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1 Attorney Docket No. 79622

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3 EXTENDABLE HULL-MOUNTED SONAR SYSTEM

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5 STATEMENT OF GOVERNMENT INTEREST

6 The invention described herein may be manufactured and used
7 by or for the Government of the United States of America for
8 governmental purposes without the payment of any royalties
9 thereon or therefor.

10

11 CROSS REFERENCE TO OTHER PATENT APPLICATIONS

12 Not applicable.

13

14 BACKGROUND OF THE INVENTION

15 (1) Field of the Invention

16 The present invention relates generally to hull-mounted
17 sonar systems. More particularly, this invention relates to a
18 hull-mounted system to extend the location of arrays from the
19 hull to improve performance.

20 (2) Description of the Prior Art

21 Undersea craft, such as submarines use spherical arrays,
22 towed arrays, and other hull-mounted arrays for sonar sensors.
23 The size of a spherical array on a submarine is traditionally

1 limited to roughly the diameter of the submarine's hull. While
2 acceptable performance levels are provided for, an increased
3 capability for sonar detection and tracking performance is always
4 desired, especially in the forward and rearward looking
5 directions. Currently, the size of the array (volumetric
6 aperture), flow noise, and blockage due to the physical location
7 of the array on the hull, are limiting influences on sonar
8 performance. In addition, hull-mounted sonar sensors often are
9 subject to hull-borne vibrations and noises

10 Thus, in accordance with this inventive concept, a need has
11 been recognized in the state of the art for a system for
12 laterally extending sonar arrays from a submarine to provide
13 significant increases in array aperture in all directions, and to
14 fold up the arrays into grooves in the hull to reduce noise
15 during transit.

16

17 SUMMARY OF THE INVENTION

18 The first object of the invention is to provide an
19 improvement for a system for deploying and towing at least one
20 sonar array.

21 Another object of the invention is to provide a system to
22 extend sonar transducer arrays radially outwardly from a
23 longitudinal axis of a submarine to improve its performance.

1 Another object of the invention is to provide a structure
2 that extends arrays of transducers laterally from a submarine to
3 improve performance thereof and folds along the hull to reduce
4 noise during transit at higher speeds.

5 Another object of the invention is to provide an extendable,
6 hull-mounted sonar system to increase detection, classification,
7 and localization performance particularly in the forward and rear
8 directions and have improved self-noise measurement.

9 Another object of the invention is to provide for improved
10 detection for avoidance of mines, ocean-bottom sensing, under-ice
11 sensing, sensing of incoming radar and laser signals, and EMI and
12 RFI signals.

13 Another object of the invention is to provide for increased
14 array gain, volumetric aperture, and hull-borne noise rejection
15 for submarines, surface ships, weapons, and unmanned underwater
16 and surface vehicles.

17 Another object of the invention is to provide a system for
18 deploying towed arrays from and/or between each arm of deploying
19 structure to maintain high-resolution capabilities in forward,
20 aft, and side-looking directions.

21 Another object of the invention is to provide an improved
22 system for deploying arrays using either natural, or biasing

1 tension of the arms of the array or cables to deploy radially
2 extendable arms.

3 Another object of the invention is to provide a system for
4 deploying transducer arrays arranged in a three-dimensional
5 umbrella-like volume.

6 Another object of the invention is to provide a system for
7 deploying arrays capable of transmitting active acoustic and non-
8 acoustic energies and detecting passive and active acoustic
9 energy as well as non-acoustic energy at low, mid, and high
10 frequencies, and monitoring and canceling ship / hull self-
11 generated noise.

12 Another object of the invention is to provide a system for
13 deploying arrays from a submarine at all positions from fully
14 radially deployed to completely stowed in grooves on the hull of
15 the submarine to provide for sensing while underway or stopped.

16 Another object of the invention is to provide a system for
17 deploying arrays in deep water, shallow water, or shallow bottom
18 depth by adjusting the extension of the structural arms.

19 These and other objects of the invention will become more
20 readily apparent from the ensuing specification when taken in
21 conjunction with the appended claims.

22 Accordingly, the present invention provides a system to
23 extend at least one array from the hull of a submarine while it

1 is in motion. A plurality of biased arms extend radially
2 outwardly from the hull in circumferentially, nominally equal-
3 distantly-spaced relationships from one another, and passive
4 and/or active transducer elements of arrays are optionally
5 mounted on the arms, trail in the water from the arms, or extend
6 between different ones of the arms or between arms and the hull.
7 The system of arms and transducer arrays are folded into elongate
8 longitudinal grooves in the hull or within some other fairing-
9 like structures on the hull to lower noise during higher speed
10 transit by the submarine.

11

12 BRIEF DESCRIPTION OF THE DRAWINGS

13 A more complete understanding of the invention and many of
14 the attendant advantages thereto will be readily appreciated as
15 the same becomes better understood by reference to the following
16 detailed description when considered in conjunction with the
17 accompanying drawings wherein like reference numerals refer to
18 like parts and wherein:

19 FIG. 1 is an isometric view of the system of this invention
20 mounted on a submarine while underway;

21 FIG. 2 is a side view of the system of this invention
22 partially deployed or during higher speed transit by the
23 submarine;

FIG. 3 is an isometric view of the arms and the array closed and stowed in longitudinal grooves, or recesses on the outer hull of the submarine for high-speed transit; and

FIG. 4 is an isometric view of a modified system mounted on an unmanned undersea vehicle.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, umbrella-like system 10 is shown operationally deployed in an extended position to increase detection, classification, and localization and other sensor function performances, particularly in forward and aft looking directions from a suitable platform, such as submarine 50. System 10 in accordance with this invention also can be provided on other platforms including surface ships, weapons, and unmanned underwater and surface vehicles to enhance these performance capabilities in diverse applications.

System 10 has a forward ring-shaped support 12 secured to forward portion 52 on outer hull 54 of submarine 50 in a forward annular recess 56, and ring-shaped support 12 secures a plurality of arms, or arms 20 to outer hull 54. Arms 20 are made from a flexible and resilient material, such as spring steel, fiberglass, or composites, for example, that exerts a force that biases, or urges arms 20 to extend radially outwardly from

1 longitudinal axis 51 and hull 54 of submarine 50 in
2 circumferentially, nominally equal-distantly-spaced relationships
3 from one another. This relationship of arms 20 can be changed
4 and adapted to accommodate different hull designs and missions as
5 the case may be. Arms 20 have a stronger, or reinforced section
6 22 of the biased material to reduce and distribute concentrations
7 of stresses and strains in each arm 20 and help them remain
8 extended while submarine 50 is underway.

9 Each of arms 20 has a first array 30 of at least one, but
10 probably many transducers, that may include acoustic projectors
11 and/or sensors (hydrophones) appropriately mounted along their
12 length and face forward, sideward, and/or aft. The transducers,
13 or sensors for first array 30 additionally may include sensors
14 for temperature, salinity, electromagnetic energy projection and
15 detection (antennas), etc. System 10 additionally has one or
16 more nominally neutrally buoyant second arrays 32 each connected
17 to an end portion 24 of each arm 20 to trail along behind end
18 portions 24 in streamer-like fashion that will not droop or hang
19 askew across the water flow. Each second, or trailing array 32
20 also may be made up of a variety of one or many transducers that
21 may include acoustic projectors or sensors (hydrophones) and/or
22 sensors of temperature, salinity, electromagnetic energy
23 projection and detection (antennas), etc. Arrays 32 are likely

1 to be in an elongated hose-like structure that also contains
2 their power and signal transmission leads and possibly a
3 dielectric fluid. The power and signal transmission leads from
4 these arrays and others to be described below extend to and
5 through the inner pressure hull (not shown) of submarine 50 to
6 monitors and computer systems (not shown) for signal processing,
7 use, storage, and/or transmission to distant stations.

8 Some of the transducers of first and second arrays 30 and 32
9 can be disposed along the arrays and appropriately oriented
10 and/or shaded to monitor self-generated noise of submarine 50 and
11 system 10. This feature gives awareness so that improvements in
12 the design of submarine 50 and system 10 can be made and gives
13 real-time indications at preferred operational speeds to monitor
14 and minimize any own-ship radiated signals.

15 Individual fish-line-like towing cables 32a may be
16 interposed between end portions 24 and second arrays 32 so that
17 second arrays 32 can be towed through the water at least several
18 hundred feet behind submarine 50 and thus isolated from much of
19 the turbulence and own-ship noise created during passage.
20 Trailing second arrays 32 and cables 32a can be extended from
21 storage compartments (not shown) within arms 20 during their
22 deployment, and these arrays can be pulled into these

1 compartments for stowage when data gathering is completed, or
2 high-speed departure is called for.

3 A cable 40 is connected between an aft ring-shaped support
4 14 in an aft annular recess 58 in hull 54 and each end portion 24
5 of each arm 20. Ring-shaped support 14 may have internal
6 windlasses (not shown) associated with it that are each connected
7 to a separate cable 40 and are controlled from within submarine
8 50 to each selectively pay out and retrieve each cable 40, or a
9 single windlass associated with support 14 might be connected to
10 all cables 40 to are simultaneously and equally pay-out or reel-
11 in cables 40. When cables 40 are payed-out from windlasses of
12 ring-shaped support 14, the biasing of the material of arms 20
13 causes them their associated arrays 30 and 32 and cables 40 to
14 radially extend outwardly from longitudinal axis 51 in
15 circumferentially, nominally equal-distantly-spaced relationships
16 from one another to the fully extended position as shown in FIG.
17 1. This extension of arms 20 and first and second arrays 30 and
18 32 will be maintained at a predetermined design speed (about five
19 knots) so that arrays 30 and 32 can transmit, receive, and sense
20 data. When speed of submarine 50 is increased beyond the design
21 speed, or if cables 40 are partially retrieved, or reeled-in by
22 windlasses of aft ring-shaped support 14, the biasing force of
23 the biasing material of arms 20 is overcome, and each arm 20

1 bends, and arrays 30 and 32 are pulled toward and closer to hull
2 54, see FIG. 2 in conjunction with FIG. 1. This shape of arms 20
3 and their sensors of first and second arrays 30 and 32 might be
4 created and maintained by reeled-in cables 40 or the flow of
5 seawater during higher speed transit.

6 Preferably, during higher speed transit, each interconnected
7 cable 40 can be reeled-in more completely on its windlass of aft
8 ring-shaped support 14 and each second array 32 and cable 32a are
9 pulled, or retracted into their respectively interconnected arm
10 20. Then, further reeling-in of each cable 40 causes each of
11 arms 20 with its stowed array 32 and exposed array 30 to be
12 stowed in a separate one of a plurality of elongated longitudinal
13 grooves 60 in hull 54, see FIG. 3 in conjunction with FIGS. 1 and
14 2. Each longitudinal groove 60 is sized to receive and stow a
15 separate arm 20 and arrays 30 and 32. Stowage of arms 20 and
16 arrays 30 and 32 in longitudinal grooves 60 reduces flow noise
17 that would otherwise be created if they were left outside hull
18 54. Since transducers, including sensors and projectors, of
19 array 30 may be exposed to the ambient water, they can remain
20 activated to receive and/or transmit data while arms 20 and
21 arrays 30 and 32 are stowed in longitudinal grooves 60. This
22 feature allows submarine 50 to have multi-array sensing along the

1 longitudinal length of hull 54 while at rest or any speed
2 underway.

3 Optionally, aft ring-shaped support need not be at the aft-
4 most position on submarine 50 but could be located somewhat
5 forward. This option allows arms 20, their associated arrays and
6 grooves 60 to be shorter with a consequent reduction in aperture
7 that may be adequate for less demanding data-gathering needs.

8 An active lifting structure 26 can be mounted on each of end
9 portions 24 of arms 20 (only a few are shown to avoid cluttering
10 the drawings). Lifting structure 26 has vane-like surfaces (not
11 shown) that hydro-dynamically react with the flow of water during
12 transit of submarine 50. This reaction creates a force that
13 augments the biasing force of arms 20 to assist the radial
14 displacement of arms 20 from longitudinal axis 51 to their fully
15 extended position. A compartment (not shown) may be contained in
16 each lifting structure 26 to deploy and stow each array 32 and
17 towing cable 32a. When lifting structures 26 are used, a
18 suitable stowage recess 60a is provided adjacent to each groove
19 60 in hull 54 to receive the lifting structures during high-speed
20 transit.

21 In addition to first arrays 30 on arms 20 and second arrays
22 32 trailing behind arms 20, system 10 can have third arrays 34 of
23 transducers that may include projectors and sensors transversely

1 extending between different ones of arms 20, and fourth arrays 36
2 of transducers that may include projectors and sensors that can
3 be supported on cables 30 where they reach between end portions
4 24 of arms 20 and aft ring-shaped support 14. Arrays 34 and 36
5 may be retracted, or pulled into arms 20 and aft ring-shaped
6 support 14 when need be. This composite arrangement of arrays
7 30, 32, 34, and 36 can be selectively tailored with sensors,
8 spacing, weighting, and orientation to assure gathering of
9 discrete data from different sources of interest within the
10 three-dimensional volumetric umbrella created by system 10. The
11 transducers of arrays 30 and 32, and optionally arrays 34 and 36
12 provide a composite volumetric sensor array having an aperture of
13 ten, twenty, or even thirty times the diameter of a spherical
14 array that would fit inside the platform, in this case submarine
15 50.

16 System 10 can be back-fitted onto existing conventional
17 submarines. In this case, the conventional submarine does not
18 have forward annular recess 56 and aft annular recess 58 of
19 submarine 50 supra. Instead, forward ring-shaped support 12 and
20 aft ring-shaped support 14 are adapted to be slipped onto the
21 outer forward and aft surfaces of the outer hull of the
22 conventional submarine that are, generally speaking, tapered.
23 Frictional engagement may be all that is needed, although

1 additional attachment structure for clamping the supports on the
2 hull may be needed. In addition, since the conventional
3 submarine has no longitudinal grooves 60 as described with
4 respect to submarine 50, the arms and arrays lie on the outer
5 surface of the outer hull during high-speed transit, or suitable
6 hull-mounted fairings might be added. Electrical power and
7 data leads would be coupled through the inner pressure hull as
8 described above. This capability would allow a conventional
9 submarine to be temporarily fitted with system 10, which can be
10 removed at the end of deployment, or left in a remote area as a
11 remote monitoring station to transmit signals back to the
12 submarine, surface ship, or other vessel. However, when system
13 10 is to be left to function as a remote station, a self-
14 contained power supply, transmitter, and processing electronics,
15 etc., must be left behind with it. When the array is being used
16 while attached to the submarine, power and data is transmitted
17 between the sub and the array via a suitable multi-function
18 cable.

19 Referring to FIG.4, another option for system 10 is to place
20 it on autonomous or towed unmanned submersibles 70 (or surface
21 craft) to improve their capabilities. An exemplary unmanned
22 autonomous submersible 70 capable of remote preprogrammed or
23 remotely controlled operations is depicted and has arms 20 with

reinforced sections 22 and cables 40 deploying and retrieving one or more of arrays 30, 32 (and cables 32a), 34a, and 36 downwardly and outwardly from its bottom side 72. A sample application of this arrangement might be used to sense and map the location of mines so that they can be avoided, destroyed or otherwise dealt with. The arms and sensors could be extended otherwise for other sensing purposes. Another option would be to deploy other autonomous submersibles 70 having different packages of sensors and/or different orientations of arms and arrays to monitor different phenomena. Many operational options are available, such as, letting such submersibles 70 lie on the bottom for some time, and then activate them to monitor a region or launch an attack. A towed design might also be used; however, it might be better to tow such a submersible 70 behind and to the side of a towing vessel to avoid activation of ordnance by the towing craft. System 10 in accordance with this invention is a welcome modification for unmanned craft, because they usually are smaller and inherently have a limited acoustic apertures and related acoustic capabilities. Thus, system 10 can be modified with different arrays at different orientations to selectively expand the capabilities of these unmanned craft.

Referring to FIG. 3, the deployment sequence of system 10 first, has arms 20 stowed in longitudinal grooves 60. Next, arms

1 20 are extended radially outwardly from longitudinal axis 51 of
2 submarine 50 either by the natural biasing action or tensile
3 stiffness of the biasing material of arms 20 and/or the force
4 produced by active lifting structures 26 hydro-dynamically
5 reacting with the flow of water as submarine 50 is underway, see
6 FIG. 2. Gear systems or pneumatic piston structure inside of
7 hull 54 might be made available to help radially outwardly
8 displace arms 20. FIG. 1 shows first array 30 in its fully
9 deployed (open) position, and second, third and fourth arrays 32,
10 34, and 36 are extended and deployed in a three-dimensional
11 umbrella-like volume. Retrieval of arms and arrays calls for
12 reversing this sequence. Arrays are retracted and cables 40 are
13 reeled-in to pull the arms and arrays into longitudinal grooves
14 60 into the stowed position.

15 System 10 in accordance with this invention provides
16 increased detection, classification, and localization performance
17 in forward and rearward looking directions, and gives improved
18 self-noise measurement for submarines, surface ships, weapons,
19 and unmanned underwater and surface vehicles. System 10 also
20 allows for increased array gain, volumetric aperture (very large
21 aperture arrays), and rejection of hull-borne noise over existing
22 submarine sonar and other sensor systems. When various sensors
23 are mounted on this device it can also be used as a platform for

1 mine avoidance, ocean bottom sensing, under ice sensing, radar
2 detection, laser detection, and electromagnetic/radio detection.
3 Each arm 20 can additionally deploy towed second arrays 32 of
4 transducers which may include sensors and projectors to detect
5 passive and active acoustic energy as well as non-acoustic energy
6 at low, mid, and high frequencies. System 10 of arrays of
7 sensors can monitor ship / hull own self noise and can fully use
8 its sensors even when in the fully stored position. System 10
9 can deploy lines of hydrophone arrays or other sensors strung
10 between arms 20 for detection purposes and can deploy its sensor
11 arms 20 at any position from fully deployed to fully stored in
12 grooves, even while the submarine (or other vessel) is moving
13 forward through the water. System 10 can use its sensors even
14 when in the fully stored position and adapts for use in deep
15 water, shallow water, or shallow bottom depth by adjusting the
16 deployment of the individual arms. System 10 reduces drag caused
17 by the flow of water at higher speeds due to bending of arms 20
18 with the flow of water and maintains high resolution forward,
19 rearward, and side-looking capabilities at all submarine (or
20 other vessel) speeds.

21 Having the teachings of this invention in mind,
22 modifications and alternate embodiments of this invention may be
23 fabricated to have a wide variety of applications in other

1 systems. For example, while system 10 is disclosed herein as a
2 system of up to four arrays, it is clear that other
3 configurations of arms 20 and arrays may be provided or the
4 sensors in the arrays could be different within the scope of this
5 inventive concept. One skilled in the art to which this
6 invention pertains could make such modifications to accommodate
7 different rates of dynamic flow of water past submarine 50 and
8 still be within the scope of this invention.

9 The disclosed components and their arrangements as disclosed
10 herein all contribute to the novel features of this invention.
11 System 10 of this invention provides a reliable and cost-
12 effective means to improve the capabilities of arrays of sensors
13 for a vessel underway. Therefore, system 10 as disclosed herein
14 is not to be construed as limiting, but rather, is intended to be
15 demonstrative of this inventive concept.

16 It will be understood that many additional changes in the
17 details, materials, steps and arrangement of parts, which have
18 been herein described and illustrated in order to explain the
19 nature of the invention, may be made by those skilled in the art
20 within the principle and scope of the invention.

1 Attorney Docket No. 78622

2
3 EXTENDABLE, HULL MOUNTED SONAR SYSTEM

4
5 ABSTRACT OF THE DISCLOSURE

6 A system to extend transducer arrays from the hull of a
7 vessel while it is underway provides for increased array gain,
8 volumetric aperture (very large aperture arrays), and rejection
9 of hull-bound noise for submarines, surface ships, weapons, and
10 unmanned underwater and surface vehicles. A plurality of arms
11 extend radially outwardly from the hull of a submarine, and
12 passive and/or active elements of the arrays are mounted around
13 the hull on the arms, trail in the water from the arms, or extend
14 between different ones of the arms or between arms and the hull.
15 The system of arms and the array are folded into elongate
16 recesses in the hull to lower noise during higher speed transit
17 by the submarine. The arrays can be made up of sensors and/or
18 projectors of radar, sonar signals, optical energy, vibrational
19 energy, magnetic influence, temperature, etc., and combinations
20 of these sensors.

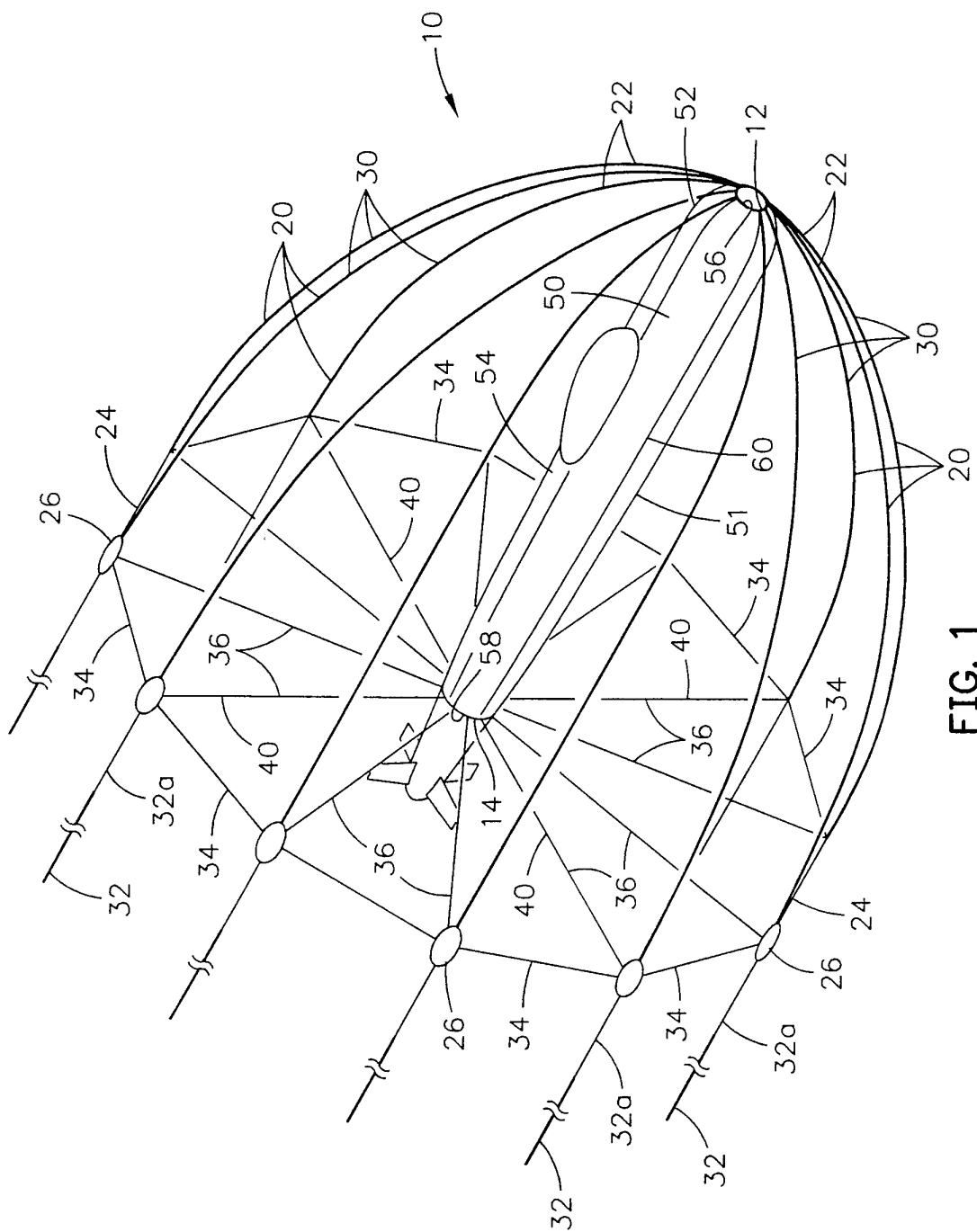
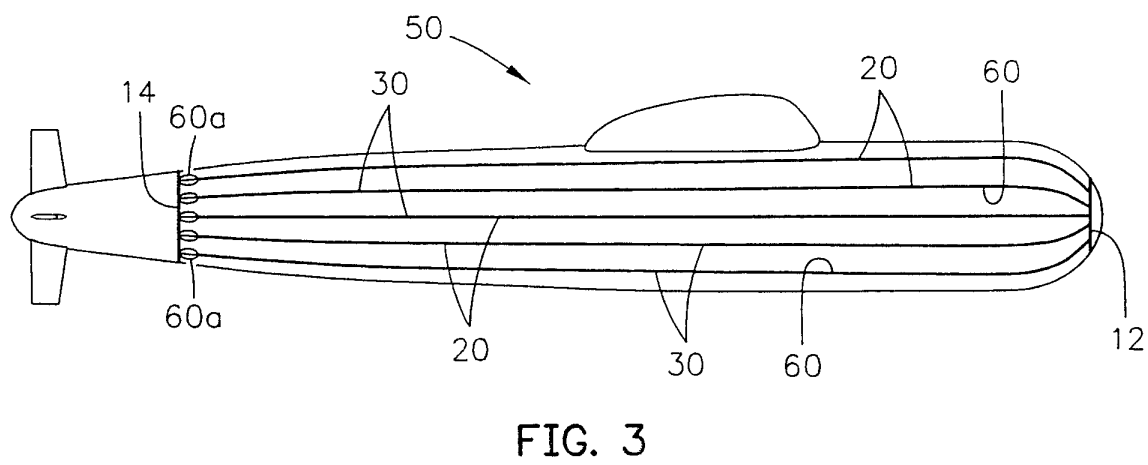
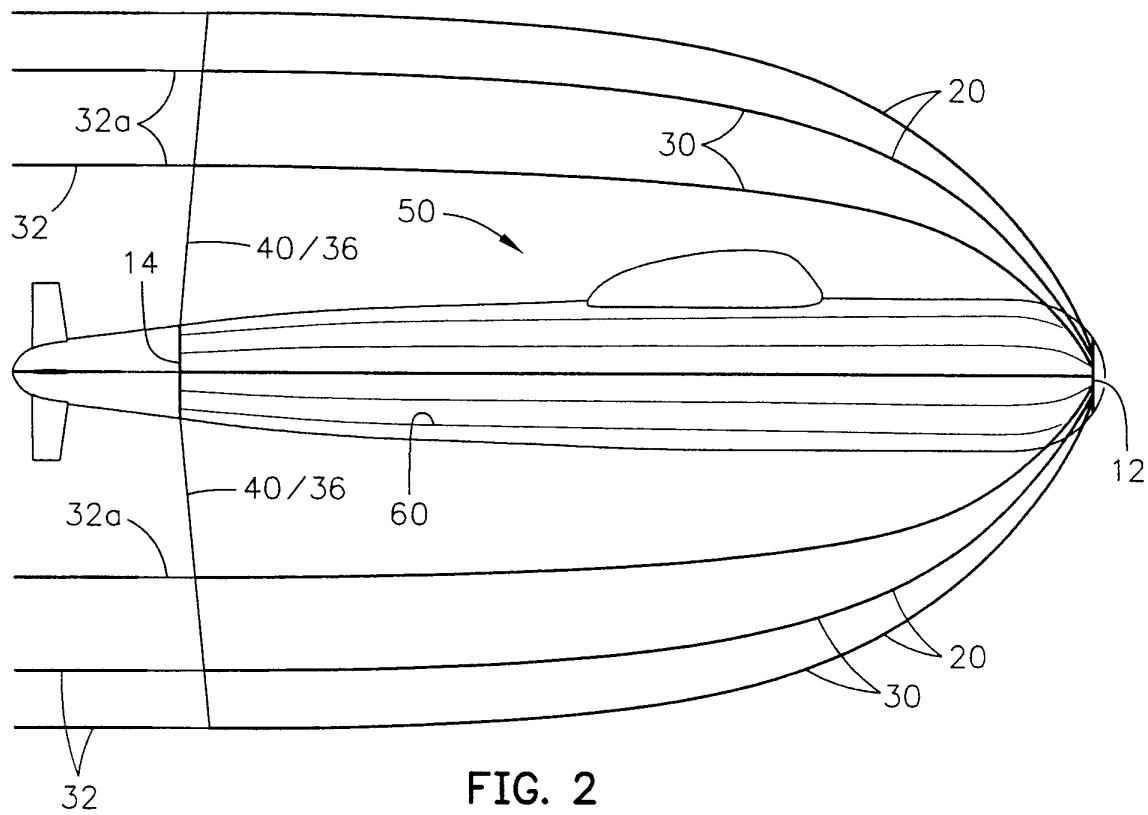


FIG. 1



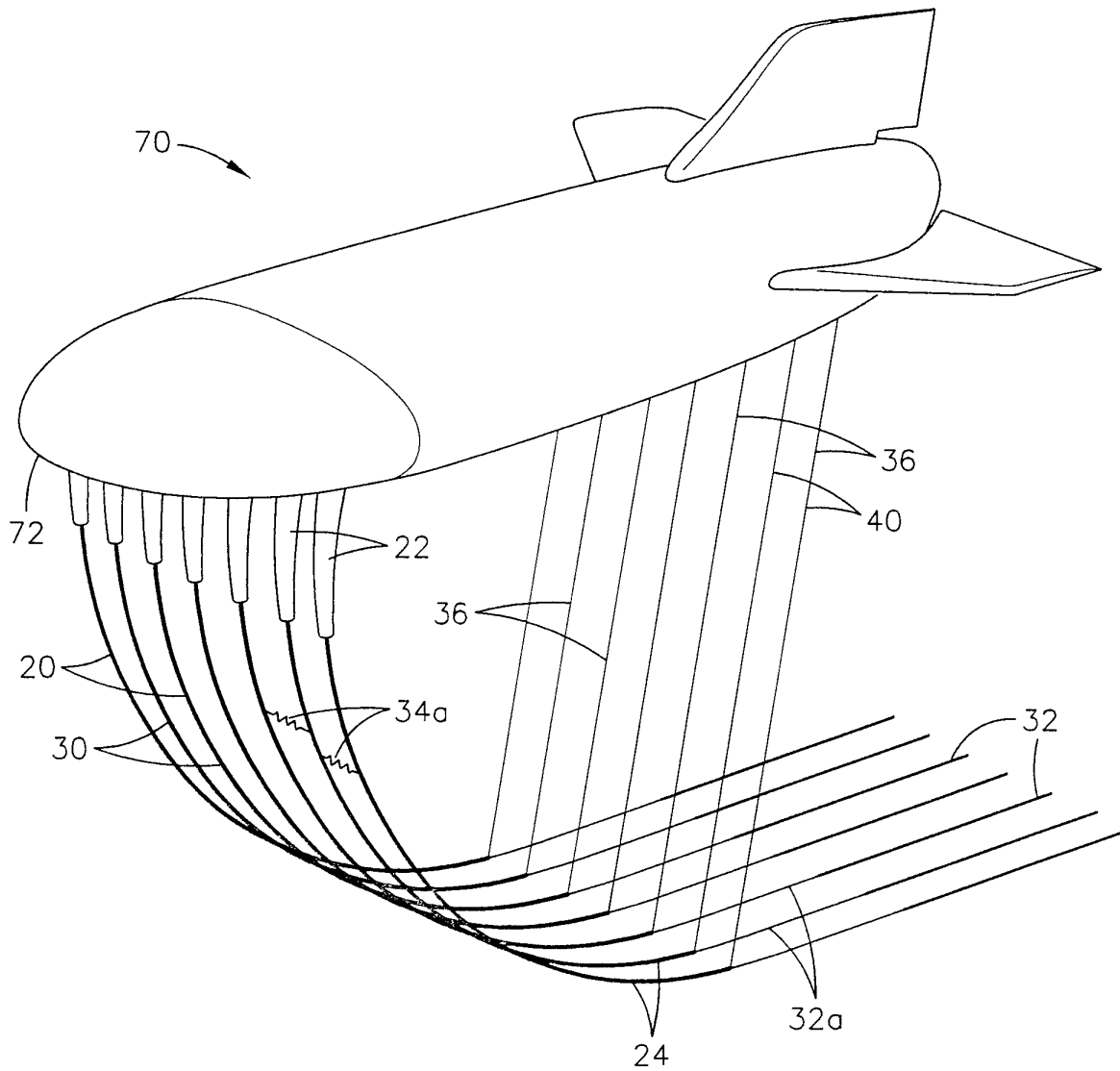


FIG. 4