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NOTICE

The above identified patent application is available for licensing. Requests for information should be addressed to:

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1 Attorney Docket No. 83278

2 FREE-FLOATING ALTITUDE STABILIZED SYSTEM З 4 STATEMENT OF GOVERNMENT INTEREST 5 6 The invention described herein may be manufactured and used by or for the Government of the United States of America for 7 8 Governmental purposes without the payment of any royalties thereon or therefor. 9 10 BACKGROUND OF THE INVENTION 11 12 (1) Field of the Invention 13 The present invention relates generally to free-floating-14 devices, and more particularly to a free-floating system that adaptively adjusts to wave motion in order to maintain a 15 16 predetermined altitude of the system at the water's surface or at 17 some predetermined depth. 18 (2) Description of the Prior Art A variety of floating systems are used to keep radio or 19 20 acoustic communication links above the water's surface. 21 Frequently, to maintain operable communication links, it is necessary for the communication equipment (e.g., acoustic, 22 23 optical, electronic, etc.) to maintain a stable or constant 24 altitude. This is especially true when the communication 25 equipment is part of a tracking system where changes in altitude

26 can cause signal disturbances that lead to corrupt distance
27 measurements.

SUMMARY OF THE INVENTION

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Accordingly, it is an object of the present invention to provide a system that can freely float at the water's surface and adaptively stabilize itself in terms of altitude in the presence of wave motion.

7 Another object of the present invention is to provide a 8 free-floating altitude stabilized system for maintaining a 9 floating body at a predetermined altitude in the water in the 10 presence of wave motion.

Other objects and advantages of the present invention will become more obvious hereinafter in the specification and drawings.

In accordance with the present invention, a free-floating 14 altitude stabilized system includes a body that is buoyant in the 15 16 water at a predetermined water depth. A plurality of wire coils are linearly aligned with one another in a vertical direction and 17 18 coupled to the body. Each wire coil is independently energizable 19 such that an induced magnetic field is generated by any of the 20 wire coils that are energized. A float is coupled to the body in 21 such a way that it is capable of independent movement relative 22 thereto. A magnet, fixedly coupled to the float, emits a 23 magnetic field. A control system is provided to energize a 24 selected one or more of the wire coils in such a way the magnetic 25 field and induced magnetic field react with one another to 26 generate movement of the float vertically in a direction that is 27 the same as a vertical component of wave motion.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, features and advantages of the present invention will become apparent upon reference to the following description of the preferred embodiments and to the drawings, wherein corresponding reference characters indicate corresponding parts throughout the several views of the drawings and wherein:

FIG. 1 is a schematic diagram of a free-floating altitude
stabilized system according to an embodiment of the present
invention;

10 FIG. 2 is a schematic illustration of an unmanned underwater 11 vehicle (UUV) equipped with the free-floating altitude stabilized 12 system of the present invention; and

FIG. 3 is a enlarged partial view of the UUV in FIG. 2 illustrating the use of magnetic field sensors positioned linearly and vertically along the UUV body for sensing the position and velocity of the surrounding flotation collar.

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DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

19 Referring now to the drawings, and more particularly to FIG. 20 1, a free-floating altitude stabilized system according the 21 present invention is contained within dashed-line box referenced 22 by numeral 10. Altitude stabilized system 10 can be positioned 23 at the water's surface or at some predetermined depth in the open 24 ocean, sea or a river. Thus, it is to be understood that the 25 choice of water venue and depth of system 10 are not limitations of the present invention. However, by way of illustrative 26

example, it will be assumed that the desired altitude for system
 10 is at the water's surface referenced by numeral 102.

Altitude stabilized system 10 includes a magnet structure 12 3 and a wire coil structure 14. Each of magnet structure 12 and 4 wire coil structure 14 are maintained on bodies (not shown in 5 FIG. 1) that are mechanically coupled to one another while also 6 7 being capable of independent flotation and movement at water surface 102. Further, both magnet structure 12 and wire coil 8 structure 14 are untethered. That is, they are both freely-9 floating at (or near) water surface 102 so that both freely 10 11 experience surface wave motion occurring at or near water surface 12 102.

The basic operating principle utilized by the present 13 14 invention can be explained as follows. Magnet structure 12 is a 15 permanent magnet or an electromagnet that emits a magnetic field. 16 Wire coil structure 14 is a vertical, linear arrangement of 17 independently energizable wire coils, three of which are illustrated as coils 14A, 14B and 14C. Additional or fewer coils 18 19 can be used without departing from the scope of the present invention. When one or more of coils 14A-14C are 20 21 energized (i.e., supplied with current), an induced magnetic 22 field is generated. Depending on the location and direction of 23 the induced magnetic field, the magnetic field of magnet 24 structure 12 is either repelled or attracted by the induced 25 magnetic field generated by the energized portion of wire coil 26 structure 14. The repulsion or attraction reaction between 27 magnet structure 12 and wire coil structure 14 causes relative

1 movement of magnet structure 12. The amount and direction of 2 relative movement of magnet structure 12 is determined by the 3 strength and direction of the induced magnetic field generated by 4 wire coil structure 14.

5 The remaining portion of altitude stabilized system 10 is an 6 adaptive control loop that controls the location and direction of 7 the induced magnetic field. Location of the induced magnetic 8 field is controlled by selecting which one or more of wire coils 9 14A-14C to energize. The control loop controls the direction of 10 the induced magnetic field by controlling the direction in which 11 electric current will flow through the selected wire coil(s).

The control loop includes a dynamic parameter measurement 12 system 20 coupled to structures 12 and 14 for measuring various 13 dynamic parameters that describe the relative movement between 14 structures 12 and 14. These dynamic parameters include vertical 15 16 acceleration of wire coil structure 14 and the position/velocity of magnet structure 12 relative to wire coil structure 14. 17 It is to be understood that the particular devices/methods used to 18 19 obtain these parameters is not a limitation of the present 20 invention. However, by way of example, an embodiment of the 21 present invention will be explained in detail later in the 22 description.

23 Measurement system 20 supplies inputs to a controller 22 24 which processes the inputs in accordance with a desired function. 25 The goal of the function can be tailored for a given 26 application. For example, in the illustrative case of trying to 27 stabilize the altitude of system 10 at water surface 102, the

control function will operate to keep vertical acceleration of 1 wire coil structure 14 at zero. To do this, controller 22 2 processes the data supplied thereto and generates a control 3 signal for a bi-directional current control device 24. Based on 4 this control signal, current control device 24 supplies electric 5 current in a selected direction to selected one(s) of wire coils 6 7 14A-14C. Such current control devices are well known in the art and will not be described further herein. The current to be 8 controlled by device 24 can be generated by a combination of a 9 DC-to-DC converter 26 powered by a battery 28. Voltage supplied 10 . 11 by battery 28 should be sufficient to overcome any back EMF in wire coil structure 14. 12

Altitude stabilizing system 10 can be incorporated in a 13 variety of sea-going systems. By way of example, system 10 could 14 15 be included on an unmanned underwater vehicle (UUV) having an onboard system (not shown in FIG. 1) that must be maintained at 16 17 or above water surface 102. A representative example of such an embodiment is illustrated in FIG. 2 where a UUV 50 has a body 52 18 19 housing wire coil structure 14 and a flotation collar 54 housing 20 magnet structure 12. Dynamic parameter measurement system 20 (FIG. 1) can be realized by an accelerometer 20A mounted on/in 21 body 52 and position/velocity sensors 20B mounted on/in body 52 22 for sensing the position and velocity of collar 54 relative to 23 24 body 52. The remaining control loop elements of altitude stabilized system 10 described above are omitted from FIG. 2 for 25 26 clarity of illustration.

Body 52 is buoyant in the water at a predetermined depth of 1 operation which, for the illustrated embodiment, is at water 2 surface 102 such that a small portion of body 52 extends above 3 water surface 102. A communications link (represented by antenna 4 200) could be housed/supported by the portion of body 52 that 5 extends above water surface 102. For purpose of illustration, 6 the altitude of this portion of body 52 must be maintained for 7 proper operation of communications link 200. Collar 54 can be 8 disposed about body 52. Collar 54 is coupled to body 52 such 9 that it can freely travel or ride up and down on body 52 as 10 indicated by two-headed arrow 56. 11

Referring now simultaneously to FIGs. 1 and 2, an operational example of the present invention will be described. For discussion purposes, it will be assumed that wave motion at water surface 102 is such that body 52 will tend to experience downward motion. That is, the vertical component of the wave motion is directed downward.

As body 52 begins to descend, accelerometer 20A detects the 18 downward acceleration of body 52, while the position and velocity 19 20 of magnet structure 12 is detected by position/velocity sensors 21 The sensed data is processed by a control function 20B. programmed into controller 22. In the case of maintaining body 22 23 52 at water surface 102, the control function determines which 24 one or more of wire coils 14A-14C must be energized such that 25 magnet 12/collar 54 can be driven vertically downward at a higher velocity than the vertical component of wave motion. 26 This 27 downward movement of collar 54 will create a reactive force

between collar 54 and body 52 that will tend to drive body 52 1 upward relative to collar 54. Note that the wire coil(s) to 2 energize and current direction can be selected to create a 3 repulsive or attractive reaction between magnet structure 12 and 4 the energized one(s) of wire coils 14A-14C. This type of control 5 will continue during the duration of downward wave motion with 6 the control function operating to minimize or zero the vertical 7 acceleration of body 52. When the wave motion reverses 8 direction, the control process is repeated except that collar 54 9 10 will be driven upward.

The above-described reactive force occurring between collar 11 12 54 and body 52 is an electromagnetic force "F" that results from 13 wire coil structure 14 moving through the magnetic fields of magnet structure 12. Force F is a function of magnetic flux B 14 15 generated by magnet structure 12, the total length "1" of the 16 energized one(s) of wire coils 14A-14C moving through flux B, and 17 the current "i" supplied to the selected wire coil(s). 18 Specifically,

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$$F = Bli$$
 (1)

Therefore, current control device 24 can control the location and direction of electromagnetic force F acting between collar 54 and body 52 to effectively control the relative movement therebetween by i) controlling which coil(s) receives current and ii) controlling the direction of the current.

Using the above described approach, a control method can be derived (for use by controller 22) to, for example, zero the vertical acceleration of body 52. By constantly operating

controller 22 with a goal of zeroing vertical acceleration of
 body 52, the present invention automatically adapts to changing
 wave conditions while stabilizing the altitude of body 52.

Position/velocity sensors 20B can be implemented in a Δ variety of ways. One way is illustrated in FIG. 3 where a 5 plurality of magnetic field sensors 21 are distributed linearly 6 along the length of body 52. Each of sensors 21 could be a Hall 7 effect sensing coil that senses the magnetic field from magnet 8 9 structure 12. Controller 22 would use the outputs of sensors 21 to determine both position and velocity of magnet 12/collar 54 as 10 would be understood by one of ordinary skill in the art. 11

12 The advantages of the present invention are numerous. Α free-floating system can have its altitude in the water 13 stabilized in an autonomous and adaptive fashion. Thus, the 14 15 present invention can adapt to changing wave conditions. This 16 will make the present invention useful as support housing for any 17 communications or other system that needs to be maintained at a 18 stabilized altitude at the water's surface or at a specific depth thereunder. 19

Although the present invention has been described relative to a specific embodiment thereof, it is not so limited. Thus, it will be understood that many additional changes in the details, materials, steps and arrangement of parts, which have been herein described and illustrated in order to explain the nature of the invention, may be made by those skilled in the art within the principle and scope of the invention,

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FREE-FLOATING ALTITUDE STABILIZED SYSTEM

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ABSTRACT OF THE DISCLOSURE

A free-floating altitude stabilized system is provided. 6 Independently energizable wire coils are linearly aligned with 7 one another in a vertical direction on a buoyant body. An 8 induced magnetic field is generated by any of the wire coils that 9 10 are energized. A float housing a magnet is coupled to the body in such a way that it is capable of independent movement relative 11 thereto. A control system energizes a selected one or more of 12 the wire coils in such a way the magnet's magnetic field and wire 13 14 coil's induced magnetic field react with one another to generate 15 movement of the float vertically in a direction that is the same 16 as a vertical component of wave motion.



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F16.3

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