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IoT Sea Level Monitoring Development and Field Testing Study

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ABSTRACT

The measurement of sea level is essential to oceanography because it provides vital information about the ocean environment, such as tides, currents, and water temperature. This research aimed to develop an Internet of Things (IoT)-based sea level monitoring device that can precisely measure sea level and transmit data in real time. An ESP32 microcontroller, a Global System for Mobile Communications (GSM) module, an MS5803-14BA sensor, and a battery constituted the device. To protect the electronics from the ocean environment, the components were assembled on a Printed Circuit Board (PCB) board and placed within a waterproof box. The field test was conducted for 17 hours at the Class 1 Navigation Office Port in Tanjungpinang, and the Ubidots platform was used to monitor the data. The device accurately measured sea level with an Root Mean Square Error (RMSE) of 0.69 cm and an accuracy rate of 99.47%, according to the results. However, the field test also revealed problems with data transmission, with 18.81% of the data not being transmitted to the server. This low data transmission rate may have been caused by low Received Signal Strength Indicator (RSSI) levels and signal quality issues with the operator. This study demonstrated the viability of utilizing an Internet of Things-based sea level monitoring device to precisely measure sea level and transmit data in real time. It provides valuable information for the improvement and further development of sea level monitoring systems.

Keywords : IoT, Sea Level Monitoring, MS5803-14BA Sensor, Sensor Accuracy, RMSE, Data Transmission.

INTISARI

Pengukuran permukaan laut penting dalam oseanografi karena memberikan informasi penting tentang lingkungan laut, termasuk pasang surut, arus, dan suhu air. Penelitian ini bertujuan untuk mengembangkan perangkat pemantauan permukaan laut berbasis IoT yang dapat mengukur permukaan laut secara akurat dan mengirimkan data secara real time. Perangkat ini terdiri dari berbagai komponen: Mikrokontroler ESP32, Modul Global System for Mobile Communications (GSM), sensor MS5803-14BA, dan baterai. Komponen-komponen tersebut dirakit pada papan Printed Circuit Board (PCB) dan ditempatkan di dalam kotak tahan air untuk melindungi perangkat elektronik dari lingkungan laut. Uji lapangan dilakukan selama 17 jam di Kantor Navigasi Pelabuhan Kelas 1 Tanjungpinang, dan data dipantau melalui platform Ubidots. Hasil penelitian menunjukkan bahwa alat tersebut mengukur tinggi permukaan laut secara akurat, dengan nilai Root Mean Square Error (RMSE) sebesar 0,69 cm dan tingkat akurasi sebesar 99,47%. Namun, uji lapangan juga mengungkapkan adanya masalah transmisi data, dengan 18,81% data tidak terkirim ke server. Kecepatan transmisi data yang rendah ini mungkin disebabkan oleh rendahnya tingkat Received Signal Strength Indicator (RSSI) dan masalah kualitas sinyal operator. Studi ini menunjukkan kelayakan penggunaan perangkat pemantauan permukaan laut berbasis IoT untuk mengukur permukaan laut secara akurat dan mengirimkan data secara real-time. Hal ini memberikan informasi berharga untuk pengembangan lebih lanjut dan peningkatan sistem pemantauan permukaan laut.

Kata kunci: IoT, Pemantauan Permukaan Laut, Sensor MS5803-14BA, Akurasi Sensor, RMSE, Transmisi Data.

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I. INTRODUCTION

Measuring tidal patterns and sea level is critical to stakeholders, including coastal communities, disaster relief organizations, the tourism industry, and the maritime sector [1], [2]. In response to this need, numerous studies have been conducted on designing sea level measuring devices utilizing various technologies. For instance, research [3]–[5] utilized acoustic sensors in their studies, while Egistian (2021) developed a sea level measuring device that utilized the water pressure sensor [6]. However, this device has some limitations, such as the use of a temporary accumulator battery and the need for the Digital Number output of the pressure sensor to be converted before use. On the other hand, the advantage of the study is that it utilized the Internet Of Things (IoT) system and the Global System for Mobile Communications (GSM) module.

The MS5803-14BA, a commonly employed air pressure sensor for measuring water depth, has been the subject of investigation by multiple researchers [7]–[9]. The sensor exhibits a notable precision of up to 0.2 mbar and possesses an ideal resolution of 1 cm water depth. It encompasses a range spanning from 0 to 14 bar and is accompanied by factory calibration data indicating a value of 1000.5 mbar. Additionally, the device is furnished with a jelly protection mechanism and a stainless-steel cap that possesses anti-magnetic properties. These features contribute to its ability to withstand water pressure of up to 30 bar [10].

As the power supply is a crucial component in any electronic circuit, it is important to ensure that it provides a constant current and voltage supply. This study uses a battery power supply, but a solar panel supplements it as an alternative energy source. Solar panels, also known as solar cells, convert solar energy into electrical energy, providing a sustainable energy source [11].

To summarize, the proposed instrument for measuring sea level is designed using the MS5803-14BA water pressure sensor. The ESP32 microcontroller process the readings from the water pressure sensor, which is stored on an SD card. The measurement results are displayed on the Ubidots platform, which is connected to the internet via GPRS communication on the GSM module. The device will be powered by a battery, with a solar cell as an alternative power source.

II. METHODOLOGY

A. Study Location and Time

This research was carried out from July to December 2022. The design, fabrication, and testing of the device were conducted at the Electrical Engineering Laboratory of Maritime Raja Ali Haji University, Tanjungpinang. In addition, field testing of the device was conducted at the Class I Navigation District Office Port Tanjungpinang, Bintan Regency, Riau Islands, Indonesia (Figure 1).

Figure 1. Class I Navigation District Office Port Tanjungpinang

B. Instrument Design

The sea-level measuring instrument is designed from several main components: the MS5803-14BA air pressure sensor, ESP32 microcontroller, DS3231 RTC module, Micro SD Card Shield, and SIM900A GSM module. This research device uses the MS5803-14BA pressure sensor to measure the water pressure, which is then converted into water depth. The microcontroller used in this research is the ESP32 module with two units. The first is a peripheral device that reads the data received from the MS5803-14B air pressure sensor and waits for characters from the Controller device to retrieve and send sensor data. The second ESP32 is used as a controller device to request data and awaken the peripheral device by sending characters. Finally, the obtained data is processed and stored on the micro SD and sent using the SIM900A GSM module to the Ubidots platform. The system design block diagram can be seen in Figure 2.

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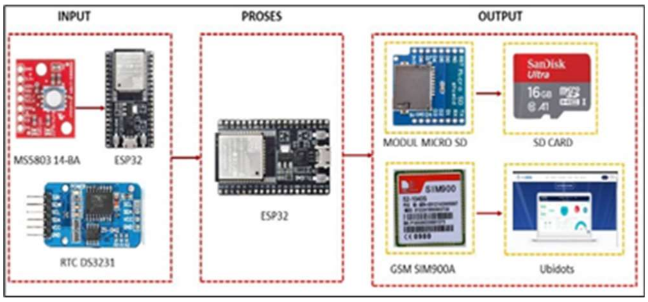

Figure 2. Diagram Block Design System

C. Data Analysis

This study aims to determine the accuracy and precision of the MS5803-14BA water pressure sensor by converting the data obtained from the sensor into water depth using the hydrostatic pressure formula. The hydrostatic pressure formula considers the height of the water surface (h) in m , pressure (P) in Pa, water density (ρ) kg·m^{-3}, and earth's gravity (g) m·s^{-2}.

$$h = \frac{P}{\rho \times g} \quad (1)$$

After converting the data from the MS5803-14BA water pressure sensor, the next step is to perform calibration. This calibration result will help determine the difference between the sensor's measurement and the water depth reading. The Root Mean Square Error (RMSE), expressed in meters (m) as shown in Equation 2 is used to compare the estimated results with field data to determine the accuracy and precision of the MS5803-14BA water pressure sensor. The compararison using ruler The smaller the RMSE value, the better the prediction results [12], [13]. The tides staff was used as a reference to compare the depth values obtained from the sensor with the actual water depths. This comparison allows for an assessment of the sensor's performance in accurately measuring water depth. The standard deviation formula determines how precise the sensor measures water depth.

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n} e_i^2} \quad (2)$$

Simple linear regression establishes a relationship between a dependent variable and one independent variables [14], [15]. In this study, variable 1 (x_i) represents the sensor data, and variable 2 (y_i) represents the calibrator data.

$$y_i = ax + b \quad (3)$$

After comparing the sensor data and calibrator data using linear equations, the coefficient of determination (R^2) is obtained. The coefficient of determination formula shown in Equation 4 based on [16]. The coefficient of determination is used to determine the closeness of the sensor reading to the actual water depth [17]. This linear regression equation, which integrates the relationship between individual data points (y_i), their mean ($\bar{y}_i$), and the predicted values ($\hat{y}_i$), will be incorporated into the microcontroller.

$$R^2 = 1 - \frac{SSE}{SST} \quad (4)$$

$$SSE = \sum_{i=1}^{n}(y_i - \hat{y}_i)^2 \quad (5)$$

$$SST = \sum_{i=1}^{n}(y_i - \bar{y}_i)^2 \quad (6)$$

Finally, a comparison is made between the sensor data and the server data using the Packet Loss Ratio. The Packet Loss Ratio compares the data packets lost (P_L) and the stored measurement data (P_{TS}) [18] as shown in the equation 7.

$$Packet\ Loss\ Ratio = \frac{P_L}{P_{TS}} \times 100\% \quad (7)$$

III. RESULTS AND DISCUSSION

A. Instrument Development

The device is made by creating a schematic and a PCB board. This device operates as a controller device. Two parts to the PCB board are made, the top part and the bottom part. The top consists of the ESP32 Microcontroller, DS3231 RTC Module, and LED. The bottom consists of the Micro SD Card, SIM900A GSM Module, MS5803-14BA sensor, and battery. The components in this PCB are shown in Figure 3. This PCB is included inside the box (Figure 4).

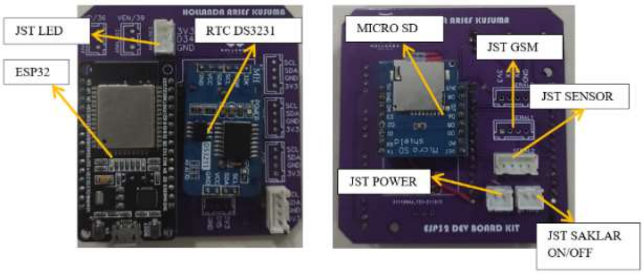

Figure 3. The components attached to PCB

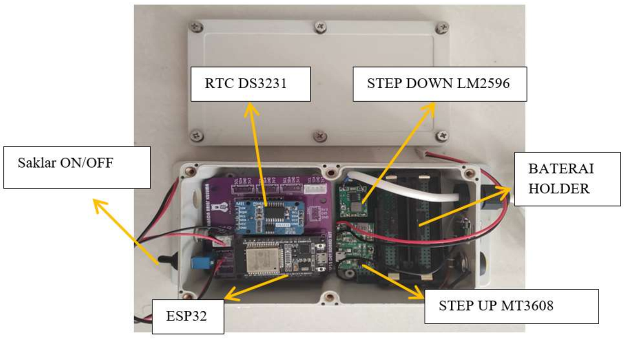

Figure 4. Components attached inside the box

The box was drilled with six holes on both sides. One side of the box has holes for the push button, solar panel cable, and voltmeter, while the other has holes for the switch, LED, and cable connection to the sensor and ESP32. The arrangement of these components within the box can be seen in Figure 5. The peripheral device comprises the ESP32 and MS5803-14BA sensors. Since it will be placed underwater, it has been waterproofed using resin (as shown in Figure 6). This device requires an average power of 0.59 W, with an estimated usage time of 1.63 days. Therefore, a solar panel is needed in this device to ensure a continuous power supply for the battery.

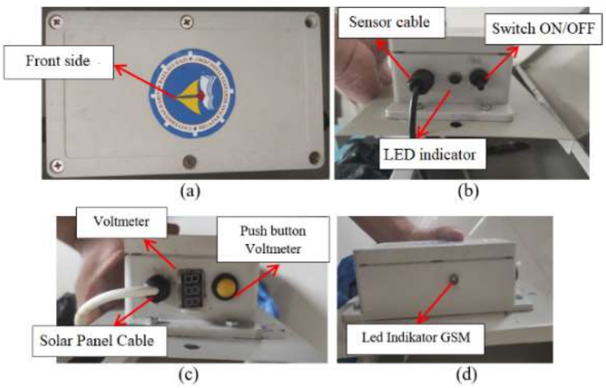

Figure 5. Components attached outside the box

Figure 6. Peripheral device

B. Field Test

The field test was conducted for 17 hours from 12:46 on November 30, 2022, to 5:56 on December 1, 2022, at the Tanjungpinang Class 1 Navigation Office Port. The device sends data every 10 minutes and is monitored through the Ubidots platform. All data is stored on the micro SD Card. The placement diagram of the tool can be seen in Figure 7. The placement position of the device during the field test can be seen in Figure 8. The field test data on the Ubidots platform is shown in Figure 9. The data display contain depth, water temperature, and GSM signal quality. There are line plot for each parameter to see the pattern.

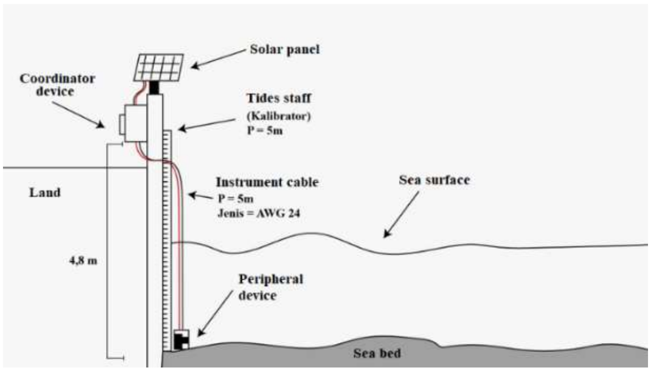

Figure 7. Placement the monitoring device diagram

Figure 8. Device placement at the harbour

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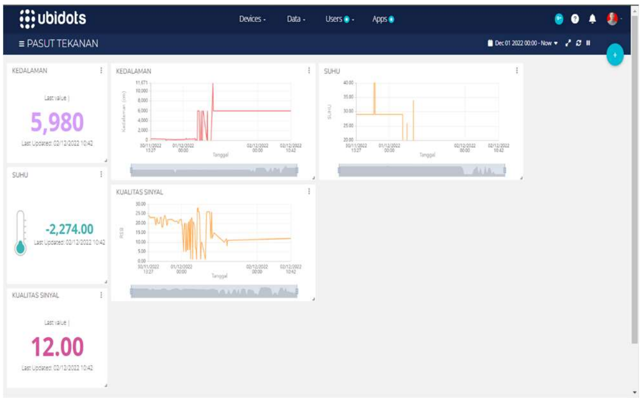

Figure 9. Sea level data display in Ubidots

C. Sea Level Validation

The comparison between the device sensor readings and the tides staff average is fairly good, as shown in Figure 10. During the high tide or the process towards high tide, the sensor reading is not much different from the manual average. However, during the process toward low tide, the difference between the sensor reading and the tides staff average is greater than during high tide. The comparison result between the sensor reading and the tides staff average gives an RMSE value of 0.69 cm, an accuracy rate of 99.47%, and an error rate of 0.53%. Based on the obtained values, it is concluded that the MS5803-14BA pressure sensor can measure the sea level.

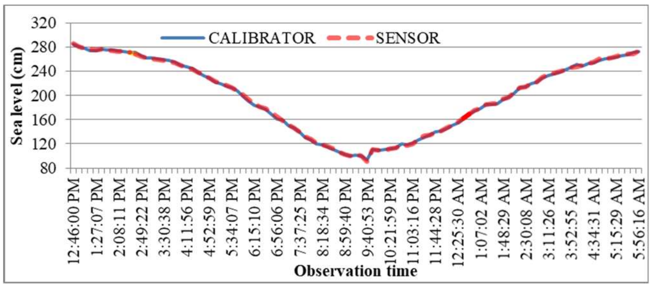

Figure 10. Sea level comparison between sensor and calibrator

D. Packet Loss Ratio

During the 17-hour field data collection process, 101 data were stored on the micro SD card, but only 82 were sent to the server. As a result, the Packet Loss Ratio was 18.81% (Figure 11).

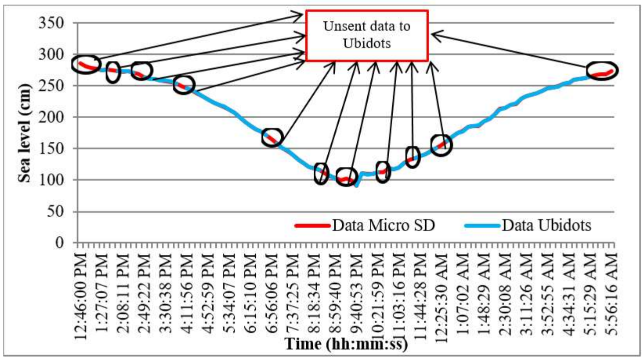

Figure 11. Data comparison between micro SD and server Ubidots

In this case, 81.19% of the data collected during the 17-hour field data collection process was successfully sent to the server, meaning that 18.81% of the data may have been lost or failed to be transmitted.

E. Discussion

In this study, a monitoring device was developed to measure the sea level. The device consisted of various omponents: the ESP32 Microcontroller, DS3231 RTC Module, LED, Micro SD Card, SIM900A GSM Module, MS5803-14BA sensor, and a battery. The components were assembled on a PCB board and placed inside a waterproof box. The device was field-tested at the Tanjungpinang Class 1 Navigation Office Port for 17 hours, and data was monitored through the Ubidots platform.

ESP32 is suitable for this application because it has a minimum power consumption. Based on [19], [20], the power consumption can be reduced using the sleep mode function. Moreover, ESP32, programmed using Arduino IDE based on C/C++, was fast in executing time [21].

The GSM module implemented in this instrument can make this instrument send the data to Ubidots. This SIM900A sends data using AT Commands [22], [23]. AT+CIPSEND is the crucial command to ensure the server receives the data [24]. Ubidots offer a user-friendly interface to display data [25]–[27]. he micro SD card embedded in this instrument secures the data when the network is unavailable.

The comparison between the device's sensor readings and the tides staff average showed a good correlation, with an RMSE value of 0.69 cm, an accuracy rate of 99.47%, and an error rate of 0.53%. These values suggest that the MS5803-14BA pressure sensor can accurately measure the seawater surface height [28], [29]. Furthermore, the peripheral device encapsulation using resin can protect the electronics for oceanographic applications [30].

However, the field test results also revealed some data transmission issues. During the 17-hour field data collection, only 81.19% (82 out of 101) of the data collected was successfully sent to the server, meaning that 18.81% of the data may have been lost or failed to be transmitted. The low RSSI level may cause packet loss and issues in operator signal quality [18], [31], [32].

Understanding the underlying causes of these data losses and implementing strategies to enhance data transmission in subsequent data collection endeavors are imperative. Enhancement of network connectivity, implementation of error detection and correction techniques, and utilization of more dependable data transmission protocols are potential avenues for achieving this improvement. Additional research is required in order to comprehensively address these concerns and enhance the overall performance of the device.

IV. CONCLUSION

An IoT sea level monitoring device was tested for accuracy and effectiveness using the ESP32 Microcontroller, GSM Module, MS5803-14BA sensor, and battery. Good measurement accuracy was achieved with an RMSE of 0.69 cm and 99.47% accuracy. The field test showed 18.81% of data not reaching the server due to transmission issues. Examine the causes of these data losses and improve data transmission in future tests. Improved network connectivity, error detection and correction, or reliable data transmission protocols can do it. Addressing these issues and improving device performance requires more research.

V. ACKOWLEDGEMENTS

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