Different Approaches to Design a Meteorological Buoy for Weather Monitoring Purposes

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***Abstract*— This project is to study and design a meteorological buoy. It mainly covers and compares two approaches to design a meteorological buoy where their functions are same. The comparison will be made between mechanical structure, type of sensors, and electronics system design and power consumption issues.**

***Index Terms*—Meteorological Buoy, Sensors, Power Consumption**

I. INTRODUCTION

Weather buoys are the devices that measure and collect weather or ocean related data and forward to base station. Most of weather buoys measure parameters such as air temperature, water temperature wave height wave period, barometric pressure, relative air humidity , wind speed (steady, average and gusting), and wind direction. The buoys transmit the data via satellite, VHF marine radio or similar technologies to base station (e.g. meteorological centre) for use in weather forecasting and climate study. Meteorological buoys appear in two major types which are moored buoys and drifting buoys [1].

This paper mainly focuses on different approaches to design a weather buoy. Two buoys were constructed, which are 1M buoy and 2M buoy which name after the buoy dimension to ease the explanation in later session. It emphasize in comparing the electronics system's features and specification of both buoys such as sensors used, communication methods and system power consumption, which is very important to a buoy as a standalone system.

II. COMPARISON BETWEEN 1M BUOY AND 2M BUOY

A. Mechanical Design

Mechanical design of both buoys is similar. Size is the only difference between them. 1M buoy has buoy dimension with diameter 1 meter where 2M buoy has diameter of 2 meters.

B. Electronics System

1) Overview

Both buoys serve the same purpose which measure and forward weather data to base station via same method. Data that collected are buoy's position (Latitude and Longitude), buoy's magnetic heading, wind speed (average and gusting), wind direction, air temperature, relative humidity, ocean current speed, ocean current direction, water temperature, wave height and wave period. Although both buoys have the same features and functionality, but the electronics system design is different. Fig. 1. and Fig. 2 shows the electronics system design for 1M buoy and 2M buoy respectively.

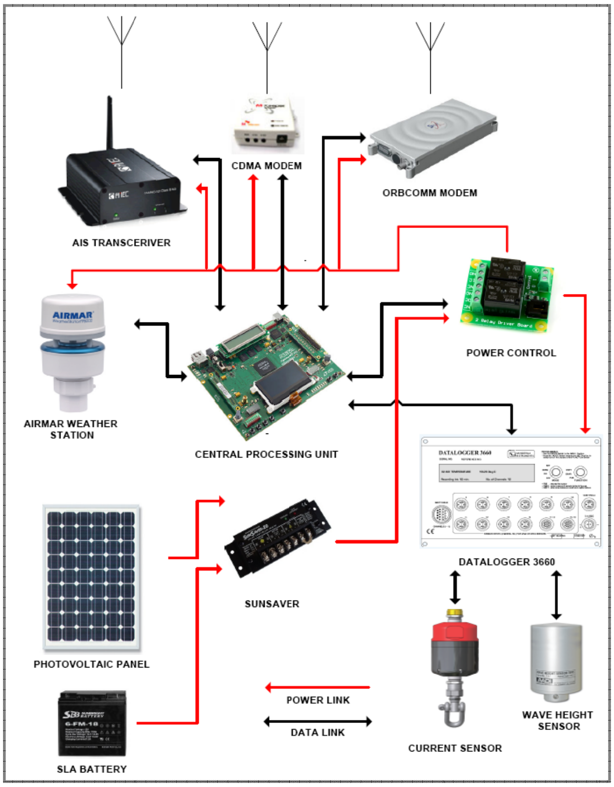

Fig. 1. Electronics System Design of 1M Buoy

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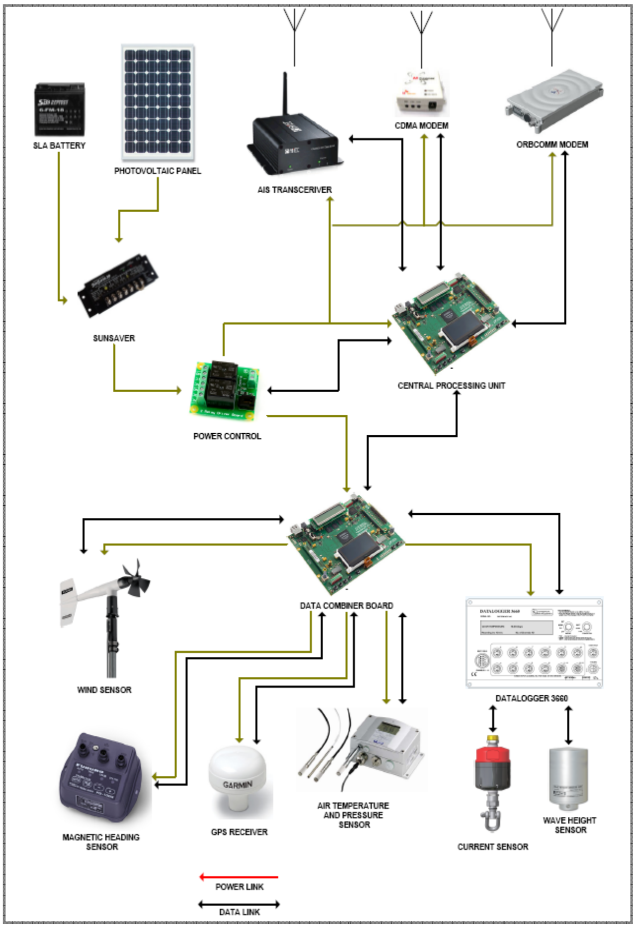

Fig. 2. Electronics System Design for 2M Buoy

The major differences between both buoy electronics system design is type of sensor used in measuring weather parameters. 2M buoy used more sensors compare to 1M buoy which rely on AIRMAR weather station that able to provide rich weather information. There are advantages and disadvantages between these two methods, details will be discussed in coming sub-section 2. Besides there are two processing boards that used in 2M buoy, whereas there is only one in 1M buoy. Even though both buoys' design is different, since they are attemping to have the same function, hence both buoys have the same output parameters and communication system.

2) Sensors Used

Type of sensor is major differences among both buoys. Even both buoys will capture same weather parameters, but total amount of sensors in 1M buoy are much lesser than 2M buoy. In 1M buoy design, smaller mechanical structure design cause space limitation for sensors and antennas mounting, hence AIRMAR weather station (PB200) is chosen as main sensor unit. It able to provide buoy's latitude and longitude position, UTC time, buoy's magnetic heading, air temperature, relative humidity, air pressure, wind speed and wind direction information. It is a highly integrated weather station and come with a highly compact housing and stable under most sea condition. Thus it is suitable for small buoy design. For 2M buoy, AIRMAR weather station was replace by several other sensors. This is due to data consistency consideration. Since AIRMAR weather station provides over 60 percent of all weather information, once it damaged, over 60 percent of weather parameters will be lost. To reduce the problem to the minimum, multiple sensors design is applied. If a sensor is damaged, only its related weather parameters will be lost.

Another difference between AIRMAR and sensors on 2M buoy is wind speed and direction sensor. AIRMAR used sonic anemometer where 2M buoy used windmill anemometer. Sonic anemometer has the advantages of no moving part and small in size, besides that, since AIRMAR had integrated with heading sensors, it able to provide true wind direction. Compare to AIRMAR, windmill anemometer appear in bigger size and able to provide apparent wind direction only. External heading sensor is needed to calculate true wind direction. Since 2M buoy has magnetic heading sensor to provide buoy heading, by integrated both apparent wind direction and magnetic reading, true wind direction can be obtained. The equation is shown as (1).

$$\theta_T = \theta_A + \theta_M$$

Where:
θ_T = True Wind Direction
θ_A = Apparent Wind Direction
θ_M = Buoy Magnetic Heading (1)

But it has the advantage of can provide higher accuracy of both wind speed and direction over AIRMAR weather station. Comparison of wind speed and direction's accuracy had been made between AIRMAR weather station and windmill anemometer from RM YOUNG. Table I shows the rated accuracy of both sensors and an experiment was conducted by AIRMAR Technology among both sensors. Result and graph will be discussed in section III.

In addition, air temperature, relative humidity, air pressure and magnetic heading sensor able to provide more accurate data compare to AIRMAR weather station. In term of GPS receiver, comparison cannot be made due to buoys always have a clear sky and GPS signal always active, same results are obtained. There is no comparison among water temperature, water current speed and direction, wave height and period because same sensors are used. Table I compares sensors' accuracy between both buoys [2] [3] [4].

TABLE I
DATA ACCURACY OF 1M BUOY AND 2M BUOY

	1M Buoy	2M Buoy
Wind Speed and Direction	As in Fig. 4. [2]	As in Fig. 4. [5]
Magnetic Heading	±3° (Freedom of tilt angle: 45°) [2]	±1.5° (Freedom of tilt angle: 45°) [4]
Relative Humidity	± 4 % RH (10 … 95%) [2]	± 1 % RH (0 … 90%) [3] ± 1.7 % RH (90 … 100%) [3]
Air Temperature	± 1 °C [2]	± 0.4 °C [3]
Air Pressure	± 2 hPa [2]	± 0.45 hPa [4]

3) Communication System

Both buoys are designed to serve the same purposes; hence the output parameters and communication methods are the same. Normally, data will be forwarded to base station via 4 methods which are satellite, AIS, SMS and TCPIP. Data send via satellite is simple by using service and modem provided by ORBCOMM Inc. Data that sent to ORMCOMM modem will store in buffer and forwarded to base station using email once the modem successfully connected to satellite. Besides, AIS is another option for base station to receive data from buoy. Same with satellite service, a specific modem is used in AIS. Since there is no need of satellite or other similar devices, data will broadcast once it is ready.

Another option to transmit data to base station is via telecommunication service on CDMA network. Typical service that will be provided by telecom service provider is SMS service and TCPIP service. Extra care need to be perform if using TCPIP method, due to this method will open a port on a specific IP address and data will be sent using TCP/IP packet. Proper network setting is needed before data can be received via TCP/IP.

4) Power Consumption

Power system designed is same for 1M buoy and 2M buoy. Sealed lead acid (SLA) rechargeable batteries are used as power source due to durability and stability of its chemical substances under all condition. Additionally, photovoltaic panels are added as charging unit for batteries. Both battery and solar power are managed through a power distribution module Sunsaver inside the buoy. The Sunsaver is fully automatic PV system controller that includes electronic functions to protect both the controller and the PV system. An optimized voltage PWM algorithm is utilized in battery charging/discharging purpose [6].

Although the design of power system is the same, but the capacity of power source and charging capability of both buoys are different. 1M buoy is small in size and it has restriction on space, while 2M buoy has much larger space and able to carry more batteries and photovoltaic panels. In 1M buoy's mechanical design, it can only fit one SLA battery with capacity of 120AH and two 25 watts photovoltaic panels; where for 2M buoy, it is design to operate with four SLA batteries with total capacity of 480AH and three 50 watts photovoltaic panels.

Even though both system using different electronics design, however current consumption of both designs are same which is around 1A during active data collecting state and 4A during data are transmitting via ORBCOMM, AIS and CDMA modem(reading is acquired using multi-meter). Consider data need to be transmitted to base station once per hour; power consumption of the system is 1AH. Due to data transmission process takes a very short time to transmit the data; therefore the transmission power consumption can be ignored.

Assume there is cloudy or rainy day continuously, battery charging system is not working as the result of weak sunlight. Battery become the only power source to operate the buoy. In such condition, battery will be exhausted after 120 hours for 1M buoy, 480 hours for 2M buoy. The duration can easily calculated by dividing capacity of batteries to current consumption of the system.

Besides that, both buoys are also has different charging rate since the total number and power rating of photovoltaic panel used are not same. To ease the calculation, assume that batteries are exhausted and photovoltaic panels able to supply full power all the time. The time required to charge the buoys can be calculated using equation (2):

$$T = C \Big/ \left(\frac{P \; x \; N}{V}\right)$$

Where
T = Total charging time
C = Total capacity of batteries used
P = Power rating of photovoltaic panel
N = Total number of photovoltaic panel
V = Battery's voltage rating (2)

From equation (2), total charging time for 1M buoy is 28 hours and 38.4 hours for 2M buoy. Table II illustrates the difference between 1M buoy and 2M buoy in term of power capacity, consumption and charging rate.

TABLE II
POWER COMPARISON

	1M Buoy	2M Buoy
Battery Capacity	120AH	480AH
Solar Panel Rating	25W x 2	50W x 3
Power Consumption	1AH	1AH
Capability to Operate without Charging	120 Hours	480 Hours
Charging Rate (Empty to Full)	28 Hours	38.4 Hours

5) Data Processing

1M buoy and 2M buoy applied different processing system. 1M buoy uses central processing system, where all receive, error checking, pre-processing, post processing, data encapsulation and transmission process are done by only one controller; while 2M buoy introduce distributed processing system. Tasks are divided to several parts and few controllers are used to perform specific task. Fig. 3 (a) and (b) illustrates central processing system and distributed processing system respectively.

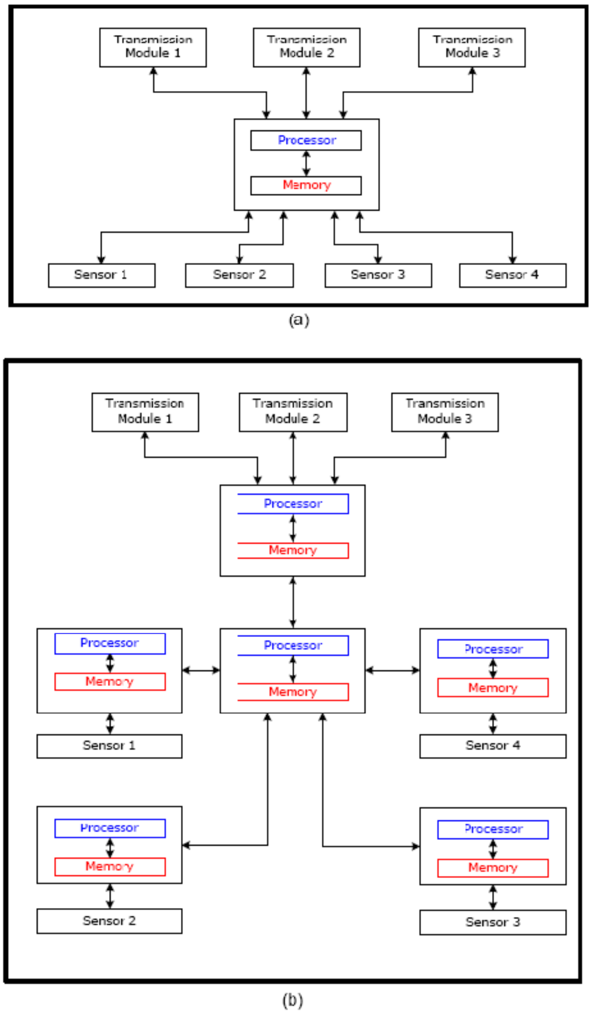

Fig. 3 (a). Central Processing System
(b). Distributed Processing System

1M buoy used centralize processing method, where one processor process all the data. This method is easier in circuit designing but it causes difficulties in firmware design. The basic program flow as follow:

1. Read sensor reading from sensor 1 to sensor 4 in sequence.
2. Determine validity of data (e.g. checksum) and discard invalid data packet.
3. Timeout checking. Report error if error occurs or data absent continuously for a certain duration.
4. Capture valid data and data post processing.
5. Check if time to send data to base station.
6. If not the time to send data, loop to step 1. Else go to next step.
7. Pack outgoing data into proper format and forward via CDMA, ORBCOMM or AIS.
8. Go to step 1.

Among these steps, step 1 and 3 need the processing power and timing accuracy most. Since incoming data might come concurrently, reading sensor one by one in sequence might cause losing of data; this will produce non-accuracy in final result. Furthermore, timeout checking requires high amount of memory due to data need to be hold and compare to determine is timeout occur. The more sensors are used, the more memory space is needed. Additional check need to be perform to prevent memory overflow occur which will cause a very serious system problem (e.g. system hang).

To improve this design, distributed processing system is applied. Multiple processors are used to prevent main processor from overhead. Although it makes circuit design more complicated, but it result in higher system stability, easier firmware design and maintenance. Basically, tasks are divided into three categories, which are sensor reading and validation, data combine and timeout checking, and data post processing and transmitting. The program flow of each category as follow:

Sensor reading and validation:

1. Read sensor value from sensor continuously. Total numbers of sensors are equal to total number of controller. All sensor data are read simultaneously.
2. Determine validity of data and discard invalid data.
3. Forward valid data to data combine processor
4. Go to step 1.

Data combine and timeout checking:

1. Read sensor value from sensor reading processor.
2. If data not read, check is timeout occurring to determine sensor's status.
3. Combine all sensors' data and pack into only one packet and forward to main processor. Each sensor value will tag with "V"/"A" for valid data identification.
4. Go to step 1.

Data post processing and transmitting:

1. Receive data from data combine board. Data will be discarded if string checksum and calculated checksum are not equal.
2. If data without error received, data post processing will be performed (e.g. average, gust calculation, time synchronization etc.).
3. Check is time to send data. If no continue to received and process data from data combine processor. Else go to step 4.

4. Pack outgoing data into proper format and forward via CDMA, ORBCOMM or AIS.
5. Go to step 1.

By utilizing distributed processing system, processor overhead and data missing problems are able to be solved. Due to each sensor is connected to one controller that specific to process its data, hence memory overflow problem will not appear. Hence, this will increase overall performance of buoy's system.

III. DISCUSSION AND CONCLUSION

This paper mainly focus in introduce multiple approaches to design a meteorological buoy for weather monitoring purpose. Many meteorological buoys can perform same tasks but they can be design in different way. This paper introduces two ways to design a weather buoy which achieve same goal. Both buoys have advantages and disadvantages compare to each other.

Experiments were conducted by AIRMAR Technology Corporation, which compare data accuracy between AIRMAR weather station and other products that available in market (e.g. VAISALA, RM YUONG etc). Following are the experiment's result which taken from PB200 & LB150 Weather Station Technical Presentation from AIRMAR Technology [5]. Fig. 4 shows the comparison graph of wind speed and direction accuracy between AIRMAR weather station and windmill anemometer from RM YOUNG. Fig. 5 presents the comparison of AIRMAR weather station relative humidity accuracy with sensor from Vaisala. Comparison of air temperature between AIRMAR weather station and Vaisala air temperature sensor is shown in Fig. 6 and Fig. 7.

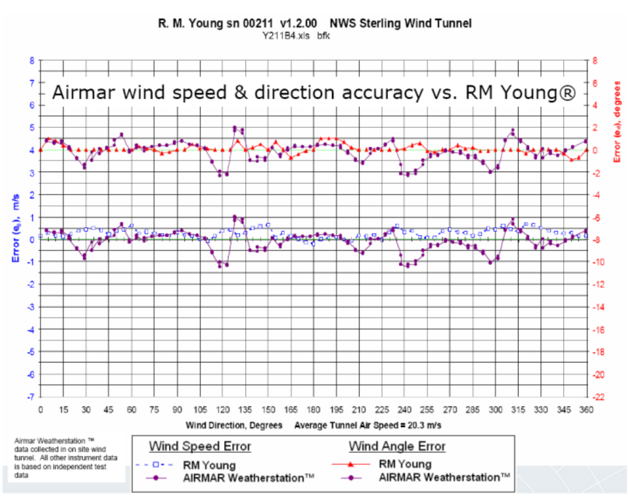

Fig. 4. Wind Speed and Direction Accuracy (AIRMAR vs. RM YOUNG) [5]

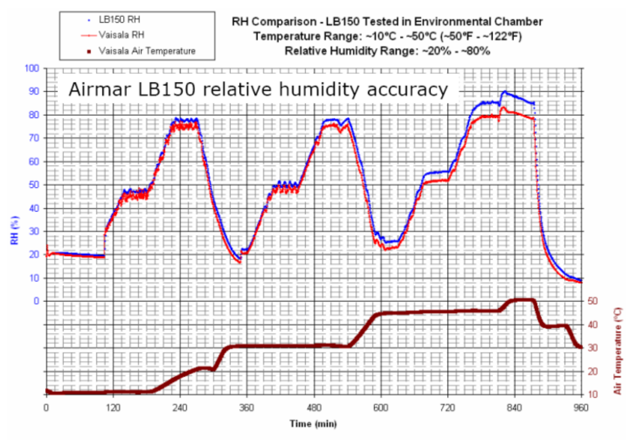

Fig. 5. Relative Humidity Accuracy (AIRMAR vs. Vaisala RH Sensor) [5]

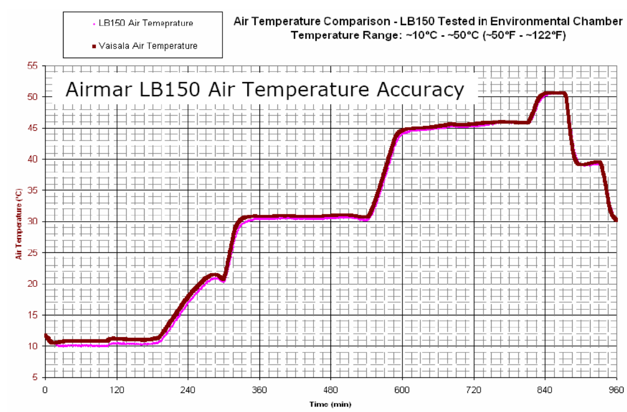

Fig. 6. High Air Temperature Accuracy (AIRMAR vs. Vaisala Air Temperature Sensor) [5]

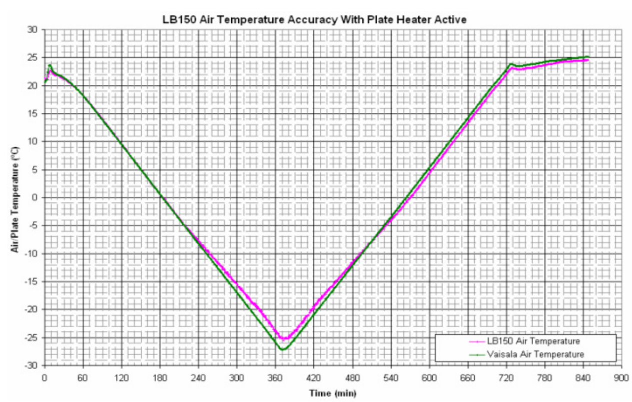

Fig. 7. Low Air Temperature Accuracy (AIRMAR vs. Vaisala Air Temperature Sensor) [5]

1M buoy has the advantages of small in size, compact in sensors used and ease for installation since the system is less complex. For 2M buoy, size is bigger, but it able to provide more accurate data over 1M buoy. Depending to the application, both buoys can be selected for weather monitoring purpose.

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