Analysis of angular resolution and range resolution on multibeam echosounder R2 Sonic 2020 in Port of Tanjung Perak (Surabaya)

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Abstract. Utilizing a multibeam echosounder considers several factors based on its specifications, such as selectable frequency and selectable swath angle. It is done for multibeam efficiency and being usable in any situation. This research will analyze the Angular Resolution and Range Resolution. The purpose is to determine the ability of Multibeam echosounder in detecting small objects.

1. Introduction
Maintaining pond of port is important to maintain the depth of a pond caused by the process of sediment transport. The part of port maintaining is dredging. The purpose is to convinced the shipping activities are safe. Indonesia’s Ports which require a periodic dredging maintenance are Belawan, Palembang, Tanjung Priok, Surabaya, and Pontianak. This is caused by its location of the ports close from the estuary [1].

Required data to support the dredging is seabed morphology. The data is obtained from the result of bathymetry survey and being visualized into a bathymetry charts. The survey was use an acoustic instrument named multibeam echosounder [2].

Utilizing a multibeam echosounder considers several factors based on its specifications, such as selectable frequency, selectable swath angle and detecting small objects. It is done for multibeam efficiency and being usable in any situation. This research will analyze the ability to distinguish neighboring objects (Angular Resolution) and the ability to distinguish the height of an object (Range Resolution). This research will analyze the Angular Resolution and Range Resolution. The purpose is to determine the ability of Multibeam echosounder in detecting small objects.

2. Data and methods
2.1. Data
The data used in this study consisted of:
a. Multibeam Echosounder (MBES) Raw Data and Its Specification
   Data is taken on November 15th, 2019. MBES data requires tidal correction and sound velocity correction. Data collection is done by changing of frequency and swath angle. It produces 14 lines included with the patch test. The resulting format of Multibeam Echosounder R2 Sonic 2020 is .sbd.

b. Offset Static Data
   Offset static measurement is an activity to determine the location of each instrument or sensor which installed on the boat and it refers to reference point (Centre of Gravity) [3].

c. Tidal Data
   Tidal data is used for depth correction of MBES data processing.

d. Sound Velocity Data
   Sound velocity data is used to correct Multibeam Echosounder data.

e. Global Navigation Satellite System (GNSS) Data
   Accuracy test to determine the level of accuracy of the horizontal positioning system.

2.2. Equipments
The equipment that used in this research are:

a. Pandu 047 Boat
   This boat is available in the port of Tanjung Perak Surabaya, the speed of the boat used is approximately 4 knots.

b. Multibeam Echosounder R2 Sonic 2020
   Based on technical specifications, a frequency of 400 kHz can be used up to a depth of approximately 100 m and a frequency of 200 kHz can be used up to a depth of 200 meters. This research using frequency of 400 at a depth of 20 m to 30 m and swath angle of 110 degrees [4].

c. GNSS Veripos LD8
   GNSS Veripos LD8 obtained horizontal positioning accurately [5].

d. Qimera
   This software is used for processing of multibeam echosounder data

e. Eiva Navisuite
   This software is used for data acquisition

f. ArcGIS
   This software is used to display and perform spatial data processing.

g. Microsoft Office
   This word and number processing tool is used to do calculating and reporting.

2.3. Methods
2.3.1. Input Data into NaviEdit.
The data entered consists of raw data of multibeam echosounder, sound velocity data, tidal data, and offset static data. Tidal data and sound velocity data used are on November 15, 2019 which is saved with the format (.txt). The order of writing on tidal data starts from date - month - year - hour - minute - second – elevation.

2.3.2. Patch Test in NaviModel.
Patch test aim to determine the mounting angle of the transducer on a multibeam, relative to the three axes of the ship's local coordinate system. These three axes are often referred to as roll, pitch and yaw angles [6].

The speed of the ship in taking the pitch data is same. The area used can also be selected by line or by polygon. In collecting the roll data, it must be on a relatively flat seabed and taken 2 times round trip in one line. In collecting yaw data, 2 parallel lines are used with the same direction and there are
objects on the seabed [7]. To calculate pitch, roll and yaw values, it can use Calculate Calibration tool.

2.3.3. Points to Digital Terrain Model (DTM).
   After patch test, next step is to convert points into DTM. In this study, to identify an object (adjacent and height) can be done with the DTM display.

2.3.4. Data Cleaning.
   One of the causes of noise is not taking sound velocity data. There are four main methods used in data cleaning process, namely Automatic, Semi-Automatic, Manual and WriteBack. The semi-automatic method is divided into several methods, such as Histogram Plane Cleaning, Histogram Spike Shooting, Distance to Surface Cleaning, Stencil Reject, Stencil Accept.

2.3.5. Analyze Range Resolution and Angular Resolution.
   Spatial resolution is divided into two types, namely range resolution and angular resolution. Range resolution explains the ability of the Multibeam echosounder to distinguish the height of an object, determining the range resolution value using the bandwidth function. Range resolution is calculated by multiplying the wavelength (pulse length) with sound velocity, and dividing it in half to account for ping round-trip times. The following is the formula used in determining range resolution values [8].

   \[
   \text{Range resolution} = \frac{\text{pulse length} \times \text{sound speed}}{2}
   \]  

   The duration of the pulse length is equal to the reciprocal of the bandwidth.

   \[
   \text{Pulse length} = \frac{1}{\text{bandwidth}}
   \]  

   Angular resolution explains a value that indicates the Multibeam echosounder's ability to distinguish adjacent objects. Angular resolution is inversely proportional to the wavelength (\(\lambda\)) and dimensions of the transducer (\(L\)), [9].

   \[
   \text{Angular resolution} = \frac{1.22 \times \lambda}{L}
   \]  

   The ability of Multibeam Echosounder to identify an object on the seabed can be determined by calculating the value of range resolution and angular resolution.

3. Results and Discussion

3.1. Static Offset Measurement
   The transducer from MBES is tilted at an angle of 12 degrees. This is because there is a boat engine next to the transducer. Each instrument is placed on the ship with an offset value to the Center of Gravity (CoG). The results of the static offset measurement can be seen in Table 1.

   **Table 1. Instrument Offset**

   | No | Instrument          | X (m) | Y (m) | Z (m) |
   |----|---------------------|-------|-------|-------|
   | 1  | Multibeam Echosounder | -2.36 | -3.27 | -1.50 |
   | 2  | MRU                 | -0.20 | 1.99  | 1.17  |
   | 3  | GNSS                | 0.00  | -0.25 | 3.78  |
   | 4  | Heading Sensor      | 0.00  | 4.34  | 3.78  |
3.2. Sound Velocity
During the survey, 2 sample points for sound velocity measurements were taken, that is, in the noon and in the evening. Sound velocity data taken at coordinates 692082.32; 9205132.17 m. Sound velocity data was taken at 11:52 WIB and 15:55 WIB. The average sound velocity in Tanjung Perak Surabaya is 1,548.4 m/s.

3.3. Accuracy Test
This test is carried out on land. The location for the accuracy test is BMG021-1004, which is located at Pelindo III Ship Terminal, Perak Barat, Krembangan, Surabaya. The instrument used is GNSS Veripos. Based on the tests, the best accuracy value that can be produced is 16.91cm as seen in the Figure 1.

![Figure 1. Result of Accuracy Test.](image)

3.4. Tide Observation
Tidal data is carried out for 5 hours, from 11:00 WIB to 16:00 WIB. Tide data is taken using Valeport Tidemaster. This tool is placed at Port of Nilam Tanjung Perak, Surabaya. The graph below (Figure 2) explains the tide observation in this study.

![Figure 2. Tide Observation.](image)

3.5. Range Resolution and Angular Resolution
Range resolution (RR) is the minimum distance measured from 2 separate echos. On the specifications, Multibeam echosounder R2 Sonic 2020 has a bandwidth (B) of 60 kHz. The average of sound velocity in the study area is 1548.4 m/s. The following is the formula used in determining range resolution values [8].
The range resolution result of the Multibeam echosounder R2 Sonic 2020 is 12.9 mm. It can be said that multibeam echosounder R2 Sonic 2020 has the ability to distinguish the height of an object up to 12.9 mm or 0.0129 m.

The variables used to calculate angular resolution value are wavelength (\(\lambda\)) and dimensions of the transducer (L). The R2 Sonic 2020’s transducer has dimensions of 0.14 m x 0.16 m x 0.13 m. The frequency (f) used in this study is 400 kHz with sound velocity (c) in the study area is 1548.4 m/s. The following is the formula used to determine the wavelength.

\[
\lambda = \frac{c}{f}
\]  
\[\lambda = \frac{1548.4 \text{ m/s}}{400 \text{ kHz}} \]  
\[\lambda = 0.004 \text{ m}\]  

After the wavelength value is obtained, then the value entered into the angular resolution formula. The formula for determining the angular resolution value is as follows [9].

\[
AR = \frac{L}{1.22 \times \lambda} \quad \text{(for } L > 4\lambda \text{)}
\]  
\[AR = \frac{0.14}{1.22 \times 0.004} \]  
\[AR = 0.0337 \text{ m} \]  
\[AR = 33.7 \text{ mm}\]  

It can be said that multibeam echosounder R2 Sonic 2020 with a frequency of 400 kHz has the ability to distinguish adjacent objects within 33.7 mm or 0.0337 m. The use of 200 kHz frequency on the multibeam echosounder R2 Sonic 2020 can distinguish adjacent objects within 67.5 mm or 0.0675 m.

4. Conclusions

The R2 Sonic 2020 performs the sound waves with accuracy value around 16.91 cm and the velocity in that area is 1548.4 m/s. In this study, from the results obtained, it can be concluded that the multibeam echosounder R2 Sonic 2020 has the ability to distinguish the height (range resolution) of an object up to 12.9 mm or 0.0129 m. Multibeam echosounder R2 Sonic 2020 with a frequency of 400 kHz also has the ability to distinguish adjacent objects (angular resolution) within 33.7 mm or 0.0337 m with noted that the wavelength that used in this research is about 0.004 m.

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