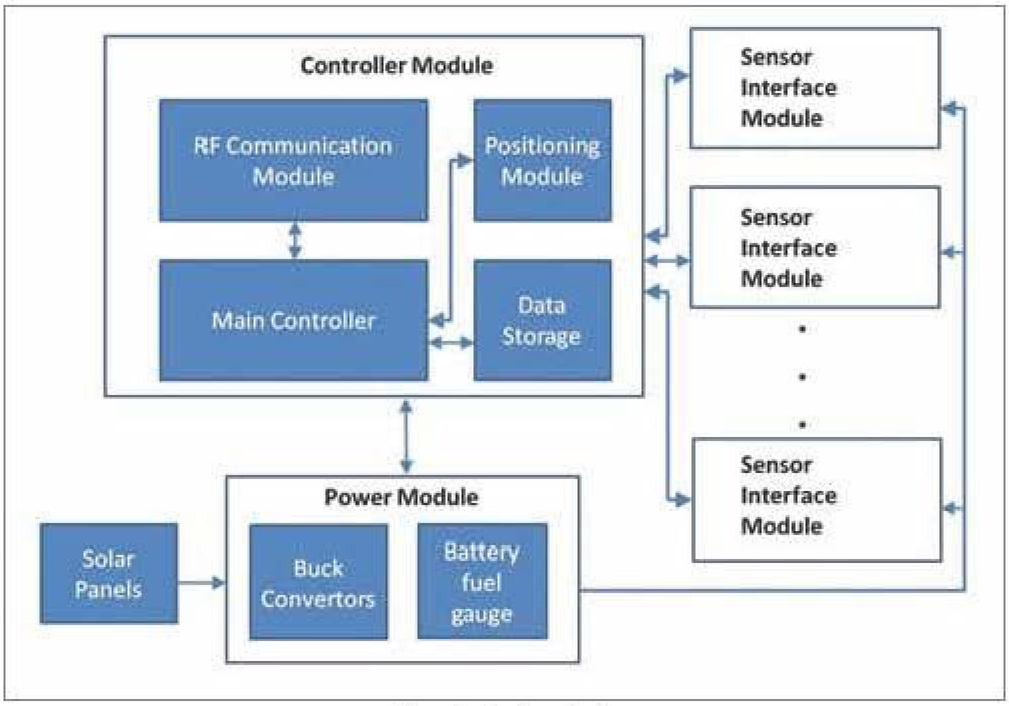


Figure 6: System design

Sains Malaysia (USM) in Nibong Tebal, Penang. We are also proactively looking for collaborative partners to expand our R&D works and potential field trials. This work was funded by the Ministry of Science, Technology and Innovation (MOSTI), e-Science 305/PELECT/6013410 and Universiti Sains Malaysia.

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