Development of an Electro-Optic Mooring System for Oceanographic Buoy

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Abstract—This study is part of a project to develop and improve mooring systems for oceanographic use that include an electro-optical sensor, 1MHz Nortek Aquadopp Doppler Profiler and AIRMAR multipurpose Sensor. The adaption of Doppler current profilers to measure directional wave spectra has provided a new instrumentation approach to coastal and nearshore oceanographic studies. The HBIOB is developed are light weight and of a compact design, and can be easily installed in marine environment. Since there are no base station and gateways in marine environments, we selected CDMA and Orbcomm to send the data information. Therefore, the data can be sent by either e-mail service or Short Message Service (SMS). This paper will present some of scientific sensor results regarding real-time oceanographic and meteorological parameters such as wind spend, wind direction, wave direction, and etc. The modeling and test results highlight the engineering challenges associated with designing these systems for long lifetimes. It can also be used in future application to build wave observation buoy network in real-time using multiple ubiquitous buoys that share wave data and allow analysis of multipoint, multi-layer wave profiler.

Index Terms— Haeundae Bay Interpretive Oceanographic Buoy (HBIOB), Short Message Service (SMS)

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I. INTRODUCTION

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

Every oceanographic buoy has a specific response to waves and currents depending on many factors, including its specific size, shape, ballast, and mooring [2]. This response may affect the accuracy of current and wave measurements made from the buoy platform. It is important to validate these oceanographic measurements and consider how much options as sample rate and average interval may be configured to optimize both accuracy and power draw.

The primary objectives in this research is to design and construct a oceanographic buoy that can measure of ocean surface and underwater information, store these measurement and communicate them elsewhere, [5] e.g. User can change the setting of the buoy from base station. We estimate a deployment time of 1 to 2 months or more depending on conditions. We adopt a design that remains almost completely below the surface to avoid drift due to the wind acting on exposed structure. We report on the design, construction and successful, initial testing of our prototype and future plan.

As shown in Fig 1, mounted on the tower are a radar reflector, Coast Guard approve flashing light, telemetry antennas, meteorology sensors, solar panels, electronic system and etc. The large diameter allows a person to lean into the well to work on batteries at 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 construction in the indoor.

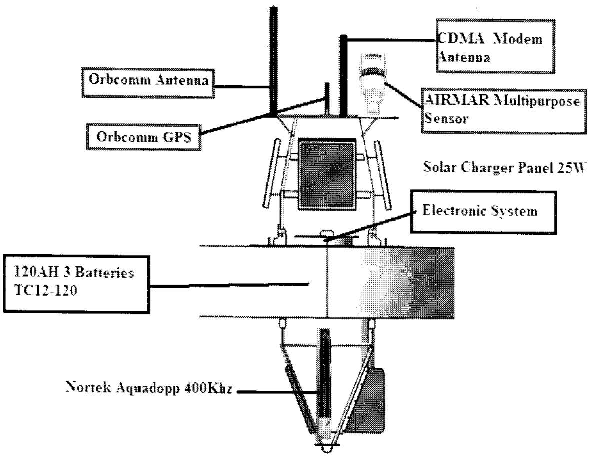


Fig. 1 A cross-sectional schematic of the HBIOB buoy platform

II. SYSTEM REQUIREMENTS

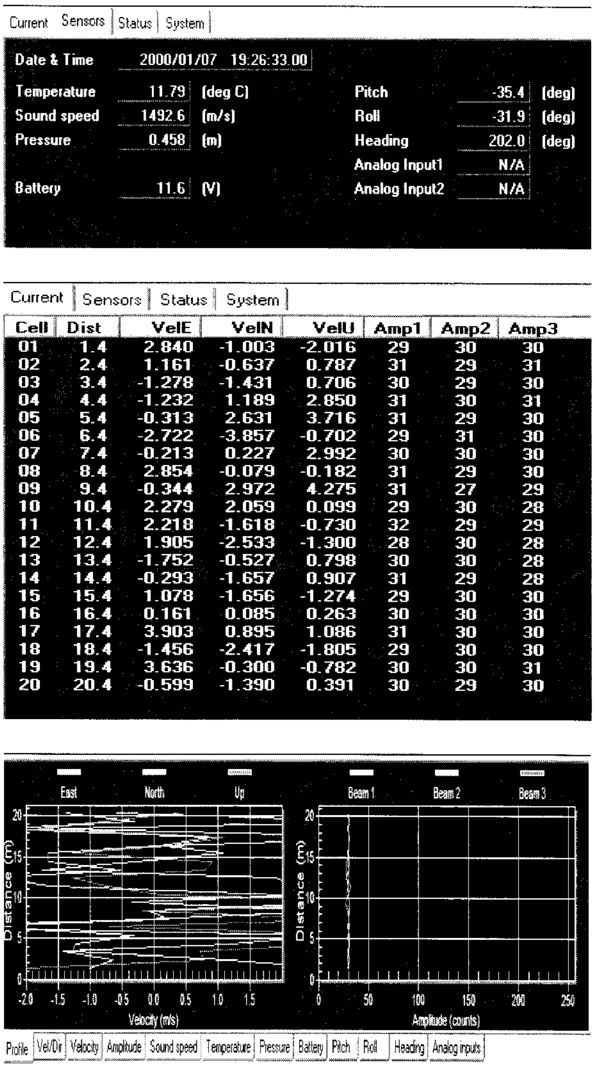
A. AIRMAR Multiple Environment Sensor Requirement

The AIRMAR WeatherStation PB100 has a built-in Global Positioning System with antenna, receiver, and position determining electronics. The AIRMAR WeatherStation transmits standard NMEA 0183 sentences on its output channel. The GPS receiver in the AIRMAR Weather Station takes approximately one minute on average to achieve a position fix after power is first applied. The standard baud rate for input and output channels is 4800 baud, though if desired this may be increased to 38400 baud via proprietary command.

1. GPS fix location data (Latitude & Longitude) is provided in the $GPGGA sentences
2. Standard heading data is provided in $HCHDG
3. Wind speed and Wind direction referenced to vessel are available in $WIMWV

B. Aquadopp Doppler Profiler Precision Requirement

The Aquadopp head contains three acoustic transducers which is the tilt sensor, the temperature sensor, and pressure sensor. The Aquadopp Doppler Profiler measures current velocity in multiple levels over roughly a 10 m depth range. It is important to remember that the Aquadopp Profiler collects raw wave data. Therefore the data, by inspection, may not be entirely meaningful. This raw data must go through a processing step before it can be used to interpret the waves on the surface. The Aquadopp Profiler uses the Doppler Effect to measure current velocity by transmitting a short pulse of sound, listening to its echo and measuring the change in pitch or frequency echo. Long experience with Doppler current sensors tells us that the small particles the Aquadopp Profiler sees move on average at the same speed as the water – the velocity it measures is the velocity of the water. It is important to remember that the Aquadopp Profiler collects raw wave data. Therefore the data, by inspection, may not be entirely meaningful. This raw binary data as shown in Fig. 2 must go through a processing step before it can be used to interpret the waves on the surface.



Cell	Dist	VelE	VelN	VelU	Amp1	Amp2	Amp3
01	1.4	2.840	-1.003	-2.016	29	30	30
02	2.4	1.161	-0.637	0.787	31	29	31
03	3.4	-1.278	-1.431	0.706	30	29	30
04	4.4	-1.232	1.189	2.850	31	30	31
05	5.4	-0.313	2.631	3.716	31	29	30
06	6.4	-2.722	-3.857	-0.702	29	31	30
07	7.4	-0.213	0.227	2.992	30	30	30
08	8.4	2.854	-0.079	-0.182	31	29	30
09	9.4	-0.344	2.972	4.275	31	27	29
10	10.4	2.279	2.059	0.099	29	30	28
11	11.4	2.218	-1.618	-0.730	32	29	29
12	12.4	1.905	-2.533	-1.300	28	30	28
13	13.4	-1.752	-0.527	0.798	30	30	28
14	14.4	-0.293	-1.657	0.907	31	29	28
15	15.4	1.078	-1.656	-1.274	29	30	30
16	16.4	0.161	0.085	0.263	30	30	30
17	17.4	3.903	0.895	1.086	31	30	30
18	18.4	-1.456	-2.417	-1.805	29	30	30
19	19.4	3.636	-0.300	-0.782	30	30	31
20	20.4	-0.599	-1.390	0.391	30	29	30

Fig. 2 Sampling Parameters for Nortek 1Mhz ADCP with sampling rates is 1 Hz and 20 size cells.

The Aquadopp Profiler measures the current profiler in water using acoustic Doppler technology. It is designed for stationary applications and can be deployed on the bottom, on a mooring rig, on a buoy or on any other fixed structure. It is a complete instrument and includes all the parts required for a self contained deployment with data stored to an internal data logger. Each beam of Aquadopp Profiler measures velocity parallel to the beam and does not sense the velocity perpendicular to the beam at all. The Aquadopp profiler senses the the full 3D velocity with three beam, simple trigonometry is sufficient to compute the velocity in any direction. The Aquadopp Profiler will still provide a good measurement in a non-uniform flow if the horizontal variations are linear.

The Aquadopp Profiler uses three acoustic beams slanted at 25° to accurately measure the current profile in a user selectable number of cells. In this research, the Aquadopp Profiler is configured to operate with acoustic frequency 1 MHz, whereby the maximum profiling range is 12 – 20 meters. Each cell size is 0.3 – 4 meters. The Aquadopp is configured to output 20 numbers of cell with sampling rate 1 Hz.

III. SYSTEM STRUCTURE

A. Wide Area Ocean Transmission Network

HBIOB has been equipped with a commercial CDMA modem and Orbcomm Modem for data transmission purpose. Orbcomm is a commercial wireless communication company providing messaging and data transmission services through email. Basically, the Fig 3 below show how the buoy established transmission via satellite communication with Orbcomm modem and CDMA station with CDMA modem in the buoy.

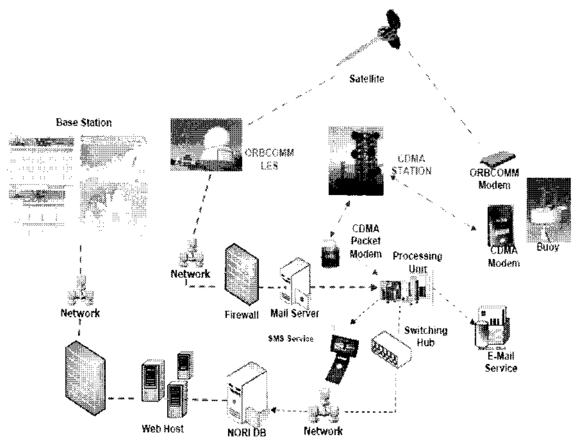


Fig. 3 Buoy System communicates with remote devices via CDMA modem and Orbcomm modem

The CDMA modem we used in HBIOB is used to transmit and receive AT command sent from base station. The HBIOB will be able to transmit data via CDMA if the HBIOB is located within the CDMA coverage zone. However, if the HBIOB is out of CDMA receiving coverage zone, the HBIOB can use Orbcomm as data transmission module. The CDMA modem is the key component of this data acquisition system. The communication between microprocessor and CDMA modem modular design allows future system configurations. It allows two-way communication and diagnostics enabling the user to remotely manage and configure the system. The CDMA controls the data sending interval, the target number station that data send to, and query message that reply from buoy. The microprocessor will only process the SMS once the SMS Command Syntax protocol is same as below:

SMS Command Syntax:

```
$SDSMS, x,  x,  x
        |   |   |
        1   2   3
```

1. Command Type (1: change, 2: Query, 3: Response)
2. Value Type (1: phone Number, 2: Send Interval (Minutes))
3. Value (*Data Interval : 10 minutes ~ 120 minutes)

Example SMS Command:

- $SDSMS,1,1,01012345678

* HBIOB buoy will send the data to "01012345678"

- $SDSMS,1,2,10

* The HBIOB will transmit measured data every 10 minutes interval

B. Solar Panel

A unique power control system was developed combining rechargeable batteries with power generation from multiple sources, including:

- 3 x 120 Ah 12V TC12-120 batteries for a total of 480 Ah reserve capacity
- 6 x 55 Watt Solar Panels

Power is managed though a power distribution module Sunsaver inside the well of the buoy. The SunSaver is a fully automatic PV system controller that includes electronic functions to protect both the controller and the PV system. Battery charging or discharging is managed by a constant voltage PWM algorithm that has been optimized.

C. Secure Digital Card as Storage

For backup purpose, the HBIOB is equipped with 1GB ScanDisc SD memory features. The text files that contain in SD memory save all the sensors data which is processed by microcontroller before sending to base station. The ScanDisc SD memory module with built-in Real Time Clock features provides timing information as backup timing information to microcontroller.

IV. DATA LOGGER BOARD DEVELOPMENT

The buoy data logger board system was designed to be power efficient, self-contained, and programmable for different application [4]. Care has been taken to balance the power consumption and performance requirement because the buoy is integrated in a stand-alone system that is battery operate. The power down mode saves power during deployments and prevents the batteries from dissipating between deployments. Therefore, microprocessor will turn on each sensor independently. Once the microprocessor finish gather and process the data, the sensors will be turned off in order to save batteries power. The basic application design of the HBIOB electronic system is shown in Fig.4.

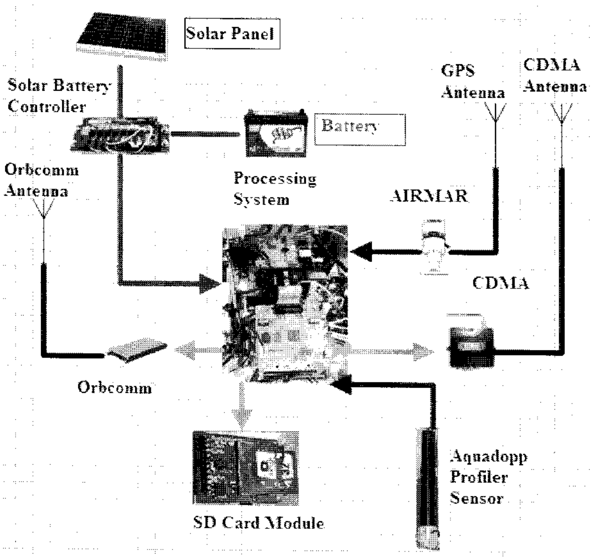


Fig. 4 Construction and Electronic Design of the Buoy system

Raw data collections are made continuously on the buoy and 10 minutes averages and 30 second maximum processed data are reported to base station and stored into Secure Digital Card. Current measurements are made by an acoustic Doppler current profiler mounted below the buoy. The resulting has a bin size of 8 meters, extends down to 500 meters below the surface, and is reported once the microprocessor turning the sensors on.

V. EXPERIMENTAL RESULT

A 2-month long experiment was conducted in an effort to evaluate the performance of the buoy mounted Aquadopp Doppler Profiler and AIRMAR sensor. The buoy was deployed on the water in the central part of the Haeundae Bay, Busan, South Korea (35.1337 N, 129.1468 E). In an effort to evaluate buoy motion and optimize the current measurement average interval, the buoy-mounted Aquadopp Profiler was configured to sample velocity profiles and engineering data (pitch, roll, heading, etc) at 1 Mhz for 1 second with 20 cell sizes.

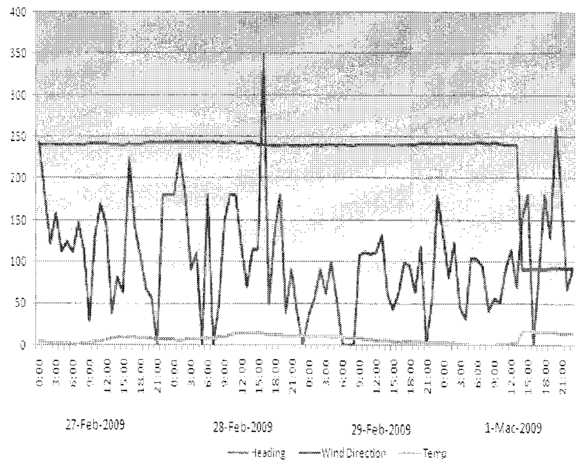


Fig. 5 Collection of HBIOB metrological raw data vs times from 27th Feb – 1st of March 2009.

The Fig.5 above is showing the buoy Heading, Wind Direction and Current temperature experienced by HBIOB deployed off in Haeundae Bay. These set of data were taken from 27th February 2009 to 1st March 2009 with 1 hour observation interval. This section is not intended for a detailed reporting of scientific results obtained during at sea testing but simply gives an overview of the overall performance of the HBIOB. These model runs were made without changing the mooring system specification from the original values used during the design phase. It would be possible to tune the model to match the measured results more accurately, but this needs to be done in a way that improves the agreement across the entire range of conditions, not just at a few selected wind, wave, and current conditions.

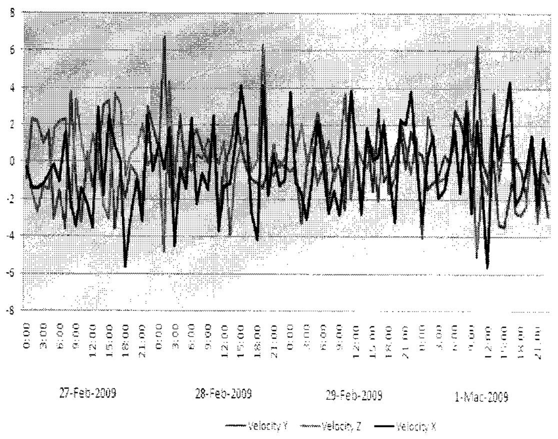


Fig. 6 Current Velocities measured with a downward looking 1 Mhz Nortek Aquadopp Profiler

As mentioned early, the Aquadopp Profiler measure velocity components parallel to its three beam. The current wave velocity 3 dimensional information velocity X, velocity Y and Velocity Z is provided by Aquadopp Profiller , which is mounted under the HBIOB is shown in Fig.6. The surface current conditions are estimated from current measurement made via Acoustic Doppler measurements at HBIOB moorings in Haeundae Bay. After microprocessor gathers AIRMAR and Aquadopp Profiler raw data, if the experiment were required to send more than 90 bytes of operational data; the system will use Orbcomm modem to transmit the data to base station. The transmission of the data via Orbcomm modem from satellite to gateway requires 15 minutes. Therefore, the processed complete data packet will be sent in mail format to email account every hour (Orbcomm data interval setting is 1 hour). By default, the operational data will be sent by CDMA every interval that defined by user.

The final HBIOB mooring design is the result of many tradeoffs between requirements regarding buoy size, instrumentation payload, power-gathering capability operational consideration and reliability concerns. 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 purpose. Furthermore, the communication link between buoy and base station is two way, allowing user to send commands to remote the system, its data-handling protocols or observation schedules in response to events observed in the harvested data stream. Command can be sent via SMS to the HBIOB to change the experiment parameter in response to interesting phenomena. The interval between current data and next data can be configured if the CDMA modem in HBIOB received defined interval configuration SMS from any hand phone.

. For the design work, the wind, waves and currents are all assumed to be from the same direction. The dynamics of the mooring may be significantly different if the wind and waves are from a different direction from the currents, which is possible. [7]

CONCLUSION

The richness of the data during this experiment allowed for some excellent comparisons and analysis with which to evaluate the performance of the HBIOB for current and wave measurements in support of the Korea Meteorological Administration (KMA) real-time observation program. The experiment results show that the programming algorithm in buoy system can effectively perform the task that request by user. The collections of result presented in this paper may be effective to predict the real-time oceanographic and meteorological parameters. This result is important for validation of the model, and its subsequent use for two main purposes, designing future deployments with this data logger board system, and informing the testing program designed to determine and extend the service life of these systems.

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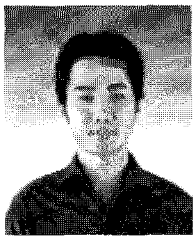

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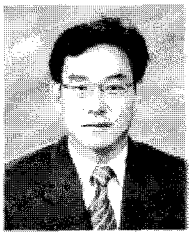

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