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(54) **TRANSMITTER AND RECEIVER**

(57) A rescue system 10 for rescuing a mariner at sea is described. The system 10 comprises a distress beacon 11 for the mariner, the distress beacon comprising a transmitter 111 arranged to transmit a first acoustic signal at a first frequency in water. The system 10 comprises a receiver 12 arranged to receive the transmitted first acoustic signal. The system 10 comprises a controller 13 arranged to cause an autonomous watercraft 14 for rescuing the mariner to be launched, in response to the received first acoustic signal.

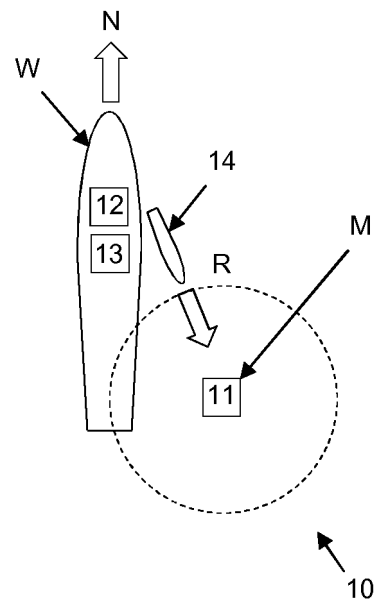


Fig. 2B

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Description

Field

[0001] The present invention relates to transmitters, for example distress beacons, and corresponding receivers. Particularly, the present invention relates to a system comprising a distress beacon and a corresponding receiver for rescuing a mariner at sea, for example.

Background to the invention

[0002] Generally, safety at sea is a concern. For example, in a man overboard (MOB) event of a mariner from a watercraft at sea, there may be potential loss of life if rescue is not timely. Rescue may be problematic due to an absence of an alert or a delayed alert of the MOB event. Even if an alert of the MOB event is prompt, a rescue time may still be extended due to rescue manoeuvring, such as stopping and/or turning, of the watercraft. During the rescue time, illness and/or injury may be sustained by the mariner. For example, onset of hypothermia may be relatively quick. In water at 4.5 °C to 10°C, loss of dexterity typically results in at most 5 minutes, unconsciousness usually occurs within from 30 minutes to 60 minutes and expected survival times, assuming the mariner does not succumb initially and rapidly to death by cold shock, are only from 1 hour to 3 hours; this survival time being dependent on factors such as the protective clothing worn, the sea-state, and the level of injury. Colder temperatures reduce these times. An effective stopping distance of the watercraft may relatively long, for example up to 8 km or more for large watercraft such as container ships, cruise lines or aircraft carriers. A turning circle diameter of the watercraft may be relatively large, for example 3 - 4 times a length between perpendiculars of the watercraft and thus about 1 km for container ships, cruise lines or aircraft carriers. However, for military convoys, for example, such rescue manoeuvring may not be permitted for operational reasons. Even if rescue manoeuvring of the watercraft is effected, location of the mariner in the sea may be problematic due to a relatively small size of the mariner, sea conditions and/or movement, such as drifting, of the mariner.

[0003] Hence, there is a need to improve rescue systems for rescuing mariners at sea.

Summary of the invention

[0004] It is one aim of the present invention, amongst others, to provide a rescue system for rescuing a mariner at sea which at least partially obviates or mitigates at least some of the disadvantages of the prior art, whether identified herein or elsewhere. For instance, it is an aim of embodiments of the invention to provide a rescue system for rescuing a mariner at sea that responds more quickly to a man overboard event. For instance, it is an aim of embodiments of the invention to provide a rescue

system for rescuing a mariner at sea that effects rescue more quickly. For instance, it is an aim of embodiments of the invention to provide a rescue system for rescuing a mariner at sea that improves targeting, locating and/or approaching of the mariner.

[0005] According to a first aspect, there is provided a rescue system for rescuing a mariner at sea, the system comprising:

- 10 a distress beacon for the mariner, the beacon comprising a transmitter arranged to transmit a first acoustic signal at a first frequency in water;
- a receiver arranged to receive the transmitted first acoustic signal; and
- 15 a controller arranged to cause an autonomous watercraft for rescuing the mariner to be launched, in response to the received first acoustic signal.

[0006] According to a second aspect, there is provided a distress beacon for a mariner, the beacon comprising a transmitter arranged to transmit a first acoustic signal in water, wherein the first acoustic signal has a frequency in a range from 80 kHz to 400 kHz.

[0007] According to a third aspect, there is provided an autonomous watercraft for rescuing a mariner having a distress beacon, the watercraft comprising a second transceiver, wherein the watercraft is arranged to navigate towards the beacon based, at least in part, on a first acoustic signal in water received therefrom.

30 According to a fourth aspect, there is provided a method of controlling a distress beacon for a mariner, the beacon comprising a transmitter, the method comprising:

- 35 transmitting, by the beacon, a first acoustic signal in water in response to immersion therein, wherein the first acoustic signal has a frequency in a range from 80 kHz to 400 kHz.

[0008] According to a fifth aspect, there is provided a method of controlling an autonomous watercraft for rescuing a mariner having a distress beacon, the method comprising:

- 45 transmitting, by the beacon, a first acoustic signal in water;
- receiving, by the watercraft, the transmitted first acoustic signal; and
- navigating, by the watercraft, towards the beacon based, at least in part, on the received first acoustic signal.

[0009] According to a sixth aspect, there is provided use of a first acoustic signal, having a frequency in a range from 80 kHz to 400 kHz, in water as a distress signal.

55

Detailed Description of the Invention

[0010] According to the present invention there is provided a rescue system for rescuing a mariner at sea, as set forth in the appended claims. Also provided is a distress beacon, an autonomous watercraft, a method of controlling a distress beacon, a method of controlling an autonomous watercraft and use of a first acoustic signal. Other features of the invention will be apparent from the dependent claims, and the description that follows.

[0011] Throughout this specification, the term "comprising" or "comprises" means including the component(s) specified but not to the exclusion of the presence of other components. The term "consisting essentially of" or "consists essentially of" means including the components specified but excluding other components except for materials present as impurities, unavoidable materials present as a result of processes used to provide the components, and components added for a purpose other than achieving the technical effect of the invention, such as colourants, and the like.

[0012] The term "consisting of" or "consists of" means including the components specified but excluding other components.

[0013] Whenever appropriate, depending upon the context, the use of the term "comprises" or "comprising" may also be taken to include the meaning "consists essentially of" or "consisting essentially of", and also may also be taken to include the meaning "consists of" or "consisting of".

[0014] The optional features set out herein may be used either individually or in combination with each other where appropriate and particularly in the combinations as set out in the accompanying claims. The optional features for each aspect or exemplary embodiment of the invention, as set out herein are also applicable to all other aspects or exemplary embodiments of the invention, where appropriate. In other words, the skilled person reading this specification should consider the optional features for each aspect or exemplary embodiment of the invention as interchangeable and combinable between different aspects and exemplary embodiments.

[0015] According to the first aspect, there is provided a rescue system for rescuing a mariner at sea, the system comprising:

- a distress beacon for the mariner, the beacon comprising a transmitter arranged to transmit a first acoustic signal at a first frequency in water;
- a receiver arranged to receive the transmitted first acoustic signal; and
- a controller arranged to cause an autonomous watercraft for rescuing the mariner to be launched, in response to the received first acoustic signal.

[0016] In this way, rescue of the mariner may be improved because the autonomous watercraft is launched in response to the first acoustic signal transmitted by the

mariner's distress beacon. In this way, manoeuvring of the mariner's watercraft, for example, may not be required, since the autonomous watercraft is launched promptly for the rescue. Prompt launch of the autonomous watercraft may mean that the mariner may be returned to the watercraft without the latter needing to change course. The autonomous watercraft may, in normal sea-states, travel at much higher speeds than many watercraft, for example a yacht, a cruise liner, a merchant ship or a military watercraft.

[0017] It should be understood that the mariner may be, for example, a seaman or a passenger who has fallen overboard from a watercraft, for example a yacht, a cruise liner, a merchant ship or a military watercraft. Additionally and/or alternatively, the mariner may be any person, animal or object to which the beacon may be coupled, for example attached. It should be understood that while the rescue system is for rescuing a mariner at sea, the rescue system is also suitable for rescuing a mariner in fresh water, such as a river or lake, and/or brackish water, such as an estuary.

[0018] The distress beacon, also known as an emergency beacon, is for the mariner. It should be understood that the distress beacon is a device on and/or attached (directly and/or indirectly) to the mariner. In one example, the distress beacon comprises a coupling member, for example a clip or a carabiner, for coupling the distress beacon to the mariner and/or a garment and/or an accessory worn and/or carried by the mariner. In one example, the distress beacon is arranged to be integrated into a garment and/or an accessory worn by the mariner. For example, the distress beacon may be sized to fit in a pocket of the garment, such as a life jacket or a belt, worn by the mariner. For example, the distress beacon may be included in an accessory, such as a torch or a radio, carried by the mariner.

[0019] The beacon comprises the transmitter arranged to transmit the first acoustic signal at the first frequency in water. In other words, the first acoustic signal, having the first frequency, is transmitted through the water. In one example, the transmitter is arranged on a deployable line (also known as an umbilical line) so that the transmitter is arranged below a surface of the water during transmission. The beacon may be arranged to deploy the deployable line prior to or upon transmission. The transmitter on the deployable line may be negatively buoyant so as to remain below the surface of the water. Alternatively, the transmitter on the deployable line may be neutrally buoyant so as to remain below the surface of the water without adversely affecting buoyancy of the mariner.

[0020] In one example, the first acoustic signal comprises and/or is a coded (for example by modulation), encrypted and/or secure first acoustic signal. In this way, spoofing of the rescue system, for example by hostile third parties, may be prevented which may otherwise cause launch of the autonomous watercraft. Hostile third parties may be hoaxers which transmit a spoofed first

acoustic signal, or more seriously, an enemy platform intending to trigger acoustic signatures from the rescue system. In one example, a secure first acoustic signal is provided by an acoustic handshake between the beacon and the receiver. For example, the receiver may measure a handshake time-of-flight of the first acoustic signal: if the time-of-flight is initially too long, then the rescue system may be being spoofed. For military applications, a coded signal first acoustic is preferred so as to reduce an acoustic signature of the rescue system and hence reduce likelihood of detection.

[0021] In one example, the transmitter is arranged to transmit the first acoustic signal in response to a transmission command. In one example, the distress beacon is arranged to issue the transmission command in response to wetting, partial wetting, immersion, partial immersion and/or complete immersion of the distress beacon in the water. In one example, the distress beacon comprises a sensor, for example a moisture sensor, a buoyancy sensor or a water sensor, arranged to sense wetting, partial wetting, immersion, partial immersion and/or complete immersion of the distress beacon in the water. In one example, the transmission command is issued in response to and/or is a signal from the sensor. In one example, the beacon is arranged to differentiate between an actionable or positive trigger and a false or negative trigger. For example, wetting of the distress system's moisture sensor due to freshwater such as rain may be classified as a false trigger while wetting due to saltwater such as seawater may be classified as an actionable trigger. For example, wetting due to rain or a breaking wave may be classified as a false trigger while complete immersion for a predetermined time (e.g. at least 5 s, at least 10 s, at least 20 s) may be classified as an actionable trigger. In one example, the distress beacon is arranged to issue the transmission command in response to an input from the mariner, for example, caused by a button press.

[0022] The watercraft is an autonomous watercraft (also known as a self-piloting, self-navigating or self-steering watercraft, an automated watercraft, a robotic watercraft), arranged to move between locations without human input, for example by sensing its environment and navigating accordingly. Examples of autonomous watercraft include the Scout, the Seacharger and watercraft competing in the Microtransat Challenge, a transatlantic race for autonomous boats. In one example, the autonomous watercraft comprises and/or is a rescue watercraft. In one example, the autonomous watercraft comprises and/or is a surface watercraft, such as a boat or a rigid inflatable boat (RIB). In one example, the autonomous watercraft comprises and/or is a sub-surface watercraft, such as a submarine. In one example, the autonomous watercraft comprises and/or is a military watercraft. In one example, the autonomous watercraft comprises and/or is a military surface watercraft, such as a military boat or a military rigid inflatable boat (RIB). In one example, the autonomous watercraft comprises

and/or is a military sub-surface watercraft, such as a military submarine. The autonomous watercraft may be launched from another watercraft, from a quay or dock, from an aircraft such as a rotary wing aircraft or may be already in the water. In one example, the watercraft is a manned watercraft, for example by a crewman. In this way, the crewman may assist rescue of the mariner, for example. In one example, the watercraft is an unmanned watercraft. In this way, a risk to crewmen is removed. In one example, the watercraft is a remotely-controlled watercraft. In this way, navigation of the watercraft may be provided remotely, for example by a human controller and/or by a computer controller. In one example, the watercraft is an autonomous watercraft wherein remote control, for example by a human controller, overrides autonomous control. In this way, the human controller may assist navigation, for example in rough seas and/or to handle unexpected rescue scenarios.

[0023] The receiver is arranged to receive the transmitted first acoustic signal. In one example, the receiver is arrangeable (i.e. positionable) below a waterline, for example in the water and/or within a hull of a watercraft. In one example, the receiver is arrangeable in the water to directly receive the transmitted first acoustic signal. In one example, the receiver is arrangeable within a hull of a watercraft to indirectly receive the transmitted first acoustic signal via the hull.

[0024] The controller is arranged to cause the autonomous watercraft for rescuing the mariner to be launched, in response to the received first acoustic signal. In other words, the autonomous watercraft is launched as a consequence of the transmission and subsequent reception of the first acoustic signal. In one example, the controller is arranged to directly, for example automatically, cause the autonomous watercraft for rescuing the mariner to be launched. In one example, the controller is arranged to indirectly cause the autonomous watercraft for rescuing the mariner to be launched, for example subject to launch authorisation of the autonomous watercraft. In one example, the controller is arranged to prompt, for example via a graphical user interface, for launch authorisation, receive the launch authorisation and/or cause the autonomous watercraft for rescuing the mariner to be launched, in response to the received first acoustic signal and the received launch authorisation. For example, in a military application where tactical acoustic signature control at a given point in time might be vital, an officer may permit or deny launch authorisation. For example, if the water is calm and/or if rescue of the mariner may be effected by other means, launch authorisation may be denied.

[0025] In one example, the controller is arranged to schedule launch of the autonomous watercraft, in response to the received first acoustic signal. For example, in an event of receiving a plurality of first acoustic signals from a plurality of respective distress beacons associated with a plurality of respective mariners, the controller may prioritise a rescue sequence of the plurality of respective

mariners. In this way, rescue of a particular mariner at greater risk and/or mariners in relative mutual proximity may be prioritised. For example, a certain mariner may communicate to the controller, for example via their beacon such as by pressing a button thereon, that they are injured or not injured. For example, the controller may be arranged to schedule launch of the autonomous watercraft for a mariner who is not injured, or alternatively to the closest mariner, since the uninjured mariner may be better able to help an injured mariner climb aboard the autonomous watercraft.

[0026] In one example, the first frequency is at least 80 kHz, preferably at least 100 kHz, more preferably at least 150 kHz. For civilian applications, the lower frequencies are preferred, since a range of the rescue system is increased. However, larger transmitter transducers are required for these lower frequencies. Conversely, for military applications, the higher frequencies are preferred, as described below in more detail.

[0027] In one example, the first frequency is at most 400 kHz, preferably at most 300 kHz, more preferably at most 200 kHz.

[0028] In one example, the first frequency is in a range from 80 kHz to 400 kHz, preferably in a range from 100 kHz to 300 kHz, more preferably in a range from 150 kHz to 200 kHz.

[0029] Table 1 shows acoustic attenuation versus frequency in seawater. Due to the significant acoustic attenuation above 80 kHz, long range sonar systems in seawater at these higher frequencies may be inefficient. However, high frequency operation, such as 80 kHz or above, might be beneficial for short range communications applications, for example for private and/or covert transmissions. In this way, probability of detection of the first acoustic signal by hostile units, for example, is reduced. In addition, very high frequency acoustic signals, such as several hundred kHz or above, are generally expected to be at higher frequencies than machinery noise, for example, generated on board watercraft such as ships. In this way, the acoustic environment (also known as background) should be fairly quiet or silent at these high frequencies, thereby improving signal to noise ratios (S/N) of the first acoustic signal and/or improving detection of the first acoustic signal. Furthermore, very high frequency sonar transponders, for example the transmitter included in the beacon, may be much smaller than low frequency sonar transponders. Generally, a required thickness of a piezoelectric ceramic operating at its natural resonant frequency scales inversely with its operational frequency. For example, a piezoelectric ceramic for a transducer operating at 1 MHz is only of the order of 1.9mm thick, if using Pz27 grade PZT (lead zirconate titanate), commercially available from Meggitt Sensing Systems, Meggitt PLC (UK). Similarly, a size of the receiver, such as a sub-surface ultrasonic transducer dome on a watercraft such as a ship, may likewise be small and compact. Additionally, by operating at a high frequency, such as 80 kHz or above, the transmitter may

be less susceptible to flow turbulence acoustic noise due to a watercraft upon and/or within which the transmitter is mounted, as the watercraft, such as a ship, moves through the water surface. By operating at a high frequency, such as 80 kHz or above a transmission range of the first acoustic signal may be very short range and may thus require rapid launch of the autonomous watercraft, if using these high frequencies for covertness reasons, for example. If the launch of the autonomous watercraft is not sufficiently rapid such that the high frequency beacon may no longer be heard by the transponder, the autonomous rescue watercraft could use GPS to steer to the GPS location of the man-over board alarm point.

Table 1: Acoustic attenuation dB/km versus frequency in water at a temperature of 8°C, a salinity of 35 ppt, an operating depth of 50 meters, and an acidity of pH 8. The acoustic attenuation at the water surface is only slightly higher, typically by a fraction of a dB. Table data source: NPL website, using the algorithm of Ainslie and McCollm (1998).

Acoustic Frequency	Absorption Coefficient
1 kHz	0.06 dB/km
10 kHz	1.04 dB/km
20 kHz	3.6 dB/km
25 kHz	5.23 dB/km
30 kHz	7.27 dB/km
35 kHz	9.33 dB/km
40 kHz	11.4 dB/km
50 kHz	15.7 dB/km
80 kHz	26.5 dB/km
100 kHz	32.1 dB/km
120 kHz	36.6 dB/km
150 kHz	42.5 dB/km
200 kHz	51.6 dB/km
300 kHz	73 dB/km
400 kHz	98.5 dB/km

[0030] In one example, the first frequency is a predetermined first frequency. In one example, the first frequency is a selectable first frequency. In this way, a range of the first frequency may be controlled by selection of the first frequency, so as to reduce a risk of interception by hostile third parties, for example.

[0031] In one example, the first acoustic signal comprises a set of first frequencies. Respective first frequencies of the set of first frequencies may be different. For example, the transmitter may include two transponders or transducers, arranged to transmit different first fre-

quencies, respectively. The two transponders may be spaced apart, for example on opposite sides of the mariner. In this way, location information may be determined from the two frequencies received by the receiver, due to a difference in respective arrival times.

[0032] In one example, the controller is arranged to cause the autonomous watercraft for rescuing the mariner to be launched immediately, in response to the received first acoustic signal. In this way, a potential problem of the first acoustic signal being undetectable at, for example, a range of greater than 1 km may be avoided since the autonomous watercraft is launched immediately.

[0033] In one example, the transmitter is arranged to transmit the first acoustic signal according to a spread spectrum protocol, for example code-division multiple access (CDMA). Generally, CDMA employs analog-to-digital conversion (ADC) in combination with spread spectrum technology. In this way, the first acoustic signal may appear like noise to other receivers that are not arranged to extract the first acoustic signal, thereby improving covertness of operation. In one example, the receiver is arranged to extract the first acoustic signal according to the spread spectrum protocol, for example CDMA. In one example, the receiver is arranged to correlate with a code of the CDMA to extract the first acoustic signal.

[0034] In one example, the transmitter is arranged to repeatedly transmit the first acoustic signal. In one example, the transmitter is arranged to repeatedly transmit the first acoustic signal at regular time intervals, for example as a regular heartbeat signal. In one example, the transmitter is arranged to repeatedly transmit the first acoustic signal at irregular time intervals. In this way, probability of detection of the first acoustic signal by hostile units, for example, is reduced.

[0035] In one example, the first acoustic signal includes one or more vital signs of the mariner, for example, body temperature, pulse rate and/or respiration rate (rate of breathing) of the mariner. In one example, the beacon comprises one or more vital sign sensors arranged to sense one or more vital signs of the mariner, respectively. In this way, a health of the mariner may be determined from the one or more vital signs such that a conscious or unconscious state of the mariner may be determined, for example. In one example, the controller is arranged to prioritise a rescue sequence of a plurality of respective mariners according to their respective vital signs. In one example, the first acoustic signal includes a status of the mariner, for example conscious, not injured or injured, as input by the mariner into the beacon. In one example, the first acoustic signal includes an identifier of the mariner and/or an identifier of the beacon. In this way, rescue of a particular mariner at greater risk may be prioritised.

[0036] In one example, the beacon comprises a first transceiver comprising the transmitter. In this way, the beacon is arranged to transmit the first acoustic signal and to receive another signal, for example transmitted from the watercraft.

[0037] In one example, the system comprises the watercraft, as described above.

[0038] In one example, the watercraft is arranged to navigate towards the beacon based, at least in part, on the received first acoustic signal. In other words, the watercraft is arranged to home towards the beacon and hence the mariner, for example by determining a bearing and/or range of the beacon. In one example, the watercraft comprises the receiver or a second receiver and the watercraft is arranged to determine a Doppler effect (also known as a Doppler shift) of the first acoustic signal, as the watercraft moves towards and/or away from the beacon. In one example, the watercraft comprises a directional sonar detector, arranged to detect a direction of the first acoustic signal. In this way, the watercraft may navigate directly towards the beacon. In one example, the watercraft is arranged to measure a bi-directional time of flight of acoustic pings transmitted first from the watercraft to the beacon to trigger an immediate automatic response from the beacon. If the time of flight decreases, the watercraft is moving towards the beacon. Determining the Doppler effect is preferred.

[0039] In one example, the watercraft comprises a second transceiver arranged to transmit a second acoustic signal in water, to receive at least a part of the second acoustic signal responded by the beacon and wherein the watercraft is arranged to determine a relative bearing and/or a range of the beacon from the responded acoustic signal. In this way, the watercraft may navigate towards the beacon. The second acoustic signal may be as described with respect to the first acoustic signal. In one example, the second acoustic signal is at a second frequency. The second frequency may be as described with respect to the first frequency. In one example, the second frequency is the same as or different from the first frequency. In one example, the beacon is arranged to reduce an intensity or power of the first acoustic signal in response to receiving the second acoustic signal. In this way, covertness of the rescue may be improved.

[0040] In one example, the watercraft is arranged to control a bearing and/or a speed thereof, based at least in part on the determined relative bearing and/or the range of the beacon therefrom. In this way, the watercraft may navigate towards the beacon, for example by updating the relative bearing and/or the range of the beacon therefrom. In this way, the watercraft may continue to navigate towards the beacon irrespective of movement of the beacon, for example due to waves, wind and/or current.

[0041] In one example, the first transceiver and the second transceiver are arranged to bi-directionally communicate. In this way, beacon and the watercraft may communicate. For example, the beacon may transmit acknowledgements to the watercraft, or vice versa. For example, the beacon may transmit location information, for example global positioning system (GPS) coordinates, to the watercraft, or vice versa. For example, the beacon may transmit the GPS coordinates thereof, which are re-

ceived by the receiver and provided to the autonomous watercraft, so as to inform navigation of the autonomous watercraft. In one example, the beacon comprises a GPS device arranged to determine a GPS position of the beacon. For example, the beacon may transmit vital signs of the mariner to the watercraft. In one example, the first transceiver and the second transceiver are arranged to bi-directionally communicate using a third acoustic signal in water. The third acoustic signal may be as described with respect to the first acoustic signal and/or the second acoustic signal. In one example, the third acoustic signal is at a third frequency. The third frequency may be as described with respect to the first frequency and/or the second frequency. In one example, the third frequency is the same as or different from the first frequency and/or the second frequency. For example, if the third frequency is different from the first frequency, different frequencies may be used for causing launch of the autonomous watercraft and for communicating with the beacon. For example, the third frequency may be higher than the first frequency and thus of shorter range.

[0042] In one example, the watercraft is arranged to attenuate a speed thereof in response to an acknowledgment acoustic signal received from the beacon. In this way, collision of the watercraft with the mariner may be avoided. In one example, the watercraft is arranged to reduce a speed thereof, for example below 5 knots, below 3 knots, below 1 knot, 0 knots in response to the acknowledgment acoustic signal received from the beacon.

[0043] In one example, the watercraft is arranged to modify a course thereof in response to an acknowledgment acoustic signal received from the beacon. For example, the watercraft may be arranged to navigate a course in close proximity to the beacon and/or a circular course in close proximity to and/or around the beacon and hence the mariner, so as to facilitate rescue of the mariner and/or embarkation of the mariner onto the watercraft. For example, if the beacon and hence mariner is substantially stationary, the watercraft may stop moving so as to facilitate embarkation of the mariner onto the watercraft. For example, if the beacon and hence mariner is moving, the watercraft may move at a same speed and in a same direction beside the moving beacon and hence moving mariner, so as to facilitate embarkation of the mariner onto the watercraft. If the mariner is unconscious, rescue thereof and/or embarkation onto an unmanned autonomous watercraft may be facilitated by an electromagnetic rescue device including a small steel disk provided in a life jacket of the mariner and an electromagnet provided on the autonomous watercraft to hook the steel disk provided in a life jacket. In one example, the autonomous watercraft includes a deployable inflatable lasso for rescuing the mariner.

[0044] According to the second aspect, there is provided a distress beacon for a mariner, the beacon comprising a transmitter arranged to transmit a first acoustic signal in water, wherein the first acoustic signal has a frequency in a range from 80 kHz to 400 kHz.

[0045] The distress beacon, the mariner, the transmitter, the first acoustic signal, the water, the receiving and/or the navigating may be as described with reference to the first aspect.

5 **[0046]** According to the third aspect, there is provided an autonomous watercraft for rescuing a mariner having a distress beacon, the watercraft comprising a second transceiver, wherein the watercraft is arranged to navigate towards the beacon based, at least in part, on a first acoustic signal in water received therefrom.

10 **[0047]** The autonomous watercraft, the mariner, the distress beacon, the first acoustic signal, the water, the receiving and/or the navigating may be as described with reference to any of the first and/or second aspects.

15 **[0048]** According to the fourth aspect, there is provided a method of controlling a distress beacon for a mariner, the beacon comprising a transmitter, the method comprising:

20 transmitting, by the beacon, a first acoustic signal in water in response to immersion therein, wherein the first acoustic signal has a frequency in a range from 80 kHz to 400 kHz.

25 **[0049]** The distress beacon, the mariner, the transmitter, the transmitting, the first acoustic signal and/or the water may be as described with reference to any of the first, second, and/or third aspects.

30 **[0050]** According to the fifth aspect, there is provided a method of controlling an autonomous watercraft for rescuing a mariner having a distress beacon, the method comprising: transmitting, by the beacon, a first acoustic signal in water;

35 receiving, by the watercraft, the transmitted first acoustic signal; and navigating, by the watercraft, towards the beacon based, at least in part, on the received first acoustic signal.

40 **[0051]** The autonomous watercraft, the mariner, the distress beacon, the transmitting, the first acoustic signal, the water, the receiving and/or the navigating may be as described with reference to any of the first, second, third and/or fourth aspects.

45 **[0052]** According to the sixth aspect, there is provided use of a first acoustic signal, having a frequency in a range from 80 kHz to 400 kHz, in water as a distress signal.

[0053] The first acoustic signal, the water, and/or the distress signal may be as described with reference to any of the first, second, third, fourth and/or fifth aspects.

Brief description of the drawings

50 **[0054]** For a better understanding of the invention, and to show how exemplary embodiments of the same may be brought into effect, reference will be made, by way of example only, to the accompanying diagrammatic Figures, in which:

Figure 1 schematically depicts a rescue system according to an exemplary embodiment;

Figures 2A - 2D schematically depict the rescue system of Figure 1, in use;

Figure 3 schematically depicts a method of controlling a distress beacon according to an exemplary embodiment; and

Figure 4 schematically depicts a method of controlling an autonomous watercraft according to an exemplary embodiment.

Detailed Description of the Drawings

[0055] Figure 1 schematically depicts a rescue system 10 according to an exemplary embodiment.

[0056] The rescue system 10 is for rescuing a mariner at sea. The system 10 comprises a distress beacon 11 for the mariner, the distress beacon comprising a transmitter 111 arranged to transmit a first acoustic signal at a first frequency in water. The system 10 comprises a receiver 12 arranged to receive the transmitted first acoustic signal. The system 10 comprises a controller 13 arranged to cause an autonomous watercraft 14 for rescuing the mariner to be launched, in response to the received first acoustic signal.

[0057] In this way, rescue of the mariner may be improved because the autonomous watercraft 14 is launched promptly in response to the first acoustic signal transmitted by the mariner's distress beacon 11.

[0058] The distress beacon 11 is for the mariner. In this example, the distress beacon 11 comprises a carabiner (i.e. a coupling member) (not shown) for coupling the distress beacon 11 to a garment worn by the mariner.

[0059] In this example, the transmitter 111 is arranged to transmit the first acoustic signal in response to a transmission command. In this example, the distress beacon 11 is arranged to issue the transmission command in response to complete immersion of the distress beacon 11 in the water. In this example, the distress beacon 11 comprises a water sensor (i.e. a sensor) (not shown) arranged to sense complete immersion of the distress beacon 11 in the water. In this example, the transmission command is a signal from the sensor.

[0060] The autonomous watercraft 14 is an autonomous watercraft. In this example, the autonomous watercraft 14 is a military rigid inflatable boat (RIB) (i.e. a military surface autonomous watercraft).

[0061] The receiver 12 is arranged to receive the transmitted first acoustic signal.

[0062] The controller 13 is arranged to cause the autonomous watercraft 14 for rescuing the mariner to be launched, in response to the received first acoustic signal. In this example, the controller 13 is arranged to indirectly cause the autonomous watercraft 14 for rescuing the mariner to be launched, subject to launch authorisa-

tion of the autonomous watercraft 14, as described previously.

[0063] In this example, the first frequency is in a range from 80 kHz to 400 kHz.

[0064] In this example, the transmitter 111 is arranged to transmit the first acoustic signal according to a code-division multiple access (CDMA) protocol. In this example, the receiver 12 is arranged to correlate with a code of the CDMA to extract the first acoustic signal.

[0065] In this example, the distress beacon 11 comprises a first transceiver (not shown) comprising the transmitter 111. In this way, the distress beacon 11 is arranged to transmit the first acoustic signal and to receive another signal, for example transmitted from the autonomous watercraft 14.

[0066] In this example, the autonomous watercraft 14 is arranged to navigate towards the distress beacon 11 based, at least in part, on the received first acoustic signal. In this example, the autonomous watercraft 14 comprises a second receiver 141 and the autonomous watercraft 14 is arranged to determine a Doppler effect of the first acoustic signal, as the autonomous watercraft 14 moves towards and/or away from the distress beacon 11.

[0067] In this example, the autonomous watercraft 14 comprises a second transceiver including the second receiver 141 and a second transmitter 142, wherein the second transmitter 142 is arranged to transmit a second acoustic signal in water, to receive at least a part of the second acoustic signal responded by the distress beacon and wherein the autonomous watercraft 14 is arranged to determine a relative bearing and/or a range of the distress beacon 11 from the responded acoustic signal. In this way, the autonomous watercraft 14 may navigate towards the distress beacon 11. The second acoustic signal is as described with respect to the first acoustic signal.

[0068] In this example, the autonomous watercraft 14 is arranged to control a bearing and/or a speed thereof, based at least in part on the determined relative bearing and/or the range of the distress beacon 11 therefrom.

[0069] In this example, the first transceiver and the second transceiver are arranged to bi-directionally communicate. In this way, distress beacon 11 and the autonomous watercraft 14 may communicate.

[0070] In this example, the autonomous watercraft 14 is arranged to attenuate a speed thereof in response to an acknowledgment acoustic signal received from the distress beacon 11. In this way, collision of the autonomous watercraft 14 with the mariner may be avoided.

[0071] In this example, the autonomous watercraft 14 is arranged to modify a course thereof in response to an acknowledgment acoustic signal received from the distress beacon 11.

[0072] In use, at S11, the transmitter 111 transmits the first acoustic signal at the first frequency in the water, which is received by the receiver 12.

[0073] At S12, in response to the received first acoustic

signal, a man overboard alarm is raised and launch of the autonomous watercraft 14 authorised or alternatively not authorised.

[0074] At S13, the controller 13 causes the autonomous watercraft 14 for rescuing the mariner to be launched.

[0075] Optionally, at S14, the transmitter 111 transmits the first acoustic signal, including vital sign information and/or a distress homing signal and/or a mariner identifier, which is received by the receiver 142 of the autonomous watercraft 14.

[0076] Optionally, at S15, the transmitter 141 of the autonomous watercraft 14 transmits status information of the autonomous watercraft 14 and/or GPS coordinates thereof, which is received by the receiver 112 of the beacon 11.

[0077] Optionally, at S16, the transmitter 141 of the autonomous watercraft 14 relays the first acoustic signal, including the vital sign information and/or the distress homing signal and/or the mariner identifier which was received by the receiver 142 of the autonomous watercraft 14, optionally together with the status information of the autonomous watercraft 14 and/or the GPS coordinates thereof, which is received by the receiver 12.

[0078] Optionally, at S17, the controller 13 issues command signals to the receiver 12 for transmission to the autonomous watercraft 14.

[0079] Optionally, at S18, the issued command signals are forwarded under the water via the receiver 12 to the autonomous watercraft 14 and received by the receiver 142 of the autonomous watercraft 14.

[0080] Figures 2A - 2D schematically depict the rescue system 10 of Figure 1, in use.

[0081] A mariner M has the distress beacon 11 coupled via the karabiner to the garment thereof, the distress beacon 11 comprising the transmitter 111 arranged to transmit the first acoustic signal at the first frequency in water. A watercraft W, for example a military ship, includes the receiver 12 arranged to receive the transmitted first acoustic signal and the controller 13 arranged to cause the autonomous watercraft 14 for rescuing the mariner to be launched, in response to the received first acoustic signal. The watercraft W is moving northwards N at sea (i.e. in the water).

[0082] Figure 2A shows the mariner M upon falling overboard from the watercraft W. Upon complete immersion of the distress beacon 11 in the water, the water sensor senses the complete immersion of the distress beacon 11 in the water, the transmission command is issued by the distress beacon 11 and the transmitter 111 transmits the first acoustic signal, having an effective range R due, at least in part, due to attenuation of the first acoustic signal in the water. The first frequency of the first acoustic signal is in a range from 80 kHz to 400 kHz. The receiver 12 on the watercraft W, within the effective range R, receives the transmitted first acoustic signal.

[0083] Figure 2B shows the military RIB (i.e. the au-

tonomous watercraft 14) launched in response to the received first acoustic signal. Particularly, the controller 13 on the watercraft W causes the autonomous watercraft 14 for rescuing the mariner M to be launched, in response to the received first acoustic signal, subject to launch authorisation of the autonomous watercraft 14, as described previously. The watercraft W continues moving northwards N.

[0084] Figure 2C shows the autonomous watercraft 14 navigating towards the distress beacon 11 based, at least in part, on the received first acoustic signal. In this example, the autonomous watercraft 14 comprises a second receiver (not shown) and the autonomous watercraft determines a Doppler effect of the first acoustic signal, as the autonomous watercraft 14 moves towards and/or away from the distress beacon 11. The autonomous watercraft controls a bearing and/or a speed thereof, based at least in part on the determined relative bearing and/or the range of the distress beacon 11 therefrom. The first transceiver and the second transceiver bi-directionally communicate. The watercraft W continues moving northwards N, beyond the effective range R.

[0085] Figure 2D shows the autonomous watercraft 14 approaching the mariner M. The autonomous watercraft 14 attenuates a speed thereof in response to an acknowledgment acoustic signal received from the distress beacon 11. In this way, collision of the autonomous watercraft 14 with the mariner M is avoided. The autonomous watercraft 14 modifies a course thereof in response to an acknowledgment acoustic signal received from the distress beacon 11 and circles the mariner M, who embarks the autonomous watercraft 14. The watercraft W continues moving northwards N, beyond the effective range R.

[0086] Figure 3 schematically depicts a method of controlling a distress beacon according to an exemplary embodiment.

[0087] Particularly, the method is of controlling a distress beacon for a mariner, the beacon comprising a transmitter.

[0088] At S31, the beacon transmits a first acoustic signal in water in response to immersion therein, wherein the first acoustic signal has a frequency in a range from 100 kHz to 400 kHz.

[0089] The method may include any of the steps described herein.

[0090] Figure 4 schematically depicts a method of controlling an autonomous watercraft according to an exemplary embodiment.

[0091] Particularly, the method is of controlling an autonomous watercraft for rescuing a mariner having a distress beacon.

[0092] At S41, the beacon transmits a first acoustic signal in water.

[0093] At S42, the watercraft receives the transmitted first acoustic signal.

[0094] At S43, the watercraft navigates towards the beacon based, at least in part, on the received first acoustic signal.

[0095] The method may include any of the steps described herein.

[0096] Although a preferred embodiment has been shown and described, it will be appreciated by those skilled in the art that various changes and modifications might be made without departing from the scope of the invention, as defined in the appended claims and as described above.

[0097] In summary, the invention provides a rescue system for rescuing a mariner at sea, the system comprising a distress beacon for the mariner, the beacon comprising a transmitter arranged to transmit a first acoustic signal at a first frequency in water, a receiver arranged to receive the transmitted first acoustic signal and a controller arranged to cause an autonomous watercraft for rescuing the mariner to be launched, in response to the received first acoustic signal. In this way, rescue of the mariner may be improved because the autonomous watercraft is launched in response to the first acoustic signal transmitted by the mariner's distress beacon. In this way, manoeuvring of the mariner's watercraft, for example, may not be required, since the autonomous watercraft is launched for the rescue. In this way, the rescue system responds more quickly to a man overboard event. In this way, the rescue system effects rescue more quickly. In this way, the rescue system improves targeting of the mariner. Also provided are a distress beacon for a mariner, an autonomous watercraft, a method of controlling a distress beacon for a mariner, a method of controlling an autonomous watercraft for rescuing a mariner having a distress beacon and use of a first acoustic signal, having a frequency in a range from 80 kHz to 400 kHz, in water as a distress signal.

[0098] Attention is directed to all papers and documents which are filed concurrently with or previous to this specification in connection with this application and which are open to public inspection with this specification, and the contents of all such papers and documents are incorporated herein by reference.

[0099] All of the features disclosed in this specification (including any accompanying claims and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at most some of such features and/or steps are mutually exclusive.

[0100] Each feature disclosed in this specification (including any accompanying claims, and drawings) may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

[0101] The invention is not restricted to the details of the foregoing embodiment(s). The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims and drawings), or to any novel one, or any novel combination, of the steps of any method or process

so disclosed.

Claims

1. A rescue system for rescuing a mariner at sea, the system comprising:
 - a distress beacon for the mariner, the beacon comprising a transmitter arranged to transmit a first acoustic signal at a first frequency in water; a receiver arranged to receive the transmitted first acoustic signal; and
 - a controller arranged to cause an autonomous watercraft for rescuing the mariner to be launched, in response to the received first acoustic signal.
2. The system according to claim 1, wherein the first frequency is at least 80 kHz, preferably at least 100 kHz.
3. The system according to any previous claim, wherein the first frequency is at most 400 kHz, preferably at most 300 kHz.
4. The system according to any previous claim, wherein the transmitter is arranged to repeatedly transmit the first acoustic signal.
5. The system according to any previous claim, wherein the beacon comprises a first transceiver comprising the transmitter.
6. The system according to claim 5, comprising the watercraft.
7. The system according to claim 6, wherein the watercraft is arranged to navigate towards the beacon based, at least in part, on the received first acoustic signal.
8. The system according to claim 7, wherein the watercraft comprises a second transceiver arranged to transmit a second acoustic signal in water, to receive at least a part of the second acoustic signal responded by the beacon and wherein the watercraft is arranged to determine a relative bearing and/or a range of the beacon from the responded acoustic signal.
9. The system according to claim 8, wherein the watercraft is arranged to control a bearing and/or a speed thereof, based at least in part on the determined relative bearing and/or the range of the beacon therefrom.
10. The system according to any of claims 6 to 9, wherein

the first transceiver and the second transceiver are arranged to bi-directionally communicate.

11. The system according to claim 10, wherein the watercraft is arranged to attenuate a speed thereof in response to an acknowledgment acoustic signal received from the beacon. 5
12. A distress beacon for a mariner, the beacon comprising a transmitter arranged to transmit a first acoustic signal in water, wherein the first acoustic signal has a frequency in a range from 80 kHz to 400 kHz. 10
13. A method of controlling a distress beacon for a mariner, the beacon comprising a transmitter, the method comprising: 15

transmitting, by the beacon, a first acoustic signal in water in response to immersion therein, wherein the first acoustic signal has a frequency in a range from 80 kHz to 400 kHz. 20
14. A method of controlling an autonomous watercraft for rescuing a mariner having a distress beacon, the method comprising: 25

transmitting, by the beacon, a first acoustic signal in water;
receiving, by the watercraft, the transmitted first acoustic signal; and 30
navigating, by the watercraft, towards the beacon based, at least in part, on the received first acoustic signal. 35
15. Use of a first acoustic signal, having a frequency in a range from 80 kHz to 400 kHz, in water as a distress signal. 40

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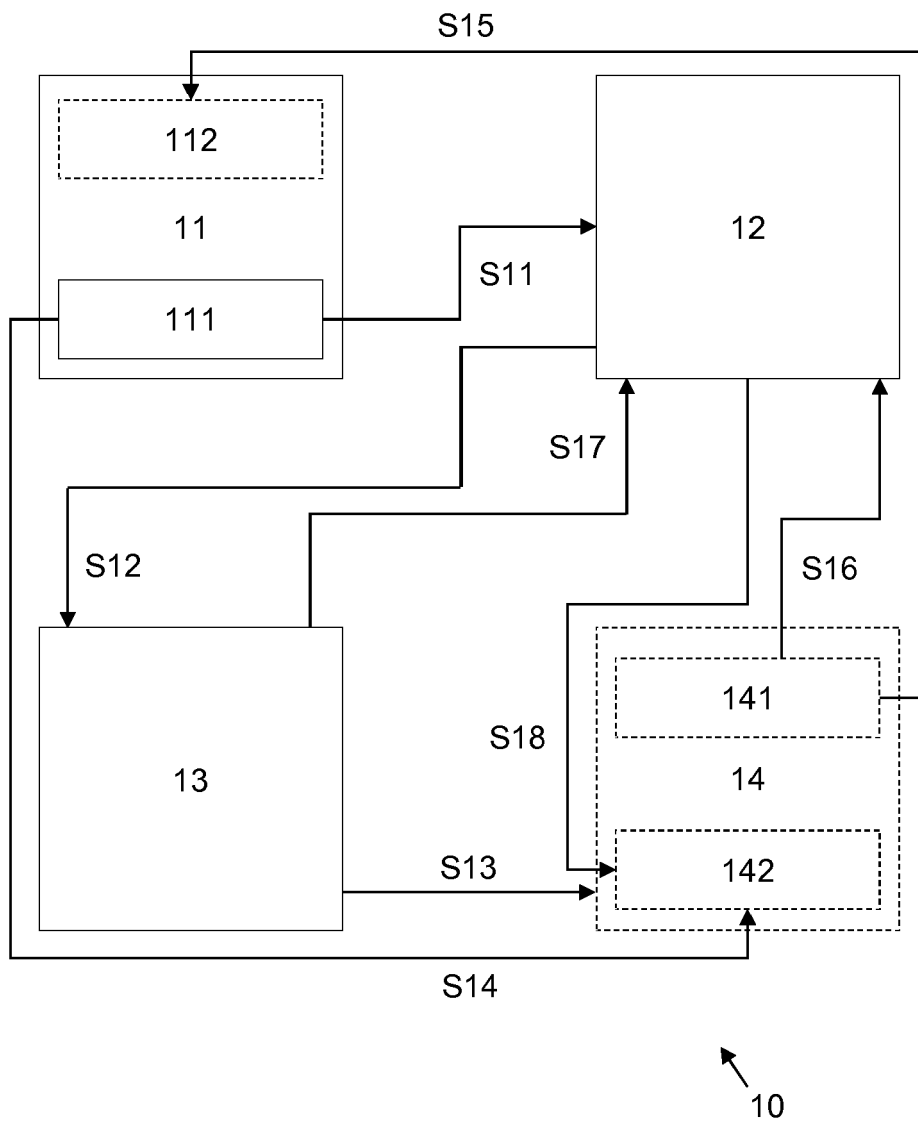


Fig. 1

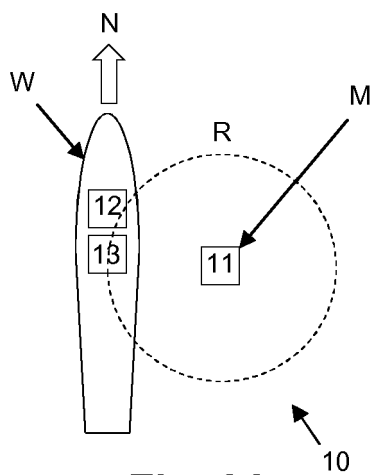


Fig. 2A

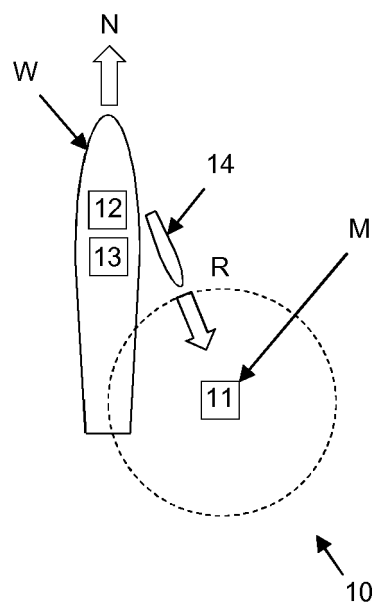


Fig. 2B

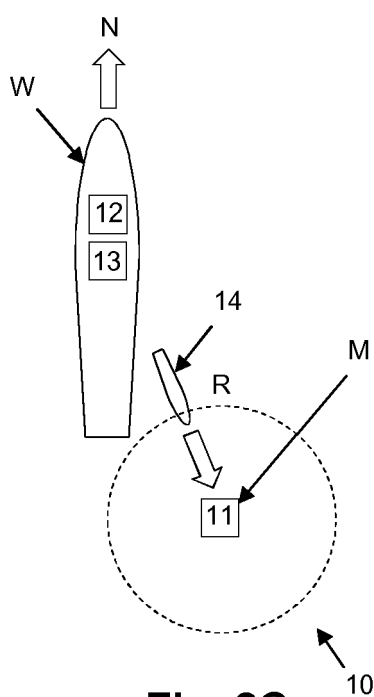


Fig. 2C

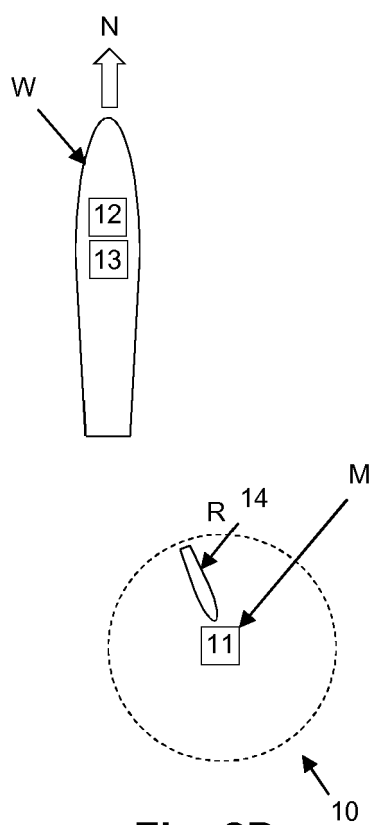


Fig. 2D

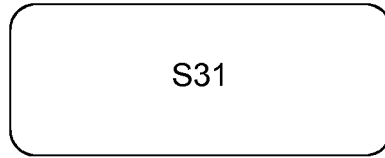


Fig. 3

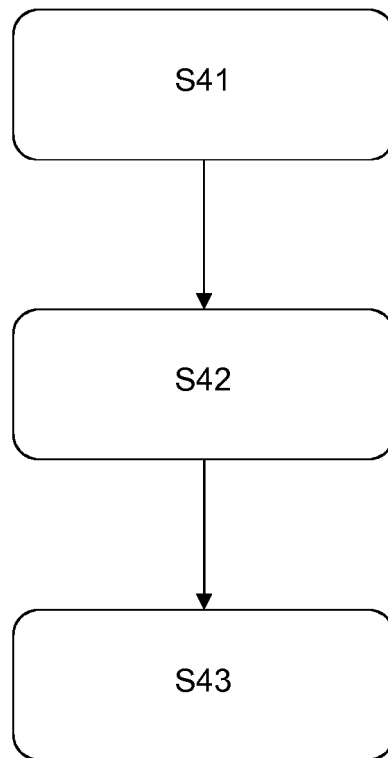


Fig. 4



EUROPEAN SEARCH REPORT

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	DE 43 11 473 A1 (DEUTSCHE AEROSPACE [DE]) 13 October 1994 (1994-10-13)	1-7,14,15	INV. B63C9/00
A	* column 5, line 8 - line 50; figures 5a,5b * * column 1, line 1 - line 50 *	8-11	B63C9/01 G08B21/08
Y	GB 2 287 564 A (FRENCH JOHN ADAM) 20 September 1995 (1995-09-20)	2,3,15	
A	* the whole document *	1,4-11,14	
Y	US 4 305 143 A (SIMMS LARRY L ET AL) 8 December 1981 (1981-12-08)	2,3,15	
A	* column 3, line 2 - line 16; figure 3 *	1,14	
A	US 4 630 205 A (OTAKA HIDEO [JP]) 16 December 1986 (1986-12-16)	1-11,14,15	
A	US 2015/307172 A1 (NG JAMES [US]) 29 October 2015 (2015-10-29)	1-11,14,15	TECHNICAL FIELDS SEARCHED (IPC)
A	US 2012/276794 A1 (MULLIGAN ANTHONY C [US] ET AL) 1 November 2012 (2012-11-01)	1-11,14,15	B63C G08B
A	US 6 558 218 B1 (HANSEN ERIC C [US]) 6 May 2003 (2003-05-06)	1-11,14,15	
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 10 July 2018	Examiner Kurzbauer, Werner
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03.82 (P04C01)



Application Number

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CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing claims for which payment was due.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☐ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☒ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

1-11, 14, 15

☐ The present supplementary European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims (Rule 164 (1) EPC).

**LACK OF UNITY OF INVENTION
SHEET B**

Application Number

EP 18 15 6628

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 1-11, 14, 15

A rescue system for rescuing a mariner at sea, the system comprising a distress beacon for the mariner, the beacon comprising a transmitter arranged to transmit a first acoustic signal at a first frequency in water; a receiver arranged to receive the transmitted first acoustic signal; and a controller arranged to cause an autonomous watercraft for rescuing the mariner to be launched, in response to the received first acoustic signal.

2. claims: 12, 13

A distress beacon for a mariner, the beacon comprising a transmitter arranged to transmit a first acoustic signal in water, wherein the first acoustic signal has a frequency in a range from 80 kHz to 400 kHz.

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

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5

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 4311473 A1	13-10-1994	NONE	
GB 2287564 A	20-09-1995	NONE	
US 4305143 A	08-12-1981	EP 0033741 A1	19-08-1981
		US 4305143 A	08-12-1981
		WO 8100496 A1	19-02-1981
US 4630205 A	16-12-1986	NONE	
US 2015307172 A1	29-10-2015	NONE	
US 2012276794 A1	01-11-2012	AU 2012239947 A1	31-10-2013
		DK 2694360 T3	16-04-2018
		EP 2694360 A1	12-02-2014
		ES 2661934 T3	04-04-2018
		HR P20180513 T1	13-07-2018
		KR 20140060260 A	19-05-2014
		KR 20150001855 A	06-01-2015
		MX 339942 B	17-06-2016
		PL 2694360 T3	29-06-2018
		PT 2694360 T	12-03-2018
		US 2012276794 A1	01-11-2012
		WO 2012139044 A1	11-10-2012
US 6558218 B1	06-05-2003	NONE	