



(51) International Patent Classification:

G01S 7/52 (2006.01) G01C 13/00 (2006.01)
G01S 15/08 (2006.01) G01C 21/00 (2006.01)
G01S 15/86 (2020.01) G01S 15/87 (2006.01)
G01S 15/93 (2020.01)

(21) International Application Number:

PCT/GB2020/050075

(22) International Filing Date:

15 January 2020 (15.01.2020)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

1900641.0 17 January 2019 (17.01.2019) GB

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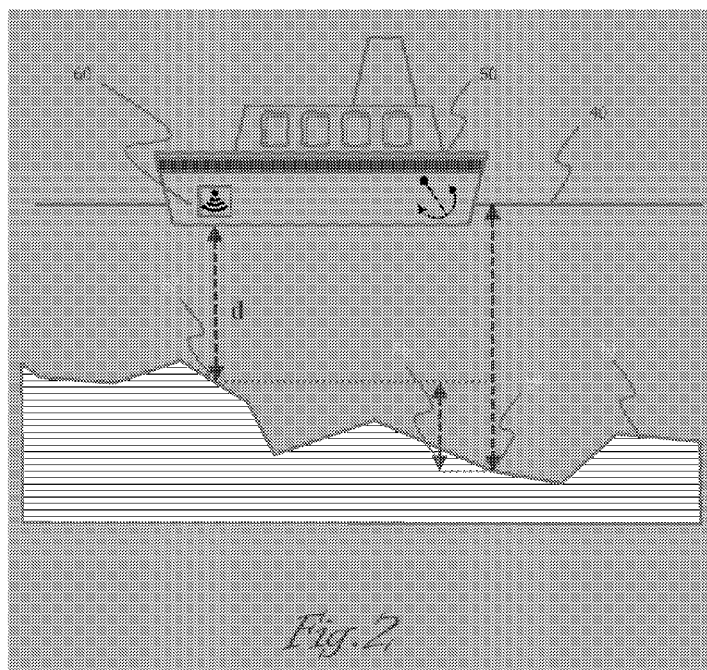
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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,

(54) Title: ECHO SOUNDER CALLIBRATION



(57) Abstract: The present invention relates to a method of calibrating an echo sounder on a marine vessel. The method comprises measuring a first water depth using an echo sounder on a marine vessel, obtaining location data for the echo sounder, obtaining a second, previously measured, water depth from another source for a location nearby to the echo sounder, comparing the first depth to the second depth, and carrying out a pre-determined action if the measured depth differs from the second depth by more than a pre-determined threshold.



TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW,
KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:

- *with international search report (Art. 21(3))*

ECHO SOUNDER CALLIBRATION

The present invention relates to a method for calibrating an echo sounder on a marine vessel.

5 BACKGROUND

Water depth information is critical for marine navigation, and echo sounding is a well-known method of determining the depth of a body of water. Sonar pulses (i.e. sound waves) are transmitted downwards into the water from the surface, and the time interval between emission and return of a sonar pulse
10 is measured. By knowing the speed of sound through the water, and the time taken for the sonar pulse to return to the surface, the local depth can be calculated. Modern marine vessels, of increasing size, are often equipped with their own echo sounders and need to be able to trust the depth information provided. The present invention provides a method of calibrating an echo
15 sounder device on a marine vessel in order to ensure increased confidence in echo sounding measurements.

SUMMARY OF INVENTION

According to a first example, there is provided a method of calibrating an echo sounder on a marine vessel. The method comprises measuring a first
20 water depth using the echo sounder on the marine vessel, obtaining location data for the echo sounder, obtaining a second water depth from another source for a location nearby to the echo sounder, comparing the first depth to the second depth, and carrying out a pre-determined action if the measured depth differs from the second depth by more than a pre-determined threshold.
25 Calibration and checking of the echo sounder can therefore be carried out whilst the marine vessel is operating at sea, rather than requiring the vessel to be in a port in order to carry out static or physical calibration/checking.

In one example, the second water depth is obtained from surveyed data for a location closest to the echo sounder. In another example, the second
30 water depth is from a second echo sounder on the same marine vessel.

In one example, obtaining the location data for the echo sounder comprises obtaining location data for the vessel, obtaining orientation data for the vessel, obtaining positional data for the echo sounder on the vessel, and calculating the location data for the echo sounder. This allows for more accurate calibration of the echo sounder.

In another example, tidal data is taken into account for the location of the echo sounder. This may provide increased accuracy of any calculations between the measured depth and any previously calculated depths.

In another example, the pre-determined threshold is dependent upon the distance between the echo sounder location and the second measured depth location.

In another example, the pre-determined threshold is dynamically updated as more depth data is measured.

In another example, the draft of the marine vessel is factored into the echo sounder depth measurements.

In another example of the invention, there is provided a computing device adapted to carry out a method comprising measuring a first water depth using an echo sounder on a marine vessel, obtaining location data for the echo sounder, obtaining a second water depth from another source for a location nearby to the echo sounder, comparing the first depth to the second depth, and carrying out a pre-determined action if the measured depth differs from the second depth by more than a pre-determined threshold.

FIGURES

The present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is an example of a nautical chart;

Figure 2 is a side-on schematic view of an example marine vessel;

Figure 3 is a top-down schematic view of an example marine vessel;

Figure 4 is an example of results obtained by the present invention; and

Figure 5 is a flow chart of an example method according to the invention.

DESCRIPTION

Careful navigation by marine vessels through shallow waters is required in order to avoid running aground; stranding the vessel and possibly causing damage. Nautical charts have been historically fundamental tools for marine navigation, and many countries require marine vessels, especially commercial ships, to carry them on-board when traversing territorial waters in their region.

Figure 1 shows a simplified example of a nautical chart 10 providing a graphical representation of a body of water 30, typically a sea, and adjacent coastal regions 20. The nautical chart 10 shown also includes points 35 indicating previously measured depth data for the water 30. Other sources of marine depth data are also available, such as digital charts, and depth information may be shown in number of ways, e.g. point data or gridded depth information.

However, the nature of a waterway (e.g. the coastline or depth values) depicted by a chart 10 (or other source of marine depth information) may change over time, and old or uncorrected charts increase the risk of a marine vessel running aground whilst traversing the waters. Therefore, most modern large vessels, for example commercial or naval ships, are also equipped with their own echo sounders to provide “live” or up-to-date depth information for their immediate locality.

The present invention provides a method of calibrating (or at least checking) on-board echo sounders to ensure they are working properly.

Figure 2 shows an example of a marine vessel 50 on a body of water 40. The marine vessel 50 is equipped with an on-board echo sounder 60. The echo sound 60 emits a sonar pulse into the water 40 from the surface toward the seabed 70 (or floor of the local body of water, e.g. lake). The sound pulse is reflected from the seabed 70 (at point 82), and returns to the surface and is detected by the echo sounder 60.

The depth d of the water 40 (i.e. the local distance to the seabed 70) is measured by multiplying the speed of sound in water v_{sound} by half the time t taken for the signal to return to the echo sounder 60 after being emitted:

$$d = \frac{v_{sound} \times t}{2}$$

Whilst the approximate speed of sound v_{sound} is known to be 1.5×10^3 m/s, the speed of sound is affected by, amongst other things pressure (and therefore depth), temperature and salinity. Therefore, for precise depth measurement the exact local speed of sound must also be measured, for
5 example by deploying a sound velocity probe into the water.

In order to calibrate the echo sounder 60, and ensure it is working correctly, the location of the echo sounder must be obtained, so that the measured depths can be compared to previously recorded depths for the same, or nearby, location. Modern marine vessels are often equipped with electrical
10 navigation equipment, such as Global Positioning System (GPS) receivers. These provide accurate geolocation data to the marine vessel, allowing the operators to identify their exact location. In a first example, the location of the echo sounder 60 is considered to be the same as the location of the marine vessel 50 upon which it is carried.

15 Once the location of the echo sounder 60 (or at least the location of the marine vessel 50 upon which it is carried) is known, a second water depth measurement for that location (or nearby location) is obtained. This second depth measurement may come from any source, including nautical chart information (digital or traditional), a second echo sounder (not shown) located
20 on the same vessel, or echo sounder measurements from a nearby other vessel. The method may also involve comparing the echo sounder depth measurement to multiple other local measurements.

In the example shown in Figure 2, the second depth measurement is obtained by locating the nearest previously charted depth to the location of the
25 echo sounder 60, shown at depth point 84. The second depth measurement (at point 84) is compared to the first water depth (at point 82) measured by the echo sounder 60 on the marine vessel 50 and the difference 86 is calculated. If the value of the difference 86 is greater than a predetermined threshold, a predetermined action is carried out. The action may take any form, such as
30 logging/flagging the measured depth as outlying from the predetermined tolerance, alerting a user directly, or perhaps automatically adjusting the echo sounder. The distance between the first 82 and second 84 points of depth measurement is also recorded.

The benefits of carrying out “on-the-go” echo sounder calibration mean that any results can be checked whilst the marine vessel is operating at sea, rather than requiring the vessel to be in a port in order to carry out static or physical calibration. This means the reliability and confidence in the echo sounder results can be maintained and/or improved during use, and any errors or problems can be identified (and possibly addressed) immediately, instead of remaining undetected until the vessel is next in port for inspection.

In a second example, in order to provide a more accurate calibration, and for echo sounders on larger marine vessels, the position of the echo sounder in relation to the nominal (or calculated) position of the marine vessel may be calculated. Figure 3 shows a top-down view of the marine vessel 50 as seen in Figure 2. The location of the marine vessel 50 is calculated by a GPS receiver (or other location device) at point A. The echo sounder 60 is located at point B on the vessel 50, a known distance A-B (and direction) from point A. By measuring the orientation (angle α) of the marine vessel 50, and knowing the distance A-B between the known location A of the vessel and the relative position B of the echo sounder 60, the accurate location B of the echo sounder 60 can be calculated. The more-accurate location data for the echo sounder 60 is used to determine the nearest previously measured depth point C which may not be the same as the closest depth point to the (nominal) location A of the vessel 50. The distance B-C between the echo sounder 60 (at point B) and previously measured depth (at point C) is also recorded.

In another example, in order to carry out more accurate depth measurements, the location of the marine vessel 50 (or the echo sounder 60) is used to obtain local tidal information. By taking the tide into account, the echo sounder 60 can be more accurately calibrated since the difference between the two measured depths can be adjusted to take the difference in tide heights into account.

In one example, and as discussed above, the second water depth is obtained from a previously surveyed data point closest to the echo sounder location. In another example, the second depth measurement may be obtained from a second echo sounder located on the same vessel. The positions of both echo sounders (and the distance between them) is known and therefore a pre-

determined threshold for any difference in their readings can be determined. In another example, the second depth measurement is provided from an echo sounder located on a second marine vessel whose position is known at the time of the second depth measurement. In another example, multiple vessels taking
5 echo sounder measurements in a relatively close proximity to each other (although not necessarily at the same time) may share the depth measurements to cross-calibrate the multiple echo sounders.

It is expected that the greater the distance between the location of the first measurement from the second measurement, the greater the variance in
10 depth between the two. For example, it is to be assumed that two separate points on the seabed 1m apart are more likely to have a smaller depth difference than two separate points on the seabed 100m apart. Therefore, in one example, the pre-determined threshold is dependent upon the distance between the first (echo sounder) location and the second measured depth
15 location.

Figure 4 shows a graph comprising example results from echo sounder measurements; plotting the difference between the first (i.e. echo sounder) and second measurements against the distance between the two measurement locations. A tolerance or threshold line is shown for both positive and negative
20 difference values, and the tolerance increases as the distance B-C between the between the first (echo sounder) location and the second measured depth location increases.

Figure 5 shows a flow chart of a method according to the present invention. At stage S1, a first water depth is measured using an echo sounder
25 on a marine vessel. At stage S2, location data for the echo sounder is obtained. At stage S3, a second (previously measured) water depth for a location nearby to the echo sounder is obtained. At stage S4, the first and second water depth measurement values are compared. At stage S5, a pre-determined action is carried out (e.g. alerting a user, or flagging the reading as an outlier) if the first
30 measured depth differs from the second depth by more than a pre-determined amount. Steps S1, S2 and S3 may be carried out in any order, or indeed at the same time.

In one example, the pre-determined threshold is dynamically updated as more depth data is measured. Therefore, as the echo sounder 60 records more depth measurements, and compares them to previously measured depths, a more accurate (i.e. tighter) error profile can be calculated.

5 In order to obtain even more accuracy in calibrating the echo sounder 60, the draft of the marine vessel 50 (i.e. how low the marine vessel sits in the water) may be taken into account during calibrating calculations. If the marine vessel 50 is heavily loaded, it may sit lower in the water, and any depth measurement should take this into account.

10 In one example, a computer device is adapted to carry out the method steps described by the present invention.

CLAIMS

1. A method of calibrating an echo sounder on a marine vessel, the method comprising:
 - 5 (S1) measuring a first water depth using an echo sounder on a marine vessel;
 - (S2) obtaining location data for the echo sounder;
 - (S3) obtaining a second water depth from another source for a location nearby to the echo sounder;
 - 10 (S4) comparing the first depth to the second depth; and
 - (S5) carrying out a pre-determined action if the measured depth differs from the second depth by more than a pre-determined threshold.
2. The method according to claim 1, wherein the second water depth is surveyed data for a location closest to the echo sounder.
3. The method according to claim 1, wherein the second water depth is from a second echo sounder on the same marine vessel.
- 20 4. The method according to any preceding claim, wherein the step of obtaining the location data for the echo sounder comprises:
 - obtaining location data A for the vessel;
 - obtaining orientation data α for the vessel;
 - obtaining positional data A-B for the echo sounder on the vessel;
 - 25 and
 - calculating the location data B for the echo sounder.
5. The method according to any preceding claim, comprising obtaining tidal data for the location of the echo sounder;
- 30 6. The method according to any preceding claim, wherein the pre-determined threshold is dependent upon the distance B-C between the echo sounder location B and the second measured depth location C.

7. The method according to any preceding claim, wherein the pre-determined threshold is dynamically updated as more depth data is measured.
- 5 8. The method according to any preceding claim, wherein the draft of the marine vessel is factored into the echo sounder depth measurements.
9. A computing device adapted to carry out the method according to any
10 preceding claim.

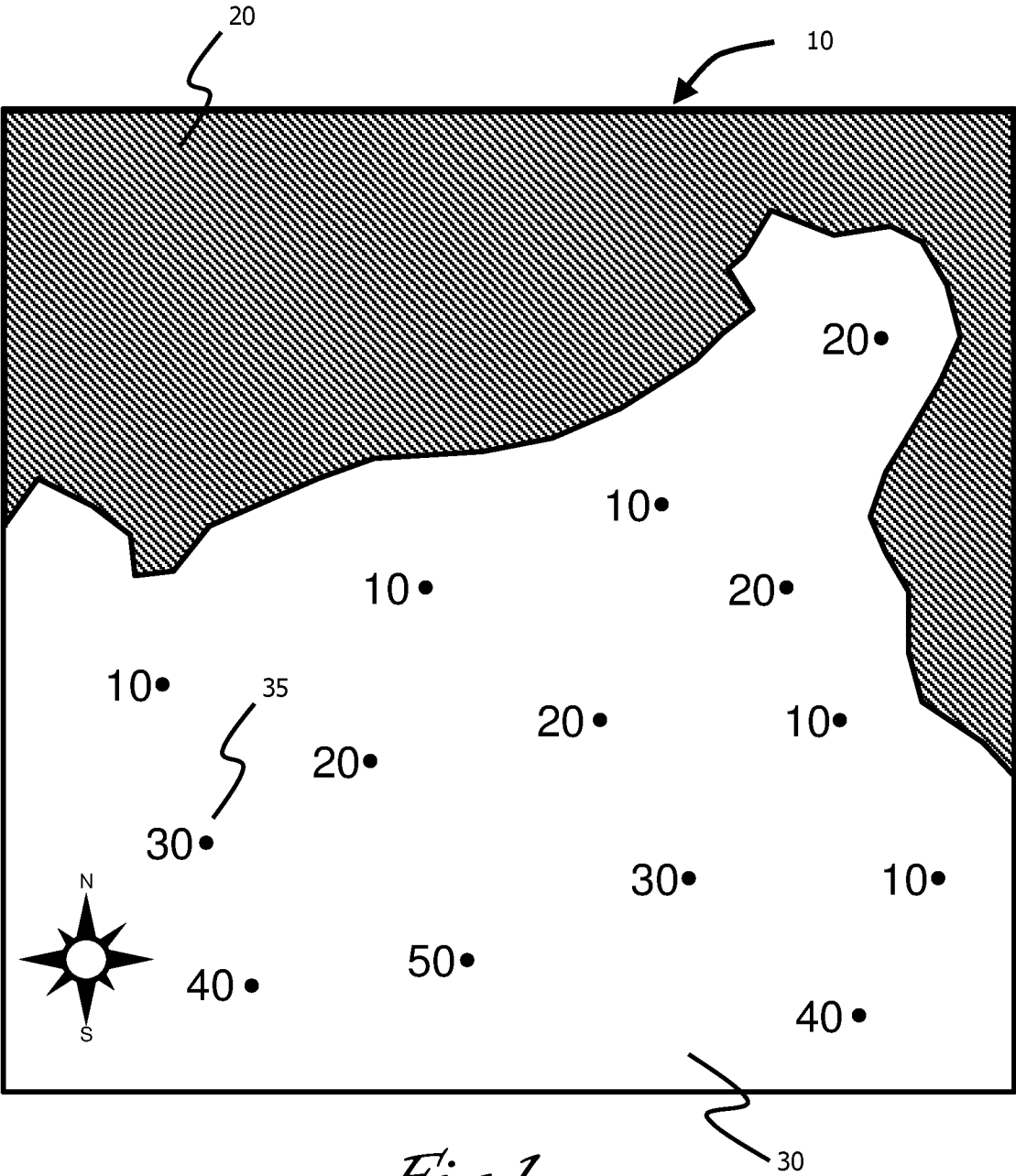
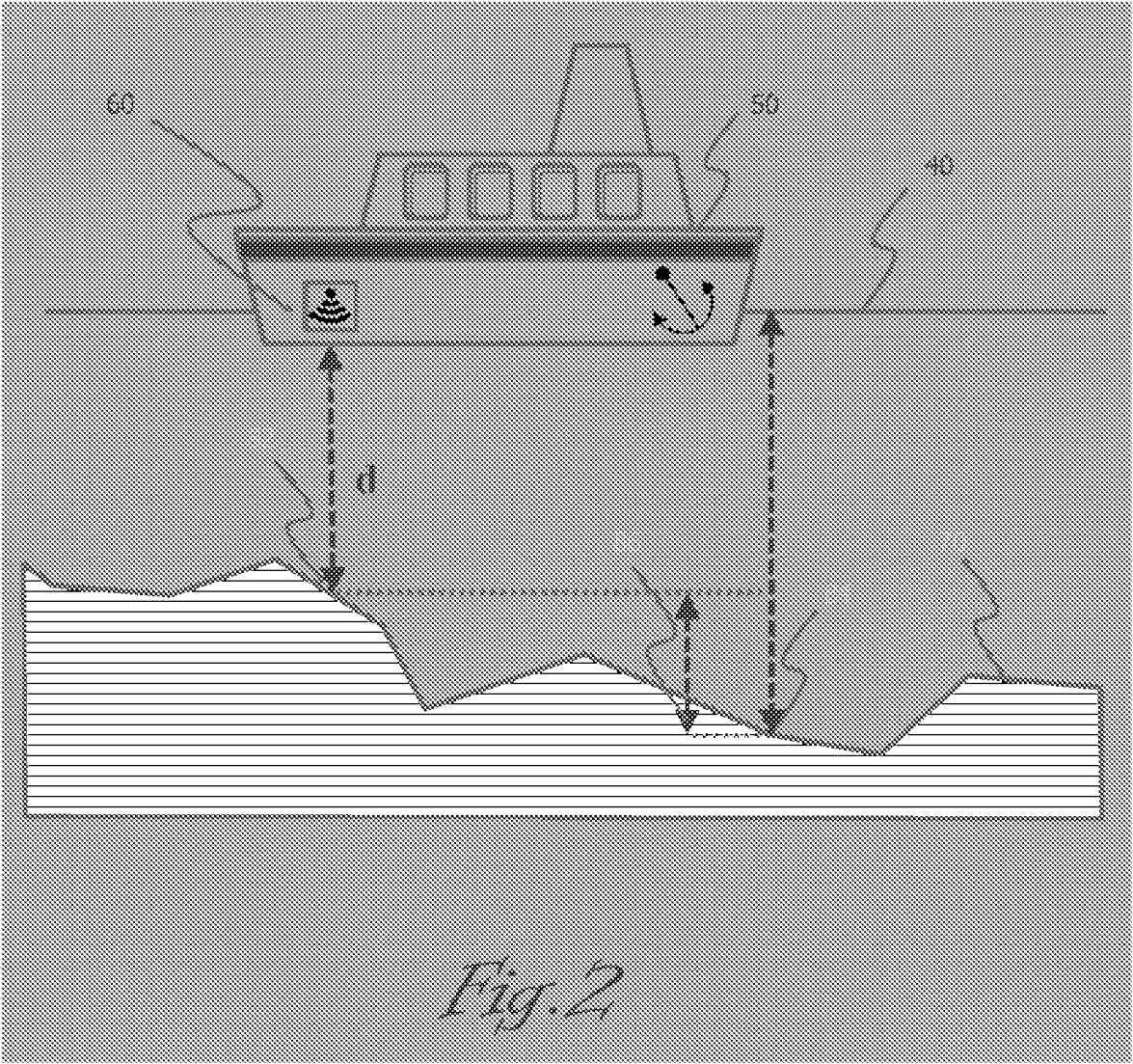
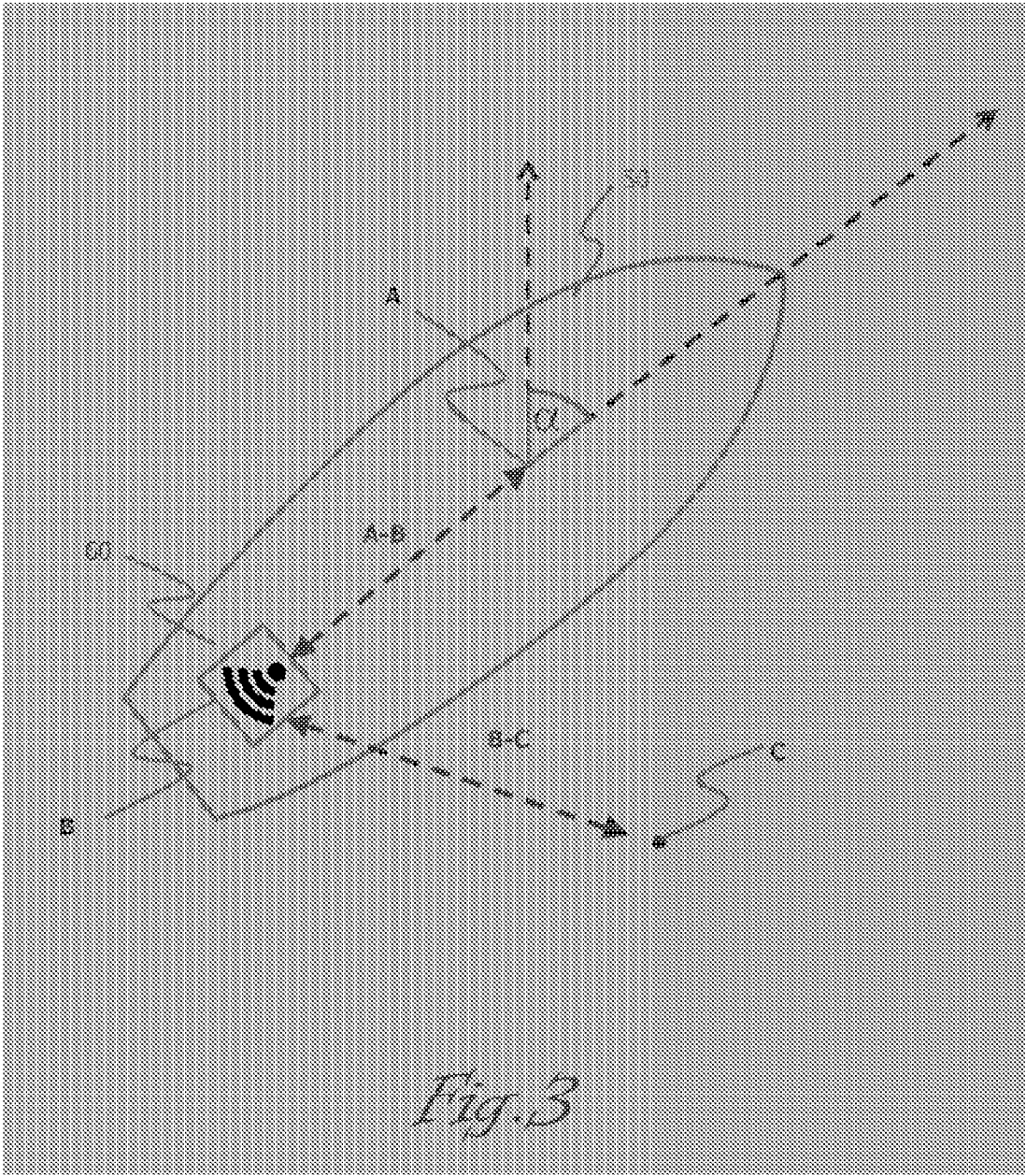
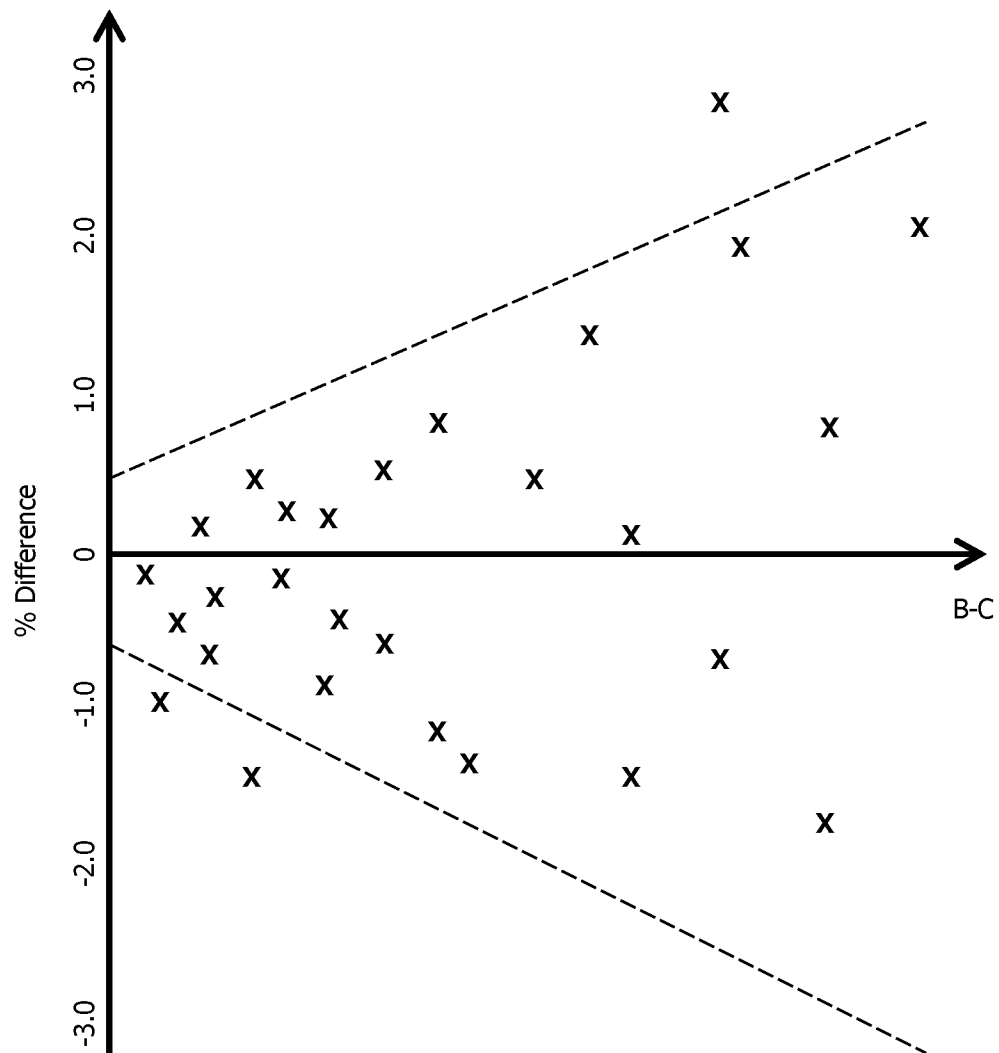
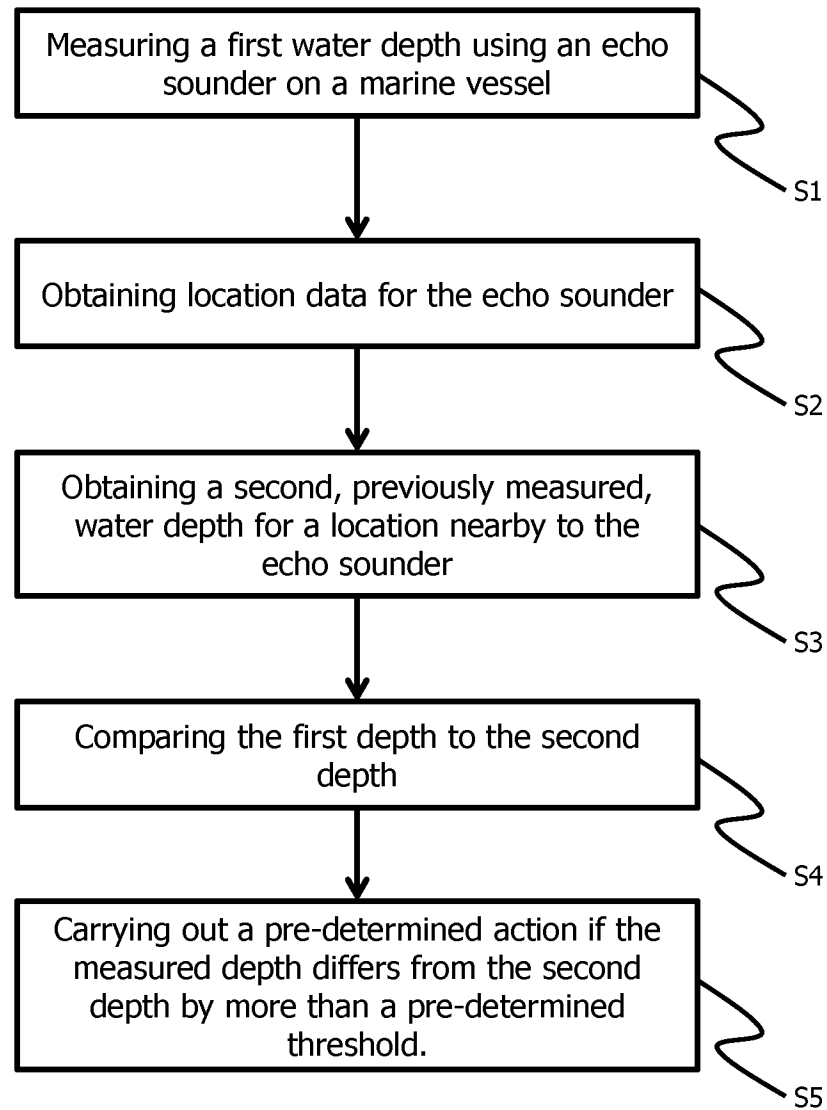


Fig.1





*Fig. 4*

*Fig.5*

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2020/050075

A. CLASSIFICATION OF SUBJECT MATTER

INV. G01S7/52 G01S15/08 G01S15/86 G01S15/93 G01C13/00
G01C21/00
ADD. G01S15/87

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G01S G01C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2014/269191 A1 (IVERSON GREGORY [US] ET AL) 18 September 2014 (2014-09-18)	1-9
Y	paragraphs [0002] - [0006], [0023], [0026] - [0038], [0076] - [0087]; figures 1-4	8

X	US 5 309 408 A (BICK E THEODORE [US] ET AL) 3 May 1994 (1994-05-03)	1-9
Y	column 1, lines 42-48 column 3, lines 37-63; figures 1-3 column 7, lines 3-8, 58-62 column 9, line 26 - column 10, line 65; figure 8	8

X	US 2018/003809 A1 (ORANGE DANIEL L [US]) 4 January 2018 (2018-01-04)	1-4,6-9
Y	paragraphs [0034] - [0041]; figures 1,2 paragraph [0053]; figure 9	8

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Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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Date of the actual completion of the international search

14 April 2020

Date of mailing of the international search report

23/04/2020

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INTERNATIONAL SEARCH REPORT

International application No

PCT/GB2020/050075

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2015/097838 A1 (STEWART LUCAS DALE [US]) 9 April 2015 (2015-04-09)	1-3,6-9
Y	paragraphs [0028], [0029], [0033] - [0035], [0038], [0039]; figures 1,5,6 -----	8
Y	US 2011/134724 A1 (KELMENSEN STEVEN [US]) 9 June 2011 (2011-06-09) paragraph [0022] -----	8

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2020/050075

Patent document cited in search report			Publication date	Patent family member(s)			Publication date
US 2014269191	A1	18-09-2014	US WO	2014269191 2014149841	A1 A1	18-09-2014 25-09-2014	

US 5309408	A	03-05-1994	EP JP KR US US	0619501 H075257 940022105 5309408 5400300	A2 A A A A	12-10-1994 10-01-1995 20-10-1994 03-05-1994 21-03-1995	

US 2018003809	A1	04-01-2018	US US WO	2016291140 2018003809 2014144970	A1 A1 A2	06-10-2016 04-01-2018 18-09-2014	

US 2015097838	A1	09-04-2015	US WO	2015097838 2015052668	A1 A1	09-04-2015 16-04-2015	

US 2011134724	A1	09-06-2011	NONE				
