3Meter Disc Buoy with Satellite Communications Infrastructure

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Abstract— Moored ocean buoys are technically feasible approach for making sustained time series observation in the oceans and will be an important component of any long-term ocean observing system. The 3M disc buoy carried Zeno 3200, MCCB, Orbcomm, Global Star and Bluetooth module. The deployments have relied on Orbcomm and Global Star as the primary satellite communications system. In addition to detailing our practical experience in the use of Orbcomm and Global Star as high latitudes, we will present some of scientific sensor results regarding real-time oceanographic and meteorological parameters such as wind speed, wave height and etc. In this paper we present the design and implementation of a small-scale buoy sensor network. One of the major challenges is that the network is hard to access after its deployment and hence both hardware and software must be robust and reliable.

Index Terms—Multi-Channel Communication Control Board (MCCB), Oceanographic mooring

I. INTRODUCTION

There is a variety of remote sensing tools housed in artificial satellites, which are very useful for monitoring the global environments. Sensors and software for measuring water temperature, wind velocity, current velocity, wave height. Mooring provide an effective way to monitor ocean life and processes by providing a platform for sensor to collect data throughout the entire water column over large temporal scales. The high temporal resolution, long-term data collected from moorings capture a board dynamic range of oceanic variability and provide important information concerning episodic and periodic processes ranging in scale from minutes to years [1],[6]. Such data greatly enhances our understanding of the earth's oceans and contributes to solving world problems such as natural disaster prediction and global warming.

Mooring provide important data sets; however, many moorings particularly those in the deep sea, do not provide comprehensive data sets in real time. Open ocean mooring are typically deployed and retrieved at six to nine month intervals for data download and analysis, and mooring servicing.

This 3M disc buoy is designed with two-way satellite communications for telemetry and commanding via low-earth orbiting (LEO) satellites. The use of these new LEO satellites allows the possibility of increasing the data throughput from remote data platforms by many orders of magnitude over the currently used Argos and GOES systems. In addition, our communication link allows commands to be sent to the buoy for failure recovery or dynamic response on interesting phenomena. [8], [9]

The ability to retrieve large amounts of data within hours of its being collected, coupled with the ability to send commands to the data platform, hast the potential of changing way remote experimentation is done in the oceanography community. The 3M disc buoy provides wave height and direction, sea surface temperature, salinity and temperature profiles, wind current speed and direction, and meteorological parameters. It is the ideal buoy for deep-water measurements, remote locations and strong conditions. Additionally, the buoy can be equipped with numerous other sensors such as pressure sensor, hippy sensor, temperature sensor, water level sensor, wind speed and direction sensor, magnetic compass sensor, impact sensor and air temperature sensor. The buoy hull design is based on the dynamic response and stability requirements from comprehensive wave tank testing. Satellite-based remote sensing has significantly extended climatologically research capabilities and global models are showing success. Pioneering global climatology, however, has had little technological support for global-scale research.

II. System Composition

In this section we describe the hardware entities of the 3M disc buoy. Our approach has been to create a buoy system a modular design so that the suite of sensors and the data-gathering software can be easily

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reconfigured in support of a variety of scientific experiments. We developed a complete platform for testing purpose.

A. Hardware Entities

These 3M disc buoy systems are constructed from steel and aluminum with a foam flotation collar. The buoy's tower is made of 6061-T6 aluminum for light weight, and electrically isolated from steel base by plastic shoulder washer. Mounted on the tower are a radar reflector, Coast Guard approved flashing light, telemetry antennas, meteorology sensors, solar panels, electronic system, wind gauge antenna and etc. One solar panel can be swung up to gain access to the instrumentation well in the center of the buoy.

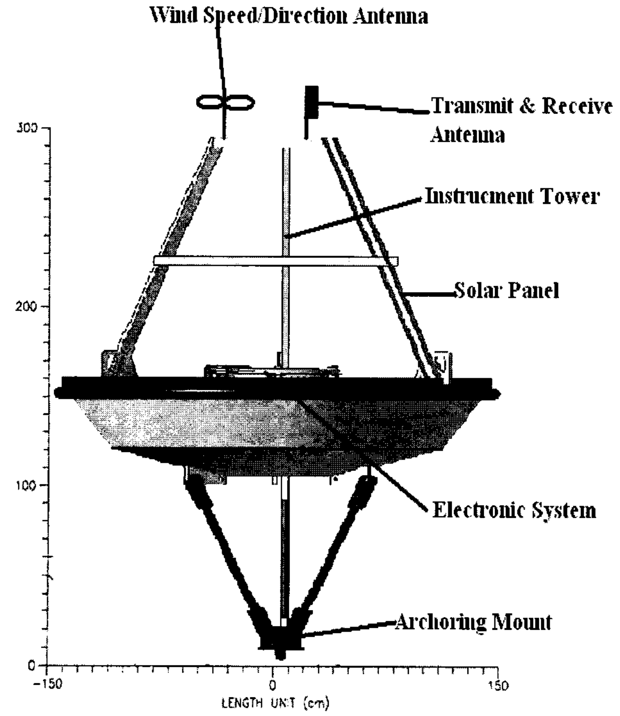

Fig. 1 A cross-sectional schematic of the 3M Disc buoy platform.

Access to the buoy's watertight electronic well is through a hatch in the top. The large diameter allows a person to lean into the well to work on batteries in the bottom. Mounting the electronics for easy servicing has always been a problem. In fact, engineering work for fixing the buoy in the open ocean is much more difficult than its constructions in the indoor. The principal cross sectional schematic are show in Fig. 1.

B. Electronic Design

The buoy electronic system was designed to be power-efficient, self-contained, and programmable for different application. Care has been taken to balance the power consumption and the performance requirement because the buoy is integrated in a stand-alone system that is battery operated. The basic application design of our system is show in Fig. 2.

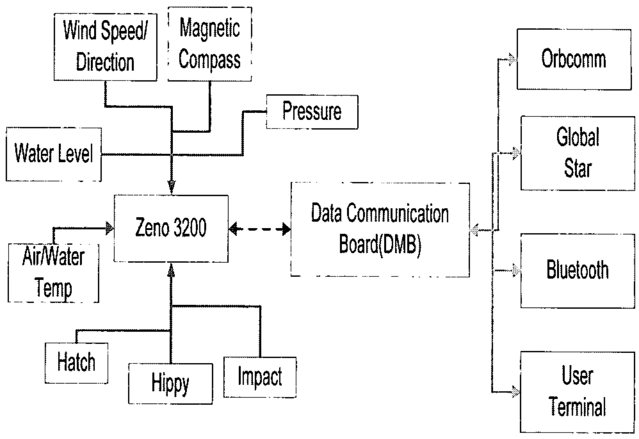

Fig. 2 Block Diagram of the modules used in buoy system

In our electronic system, we implemented Zeno 3200 to collect data from sensors, process the collected data and log into RAM and transmit the processed and collected data to MCCB. Basically the Zeno 3200 is the intelligent, versatile, low-power; 32-bit data acquisition system designed to collect, process, store and transmit data from multiple sensors. Its mechanical versatility and low power requirement allow the Zeno 3200 to operate independently and remotely in a wide range of environmental extremes that include ocean buoys. After the Zeno 3200 processed the collected data, the data will be transmitted to the MCCB. The Zeno 3200 can output data message giving measured data values in real time as well as log the data. The Zeno 3200 required 35 minutes to accumulates and records the data information from all the sensors. After the Zeno 3200 processed the data, it sends to the MCCB board. The MCCB board stores the all the data and send the data information after the MCCB board perform filtering according to the user command.

C. Algorithm Overview

The MCCB board is designed to provide additional special features for whole system. The relay layer in MCCB enable hard reset on overall system or selected device through the command send by the user. Besides, user can configure desired output format string from the Zeno 3200 by sending commands to MCCB board via Orbcomm, Bluetooth or Global Star. The main purpose of this feature is to reduce the satellite transmission latency. The programmable module is pre-programmed circuit board for data monitoring.

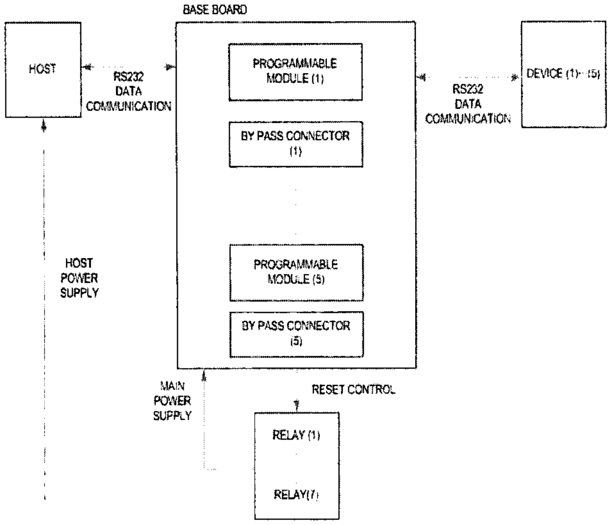

Fig. 3 Simplified block diagram of the MCCB

The MCCB is connected to the device such as Orbcomm modem, Global Star and Bluetooth module show in the Fig. 3 The host shown in the figure is referring to the Zeno 3200. The MCCB also provide hard reset when it received a power reset command from user. The command received via satellite communication. The main advantage of this feature is the 3M buoy can be reset whenever there is a failure and issue happen in the electronic system.

E. Advance Data Communication

The most important specifications driving buoy design decision are the telemetry rate that the buoy system will support for communication to shore and the amount of power delivered. At present, compact, lower-power satellite communication systems that can be powered entirely by solar cells and batteries are limited to modest data rates. Solar cell can only provide at most a few tens of watts of power to instrument on a mooring. In the case of complete failure of the main power system, a back-up power system at least partially supplied by solar could operate an Orbcomm system transceiver. Thus, in this research, our main concern is to increase the transmission reliability and only transmit selected data information from Zeno 3200 to user. With this, it decreases the transmission bandwidth and power consumption of the buoy. Basically, the Fig. 4 below show how the buoy established transmission connection via satellite communication with Orbcomm modem.

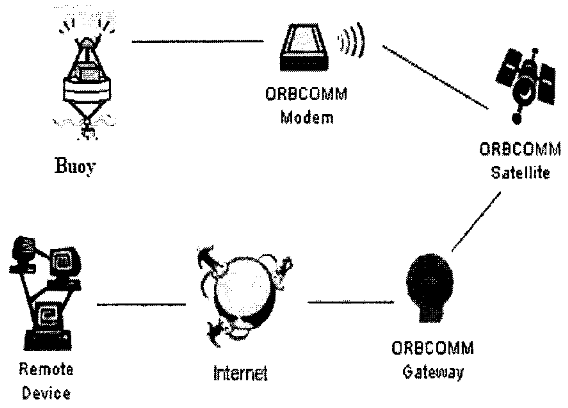

Fig. 4 Buoy system to communicate to remote device with Orbcomm modem.

The Enhanced Orbcomm Serial interface for stellar terminal is an additional set of commands, which are supported by the EL2000 and ST2500 families. This set provides additional data about the terminal and renders the control easier but does not replace the Orbcomm serial interface specification. The figure shows the format of the protocol when Orbcomm communicate with MCCB board. The microcontroller need to send this protocol followed by strings contains sensors data. The microcontroller will send header byte, packet type and packet length, starting with byte 0 including checksum. After these packets, Orbcomm will read the setting as sent by microcontroller. Every byte setting of the protocol is provided in the ST2500 Orbcomm user guide manual.

	76543210	
0	0x85	packet header byte
1	0x86	packet type
2	length byte 0	packet length, starting with byte 0, includes checksum
3	length byte 1	
4	retry count/pkt seq num	Same as SC Originated Message (packet type = 0x06), see ORBCOMM Serial Specification, Doc. No. E80050015 Revision E
5	gwy id	
6	polled	
7	ack level	
8	priority	
9	msg body type	
10	mha ref num	
11	rcpnt quan	
12	subject ind	
	rcpnt addr 0 byte 0	
	rcpnt addr 6 byte I-1	
	subj byte 0	
	subj byte j-1	
	msg body byte 0	
	msg body byte k-1	
	Check Byte 0	Fletcher Checksum
	Check Byte 1	

Fig. 5 Enhanced SC originated Message

A Qualcomm Global Star GSP-1620 satellite data modem is used in our buoy system, but any AT-command compatible unit can be integrated. The modem is connected to a small (4.1 inches diameter by 2.5 inches tall) dielectric resonator antenna installed in the top part of the buoy. The GSP-1620 modem handles two kinds of data connections: Packet over the internet or Asynchronous, routed through the public switched telephone network to a destination modem. The space segment of the Global Star system consist of 48 low-Earth-orbit satellites with good coverage up to 70 degrees latitudes. When the buoy is on the surface the MCCB switches on the satellite modem and connect it with the acquisition system which starts 9600 bps full duplex asynchronous data connection. The acquisition system configured as client transmits the available data and verifies that all previous data has arrived. The remote computer, configured as a server, has the possibility to modify in real-time the different parameters of the acquisition and data processing software. [11]

End to end paths demonstrate the final delivery of information to users is where much of the value added by commercial entities is provided. Therefore, we added Bluetooth modem in our buoy system to allow people to get data and access the data by phone. The automated data collection system contains several error-checking protocols that minimize data loss and maximize data quality. No data are lost if communication with a buoy is unsuccessful for one or more schedule calls. All data are store in a MCCB board buffer in the buoy system and any gaps in the telemetry data are filled at the next successful transmission. Raw data received from Zeno 3200 are automatically transferred to MCCB that converts the data to engineering units, generates graphic displays; filter the data according to the user request command.

III Result of Measurement Test

In order to confirm the accuracy of the theoretical calculation, the 3M disc buoy experiment was carried out in the ocean. This section is not intended for a detailed reporting of scientific results obtained during at sea testing but simply to give an overview of the overall performance of the 3M buoy. Although some applications demand real-time transmission, most require only what we refer to as 'real-enough time' data: data received on the same day in which it was collected, which is suitably timely for most purposes. In addition, the communications link is two way, allowing the researcher to send commands to remote system to alter, say, its data-handling protocols or observing schedules in response to events observed in the harvested data stream.

Two-way communication is a new possibility of particular interest to oceanographer. Commands can be sent to the 3m Disc buoy to recover from failures or to change experiment parameter in response to interesting phenomena. This type of interactivity will become more critical as expanding global climate change research creates new opportunities for research that will require flexibility in setting up and changing experiment parameters based on trends seen in the harvested data stream. With the emergence of operational oceanography, a new generation of two-way satellite communications telemetry is required to provide the connection between the base station, various modeling efforts, and environmental monitoring and management efforts. Such satellite telemetry will provide the link between the remote platform and vessels which are observing the ocean and atmosphere. Improved satellite communications for buoys means the potential exists to integrate comprehensive in situ data with satellite data into a truly global, ocean-observing system.

This buoy system has been successfully tested at sea after indoor test of two months during which the buoyancy control never failed. In this paper, a set of data are used to determine the performance of the 3M disc buoy. These sets of data are observed in ocean. These sets of data were taken from 2 May 2008 to 6 May 2008 with 1 hour observation interval. Fig. 6 shows wind speed, wind gauge and air temperature experienced by a 3M disc buoy deployed off the ocean.

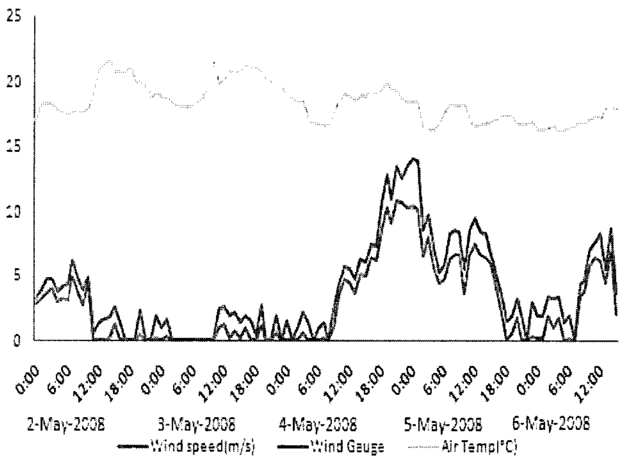

Fig. 6 Measured Wind Speed, Wind Gauge and Air Temperature

The buoy system requires 30-40 minutes for Zeno 3200 to process all data collected from sensors. The Orbcomm transmission is relatively new and untested. The experiments were therefore designed to collect as much as operational data as possible using the Orbcomm system so that our experience will allow a detailed assessment of its potential for data collection from remote location. The system offers both bent-pipe and store-and-forward two-way messaging capabilities, operating in the VHF (138-148 MHz) band. User terminals are known as 'Subscriber Communicator' (SCs). The message structure currently consists of packets transmitted at 2400bps (scheduled rise to 9600 bps), and coverage is global and near-continuous between the polar circles. Messages are acknowledged by the system when correctly received and delivered to our nominated mailbox.

The transmission of the data via Orbcomm modem from satellite to gateway requires 15 minutes. Therefore, the processed complete one data packet will be sent in mail format to email account every hour. Many of the measurement parameters are in format of a string plus integer array. A detailed analysis of the logged data provided evidence of a number of minor failures mainly present in the monitoring system.

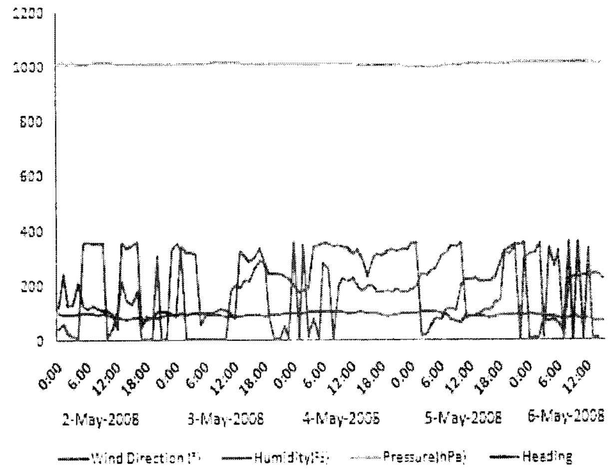

Fig. 7 Measured Wind Direction, Humidity, Pressure and Heading

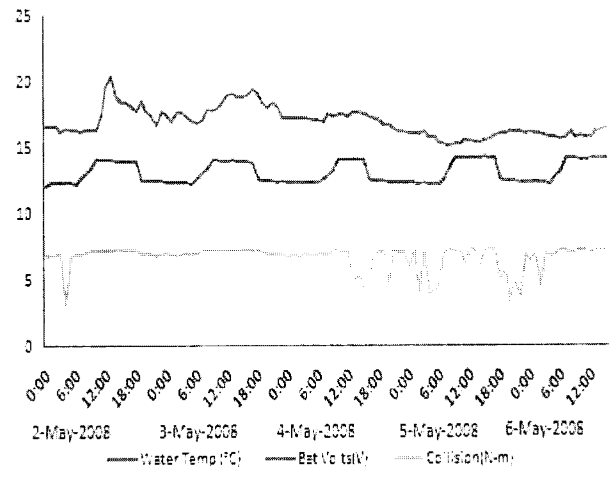

Fig. 8: Water Temp, Bat Volts and Collision

Some preliminary data of 3M disc buoy on battery voltage, water temperature and collision are given in the following figure. The collision sensors mechanically detect the buoy encounter obstruction. The sensor senses angular and compressive forces of the buoy. The buoy telemetry system and sensors are powered by solar power. Maintenance-free solar panels and sealed lead-acid backup batteries enable long-term unattended operation. For low sun radiation conditions, lithium batteries can be supplied. The batteries are connected to the data system and sensors through a diode network to prevent a failure in one part of the system from discharging the other. Thus there are two independent power systems with one battery and two solar panels each which supply power to the buoy system. This redundancy has not proven necessary in the past, but adds a level of reliability.

The solar panels on early steel buoys mounted at about a 45° angle near the water. The idea was to have the waves wash over the solar panels and clean any fouling due to birds perching on the buoys. Requirement for additional power were met by adding solar panels high on the tower, they did not have observable fouling. The power delivered by solar panel array to the battery system and then to the buoy system is harder to calculate. The four panels around the buoy assure that at least one will be in direct sun and that at least one will be in the shade. The Fig. 8 show that the readings of the battery voltage prove the solar panel is working fine. We generally design power system with a safety factor of two to account for temperature and battery inefficiencies, and the systems have supplied the necessary power.

IV. CONCLUSION

The project objectives were successfully achieved. The performance of the 3M disc buoy in sea seems need more study and evaluation and hopefully, can lead to further improvement. According the results and measurements, the data collected by the buoy have good precision from wave simulation. The experiments results show that the programming algorithm in buoy system can effectively perform the task that requested by user. Further studies are required to improve the wave properties sensing accuracy. The collection of results presented in this paper may be effective to predict the pitching, rolling, wave properties and motions of the 3M disc buoy.

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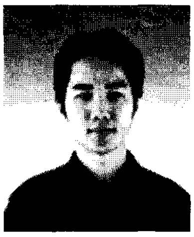

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