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- (73) Patenthaver: **ECA Robotics, Zone Industrielle Toulon Est , 262 rue des Frères Lumière, 83130 La Garde, Frankrig**
- (72) Opfinder: **MUNSCHY, Marc, 20 rue de Savoie, 67520 Marlenheim, Frankrig**
NOVELLI, Philippe, 10 passage Louis Lévesque, 44000 Nantes, Frankrig
PERIOU, Jean-Jacques, 76 rue des mésanges, 83700 Saint Raphaël, Frankrig
- (74) Fuldmægtig i Danmark: **Patrade A/S, Ceresbyen 75, 8000 Århus C, Danmark**
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Method and device for mobile magnetic measurements for controlling the magnetic signature of a vessel

5 The present invention relates to magnetic measurement systems for ships and more particularly a method and a device for mobile magnetic measurements, for example aerial, for controlling the magnetic signature of a ship.

10 All naval vessels (or ships) comprising ferromagnetic materials have a magnetic signature which makes them detectable and identifiable. Such identification can especially be used to track them, for example from systems on board aircrafts, or to initiate systems for initiating devices such as mines or torpedoes.

15 In general, the magnetic signature of a surface ship corresponds to the total field on a line or a reference plane located beneath the keel, at a distance equals to the width of the ship. It depends on the position of the ship on the globe and its orientation. It represents the deformation of the earth's magnetic field by the magnetization of the ship.

20 These magnetic signatures result essentially from two components, a substantially constant component linked to the magnetization of ferromagnetic materials used and a variable induced part which results from direct reaction of the influence of the earth's field on the ship. The variable component depends especially on the orientation of the ship in the earth's magnetic field and its inclination due to rolling and pitching.

25 For ships essentially made of electrically conductive but not ferromagnetic materials, the magnetic signature results from Eddy currents which perturb the earth's magnetic field.

30 To mask these signatures, magnetic processing (or demagnetization) can be conducted on the ship to place it in a controlled magnetic state to reduce perturbation of the earth's magnetic field.

 There are also degaussing systems for making the magnetic signature as weak as possible. They are configured according to the magnetic

signature of the ship which must be previously determined and depend on positioning and heading of the ship.

Some of these degaussing systems consist of current loops which create, on a reference plane, a magnetic field opposite the magnetic signature
5 of the ship. These loops are typically placed around the hull, in three planes (horizontal plane, vertical longitudinal plane, and vertical lateral plane), to correct the magnetic influence of the ship along the three axes of the space in which it evolves. Each plane can comprise from three to twenty loops.

To know the magnetic signature of a ship and configure its
10 degaussing system, i.e., determine the current applied to each loop, there are sea-based measurement stations comprising sensors disposed on the seabed, according to a predefined configuration. The ship whereof the signature must be determined passes over these sensors several times, according to particular trajectories. The measurements taken with each pass of the ship are used to
15 determine a magnetic model of the ship, by inverse modelling (for predicting the causes from analysis of effects). This model is used to calculate the magnetization of the ship according to its position on the globe and its route. The degaussing system is configured as a function of this estimated magnetization.

20 A disadvantage linked to the use of these measurement stations for configuring a degaussing system is the difficulty of getting recent measurements (magnetization of a ship evolves over time) and measurements corresponding to the location where the ship needs to carry out the degaussing system (measurement stations are located on a naval base which can be
25 located far from the field of operation).

To eliminate these disadvantages, there are mobile stations which can be operated temporarily outside a naval base.

By way of illustration, patent application GB 2488963 describes a
30 mobile station for measuring the magnetic signature of a ship and configuring its degaussing system. The described solution comprises two measurement assemblies designed to be immersed and measure the magnetic influence of the ship passing between these two assemblies. Each of these assemblies

comprises several magnetic sensors disposed along a vertical axis, when the mobile station is operational, to measure the magnetic influence of the ship along several horizontal submarine planes.

Even though such mobile stations offer many advantages, they are
5 difficult to use, bulky when not used and are expensive.

Other mobile stations are disclosed in documents JP2005195479, WO87/02324, FR2704065 and GB2177511.

There is therefore a need for easy-to-use mobile stations, which are compact and low-cost for measuring the magnetic signature of a ship and
10 configuring its degaussing system.

The invention resolves at least one of the above problems.

The aim of the invention is therefore a method for measuring and controlling a magnetic signature of a ship using at least one autonomous mobile vehicle provided with at least one magnetic sensor, this method comprising the
15 following steps,

- obtaining a plurality of magnetic measurements and associated positions, the obtained magnetic measurements further being associated with a heading of the ship;

- modelling magnetization of the ship as a function of the obtained
20 magnetic measurements, associated positions and at least one heading of the ship;

- estimating at least one magnetic field according to the modelling of the magnetization of the ship and of at least one navigation parameter of the ship; and

- controlling a magnetic signature reduction system of the ship as a
25 function of said at least one estimated magnetic field.

The method according to the invention thus performs a really portable system easy to use for taking magnetic measurements and controlling systems for reduction of magnetic signature, especially degaussing systems.
30 Also, the method according to the invention carries out an autonomous system and which needs no particular restrictions relative to the environment, such as minimum or maximum water depth.

According to a particular embodiment, said at least one autonomous mobile vehicle comprises means for communicating with the ship, the method further comprising a step of transmitting the plurality of magnetic measurements and the associated positions with a data-processing system of the ship, the data-processing system of the ship performing the steps of modelling, 5 estimating at least one magnetic field and of controlling the magnetic signature reduction system, the magnetic signature reduction system comprising a degaussing system of the ship.

The method according to this embodiment can therefore be 10 performed autonomously.

Still according to a particular embodiment, magnetic measurements are obtained for at least two trajectories, preferably rectilinear, of said at least one autonomous mobile vehicle moving near the ship. Magnetic measurements are preferably obtained for at least two separate headings of the ship. Magnetic 15 measurements can especially be obtained at a substantially constant height determined as a function of the air draught or of the draught of the ship.

Still according to a particular embodiment, said at least one magnetic sensor is a three axis magnetic sensor having three perpendicular axes in pairs, the obtained magnetic measurements representing the norm of a vector having 20 three components coming from the magnetic sensor. The method according to the invention is accordingly robust.

Still according to a particular embodiment, the method further comprises a calibration phase comprising a step of measuring and correcting a zero error, a step of measuring and correcting a sensitivity zero error and/or a 25 step of measuring and correcting an orthogonality error of the three axes of the magnetic sensor.

The method according to the invention can further comprise a compensation phase for compensating the magnetic influence of said at least one autonomous mobile vehicle on said at least one magnetic sensor.

30 Still according to a particular embodiment, the steps of obtaining a plurality of magnetic measurements, of modeling magnetization of the ship, of estimating a magnetic field and of controlling a magnetic signature reduction

system are repeated to refine the setting of the magnetic signature reduction system.

Another aim of the invention is a set for measuring and controlling a magnetic signature of a ship, the set comprising at least one autonomous mobile vehicle provided with of at least one magnetic sensor, said at least one autonomous mobile vehicle being configured to obtain a plurality of magnetic measurements and associated positions, the obtained magnetic measurements being associated with a heading of the ship, the set further comprising calculation means configured to model magnetization of the ship as a function of obtained magnetic measurements, associated positions and a heading of the ship, to estimate at least one magnetic field according to a modelling of the magnetization of the ship and of at least one navigation parameter of the ship and to control a magnetic signature reduction system as a function of at least one estimated magnetic field.

The set according to the invention is really portable and easy to use for taking magnetic measurements and controlling degaussing systems. Also, it does not need particular constraints relative to the environment, such as minimum or maximum water depth.

According to a particular embodiment, the calculation means are further configured to control displacements of said at least one autonomous mobile vehicle according to at least two separate trajectories, for preferably at least two separate headings of the ship, at an advantageously substantially constant height which can for example be determined as a function of the air draught or of the draught of the ship.

Said at least one autonomous mobile vehicle can especially be an aerial drone, a surface drone or a submarine drone.

The magnetic signature reduction system can comprise a degaussing system of the ship and/or a demagnetization system of the ship.

According to a particular embodiment, the calculation means comprise calculation means of the ship, the set further comprising communication means configured to transfer the plurality of magnetic measurements and associated positions to the calculation means of the ship.

Other advantages, aims and characteristics of the present invention will emerge from the following detailed description given by way of non-limiting example with respect to the appended drawings, in which:

- figures 1 and 2 schematically illustrate an environment in which the invention can be implemented, in side elevation and plan view, respectively, according to a first embodiment;
- figure 3 shows some steps of a method according to an embodiment of the invention;
- figures 4 and 5 schematically illustrate other examples of environment in which the invention can be implemented; and
- figure 6 illustrates an example of an information processing device adapted to implement an embodiment of the invention, at least partially.

According to a particular embodiment of the invention, mobile magnetic measurements are taken using an autonomous mobile vehicle such as an aerial drone, for example a rotary-wing drone, a surface drone or a submarine drone, according to several predetermined trajectories for several headings of the ship, the latter preferably being substantially immobile with a fixed heading.

It is recalled here that magnetic effects are not based on any propagation and consequently that magnetic measurements are independent of the environment in which they are taken (unless this environment perturbs the magnetic field of the location). As a consequence, a measurement taken at the same placement in the water or in the air is the same.

Measurements taken are used for performing magnetic modelling, using an inverse model, for example by using a multi-dipolar model.

This modeling makes it possible to calculate a magnetic field, for a given position and heading, and accordingly to control a magnetic signature reduction system such as a demagnetization system or a degaussing system, for example the loops of a degaussing system of a ship, as a function of the position and heading of the ship.

Moreover, knowledge of the magnetic model of the ship and that of the degaussing system make it possible to calculate a magnetic risk and to

refine the configuration of the degaussing system according to circumstances (risk of mines, risk of aerial detection, ...).

Figure 1 schematically illustrates an environment in which the invention can be implemented according to a particular embodiment.

5 As illustrated, an autonomous mobile vehicle, here an aerial drone 110, flies over a ship 100 here comprising communication means (not shown) and a communications antenna 105. This drone also comprises communication means (not shown) and a communications antenna 115. The drone 110 further comprises one or more magnetic sensors 120, preferably
10 rigidly fixed to it. By way of illustration, this drone can be the drone known by reference IT 180, sold by the company ECA.

The magnetic sensor is here a three axis magnetic sensor having preferably the three axes perpendicular in pairs, for measuring the three components of a magnetic field at a given point. This is for example a “flux–
15 gate” type sensor, for example by the English company Bartington Instruments, having sensitivity similar to that of the sensors used in submarine stations used for measuring the magnetic signature of a ship.

Also, the drone is here provided with one or more position sensors for linking a position to each magnetic measurement. Such sensors can be GPS
20 (*Global Positioning System*) sensors, accelerometers and gyroscopes or a combination of such sensors.

Alternatively (or in addition), the drone, or more generally the autonomous mobile vehicle, can be located by an external system, for example by a radar system installed in the ship.

25 The communication means of the ship 100 and of the drone 110 enable them to exchange data, for example flight instructions and/or magnetic measurements and the associated positions. These are for example communication means complying with existing standards (e.g. 869 MHz for telemetry, 5.8 GHz for video and 2.4 GHz for remote control data), allowing
30 omnidirectional communication of about 3km or directional communication of about 10km.

Of course, other means can be used to set up communications between the ship 100 and the drone 110. By way of illustration, the drone 110 can be programmed before its flight and record measurements taken during flight, with the associated positions, which are then downloaded after flight in
5 the ship, for example using a wire link or a memory card placed in the drone for performing the data recordings, this card then being transferred to a computer system of the ship.

According to a particular embodiment, the drone has a predetermined trajectory, preferably at a constant height (noted h in the figure),
10 or almost constant. The height is advantageously selected to be greater than the air draught of the ship (or the draught if a submarine drone is used) but not too high to allow for precise measurements. This height can be determined between one and one and a half the air draught (or of the draught) of the ship.

The trajectory is advantageously constituted by segments along
15 which magnetic measurements are taken. The trajectory can for example comprise nine segments, preferably rectilinear, corresponding to three passes according to three headings of the ship.

By way of illustration, as illustrated in figure 2, the drone makes three passes according to three different headings at an altitude of twenty meters (the
20 altitude having to be selected according to the height of the ship to remove any risk of hooking). The three headings can be for example east (E), north (N) and south (S). The three passes associated with each heading are preferably parallel to the longitudinal axis of the ship which is advantageously idle or at low speed (for example between 2 and 4 knots), with a fixed heading.

25 One pass can be made for example at the vertical of the ship (references 125-V for the east heading, 125'-V for the north heading and 125''-V for the south heading, in figure 2), another to larboard, for example 20 meters from the ship (references 125-B for the east heading, 125'-B for the north heading and 125''-B for the south heading, in figure 2), and the other to
30 starboard, for example also 20 meters from the ship (references 125-T for the east heading, 125'-T for the north heading and 125''-T for the south heading, in

figure 2). Other distances can be selected, especially according to the size, in particular the width, of the ship.

Each pass is made over a distance (noted d in the figure) which is preferably greater than the length of the ship, for example twice its length.

5 Magnetic measurements are taken along each pass, for example regularly over time or along the followed trajectory. By way of example, measurements can be taken at a frequency of 300 Hz, corresponding to spatial sampling of a few centimeters. At each magnetic measurement taken, the position of the autonomous mobile vehicle is noted (or information for
10 determining it later) and stored or transmitted with the magnetic measurement taken.

 The completed measurements, which form a matrix in a horizontal plane, are transmitted to a data-processing system of the ship in real time, with the associated position data, via a wireless communications link, or in non-real
15 time.

 By way of advantage, at least two passes are made for each heading and measurements are taken for at least two different headings.

 As described earlier, these measurements are used to produce a magnetic model of the ship, control a degaussing system of the latter and, if
20 needed, calculate a risk. Again, the measurements being independent of the environment in which they are taken, the modelling is the same for measurements taken below water and for measurements taken in the air.

 Figure 3 shows some steps of a method according to an embodiment of the invention. These steps can be combined into four phases:

- 25 - initialization and calibration;
 - magnetic measurements;
 - modelling; and
 - degaussing.

 As illustrated, the aim of a first step is calibration and compensation
30 of the magnetic sensor(s) (step 300).

 The aim of calibration especially is to determine errors of the magnetic sensor(s) to correct them. According to a particular embodiment,

calibration comprises measurement and correction of the orthogonality error of the measurement axes of the magnetic components, zero measurement and correction and sensitivity measurement and correction.

It is noted here that according to a particular implementation, if the
5 three components of the magnetic field are measured at each point (along the trajectory of the autonomous mobile vehicle), only the norm of the measured vector is used to model the magnetization of the ship. In fact, it proves difficult to remove measurement errors due to variations in orientation of the sensor (orientation of the autonomous mobile vehicle cannot be measured precisely
10 enough in a mark linked to the ship). However, the number of measurements taken compensates the absence of knowledge of values associated with the three axes.

Apart from the correction of measurement of the magnetic sensor, the latter is advantageously compensated for accounting for the magnetic
15 influence of the autonomous mobile vehicle (for practical reasons, the magnetic sensor cannot generally be sufficiently spaced apart from the autonomous mobile vehicle to consider that the influence of the latter is negligible).

Such compensation can be done by successive acquisitions of the magnetic field values measured for different angular positions of the
20 autonomous mobile vehicle and by setting up a correction matrix. This operation can be advantageously automated, for example during an initial flight phase which precedes measurements.

In a following phase, magnetic measurements are taken. For these purposes, the ship is first positioned in a predetermined direction (step 305), for
25 example the east heading (E), and the autonomous mobile vehicle, for example the drone 110 illustrated in figure 1, is sent near the ship.

According to a particular embodiment, the autonomous mobile vehicle is programmed before flying off or taking to the water to follow a predetermined trajectory. Alternatively, it is controlled in real time to follow the
30 latter.

As described earlier, the autonomous mobile vehicle makes several passes for each heading of the ship. In this way, for example it can make a first

pass at the vertical of the ship (V) and at a given frequency take magnetic measurements (step 310). These measurements are associated with position measurements of the autonomous mobile vehicle and transmitted to the ship or stored to be transmitted later.

5 A test is then conducted to determine if all necessary measurements have been taken for the heading of the ship (step 315). If not all measurements have been taken, the autonomous mobile vehicle makes another pass and takes the missing magnetic measurements. In this way, for example if only the pass at the vertical of the ship has been made, the autonomous mobile vehicle
10 makes a new pass, for example to larboard (B), for example 20 meters from the ship. Similarly, if a pass at the vertical of the ship and a pass to larboard have been made, a new pass, for example to starboard (T), for example 20 meters from the ship, is made.

 A test is then conducted to determine if all necessary measurements
15 have been taken for all headings of the ship (step 320). If not all measurements have been taken, the ship is positioned in a new predetermined direction (step 305), for example the north heading (N) or south heading (S). The autonomous mobile vehicle then makes several passes for the new heading of the ship. Again, it can make a first pass at the vertical of the ship (V), followed by a pass
20 to larboard and a pass to starboard. Measurements are taken during each of these passes and associated with position measurements of the autonomous mobile vehicle.

 When all measurements have been taken (according to the different predetermined headings and the different passes), the magnetization of the ship
25 is modelled as a function of the headings for which measurements have been taken (step 325).

 As described earlier, such modelling can be done according to the inverse model by using for example a multi-dipolar model. The modelling is here done as standard, by using the magnetic measurements taken and the
30 associated positions, given that the environment in which the measurements are taken, for example air or water, has no influence.

Modelling of the magnetization of the ship can be used to control a magnetic signature reduction system, in particular for setting degaussing circuits of the ship.

To that end, the magnetic field created by the ship on one or more
5 given planes has to be estimated, according to the position of the ship and its heading (step 330). The choice of planes in which the magnetic field is estimated, is determined according to the risks incurred by the ship (risk of mines, risks of aerial attacks, etc.).

The magnetic field created by the ship is then compared to the
10 effects which can be produced by the degaussing circuits, according to different possible configurations, for finding the setting for compensating as precisely as possible the magnetic field created by the ship in the selected planes, for example by extrapolation of the settings corresponding to the effects closest to the preferred effects (step 335).

15 The effects which can be produced by the degaussing circuits can be stored in a database 340 of the ship or accessible, on a remote site, by the data-processing system of the ship.

The effects are determined during construction of the ship, later, or repeatedly, by comparing the magnetic anomaly of the ship when the
20 degaussing circuits are deactivated and when they are activated with particular settings, given the position and heading of the ship.

According to the planes in which the magnetic field of the ship has been estimated and the settings of the degaussing circuits, it is possible to calculate a risk linked to the detectability of the magnetic anomaly caused by
25 the ship despite the use of the degaussing circuits (step 345).

It is observed here that steps of obtaining magnetic measurements, of modelling the magnetization of the ship and of setting the degaussing circuits can be repeated, by using the degaussing circuits, to refine this setting, as suggested by the arrow in dotted lines.

30 It is also observed here that the calculated magnetic field(s) can be used to control other types of systems for reducing magnetic signature, combined or alternatively, for example a demagnetization system of the ship.

Figures 4 and 5 schematically illustrate other examples of environment in which the invention can be implemented, according to which data exchanges between the ship and the autonomous mobile vehicle are indirect.

5 As shown in figure 4, the autonomous mobile vehicle provided with a magnetic sensor can be operated from a fixed station, referenced here 400, on the ground. The magnetic measurements taken by the autonomous mobile vehicle and the positions at which these measurements are taken are then transmitted to the ground station, via a radio communication link or once the
10 measurement mission is completed.

 These data can then be transmitted to the ship whereof the magnetization must be modelled so that it can perform this modelling. Alternatively, the modelling can be performed by the ground station which transmits the magnetic modelling of the ship to the latter. Alternatively again,
15 modelling can be done by the ground station as well as calculation of the magnetic field created by the ship after the latter has indicated its position and its heading. The ground station then transmits data representative of the magnetic field created to the ship to allow the latter for setting its degaussing circuits. Setting of the degaussing circuits can be done by the ground station or
20 by the ship.

 Figure 5 illustrates a variant of figure 4 according to which the ground station is replaced by a ship 500 separate from the ship 100 whereof the magnetization is modelled so as to set its degaussing circuits.

 There are of course other configurations using for example one or
25 more stations on the ground and one of more ships separate from the ship whereof the magnetization is modelled so as to set its degaussing circuits.

 It is also observed here that if the magnetic measurements are preferably taken when the ship is substantially immobile, it is possible all the same to take these measurements when the ship is in motion. It is then
30 necessary to associate, for each measurement, the value of the measurement with the position of the autonomous mobile vehicle and that of the ship to consider the displacement of the ship during magnetic modelling.

Figure 6 illustrates an example of a device which can be used for implementing, at least partially, an embodiment, especially steps described in reference to figure 3.

The device 600 is for example a server, a computer or computer
5 assistant.

The device 600 preferably includes a communication bus 602 to which are connected:

- a central processing unit (CPU) or microprocessor 604;
- a read only memory (ROM) 606 which can include the operating
10 system and programs such as "Prog";
- a random-access memory (RAM) or cache memory 608 including registers adapted to record variables and parameters created and modified during execution of the above programs;
- a reader 610 of removable storage medium 612 such as a
15 memory card or a disc, for example a DVD disc; and
- a graphics card 614 connected to a screen 616.

Optionally, the device 600 can also have the following elements:

- a hard drive 620 which can comprise the above "Prog" programs and data processed or to be processed according to the invention;
- 20 - a keyboard 622 and a mouse 624 or any other pointing device such as a light pen, a touch screen or a remote control letting the user interact with the programs according to the invention; and
- a communication interface 626 connected to a distributed communications network 628, for example a wireless communications network
25 and/or a local communications network, the interface being capable of transmitting and receiving data.

The communication bus enables communication and interoperability between the different elements included in the device 600 or connected to it. The representation of the bus is not limiting and, especially, the CPU is capable
30 of communicating instructions to any element of the device 600 directly or by means of another element of the device 600.

The executable code of each program allowing the programmable apparatus to execute the processes according to the invention, in particular to model the magnetization of a ship, for calculating a magnetic field according to one or more predetermined planes and/or regulate degaussing circuits, can be
5 stored for example in the hard drive 620 or ROM 606.

According to a variant, the executable code of the programs could be received by way of the communications network 628, via the interface 626, to be stored identically to that described earlier.

More generally, the program(s) could be loaded into one of the
10 storage means of the device 600 before being executed.

The CPU 604 will control and direct execution of the instructions or portions of software code of the program(s) according to the invention, instructions which are stored in the hard drive 620 or ROM 606 or else in the other above storage elements. During powering up, the program(s) which are
15 stored in a non-volatile memory, for example the hard drive 620 or ROM 606, are transferred to the RAM 608 which then contains the executable code of the program(s) according to the invention, as well as registers for storing the variables and parameters necessary for carrying out the invention.

Naturally, to satisfy specific needs a person competent in the field of
20 the invention could apply modifications to the preceding description. The present invention is not limited to the embodiments described, and other variants and combinations of characteristics are possible.

The present invention has been described and illustrated in the present detailed description in reference to the appended figures. However, the
25 present invention is not limited to the embodiments presented. Other variants and embodiments can be deduced and implemented by the person competent in the field of the invention on reading the present description and appended figures.

In particular, it is observed here that, according to some
30 embodiments, if the invention can be implemented using an aerial drone, it is also possible to use a submarine drone or a surface drone to take magnetic measurements.

Similarly, according to some embodiments, the invention can be implemented with an autonomous mobile vehicle comprising several parts connected together in a mobile manner. Such an autonomous mobile vehicle can especially comprise a part having the magnetic measurement component(s), one part having the guide element(s) and if needed one part having communication means.

It is also observed that magnetic measurements can be taken by several autonomous mobile vehicles of same type or different types. It is possible to use an aerial drone to take some of the measurements and another drone, for example an aerial drone, a surface drone or a submarine drone to take other magnetic measurements.

Finally, the autonomous mobile vehicle(s) used can comprise one or more magnetic sensors. When an autonomous mobile vehicle comprises several magnetic sensors, the data coming from each of these sensors can be transmitted to be processed and to model magnetization of the ship or can be consolidated prior to being transmitted to limit the number of transmitted data. Such consolidation can be done conventionally, for example by averaging, with or without weighting, the data obtained by each sensor.

In the claims, the term "include" does not exclude other elements or other steps. The indefinite article "a, an" does not exclude the plural. A single processor or several other units can be used for implementing the invention. The different characteristics presented and/or claimed can be advantageously combined. Their presence in the description or in different dependent claims does not exclude, in fact, the possibility of combining them. The reference signs should not be understood as limiting the scope of the invention.

Patentkrav

1. Fremgangsmåde til måling og kontrol af en magnetisk signatur af et skib (100) ved anvendelse af mindst én drone (110), der er udstyret med mindst én magnetisk sensor (120), hvilken fremgangsmåde er kendetegnet ved, at
- 5 den omfatter de følgende trin:
- opnåelse (310) af et antal magnetiske målinger og tilknyttede positioner, idet de opnåede magnetiske målinger i øvrigt er knyttet til en sejlretning for skibet
 - 10 - modellering (325) af en magnetisering af skibet på grundlag af de opnåede magnetiske målinger, de tilknyttede positioner og mindst én sejlretning for skibet
 - estimering (330) af mindst ét magnetisk felt ifølge modelleringen af magnetiseringen af skibet og mindst én navigationsparameter for skibet, og
 - 15 - kontrol (335) af et system til reduktion af magnetisk signatur af skibet på grundlag af det mindst ene estimerede magnetiske felt, kendetegnet ved, at dronen er en luftdrone.
2. Fremgangsmåde ifølge krav 1, hvorved den mindst ene luftdrone omfatter midler til kommunikation med skibet, idet fremgangsmåden i øvrigt omfatter et trin med transmission af antallet af magnetiske målinger og tilknyttede positioner til et skibsdatabehandlingssystem, idet skibsdatabehandlingssystemet implementerer et trin med modellering, estimering af mindst ét magnetisk felt og kontrol af systemet til reduktion af magnetisk signatur, idet systemet til reduktion af magnetisk signatur omfatter et system til immunisering af skibet.
- 20 25
3. Fremgangsmåde ifølge krav 1 eller krav 2, hvorved magnetiske målinger opnås for mindst to retlinjede bevægelsesbaner for den mindst ene luftdrone, der bevæger sig i nærheden af skibet.
- 30
4. Fremgangsmåde ifølge et hvilket som helst af kravene 1 til 3, hvorved magnetiske målinger opnås for mindst to forskellige sejlretninger for skibet.
- 35
5. Fremgangsmåde ifølge et hvilket som helst af kravene 1 til 4, hvorved magnetiske målinger opnås i en i det væsentlige konstant højde, der bestemmes på grundlag af skibets højde over vandlinjen eller dybgang.

6. Fremgangsmåde ifølge et hvilket som helst af kravene 1 til 5, hvorved den mindst ene magnetiske sensor er en magnetisk sensor med tre akser, der er parvis vinkelrette, idet de opnåede magnetiske målinger angiver normen for en trekomponentvektor, der stammer fra den magnetiske sensor.

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7. Fremgangsmåde ifølge krav 6, der i øvrigt omfatter en kalibreringsfase (300), som omfatter et trin med måling og korrigerende af en nulfejl, et trin med måling og korrigerende af en følsomheds-nulfejl og/eller et trin med måling og korrigerende af en ortogonalitetsfejl for de tre akser af den magnetiske sensor.

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8. Fremgangsmåde ifølge et hvilket som helst af kravene 1 til 7, der i øvrigt omfatter en kompensationsfase for at kompensere for den magnetiske påvirkning fra den mindst ene luftdrone af den mindst ene magnetiske sensor.

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9. Fremgangsmåde ifølge et hvilket som helst af kravene 1 til 8, hvorved trinnene med opnåelse af et antal magnetiske målinger, modellering af et magnetisering af skibet, estimering af et magnetisk felt og kontrol af et system til reduktion af magnetisk signatur gentages for at finjustere indstillingen af systemet til reduktion af magnetisk signatur.

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10. Samlet enhed til måling og kontrol af en magnetisk signatur af et skib (100), hvilken samlet enhed omfatter mindst én drone (110), der er udstyret med mindst én magnetisk sensor (120), hvilken mindst ene luftdrone er konfigureret til at opnå (310) et antal magnetiske målinger og tilknyttede positioner, idet de opnåede magnetiske målinger er knyttet til en sejlretning for skibet, hvilken samlet enhed i øvrigt omfatter beregningsmidler, der er konfigureret til at modellere (325) en magnetisering af skibet på grundlag af opnåede magnetiske målinger, tilknyttede positioner og en sejlretning for skibet, for at estimere (330) mindst ét magnetisk felt ifølge en modellering af magnetiseringen af skibet og mindst én navigationsparameter for skibet og for at kontrollere (335) et system til reduktion af magnetisk signatur på grundlag af mindst ét estimeret magnetisk felt, kendetegnet ved, at dronen er en luftdrone.

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11. Samlet enhed ifølge krav 10, hvori beregningsmidlerne i øvrigt er konfigureret til at kontrollere bevægelser af den mindst ene luftdrone ifølge

mindst to forskellige bevægelsesbaner for mindst to forskellige sejlretninger for skibet i en i det væsentlige konstant højde, der bestemmes på grundlag af skibets højde over vandlinjen eller dybgang.

5 12. Samlet enhed ifølge krav 10 eller krav 11, hvori systemet til reduktion af magnetisk signatur omfatter et system til immunisering af skibet.

10 13. Samlet enhed ifølge et hvilket som helst af kravene 10 til 12, hvori beregningsmidlerne omfatter beregningsmidler for skibet, idet den samlede enhed i øvrigt omfatter kommunikationsmidler, der er konfigureret til at overføre antallet af magnetiske målinger og tilknyttede positioner til beregningsmidlerne for skibet.

15 14. Samlet enhed ifølge krav 10 eller krav 11, hvori systemet til reduktion af magnetisk signatur omfatter et system til afmagnetisering af skibet.

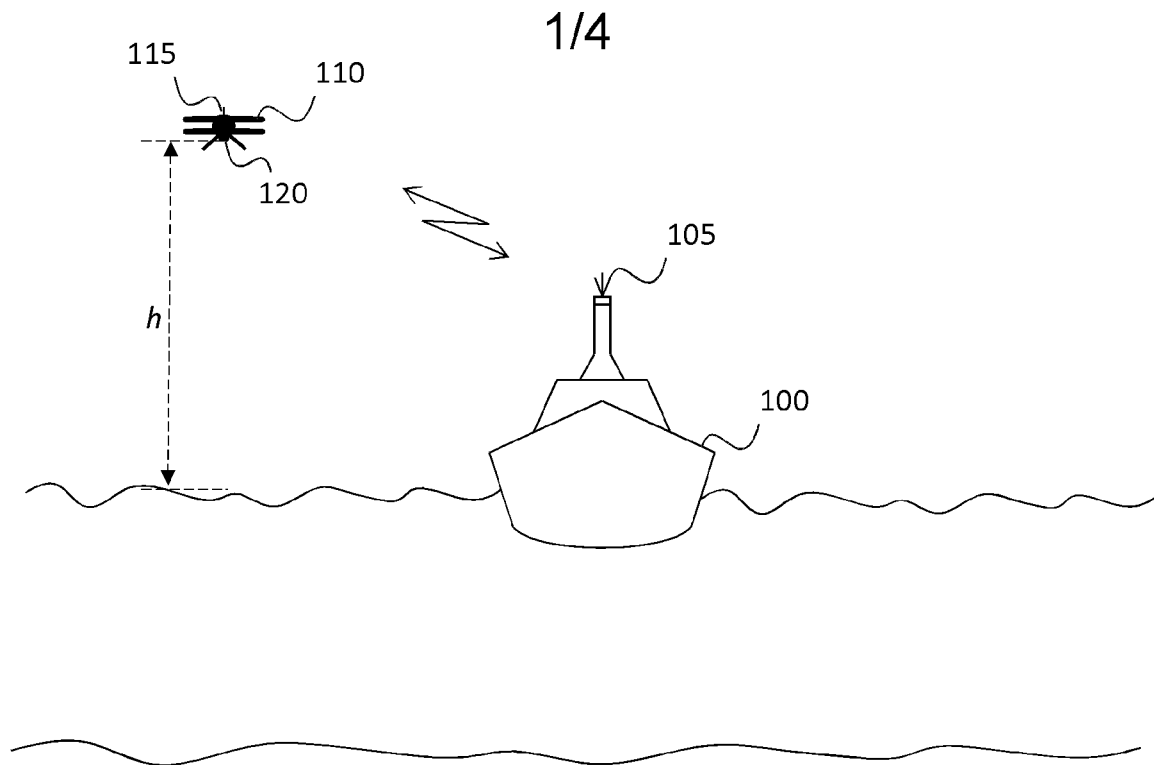


Figure 1

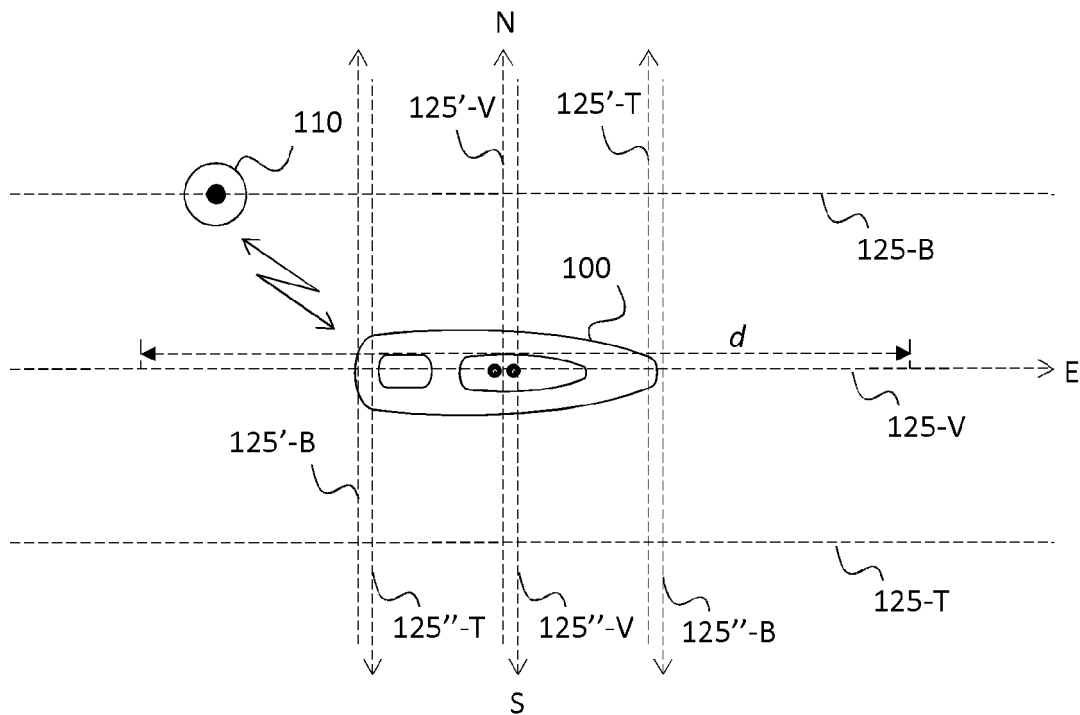


Figure 2

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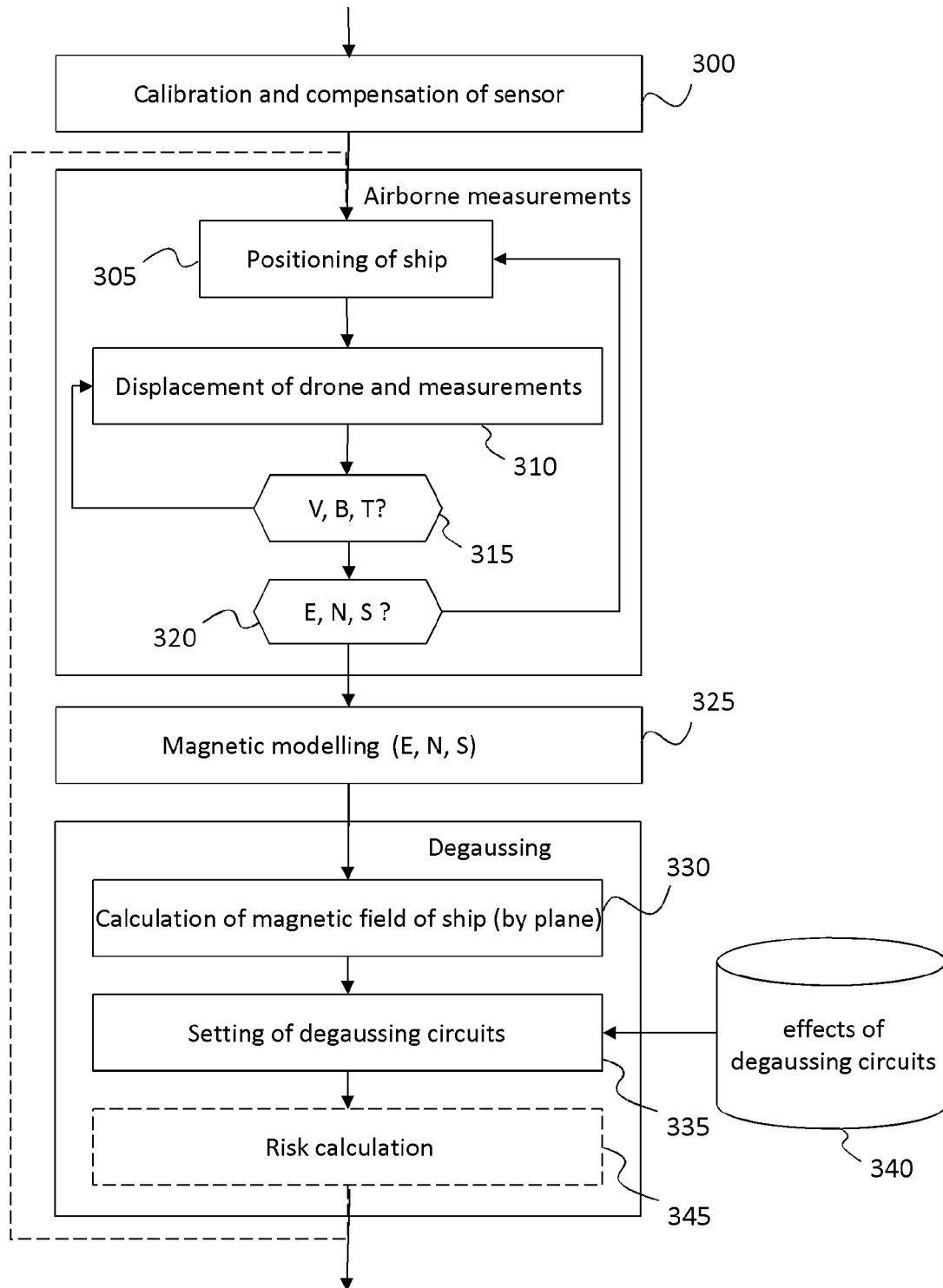


Figure 3

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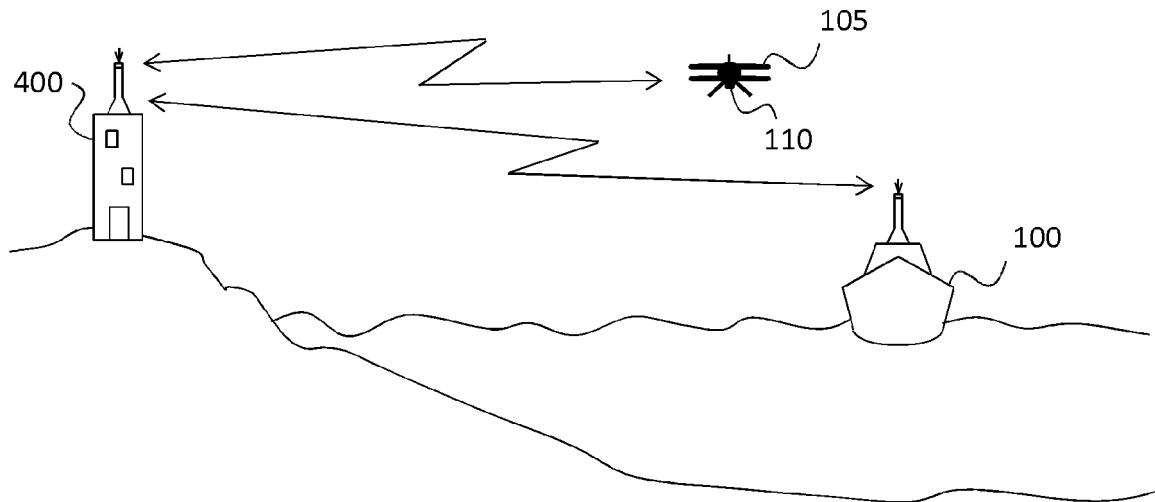


Figure 4

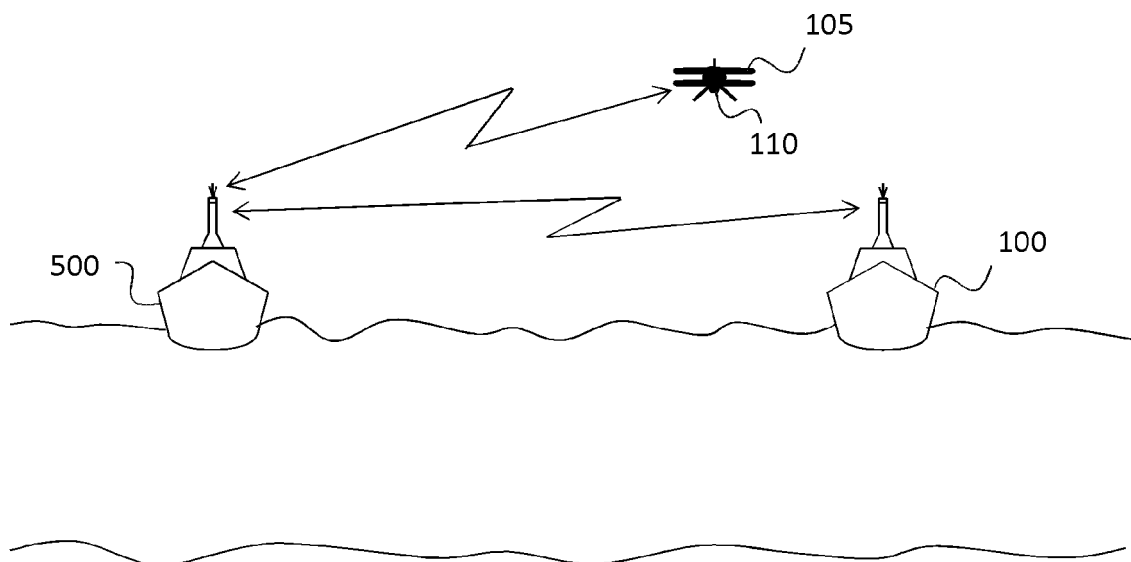


Figure 5

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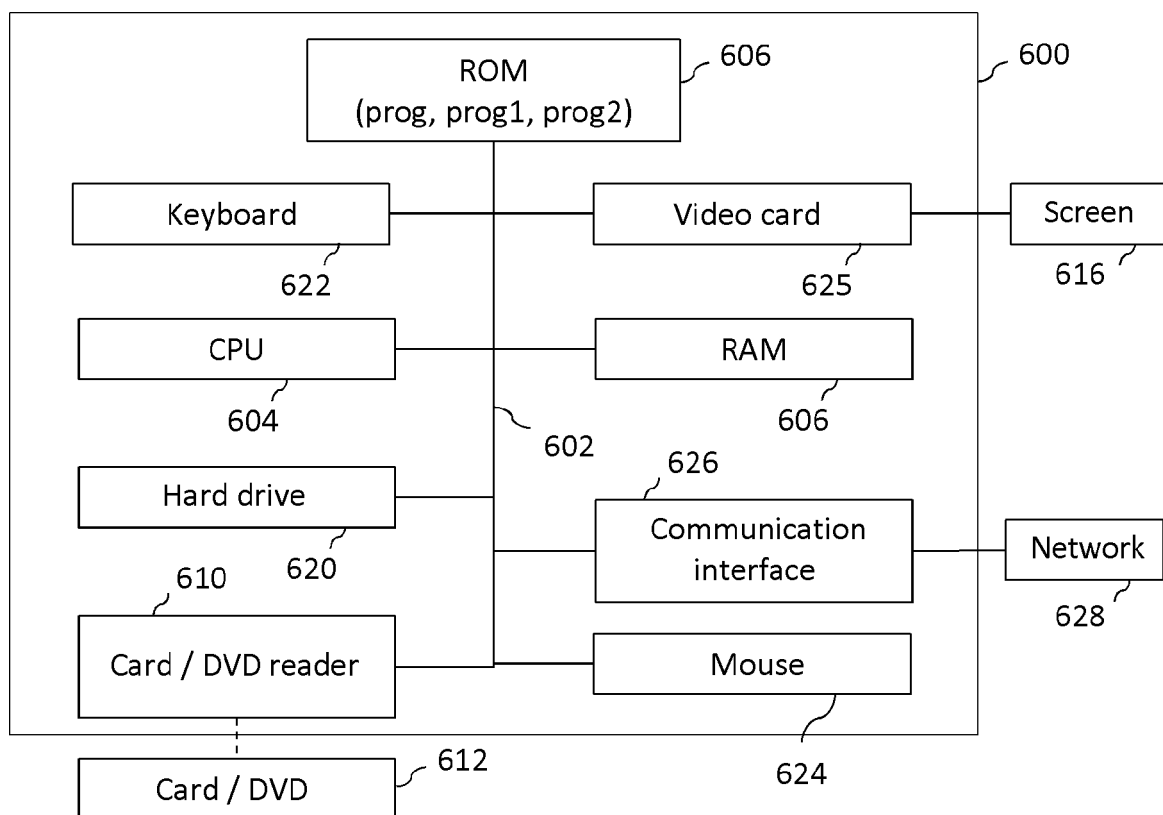


Figure 6