HIGH-LOW DETECTION OF SEA WATER WAVES WITH MULTI-SENSOR SYSTEM BASED ON IOT

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Abstract— **One of the largest island countries in the world is Indonesia which has 17,499 islands and with a total area of about 7.81 million km2. Of the entire area of Indonesia, there are 3.25 million km2 is the ocean and 2.55 million km2 is the Exclusive Economic Zone, and only about 2.01 million km2 is land. With the vastness of the sea area that Indonesia has, Indonesia has a huge marine and fisheries potential. To take the wealth of the sea, sea waves are very influential because safety will be very threatened if the waves or ocean waves are very high. There are tools to measure wave height, vibration and detect the occurrence of tsunamis caused by underwater earthquakes, namely Buoy. But this technology is still quite expensive and the treatment is difficult. In order to reduce the relatively expensive costs and facilitate such maintenance, ioT-based high-wave ocean meter is made. The device uses ultrasonic sensors for systems placed on docks with an accuracy percentage of 93.9617%. The Adafruit BNO055 sensor used to measure the height of the kaut wave has an accuracy percentage of 73.06% and can read almost any vibration with a small to relatively large force. Supported by sending data to ThingSpeak servers that use Sim800l modules with GSM technology, which is quite fast, which is the average delivery takes 17.78867 seconds.**

I. INTRODUCTION

One of the largest island countries in the world is Indonesia which has 17,499 islands and with a total area of about 7.81 million km2. Of the entire area of Indonesia, there are 3.25 million km2 is the ocean and 2.55 million km2 is the Exclusive Economic Zone, and only about 2.01 million km2 is in the form of land[1].

With the vastness of the sea area that Indonesia has, Indonesia has a huge marine and fisheries potential. Of course, the potential of the sea has a high risk to take away the natural wealth contained in it. Some of the risks it poses are tsunami disasters and high tides, the higher the waves, the higher the risk for fishermen and sailors to go to sea to take the wealth of the sea. Tsunami disasters are very detrimental, especially for people who live on the beach. In the region of Java island until 2018 alone recorded 20 times tsunami disaster[2].

There are also tools to detect the occurrence of tsunami disasters, measure vibrations and wave height caused by underwater earthquakes, namely Buoy [3]. But this technology is still quite expensive and requires difficult maintenance.

So from the problem in this study tried to make a tool similar to the Buoy system but with a relatively cheaper cost and treatments that are not too difficult.

II. RELATED WORK

A. Wave Height Measuring Device Based on Gyroscope and Accelerometer (Shoujun Wang, Lu Liu, Ruijia Jin, and Songgui Chen, 2019)
Satria Gunawan Zain et al,, conducted research on monitoring the height of sea waves. The study used accelerometer sensors and gryrooscopes as data readers to be transmitted to the server using LoRa. Functionally developed devices are fulfilled data delivery up to a radius of 3.8 km. The accuracy obtained in this study is 80% [4].

B. Wireless Ocean Wave Height Monitoring Based on Inertial Measurement Sensor UnitSatria (Gunawan Zain and Wanda Rahmawati, 2020)
The study used gyroscope sensors and accelerometers as data readers to see the height of ocean waves. The buoys in the study were compared to high meter capacitive waves under wave motion conditions close to the prototype, and the measurement results were well verified. Research this device uses inertial navigation principles, and adopting four parameters Methods for coordinating transformation. The degree of accuracy is high and meets the needs of measurement [5].

III. LITERATURE REVIEW

A. Ocean Waves

Ocean waves can be interpreted as energy transfer that can be noticed by the phenomenon of rising and falling sea water with certain periods and wavelengths. This transfer of energy in the ocean is caused by several different factors so that the waves that occur in the sea can be divided into several types.

Sea waves or can also be called sea waves can be divided into several types depending on the style of generation. This ocean wave can be caused by several factors, one of which is caused by wind (wind waves), the attraction between the earth-moon-sun (tidal waves), volcanic earthquakes or tectonic earthquakes that occur at sea, and some are caused by ships or boats.

B. *Tsunami*

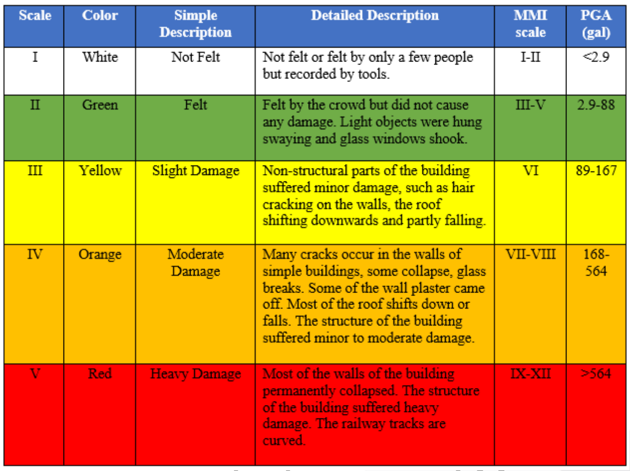
One of the major disasters that ever occurred in Indonesia was the tsunami. Tsunami is a disaster when sea water overflows suddenly with very large waves and damages very coastal areas in general. One of the causes of tsunami disasters is earthquakes both volcanic earthquakes caused by volcanic eruptions that occur in the sea, and tectonic earthquakes caused by shifts in the Earth's plates [6].

Indonesia is a country that is very vulnerable to this tsunami disaster, especially the meeting area between the Eurasian plate, indo-Australian plate, and pacific plate. Shortly before this tsunami disaster occurred there was an interval and several signs of this disaster, one of which was sea water that receded suddenly, unusual ocean waves, rumbling sounds, and earthquakes [7].

C. *Earthquake*

Earthquakes are vibrations that occur on the earth's surface caused by the sudden release of energy from within the earth. The movement of the Earth's crust is one of the causes of earthquakes[8].

In earthquake tremors there is an Earthquake Intensity Scale from the Meteorology, Climatology, and Geophysics Agency is a guide in measuring the impact of damage due to earthquake disasters collected by the Indonesian Meteorology, Climatology, and Geophysics Agency[9].



Scale	Color	Simple Description	Detailed Description	MMI scale	PGA (gal)
I	White	Not Felt	Not felt or felt by only a few people but recorded by tools.	I-II	<2.9
II	Green	Felt	Felt by the crowd but did not cause any damage. Light objects were hung swaying and glass windows shook.	III-V	2.9-88
III	Yellow	Slight Damage	Non-structural parts of the building suffered minor damage, such as hair cracking on the walls, the roof shifting downwards and partly falling.	VI	89-167
IV	Orange	Moderate Damage	Many cracks occur in the walls of simple buildings, some collapse, glass breaks. Some of the wall plaster came off. Most of the roof shifts down or falls. The structure of the building suffered minor to moderate damage.	VII-VIII	168-564
V	Red	Heavy Damage	Most of the walls of the building permanently collapsed. The structure of the building suffered heavy damage. The railway tracks are curved.	IX-XII	>564

Fig. 1 Earthquake Intensity Scale[9]

D. *IoT (Internet of Things)*

IoT (Internet of Things) is a technological paradigm that is assumed to be a network of machines that are connected to each other through the internet and able to interact with each other. IoT is recognized as one of the most important areas in the future development of technology [10].

E. *Adafruit BNO055*

Fig. 2 Adafruit BNO055

The Adafruit BNO055 is a BNO055 sensor that has been grown into a board manufactured by Adafruit. The BNO055 sensor is an IC (Integrated Circuit) in which there is a smart 9-axis Absolute Orientation Sensor system. The sensor has been integrated with a 14-bit accelerometer, a 16-bit gyroscope, and a 32-bit geomagnetic sensor. Here is the output data from the Adafruit BNO055 sensor[11].

Table 1 Adafruit BNO055 Output

No.	Output Type	Information
1	*Absolute Orientation*	Three-dimensional orientation data based on a 360-degree sphere.
2	*Absolute Orientation*	Four quaternion points to manipulate data more accurately
3	*Angular Velocity Vector*	Rotational speed of three axes in (rad/s)
4	*Acceleration Vector*	Three-dimensional acceleration (gravity + linear motion) (m/s2)
5	*Magnetic Field Strength Vector*	Three-dimensional magnetic field sensing in a tesla micro (uT)
6	*Linear Acceleration Vector*	Three-dimensional linear acceleration data (acceleration - gravity) (m/s2)
7	*Gravity Vector*	Gravitational acceleration (minus any motion) (m/s2)
8	*Temperature*	Environmental temperature in degrees Celsius (ºC)

F. *Ultrasonic Sensor*

Ultrasonic waves are sound waves that have a very high frequency of 20,000 Hz [6]. In reality ultrasonic sounds cannot be heard by humans but only by certain animals such as dogs, bat cats and dolphins.

Fig. 3 Ultrasonic Sensor

The ultrasonic sensor used is the HY-SRF05 series. The sensor can detect the distance of objects in a range of 2cm to 4m with 3mm accuracy. In general, this sensor will fire ultrasonic waves at an object or a target. The speed of the wave propagation emitted is about 340 m/s. When the wave touches the surface of the intended object, the object will reflect back the wave. The wave of reflection from the target will be captured by the sensor, then the sensor calculates the difference between the wave delivery time and the time the bounce wave is received[7].

G. *Sensor Accuracy*

Sensor accuracy is the accuracy or accuracy of the sensor in reading the values that the sensor reads. Sensor accuracy is very important in sensor testing because a good sensor is one that has accurate accuracy. In accuracy itself has several parameters in order to calculate the accuracy rate of the sensor. The parameters measured in the accuracy test are the difference, accuracy, and error values with the following equations:

Difference = | Sensor Value – Benchmark Measuring Tool Value| (1)

Y Which, errors can be formulated as follows.

$$Error\ (\%) = \left(\frac{\text{Difference}}{Comparison\ Measuring\ Tool\ Value}\right) \quad (2)$$

To measure the accuracy of this test by using the formula:

$$\text{Accuracy (\%)} = 100\% - Error \quad (3)$$

H. *Value Processing*

To get the desired value, the process of processing values is needed from the sensor reading results. Processing this value is done before the sensor reading data is sent to the ThingSpeak server, this value processing process will be done by Arduino as a controller of the device created.

1. Ultrasonic value processing
   To obtain the value of the surface of the water indermaga, the raw data read by the ultrasonic sensor must be processed first in order to get a height value. Basically raw data obtained from ultrasonic sensor readings in the form of time data. Ultrasonic waves fired from these sensors generally produce ultrasonic waves of 40kHz frequency. The speed of the wave propagation emitted is about 340 m/s. When the wave touches the surface of the intended object, the object will reflect back the wave. The wave of reflection from the target will be captured by the sensor, then the sensor calculates the difference between the time of delivery of the wave and the time the bounce wave is received. To convert the bounce time into a distance, processing and formulaing are required. The following is a data processing formula from ultrasonics.

$$S = \frac{340\ x\ t}{2} \quad (4)$$

   Information:
   S = Distance
   t = Difference between the time the ultrasonic is emitted and from the time the wave is received

   From the calculation obtained the value of the distance between the sensor and the surface of the water. Because the value needed is the height of the surface of the water, then from that distance can be formulated.

   Height of the water surface = distance of the sensor to the base – the distance of the sensor to the surface of the water (5)

2. Acceleration value processing
   The acceleration value of the sensor can be obtained from the raw data that has been obtained from the accelerometer divided by the value of the sensitivity scale factor that has been determined, which is 8. The value obtained in the form of acceleration values in three-dimensional axes, namely the X, Y, and Z axes. To unite the values, equations are used.

$$a = \sqrt{aX^2 + aY^2 + aZ^2} \quad (6)$$

   Information:
   a = Acceleration
   aX=Acceleration on the X axis
   aY=Acceleration on the Y axis
   aZ=Acceleration on the Z axis
   The acceleration value that has been obtained is still a G-force value. To eliminate the G-force value on the accelerometer can be done by reducing the G-force value (1g = 9,806 m/s2). The value obtained can then be the value of acceleration [12].

3. Processing of angular speed values
   To get the value of the angular velocity, the raw data derived from the gyroscope is also divided by the value of the sensitivity scale factor that has been determined, which is 131. The reading of the gyroscope is the angular velocity value of the axis in three dimensions namely the X, Y and Z axes.

$$\omega = \sqrt{\omega X^2 + \omega Y^2 + \omega Z^2} \quad (7)$$

   Information:
   ω=Angular speed
   ωX=Angular speed on the X axis
   ωY=Angular speed on the Y axis
   ωZ=Angular speed on the Z axis

   The value obtained from the equation above is the angular velocity value in units deg / sec. Then the value is processed again to get the rotation speed by multiplying the value of 0.0175 (1 deg/ sec = 0.0175 rad / sec) [12].

4. Calculation of wave height value
The highest acceleration value of the wave occurs when the amplitude is at the peak position so that it can be formulated by:

$$a = \omega^2 \times y \qquad (8)$$

Information:
a=Acceleration
ω=Angular speed
y=Wave height

Value y is the position of amplitude or the peak value of the wave, ω is the angular velocity, and a is acceleration. From the equation can be lowered to find the value of y as follows:

$$y = \frac{a}{\omega^2} \qquad (9)$$

Information:
a=Acceleration
ω=Angular speed
y=Wave height

5. Calculation of wave velocity value
Then to get the value of the wave speed can use the following equation:

$$\mathbf{v} = \boldsymbol{\omega} \times \mathbf{y} \qquad \mathbf{(10)}$$

Information:
v = Wave speed
ω=Angular speed
y=Wave height

6. Calculation of vibration values
PGA (Peak Ground Acceleration) is the value of the largest acceleration of ground vibrations ever to arise anywhere caused by an earthquake.[13] To get the value of vibration requires a value of gravity.

$$gravity = \sqrt{acc\ x^2 + acc\ y^2 + acc\ z^2} \qquad (11)$$

Information:
Acc X = X axis accelerometer value
Acc Y = Y axis accelerometer value
Acc Z = Z axis accelerometer value

Gravity itself is a value in the form of accelerated free fall motion towards the center of the Earth. Once the gravity value is obtained, it can be a PGA value. To get a PGA score obtained from the formula:

$$PGA = \left| \frac{(gravity\ sekarang - gravity\ sebelumnya)\ x\ 1000}{\Delta waktu} \right| \qquad (12)$$

Information:
Gravity now : The value obtained based on the gravity formula at the current time
Previous gravity : The value obtained based on the gravity formula at the previous time
ΔTime : difference is now reduced by the previous time.

IV. RESEARCH METHOD

A. Overview of the System

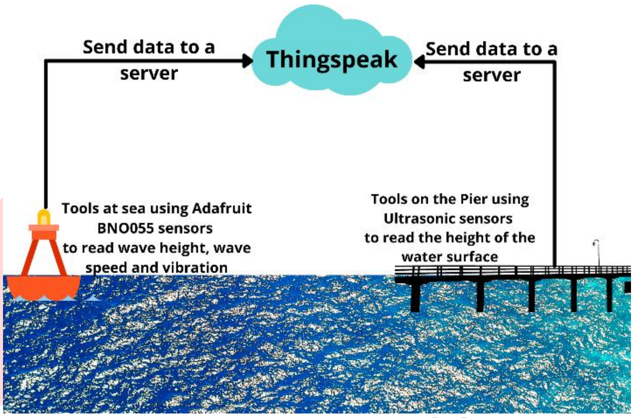


Fig. 4 System General Plan

In a built system, there are several important components. The component is hardware that serves to retrieve data and transmit it over a GSM network to ThingSpeak. Next there is ThingSpeak, which is where the data that has been sent by the hardware is stored. Here is an overview of the general plan of the system.
In this design, the BNO055 sensor is used as a sensor that will read data for the middle of the sea, in BNO055 there is a gyroscope sensor, accelerometer, and magnetometer used to read the data. As for reading data on the dock using ultrasonic sensors. For controllers used both for those in the middle of the sea and those in the dock using Arduino Uno. For data communication from the sensor to the server using sim800l as a GSM module.
The data to be sent to the server for docking is sea level height data, while for data sent from the mid-sea sensor is data on wave height, wave speed, and vibration.

B. Diagram Flow System

The system uses arduino uno as a controller that regulates and controls the sensors on the device and uses Sim800l as a module to transmit data from the hardware to ThingSpeak which acts as a data base server.

There are two tools used in this Final Task research, the first of which is found on the pier. On the device on the dock using ultrasonic sensors to read the sea level level and then processed by Arduino Uno for the data to be sent to ThingSpeak. After sending data to ThingSpeak, the sensor will re-read the data and continue to repeat until the battery or power source runs out.

The sensor used in this Final Task research is BNO055 which will read the angular amount and angular speed data and then will be processed by Arduino before being sent to ThingSpeak. After the sensor reads the required data and Arduino processes the data, the data will be sent to ThingSpeak using Sim800l. Once the data is transmitted to ThingSpeak, the sensor will reread the data every few minutes unless it runs out of electricity. Here is a flow chart of the built hardware system.

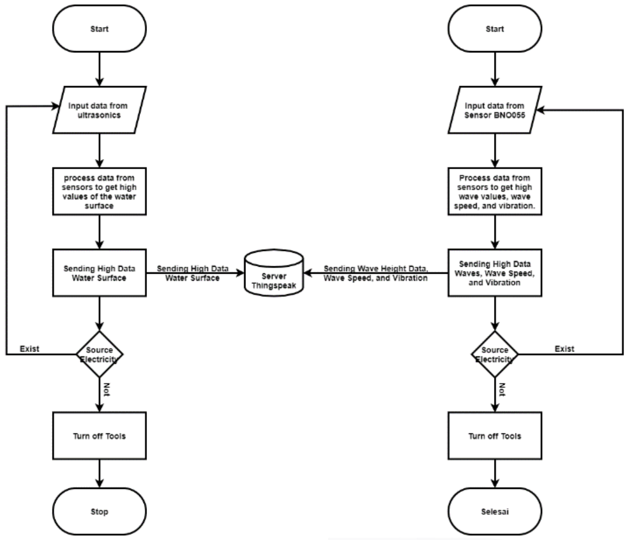


Fig. 5 Overall System Flow Diagram

C. Hardware Design

In the work of this Final Task uses 2 systems, namely those in the dock and those in the middle of the sea. Here's the scheme of the system.

1. Dock device scheme

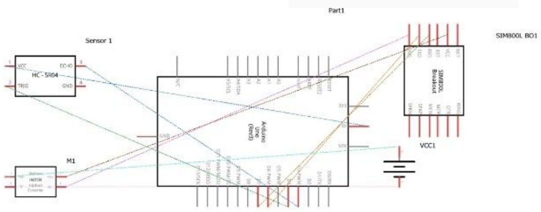


Fig. 6 Dock device scheme

On the device on the dock using ultrasonic sensors to read the sea level level and then processed by Arduino Uno for the data to be sent to ThingSpeak. After sending data to ThingSpeak, the sensor will re-read the data and continue to repeat until the battery or power source runs out. The output of this tool is the height of the water surface in the meter.

2. Marine Device Scheme

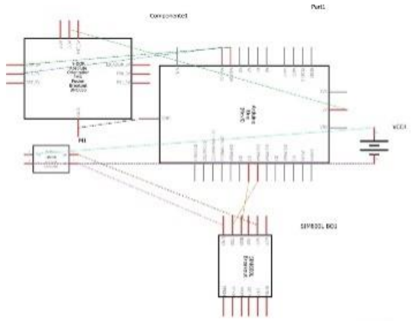


Fig. 7 Marine Device Scheme

The sensor used is BNO055 which will read the angular amount and angular speed data and then will be processed by Arduino into wave height, wave speed and vibration before being sent to ThingSpeak. After the sensor reads the required data and Arduino processes the data, the data will be sent to ThingSpeak using Sim800l. Once the data is transmitted to ThingSpeak, the sensor will reread the data every few minutes unless it runs out of electricity.

D. Supporting Software

The supporting software used in this study is ThingSpeak. ThingSpeak is an IoT (Internet of Things) platform that is often used. ThingSpeak is one of the IoT platforms with an open API, ThingSpeak communicates using the internet network. ThingSpeak is used as a useful data base server to store data processed by arduino. Here is the data stored in ThingSpeak.

V. Implementation and Testing

A. Implementation

In this system, implementation is carried out in the form of data reading, data delivery, and tried on containers containing water. Readings of data by the sensor will be done repeatedly until the power source on the battery runs out. The implementation of data delivery serves to send data to the server through the Sim800l module obtained from the sensor reading results, while the implementation on the water container is intended to replace the implementation to the outdoors.

1. Implementation of Tools

Fig. 8 Tools at Sea

The tool in Figure 8 is designed to be able to read the height of ocean waves, wave speed and vibration. This tool is put into a container that is waterproof, light and impact resistant in order to float on the surface of Sair. The material from the container must be strong so that it is not easily damaged and leaky due to friction or impact.

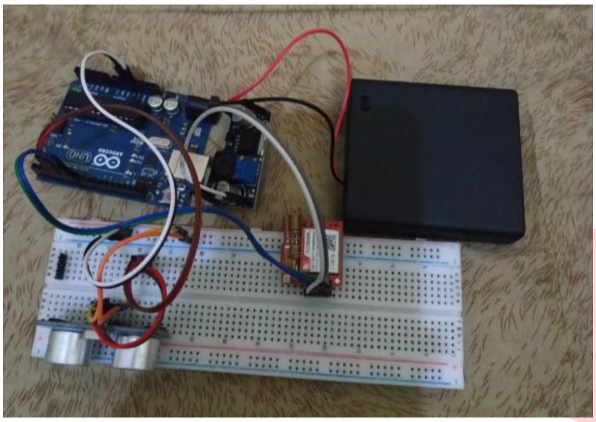


Fig. 9 Tools in the Dock

The tool in Figure 11 is a tool installed on the pier, this tool is designed to be able to read the height of sea level. This tool is put in a container that is waterproof, light and resistant to impact so as not to enter the water. Ultrasonic sensors will be outside of the container and will be coated in plastic or waterproof materials. The material from the container must be strong so that it is not easily damaged and leaky due to friction or impact.

2. Implementation of Data Delivery
In this Final Task research, data transmission will be carried out by sim800l module as a GSM module that has been connected to the internet network.

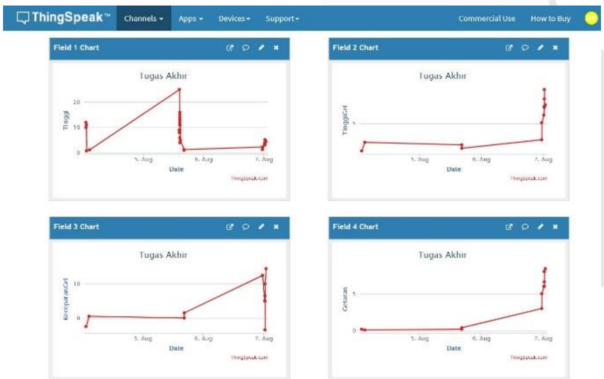


Fig. 10 Data Received by ThingSpeak

Figure 12 is a display of the results of sending data to the ThingSpeak server using Sim800l that has been connected to the internet network.

B. Testing

After testing on this tool, some test results data is obtained. Here are the results of the tests that have been done.

1. Water surface high test results
From the tests that have been done to measure the water level in this tool obtained the following results.

Table 1 High water surface testing results

No.	Ruler Measurement (cm)	Tool measurement (cm)	Difference (cm)	*Error* (%)
1	5	5,42	0,42	8,4
2		5,42	0,42	8,4
3		5,52	0,52	10,4
4		5,52	0,52	10,4
5		5,49	0,49	9,8
6	10	10,53	0,53	5,3
7		11,01	1,01	10,1
8		10,79	0,79	7,9
9		10,87	0,87	8,7
10		10,74	0,74	7,4
11	15	15,70	0,7	4,667
12		15,72	0,72	4,8
13		15,60	0,6	4
14		15,55	0,55	3,667
15		15,62	0,62	4,133
16	20	19,54	0,46	2,3
17		20,46	0,46	2,3
18		20,53	0,53	2,65
19		19,22	0,78	3,9
20		20,31	0,31	1,55
Average			0,602	6,038

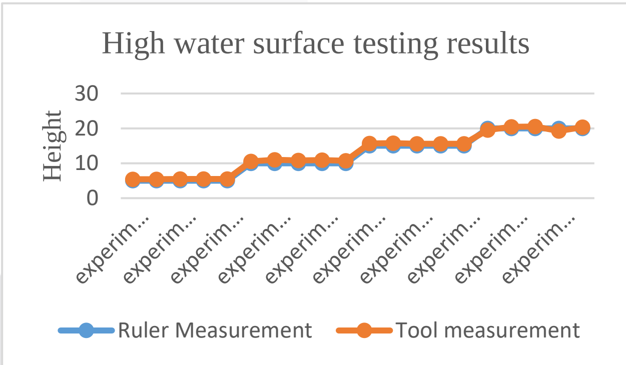


Fig. 11 Graph of water surface high testing results

From the test results, it was found that from 20 tests, with different high parameters, there was an average error of 6.0383% and an accuracy rate of 93.9617%.

2. Wave height testing results
From the tests that have been done to measure the height of water waves in this tool obtained the following results.

Table 2 Wave height testing results

No.	Ruler Measurement (cm)	Tool measurement (cm)	Difference (cm)	*Error* (%)
1	5	6,12	1,12	22,4
2		3,7	1,30	26
3		5,3	0,3	6

No.	Ruler Measurement (cm)	Tool measurement (cm)	Difference (cm)	*Error* (%)
4		10,2	5,2	104
5		7,13	2,13	42,6
6	10	13,2	3,2	32
7		15,47	5,47	54,7
8		9,7	0,3	3
9		7,9	2,1	21
10		11,7	0,7	17
11	13	12,5	1,5	11,54
12		15,87	2,87	22,08
13		12,8	0,2	1,54
14		14,34	1,34	10,31
15		19,8	6,8	52,31
16	15	17,32	2,32	15,47
17		7,89	7,11	47,40
18		15,32	0,31	2,07
19		16,76	1,76	11,73
20		20,34	5,34	35,60
Average			2,62	26,94

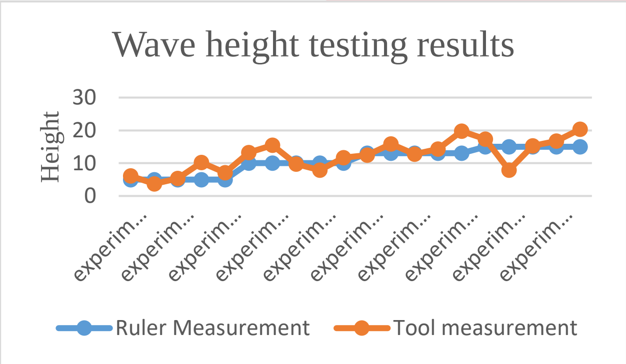


Fig. 12 Graph of Wave height testing results

From the test results, it was found that from 20 tests with different high parameters, the average error was 26.94% and the accuracy rate of the reading was 73.06%.

3. Vibration testing results
From the tests that have been done to see the vibrations felt by this tool, the following results are obtained.

Table 3 Vibration testing results

No.	Manual Vibration	Sensor Reading Results
1	Yes	Yes
2	Yes	Yes
3	Yes	Yes
4	Yes	Yes
5	Yes	Yes
6	Yes	Yes
7	Yes	Yes
8	Yes	Yes
9	Yes	Yes
10	Yes	Yes
11	Yes	Yes
12	Yes	Yes
13	Yes	Yes
14	Yes	Yes
15	Yes	Yes

From the test results, from 15 trials, the percentage of sensor success in data is very large, which is 100%. This test cannot be validated because the state is PPKM and cannot go to BMKG because it cannot visit its office.

4. Data delivery test results
From the tests that have been done to see the time needed to send data, the following results are obtained.

Table 4 Data delivery test results

No.	Delivery Time (WIB)	Time Accepted (WIB)	Time Taken (seconds)
1	14:28:41,45	14:29:02,21	20,76
2	14:29:42,42	14:30:12,01	23,59
3	14:30:43,45	14:30:58,55	15,10
4	14:31:44,30	14:31:59,26	14,96
5	14:32:45,22	14:33:00,46	15,24
6	14:33:46,12	14:34:08,70	22,58
7	14:34:48,98	14:35:01,32	12,34
8	14:35:49,87	14:36:17,28	27,41
9	14:36:50,78	14:37:09,69	18,91
10	14:37:51,61	14:38:09,22	17,61
11	14:38:52,53	14:39:07,23	14,70
12	14:39:53,76	14:40:07,42	13,66
13	14:40:54,73	14:41:06,98	12,25
14	14:41:55,22	14:42:16,31	21,09
15	14:42:56,12	14:43:12,75	16,63
Total			266,83
Average			17,78867

From the test results obtained that, from 15 data transmission trials, the average time needed is 17.78867 seconds.

5. 3-Dimensional Test Results
Based on the test of 3-dimensional motion simulation to find out the performance of sensors with 5 different positions and random slope levels, the results are obtained in the form of images and tables as follows.

Table 5 Results of 3-dimensional sensor testing

No.	Position on the Tool	Position on Simulator	Test Results
1	Flat	Flat	Succeed
2	Tilt to the left	Tilt to the left	Succeed
3	Tilt to the right	Tilt to the right	Succeed
4	Tilt forward	Tilt forward	Succeed
5	Tilted backwards	Tilted backwards	Succeed
Successfully simulated position			5/5

VI. Conclusion

Based on the results of the research and the results of the tests conducted in this Final Task study, it can be concluded that:

1. The readings by the system contained on the dock with ultrasonic sensors show a relatively small error value of 6.0383% and an accuracy obtained by 93.9617%, which has been tested with 20 experiments with different parameters and compared to manual measurements by the ruler. While the accuracy value of the water wave height reading by the Adafruit BNO055 sensor is 73.06%. The value is obtained from 20 experiments compared to manual measurement values using a ruler,

2. 2Vibration readings by Adafruit BNO055 sensor from 15 vibration tests with different vibration scales ranging from small vibrations to strong vibrations can read everything,
3. Data delivery to ThingSpeak server using Sim800l Module with GSM / GPRS technology is relatively fast with the average data delivery time is 17.78867 seconds.

VII. REFERENCE

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