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# Comparation Tidal Harmonic Based on IoT Instrument Using The Admiralty Method in Tanjungpinang Waters

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**Abstract**

Tides are the rising and falling movement of sea level caused by the gravitational force of celestial bodies such as the moon and sun on the mass of seawater on earth. The aim of this research is to compare the use of different time acquisition obtained from tidal data stored in the internet of things (IoT) instrument developed in generating tidal harmonic constants. Research activities were carried out at the international port of Dompak Island, Tanjungpinang City, Riau Islands. This tidal data obtained from the instrument was split into several time periods each 6', 16', 26', 36', 46', 56', and averaged. This data is analyzed using admiralty to generate tidal harmonic constants and identify patterns and sea level levels. Based on the results obtained, the type of tide in Tanjungpinang waters is a mixed tide (single dominant) with an F value of 2.01 to 2.07. The sea level elevation values obtained from MSL from each time series ranged from 75.83 cm to 76.60 cm, MHWL ranged from 97.17 cm to 98.24 cm. Then MLWL ranges from 58.77 cm to 59.39 cm. Meanwhile, HHWL ranges from 153.98 cm to 154.73 cm, and LLWL ranges from -2.77 cm to -1.96 cm. The difference in each time series seen from the data MSL is 7 cm. Therefore, tidal data from each time series has no significant differences. This finding indicates that the developed IoT-based instrument provides consistent and reliable tidal data, making it a suitable tool for tidal analysis in Tanjungpinang waters.

**Keywords:** Tide, Admiralty, Formzahl Numbers, Water Level Elevation

## 1. Introduction

The sea is a body of water that covers most of the earth's surface and separates land into continents and islands. Hydro-oceanographically, seas are influenced by several factors, including tides, sea surface temperature, salinity, currents, and waves (Syahri QA et al., 2024). Indonesia is an archipelagic country, most of which is ocean; this has strategic potential in the shipping sector on both a national and international scale. This shipping activity is important for understanding the oceanographic factors of the area, one of which is tides. This factor has an important role in knowing the high and low elevation of the water level in a body of water (Supriyadi et al., 2018). According to (Pasaribu RP 2022), tides are the rising and falling movement of sea level caused by the gravitational force of celestial bodies such as the moon and sun on the mass of seawater on earth. This tidal data can be analyzed with admiralty. This method is used to analyze harmonic constants and identify patterns and sea level heights in a particular area (Setyowati and Zahrina 2024). Admiralty has the advantage of being able to take into account astronomical and meteorological factors and being able to analyze in detail short ranges of tidal data (Fitriana et al., 2019).

Recently, obtaining tidal data in Indonesian waters has become increasingly challenging. This is an important problem, especially for activities carried out in waters. With this IoT-based tidal measuring equipment, it is possible to provide information regarding tidal data in certain areas. This tool can measure tides over a certain period. Previous research was conducted by (Kusuma et al., 2024) regarding the implementation of IoT-based tidal measurements for sea level monitoring. From the research results, it is explained that this instrument can provide good results and is a solution in providing accurate and cost-effective data. Apart from that, (Kusuma et al., 2021) carried out tide measurements using the Valeport Tide Master tool in Jakarta Bay and obtained quite good results. (Jefiza et al., 2023) conducted research on IoT-based tidal monitoring. As a result, this tool provides information regarding tidal data in real time, which can be viewed using a smartphone. (Suwardi et al., 2024) developed an automatic tide measuring tool that has very high data accuracy.

The aim of this research is to compare the use of different time acquisition obtained from tidal data stored in the internet of things (IoT) instrument developed in generating tidal harmonic contants..

## 2. Research Method

Research activities were carried out at the international port of Dompak Island, Tanjungpinang City, Riau Islands. The research location is presented in (Figure 1).

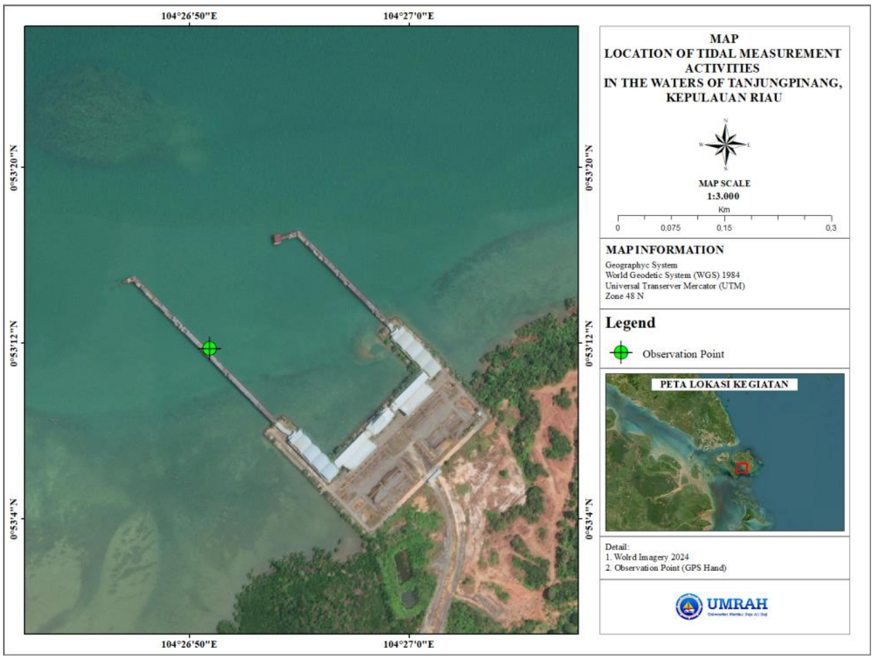


**Figure 1.** Research Location

Primary tidal data was taken for six days. The data is then entered into the stage pre-processing for filtering and adjustment time series from the data to be compared using the admiralty method. After that, the tide time series that will be compared are obtained, namely the 6th, 16th, 26th, 36th, 46th, 56th minutes and the average tide. The next stage is to analyze the data using the admiralty method to obtain harmonic constants and tidal types from each data. To measure the significance of differences in the data, statistical analysis was used, namely two-factor ANOVA. The tidal analysis process is presented in (Figure 2).

Harmonic constants from the results of the admiralty method analysis can be used to calculate numbers formzahl. According to (Suhemi 2018), this number is the division between the amplitude of the main daily tidal constant and the amplitude of the main double tidal constant. The formzahl number calculation formula is as follows:

$$F = \frac{A(K_1) + A(O_1)}{A(M_2) + A(S_2)}$$

Where:

$F$ : Formzahl Numbers
$K_1$ : Amplitude of a Single Major Tidal Component (Sun Gravitational Pull)
$O_1$ : Amplitude of a Single Major Tidal Component (Moon Gravitational Pull)
$M_2$ : Amplitude of the Main Double Tidal Component (Moon Gravitational Pull)
S_2 : Amplitude of the Main Double Tidal Component (Sun Gravitational Pull)

Tidal types based on formzahl numbers (Solom et al., 2020):

a. Semidiurnal Tides ($F \leq 0.25$)
b. Mixed tides (Double Dominant) ($0.25 \leq F \leq 1.5$)
c. Mixed tides (Single Dominant) ($1.5 \leq F \leq 3$)
d. Diurnal Tide ($F > 3$)

Water level elevation can be calculated using the formula (Fadilah et al., 2014):

$$MSL = S_0$$
$$HHWL = S_0 + Z_0$$
$$MHWL = Z_0 + (M_2 + S_2)$$
$$LLWL = S_0 - (M_2 + S_2 + N_2 + K_1 + O_1 + P_1 + M_4 + MS_4)$$
$$MLWL = Z_0 - (M_2 + S_2)$$
$$Z_0 = M_2 + S_2 + N_2 + K_1 + O_1 + P_1 + M_4 + MS_4$$

Where :
MSL : Mean Sea Level
HHWL : Highest High-Water Level
MHWL : Mean High Water Level
LLWL : Lowest Low Water Level
MLWL : Mean Low Water Level

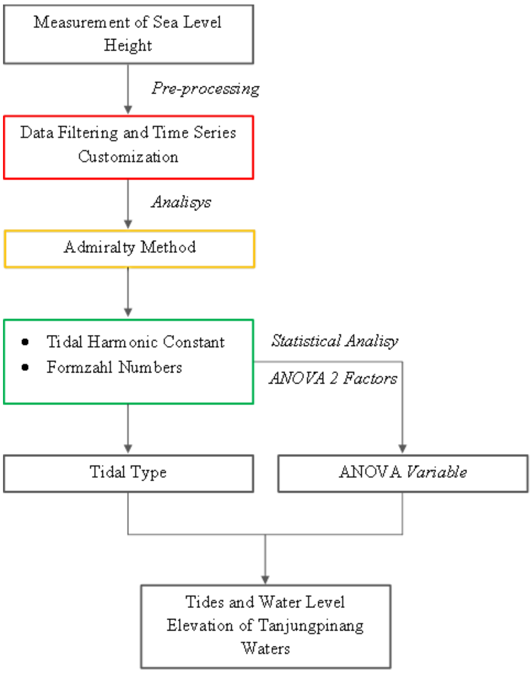


**Figure 2.** Research Procedure

## 3. Result and Discussion

This water level elevation graph (Figure 3) was obtained from six time series and average data. The graph above shows that there is a slight difference at the peak high tide point and the lowest low tide point. If measured from data (MSL) or the zero point, the highest tide is 60 cm and the lowest tide is 80 cm. So, the highest tide in these waters is 140 cm. Meanwhile, the lowest tide is 90 cm.

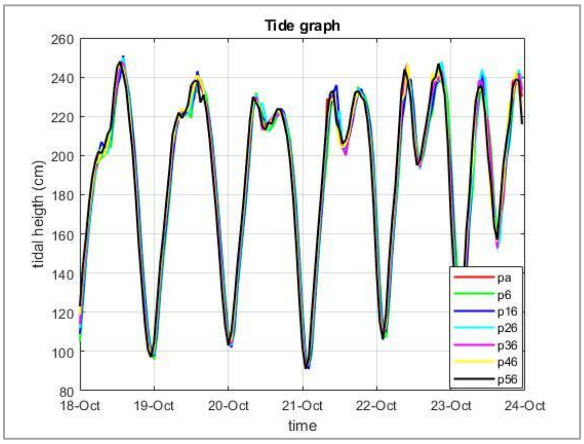


**Figure 3.** Water Level Elevation of Tanjungpinang Waters

The type of tide and the water level of Tanjungpinang waters are determined by the admiralty tidal harmonic constant $S_0, M_2, S_2, N_2, K_1, O_1, P_1, M_4, MS_4$. The results of each IoT tidal harmonic component time series are presented in (Table 1 and Table 2):

**Table 1.** Tidal Amplitude Observation

| Time | S0 | M2 | S2 | N2 | K1 | O1 | M4 | MS4 | K2 | P1 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6” | 75.83 | 14.00 | 5.50 | 11.86 | 15.41 | 23.70 | 1.75 | 1.28 | 1.49 | 5.09 |
| 16” | 75.84 | 13.43 | 5.65 | 11.46 | 15.64 | 23.86 | 1.85 | 1.25 | 1.52 | 5.16 |
| 26” | 75.98 | 13.88 | 5.61 | 11.77 | 15.38 | 24.01 | 1.71 | 1.30 | 1.52 | 5.08 |
| 36” | 75.96 | 13.59 | 5.43 | 11.92 | 15.42 | 23.93 | 1.73 | 1.25 | 1.47 | 5.09 |
| 46” | 75.92 | 13.76 | 5.49 | 11.89 | 15.21 | 24.09 | 1.80 | 1.32 | 1.48 | 5.02 |
| 56” | 76.10 | 13.78 | 5.32 | 12.03 | 15.36 | 24.09 | 1.67 | 1.17 | 1.44 | 5.07 |
| P Ave | 76.01 | 13.63 | 5.57 | 11.59 | 15.39 | 23.96 | 1.57 | 1.19 | 1.50 | 5.08 |

Source: Admiralty Analysis Results

**Table 2.** Tidal Phase Observation

| Time | M2 | S2 | N2 | K1 | O1 | M4 | MS4 | K2 | P1 |
|---|---|---|---|---|---|---|---|---|---|
| 6’ | 302.08 | 272.69 | 126.11 | 155.19 | 354.97 | 87.17 | 350.05 | 272.69 | 155.19 |
| 16’ | 297.26 | 267.85 | 119.67 | 151.72 | 352.30 | 81.38 | 346.65 | 267.85 | 151.72 |
| 26’ | 292.58 | 266.71 | 115.03 | 149.80 | 350.36 | 60.88 | 326.92 | 266.71 | 149.80 |
| 36’ | 287.03 | 262.06 | 108.84 | 147.84 | 348.17 | 57.71 | 326.49 | 262.06 | 147.84 |
| 46’ | 280.68 | 254.91 | 103.61 | 145.52 | 346.03 | 50.90 | 322.33 | 254.91 | 145.52 |
| 56’ | 276.56 | 250.87 | 100.95 | 142.41 | 343.22 | 30.99 | 304.78 | 250.87 | 142.41 |
| P Ave | 289.71 | 262.04 | 111.92 | 148.70 | 349.20 | 58.23 | 325.13 | 262.04 | 148.70 |

Source: Admiralty Analysis Results

Based on the results of the admiralty method analysis above, ten tidal harmonic components from each different time series are obtained, which are influenced by astronomical factors. This component is initial information regarding determining the type of tide and calculating sea level elevation. According to (Khairunisa et al., 2021) the magnitude of the amplitude value of the tidal component in a body of water is influenced by the generating force. The dominant harmonic component that generates tides in these waters is a single tidal component due to the gravitational force of the moon, which is 23.86 cm - 24.09 cm. Meanwhile, the lowest harmonic component is the double tidal component due to the gravitational force of the sun, which is 5.32 cm - 5.65 cm. These two components are a comparison of the tidal forces generated by the sun and moon in a body of water (Wijaya and Yanuar 2019). According to (Hamza et al., 2017) astronomical influences that can influence tides are the distance of celestial bodies such as the moon and the earth and the phase of the moon's age. Formzahl numbers of each data time series are as follows:

**Table 3.** Formzahl Numbers

| *Time Series* | *Formzahl* |
|---|---|
| 6” | 2.01 |
| 16” | 2.07 |
| 26” | 2.02 |
| 36” | 2.07 |
| 46” | 2.04 |
| 56’ | 2.06 |
| P Ave | 2.05 |

Source: Calculation Result

From the results of formzahl numbers calculations from each time series, it was found that the tidal type in Tanjungpinang waters is a mixed tides (single dominant). According to (Rumapea et al., 2024), formzahl numbers of tidal observations at Gurindam 12 Tanjungpinang obtained a value range of 0.25 to 1.5 with mixed tides (double dominant). Meanwhile, in the results of research (Khairunisa et al., 2021), this tidal data was taken in East Bintan waters and is classified as a mixed tide (double dominant) with a formzahl value of 0.66 to 0.77. There is a difference between the results of observations and previous research; this is because it is suspected that there is a lack of duration for taking tidal data so that the data must be taken again with a longer duration in subsequent research. Apart from that, the cause of the difference in tides according to (Kurniawan et al., 2019), is that tides are influenced by local factors such as seabed topography and the shape of the bay in a particular water area.

**Table 4.** Sea Water Level Elevation Values

| Elevasi | PA (cm) | P6 (cm) | P16 (cm) | P26 (cm) | P36 (cm) | P46 (cm) | P56 (cm) |
|---|---|---|---|---|---|---|---|
| **MSL** | 76.01 | 75.83 | 75.84 | 75.98 | 75.96 | 75.92 | 76.10 |
| **Zo** | 77.97 | 78.59 | 78.30 | 78.75 | 78.36 | 78.57 | 78.50 |
| **HHWL** | 153.98 | 154.42 | 154.15 | 154.73 | 154.32 | 154.49 | 154.60 |
| **MHWL** | 97.17 | 98.09 | 97.38 | 98.24 | 97.38 | 97.82 | 97.60 |
| **LLWL** | -1.96 | -2.76 | -2.46 | -2.77 | -2.40 | -2.65 | -2.40 |
| **MLWL** | 58.77 | 59.09 | 59.22 | 59.26 | 59.33 | 59.33 | 59.39 |

Source: Analysis Result

Based on the results of the analysis of sea level elevation values, the mean sea level (MSL) value was obtained for each time series ranging from 75.83 cm to 76.60 cm, the mean high water level (MHWL) ranges from 97.17 cm to 98.24 cm. Then the mean low water level (MLWL) ranges from 58.77 cm to 59.39 cm. Meanwhile, the highest high water level (HHWL) during full moon tide ranges from 153.98 cm to 154.73 cm, and the lowest low water level (LLWL) during full moon tide ranges from -2.77 cm to -1.96 cm. To see the differences in the tidal harmonic characteristics of each time series, we carried out an ANOVA test, Two Factor Without Replication. The analysis results are presented in the following table:

**Table 5.** ANOVA Analysis Result

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| *Rows* | 31778.17 | 9 | 3530.907 | 226799.8 | 3E-120 | 2.05852 |
| *Columns* | 0.03717 | 6 | 0.006195 | 0.397923 | 0.877153 | 2.271989 |
| *Error* | 0.840693 | 54 | 0.015568 | | | |
| Total | 31779.04 | 69 | | | | |

Source: ANOVA Analysis Result

Based on the results of the analysis above, the components column is sea tide data with usage time series that are different. With a confidence interval of 5 percent, $F(0.397923) < F_{crit}(2.271989)$ is obtained, which means that it fails to reject the hypothesis $H_0$ or rejects $H_1$ (there is no difference in the tidal harmonic constants of each time series). If we look at the average sea level (MSL) data, the differences between each time series and average by 7 cm. This can be interpreted that the data for each time series does not have a large significant difference, so the data is a different time series; it can be used in its entirety. The very low P value (3E-120) on the row variation indicates a strong factorization of the response variable to the observed variation. This is because the line factor shows the harmonic components of the observed tidal values.

## 4. Conclusion

Based on the analysis results of ANOVA - Two Factor Without Replication it can be concluded that the tidal harmonic constant of each time series show no significant difference. This is proven by ANOVA analysis using a confidence interval of 5 percent to obtain $F < F_{crit}$. The difference in each time series can be seen from the average sea level height (MSL) of 7 cm. This finding indicates that the developed IoT-based instrument provides consistent and reliable tidal data, making it a suitable tool for tidal analysis in Tanjungpinang waters.

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