S/H

IN THE UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF OKLAHOMA

(1) NAVICO INC. and NAVICO HOLDING AS,

Plaintiffs,

v.

(2) RAYMARINE, INC.,

Defendant.

Case No. 13 CV - 554 CVE - TLW

Jury Trial Demanded

COMPLAINT

Plaintiffs Navico Inc. and Navico Holding AS (collectively "Navico") hereby file this Complaint ("Complaint") against Raymarine, Inc. ("Raymarine"), and allege on personal knowledge as to their actions, and upon information and belief as to the actions of others, as follows:

NATURE OF THE SUIT

1. This is a claim for patent infringement arising under the patent laws of the United States, Title 35 of the United States Code.

THE PARTIES

2. Navico Inc. is a corporation organized and existing under the laws of the State of Delaware, having a principal place of business at 4500 South 129th East Avenue, Suite 200, Tulsa, Oklahoma 74134.

Fees Pd

3. Navico Holding AS is a corporation organized and existing under the laws of Norway, having a principal place of business at Nyaskaiveien 2, 4370 Egersund, Norway.

4. Navico Inc. is a supplier of marine electronic equipment.

5. On October 30, 2012, United States Patent No. 8,300,499 ("the '499 patent") was duly and legally issued for an invention entitled, "Linear and Circular Downscan Imaging Sonar." A true and correct copy of the '499 patent is attached hereto at Exhibit A.

6. On November 6, 2012, United States Patent No. 8,305,840 ("the '840 patent") was duly and legally issued for an invention entitled, "Downscan Imaging Sonar." A true and correct copy of the '840 patent is attached hereto as Exhibit B.

7. Navico Holding AS is the owner and assignee of the '499 patent, and Navico Inc. is an exclusive licensee under the '499 patent. Together, Navico owns all right, title, and interest in and to the '499 patent.

8. Navico Holding AS is the owner and assignee of the '840 patent, and Navico Inc. is an exclusive licensee under the '840 patent. Together, Navico owns all right, title, and interest in and to the '840 patent.

9. Upon information and belief, Raymarine is a corporation organized and existing under the laws of the State of Delaware, having a principal place of business at 9 Townsend West, Nashua, New Hampshire 03063.

JURISDICTION AND VENUE

10. This Court has subject matter jurisdiction over this action upon at least the following grounds:

(a) 28 U.S.C. § 1331, this being a civil action arising under the laws of the United States; and

(b) 28 U.S.C. § 1338(a), this being a civil action arising under the Patent Laws of the United States, namely, 35 U.S.C. § 1 *et seq.*;

11. This Court has personal jurisdiction over Raymarine inasmuch as Raymarine is doing business in this State, has significant contacts with this State, has offered for sale and sold infringing products in this State, maintains sales representatives in this State, has purposefully shipped or caused to be shipped infringing products into this State through established distribution channels, and/or has committed acts in this State that are the subject of the counts set forth herein.

12. Venue is proper in this District under the provisions of 28 U.S.C. § 1391(b) and (c) insofar as Raymarine has committed acts of infringement in this District.

COUNT I
INFRINGEMENT OF THE '499 PATENT UNDER 35 U.S.C. § 271

13. Navico incorporates by reference the allegations contained in Paragraphs 1 through 12 above.

14. Pursuant to 35 U.S.C. § 282, the '499 patent is presumed valid.

15. Raymarine has made, used, sold, offered to sell, and/or imported into the United States sonar systems with linear and circular downscan imaging, including but not limited to Raymarine's Dragonfly sonar/GPS with CHIRP DownVision, a68, a78, CP100, CPT100, CPT110, and CPT120, that infringe the '499 patent, and continues to do so without authority from Navico.

16. Raymarine is directly infringing, literally and/or under the doctrine of equivalents, the '499 patent, including but not limited to Claim 1 of the '499 patent.

17. Raymarine's infringing acts include, but are not limited to, the manufacture, use, sale, offer for sale, and/or importation of infringing sonar systems, including but not limited to Raymarine's Dragonfly sonar/GPS with CHIRP DownVision, a68, a78, CP100, CPT100, CPT110, and CPT120. Raymarine is therefore liable for direct infringement of the '499 patent pursuant to 35 U.S.C. § 271(a).

18. Raymarine has indirectly infringed the '499 patent by inducing infringement under 35 U.S.C. § 271(b) and by contributing to infringement under 35 U.S.C. § 271(c).

19. Raymarine markets, advertises, sells, and offers for sale its sonar systems, including but not limited to Raymarine's Dragonfly sonar/GPS with CHIRP DownVision, a68, a78, CP100, CPT100, CPT110, and CPT120, to retailers, distributors, and end users.

20. Raymarine's retailers, distributors, and end users directly infringe, literally and/or under the doctrine of equivalents, the '499 patent by acts which include, but are not limited to, using the infringing sonar systems in a manner claimed in the '499 patent.

21. Raymarine has knowledge of the '499 patent and has known of the '499 patent since at least as early as February 18, 2013, when Navico sent Raymarine a letter advising of the '499 patent.

22. Despite knowledge of the '499 patent, Raymarine actively encourages and induces its retailers, distributors, and end users to infringe the '499 patent through, among other things, Raymarine's marketing materials, advertising materials, user manuals, and

likelihood that its actions constitute infringement and/or having a deliberate disregard of, or being willfully blind to, its infringement.

40. Raymarine's infringing activities have harmed Navico, and Navico is entitled to recover damages adequate to compensate it for such infringement. Further, Raymarine's infringing activities are harming Navico and will continue to harm Navico, causing irreparable injury for which there is no adequate remedy at law unless and until preliminarily and permanently enjoined by the Court.

RELIEF SOUGHT

WHEREFORE, Navico respectfully requests that the Court enter judgment against Raymarine and against its subsidiaries, successors, parents, affiliates, officers, directors, agents, servants, employees, and all persons in active concert or participation with them, granting the following relief:

A. The entry of judgment in favor of Navico and against Raymarine for direct infringement of the '499 patent;

B. The entry of judgment in favor of Navico and against Raymarine for indirect infringement of the '499 patent by inducing such infringement;

C. The entry of judgment in favor of Navico and against Raymarine for indirect infringement of the '499 patent by contributing to such infringement;

D. The entry of judgment in favor of Navico and against Raymarine for direct infringement of the '840 patent;

E. The entry of judgment in favor of Navico and against Raymarine for indirect infringement of the '840 patent by inducing such infringement;

F. The entry of judgment in favor of Navico and against Raymarine for indirect infringement of the '840 patent by contributing to such infringement;

G. An award of damages against Raymarine for an amount that will adequately compensate Navico for Raymarine's infringement, but under no circumstances an amount less than a reasonable royalty for Raymarine's use of Navico's patented inventions as permitted by 35 U.S.C. § 284;

H. An award to Navico of all remedies available under 35 U.S.C. §§ 284 and 285;

I. A preliminary and permanent injunction prohibiting Raymarine and its subsidiaries, successors, parents, affiliates, officers, directors, agents, servants, employees, and all persons in active concert or participation with them, from further infringement of the '499 patent;

J. A preliminary and permanent injunction prohibiting Raymarine and its subsidiaries, successors, parents, affiliates, officers, directors, agents, servants, employees, and all persons in active concert or participation with them, from further infringement of the '840 patent;

K. The entry of judgment in favor of Navico and against Raymarine for pre-judgment and post-judgment interest on all damages awarded to Navico; and

L. The entry of such other and further relief that Navico is entitled to under law and any other and further relief that this Court or a jury may deem just and proper.

<u>DEMAND FOR JURY TRIAL</u>

Navico requests a trial by jury on all issues presented in this Complaint.

Dated: August 26, 2013

Respectfully submitted,

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EXHIBIT A

US008300499B2

(12) **United States Patent**
Coleman et al.

(10) **Patent No.: US 8,300,499 B2**
(45) **Date of Patent: Oct. 30, 2012**

(54) **LINEAR AND CIRCULAR DOWNSCAN IMAGING SONAR**

(75) Inventors: **Aaron R. Coleman**, Broken Arrow, OK (US); **Jeffrey W. Hanoch**, Broken Arrow, OK (US); **Brian T. Maguire**, Broken Arrow, OK (US)

(73) Assignee: **Navico, Inc.**, Tulsa, OK (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 265 days.

(21) Appl. No.: **12/460,093**

(22) Filed: **Jul. 14, 2009**

(65) **Prior Publication Data**

US 2011/0013484 A1 Jan. 20, 2011

(51) **Int. Cl.**
G01S 15/00 (2006.01)

(52) **U.S. Cl.** **367/88**

(58) **Field of Classification Search** 367/87, 367/88

See application file for complete search history.

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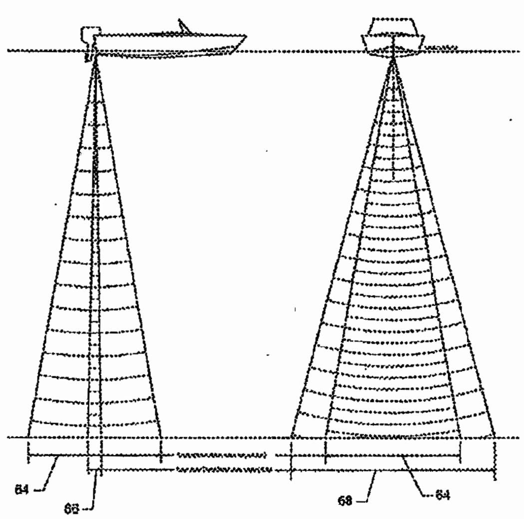
(57) **ABSTRACT**

A method for providing a combined linear and circular downscan sonar display may include receiving linear downscan sonar data from a linear downscan transducer, receiving conical downscan sonar data from a circular downscan transducer, and combining the linear downscan sonar data and the conical downscan sonar data to produce combined downscan sonar data. A corresponding computer program product and apparatus are also provided.

81 Claims, 17 Drawing Sheets
(5 of 17 Drawing Sheet(s) Filed in Color)



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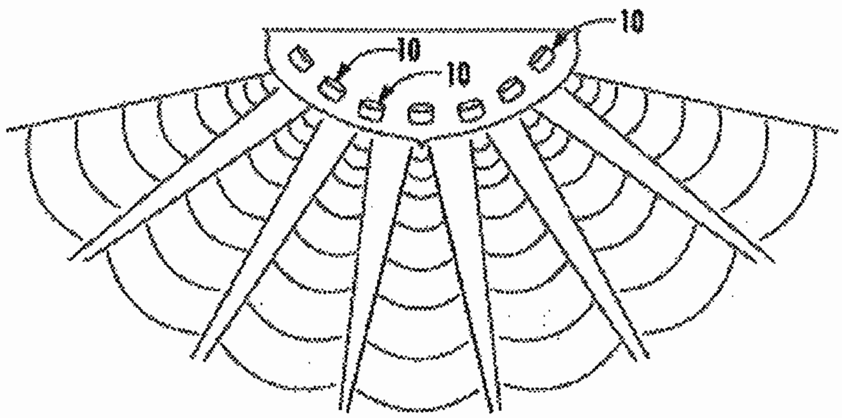


FIG. 1
(PRIOR ART)

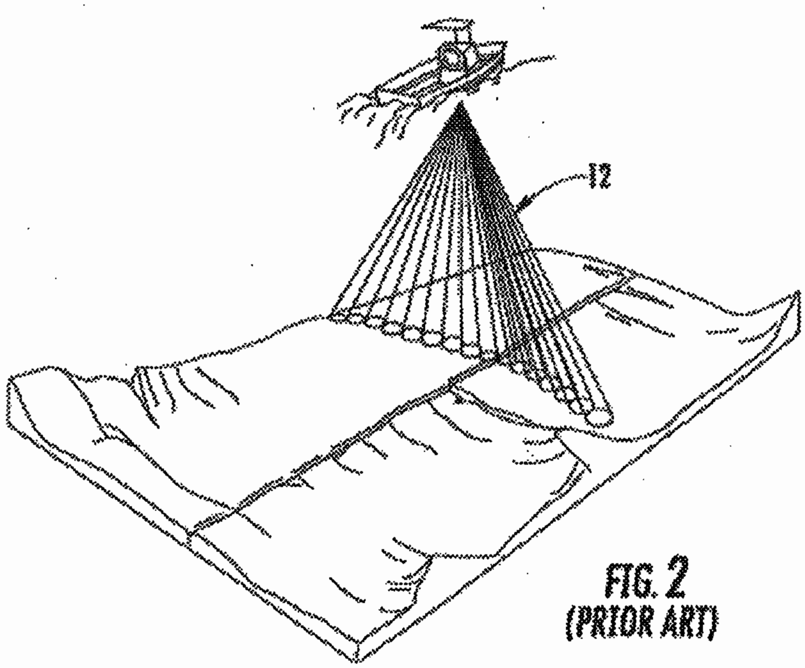


FIG. 2
(PRIOR ART)

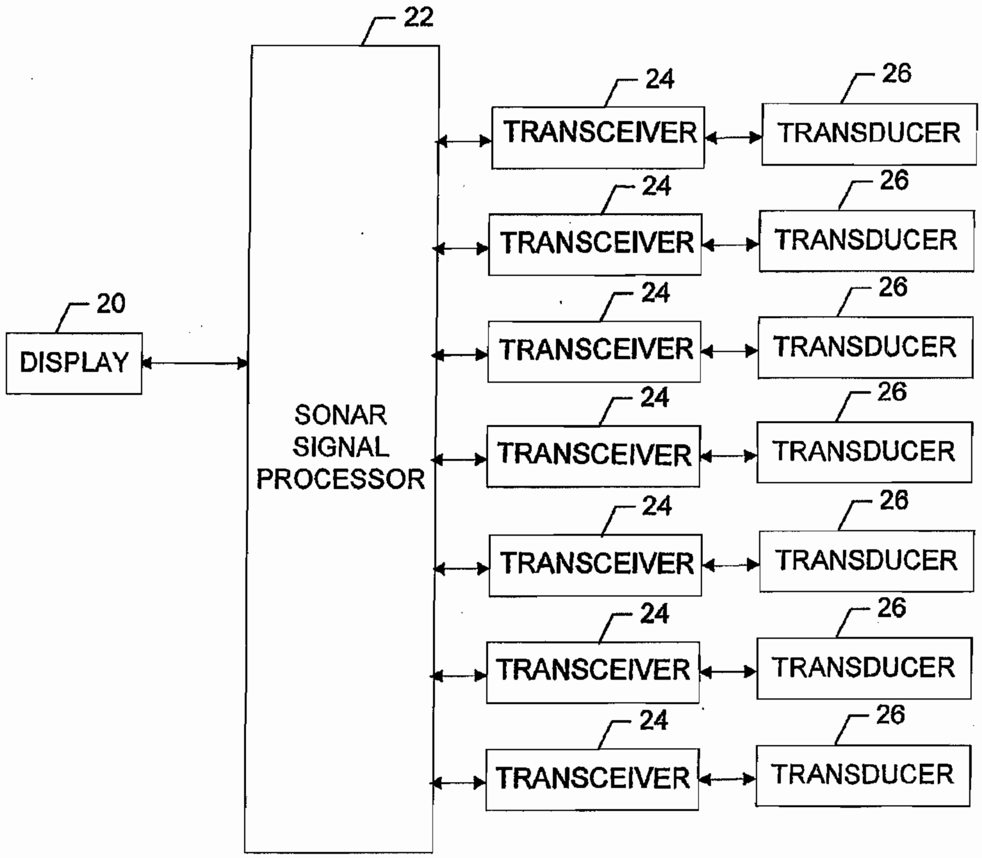


FIG. 3.
(Prior Art)

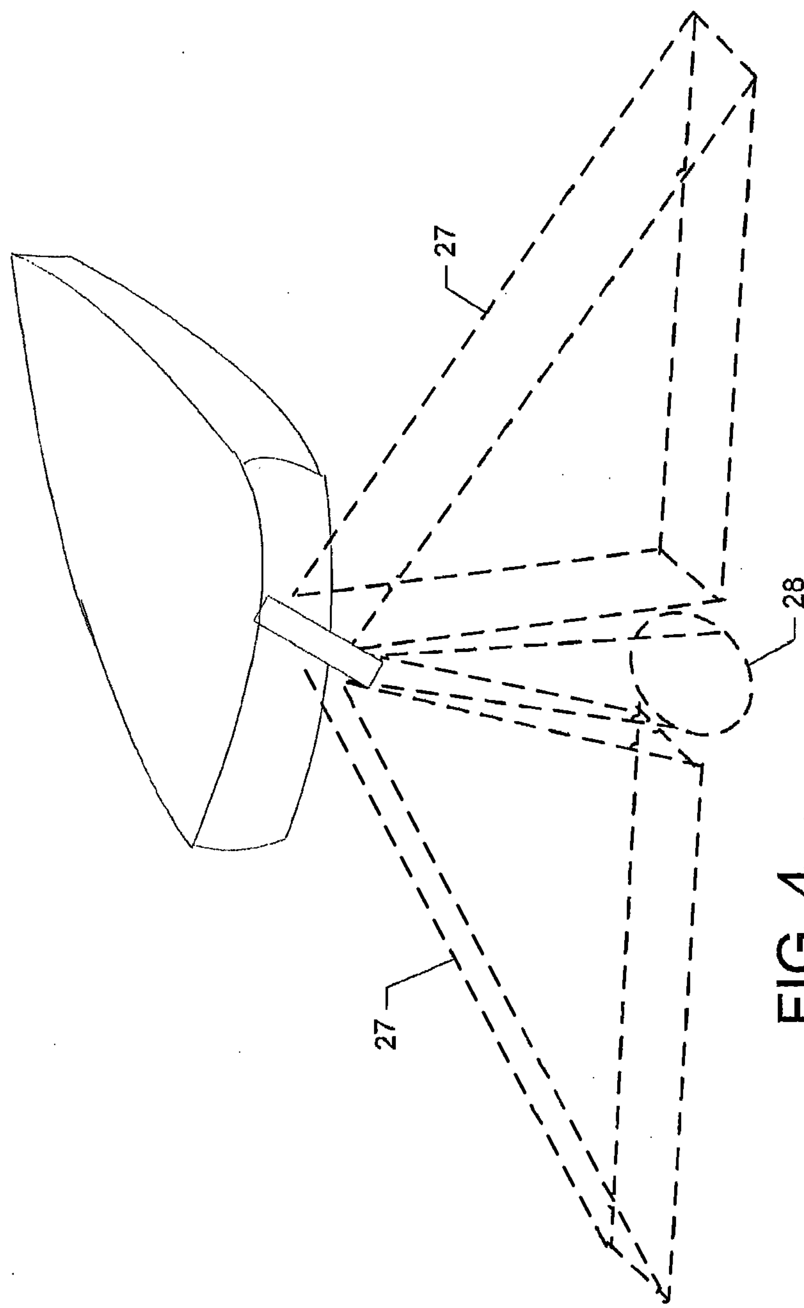
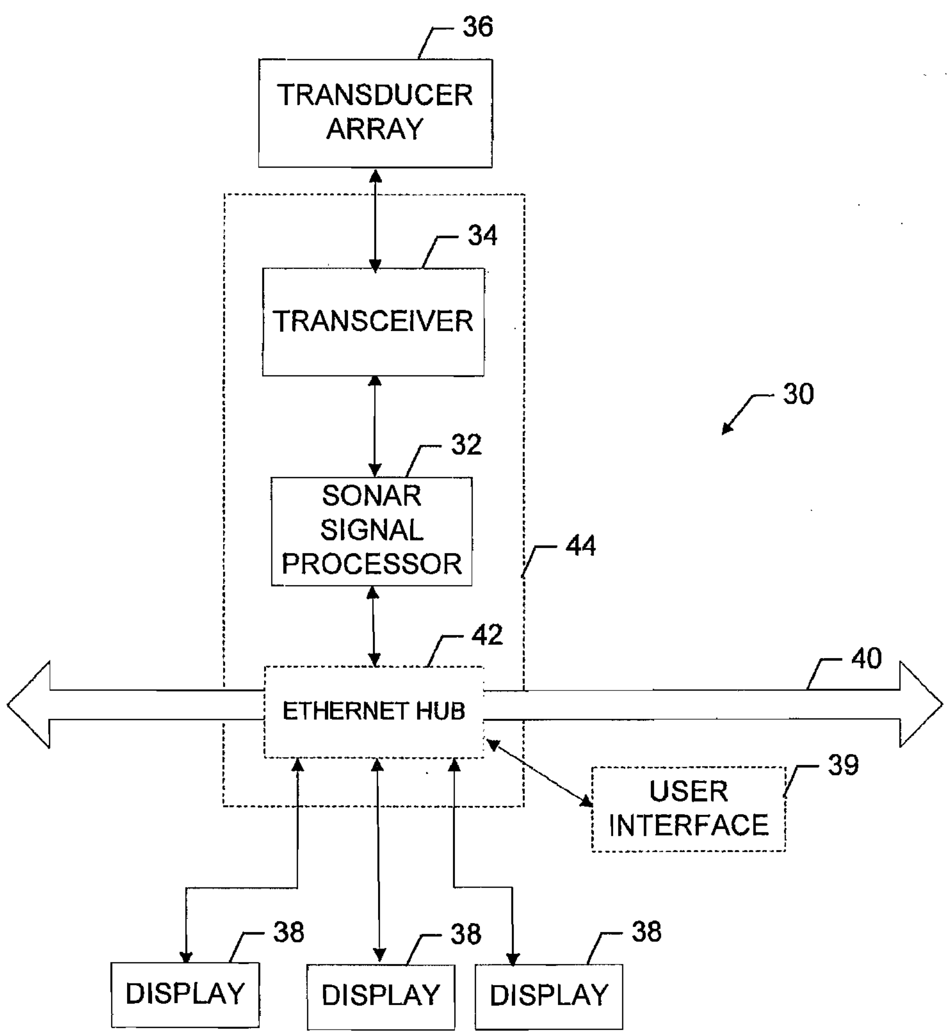


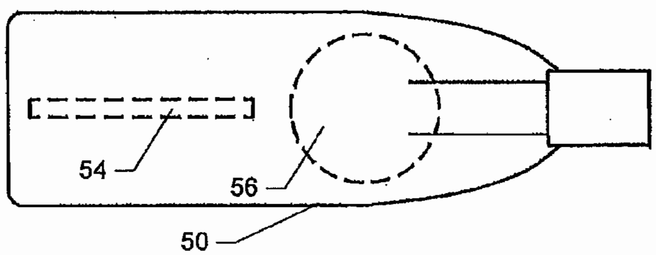
FIG. 4.
(Prior Art)



36
TRANSDUCER ARRAY
34
TRANSCEIVER
30
32
SONAR SIGNAL PROCESSOR
44
42
40
ETHERNET HUB
39
USER INTERFACE
38
DISPLAY
38
DISPLAY
38
DISPLAY

FIG. 5.

FIG. 6A.



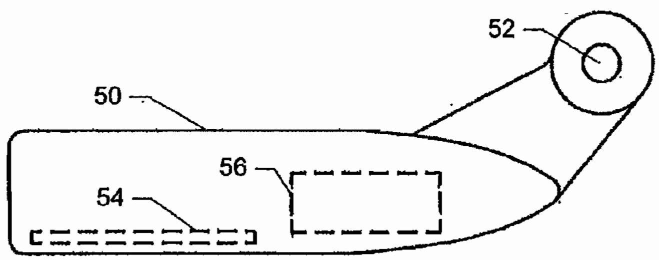


FIG. 6B.

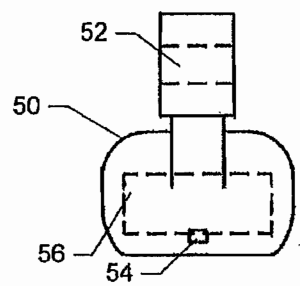
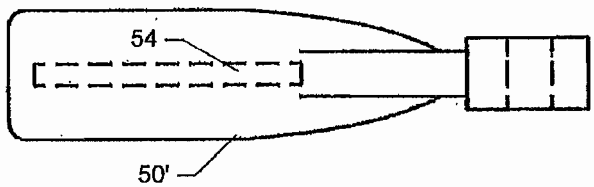


FIG. 6C.

FIG. 7A.



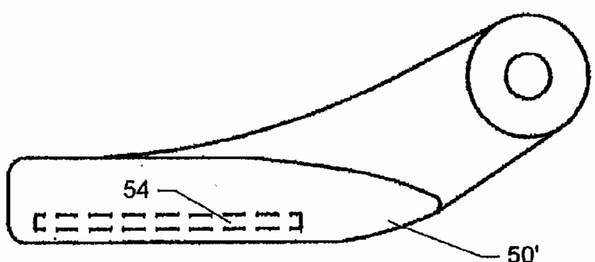


FIG. 7B.

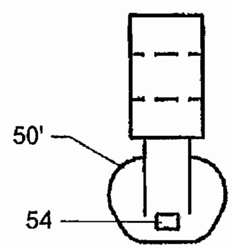
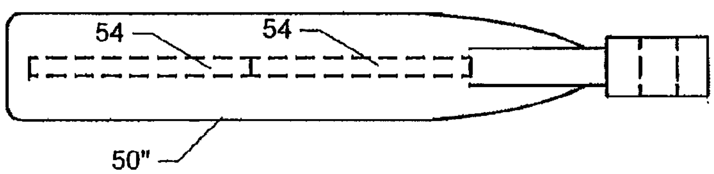


FIG. 7C.

FIG. 8A.



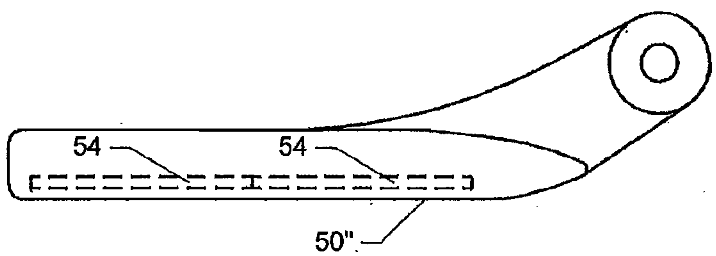


FIG. 8B.

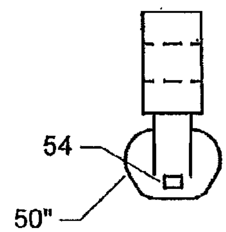


FIG. 8C.

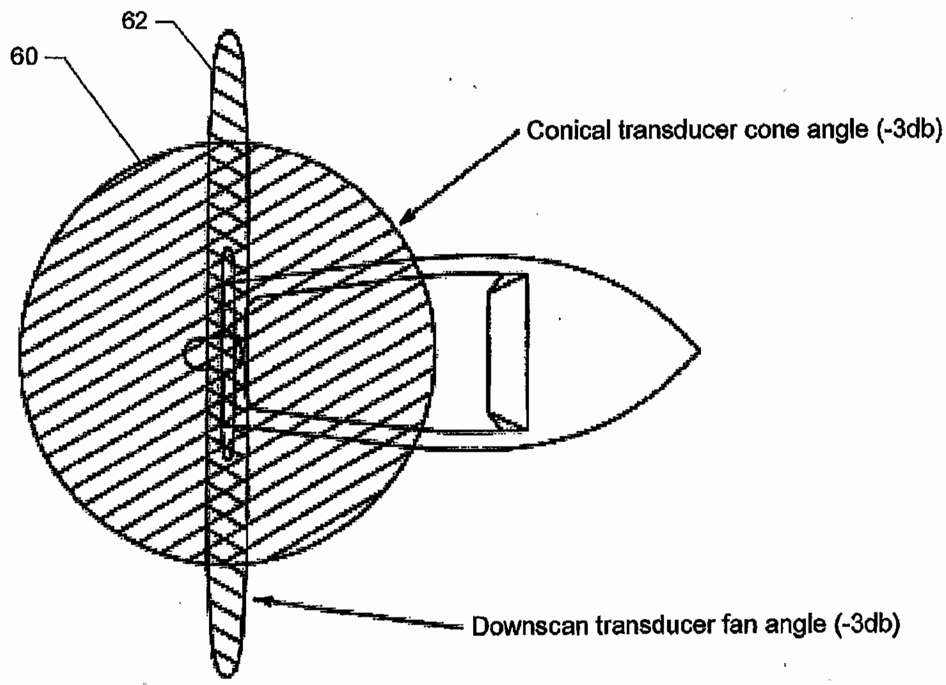

62
60
Conical transducer cone angle (-3db)
Downscan transducer fan angle (-3db)

FIG. 9A.

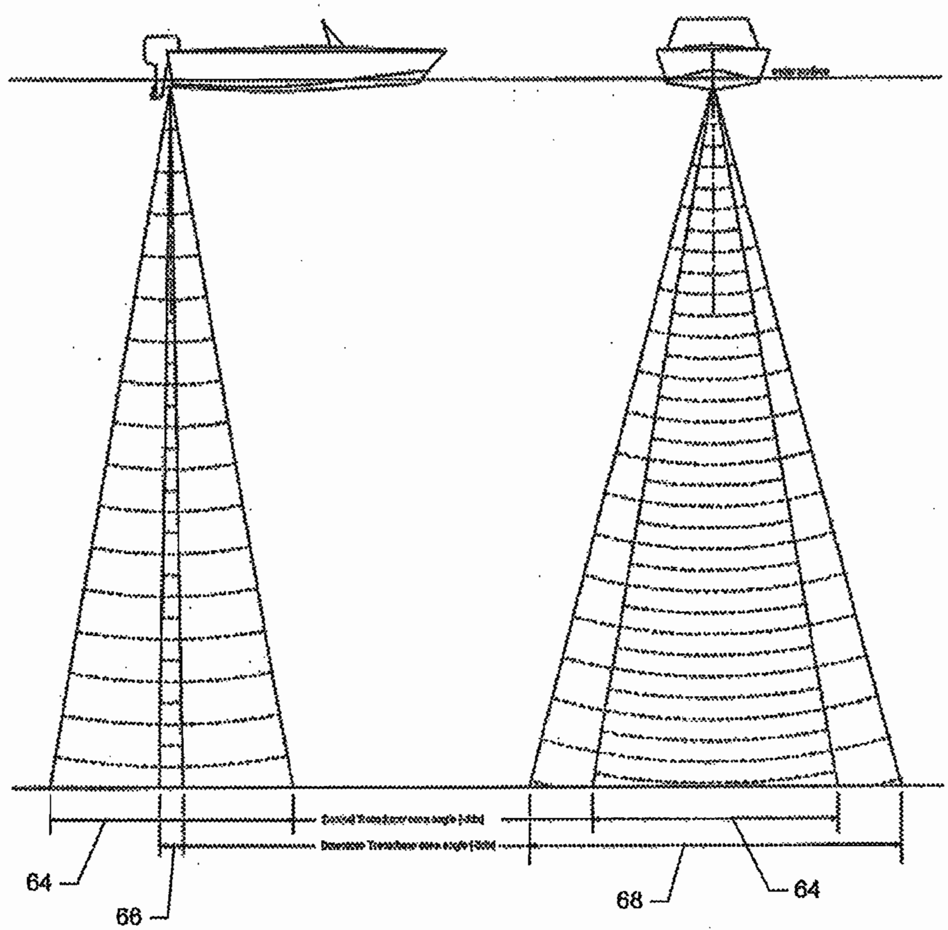


FIG. 9B.

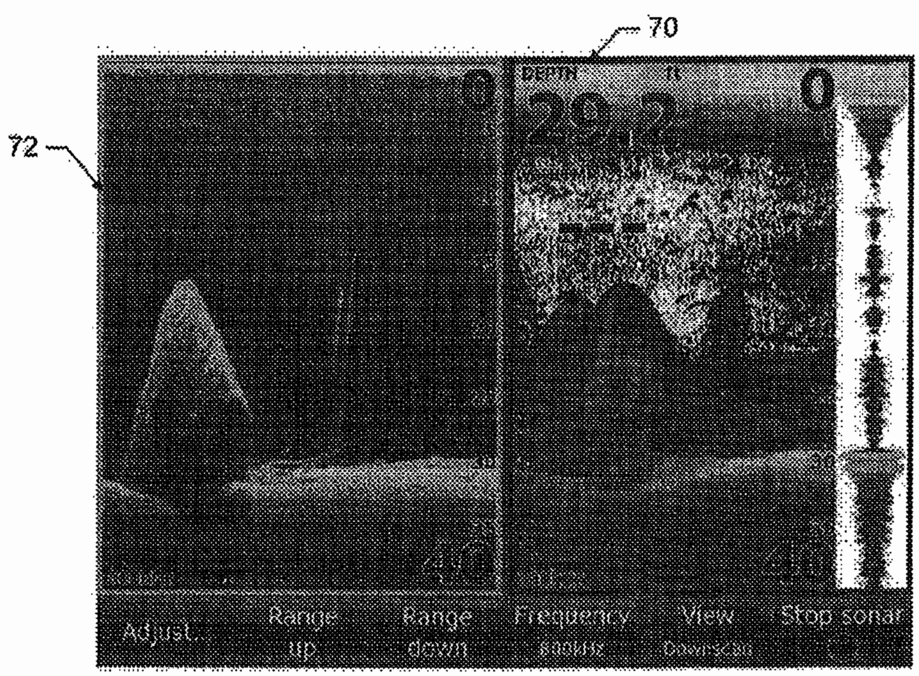
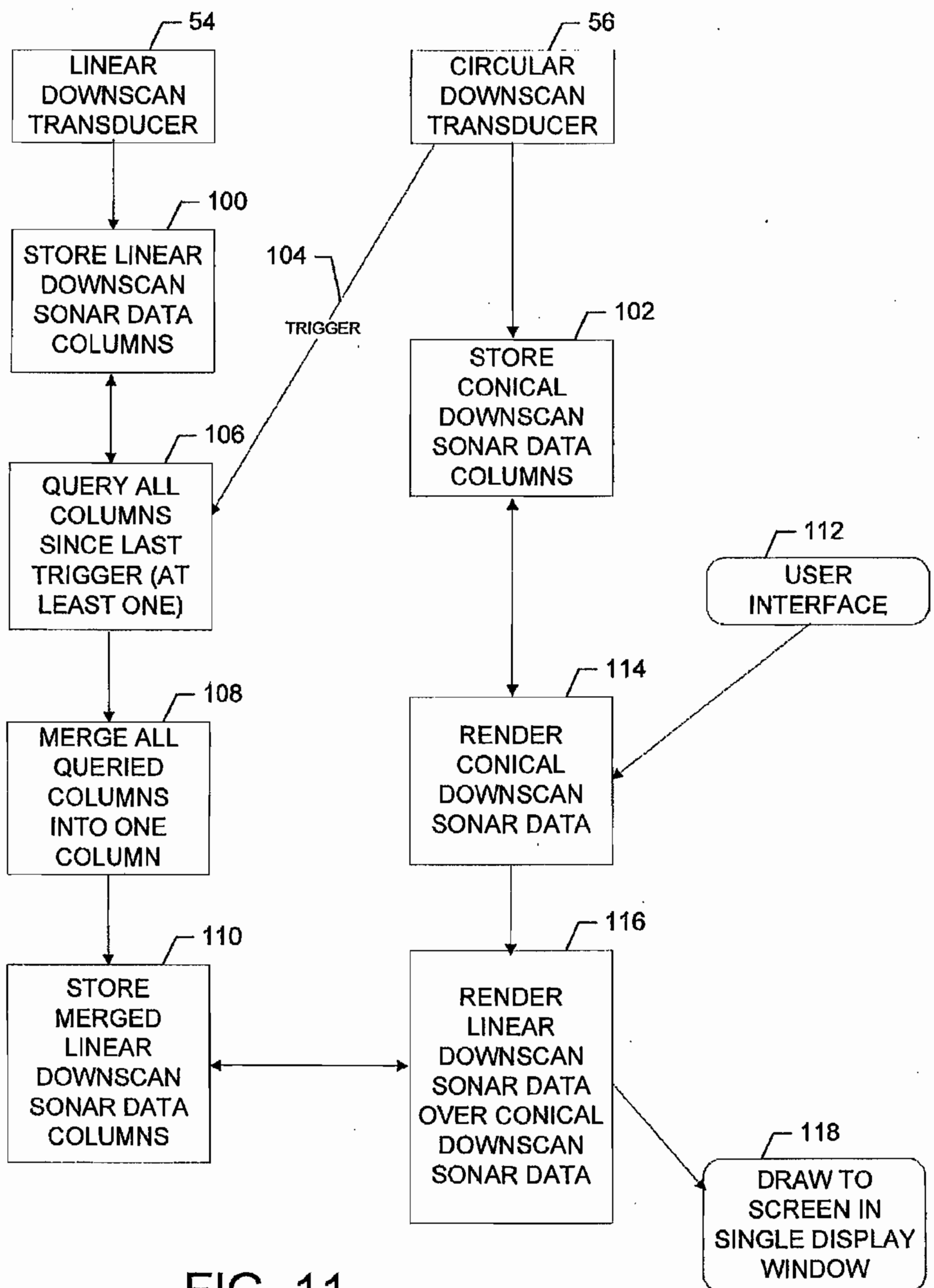

70
72
DEPTH
29.2
Adjust
Range
up
Range
down
Frequency
View
Stop sonar

FIG. 10.



54
LINEAR DOWNSCAN TRANSDUCER
56
CIRCULAR DOWNSCAN TRANSDUCER
100
STORE LINEAR DOWNSCAN SONAR DATA COLUMNS
104
TRIGGER
102
STORE CONICAL DOWNSCAN SONAR DATA COLUMNS
106
QUERY ALL COLUMNS SINCE LAST TRIGGER (AT LEAST ONE)
112
USER INTERFACE
114
108
MERGE ALL QUERIED COLUMNS INTO ONE COLUMN
RENDER CONICAL DOWNSCAN SONAR DATA
110
116
STORE MERGED LINEAR DOWNSCAN SONAR DATA COLUMNS
RENDER LINEAR DOWNSCAN SONAR DATA OVER CONICAL DOWNSCAN SONAR DATA
118
DRAW TO SCREEN IN SINGLE DISPLAY WINDOW

FIG. 11.

FIG. 12A.

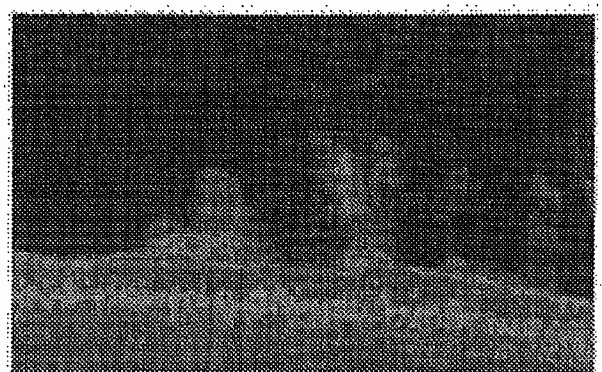


FIG. 12B.

FIG. 12C.

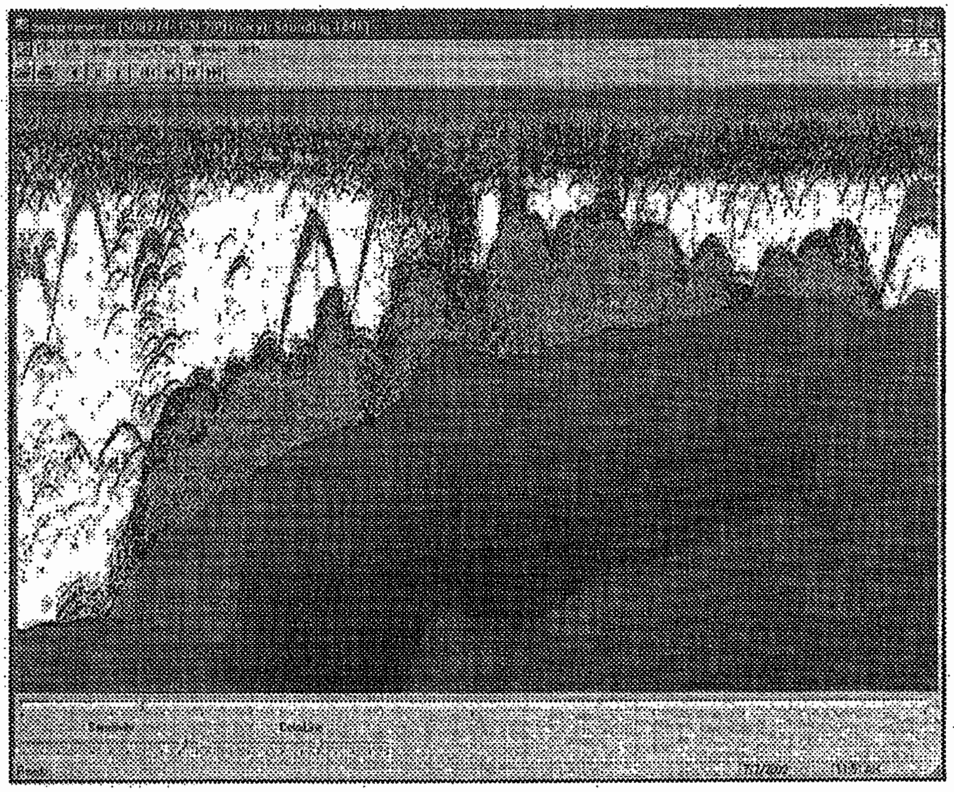


FIG. 13A.

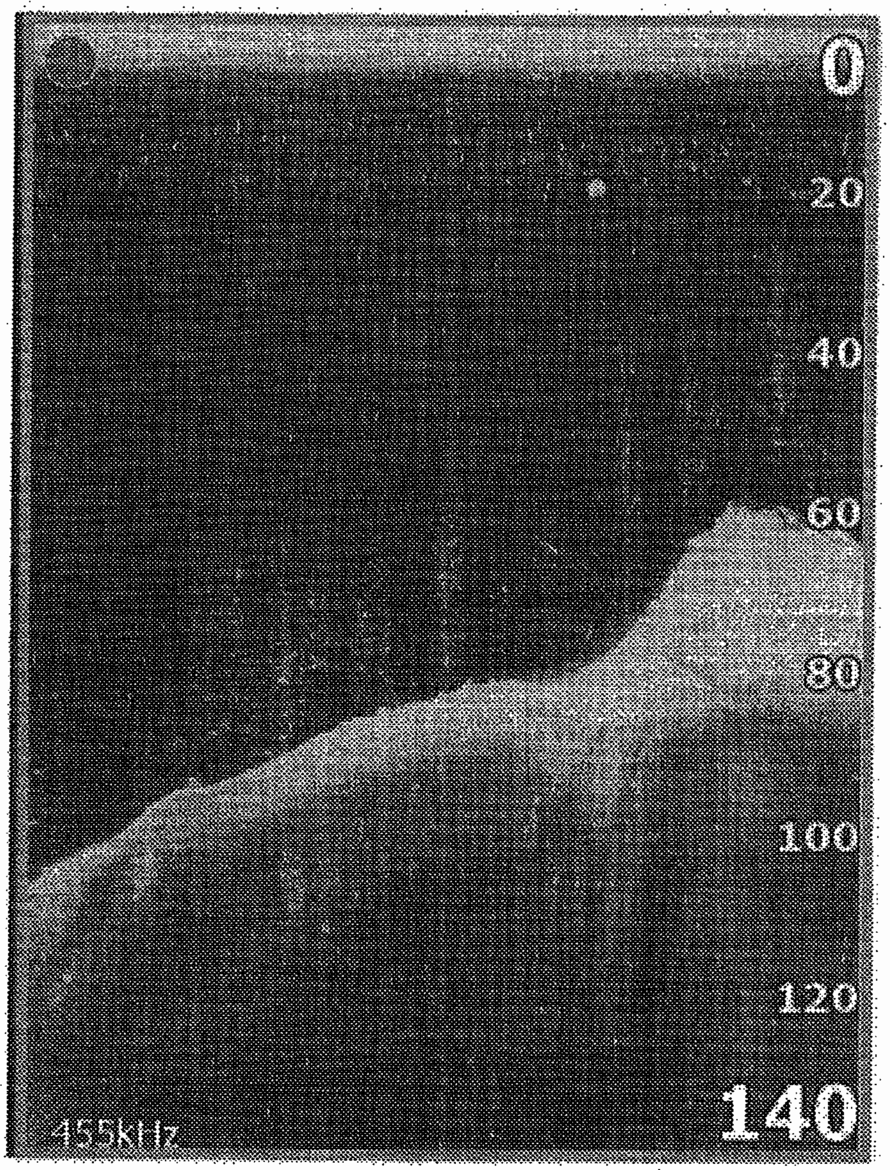


FIG. 13B.

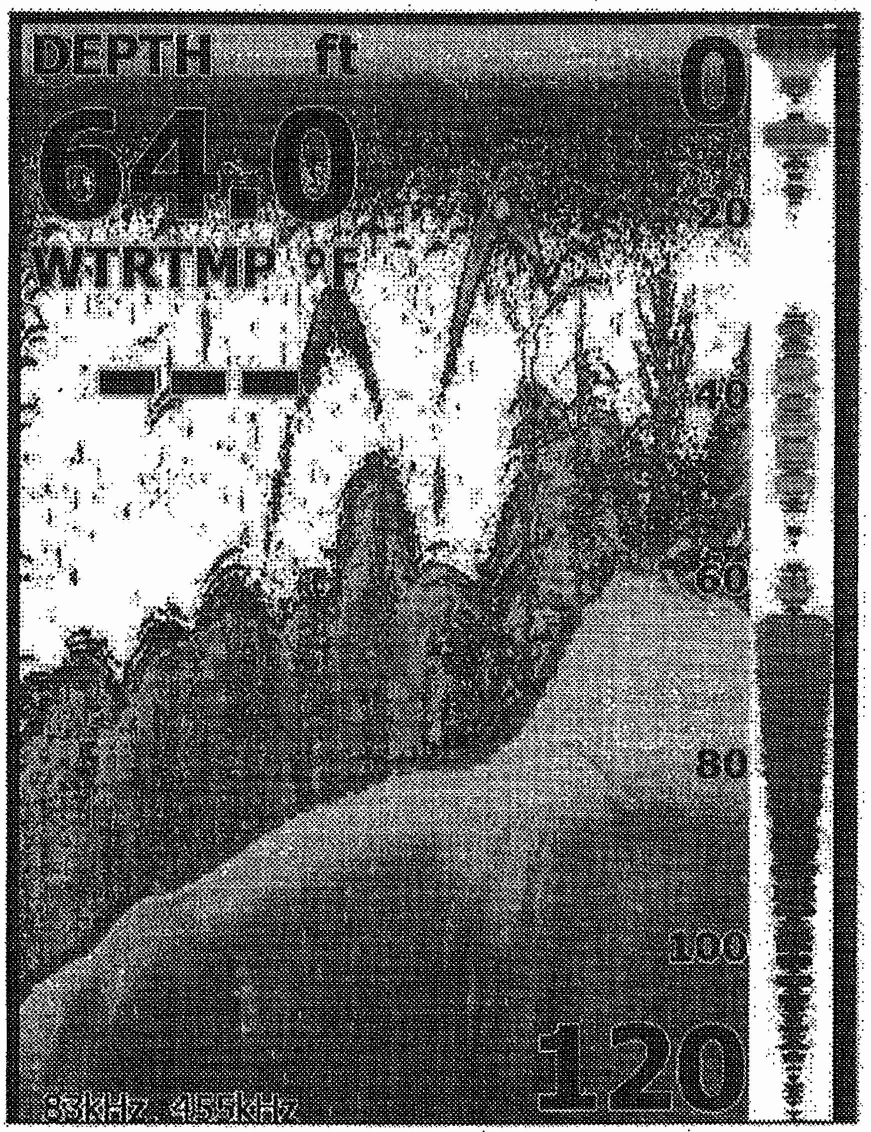
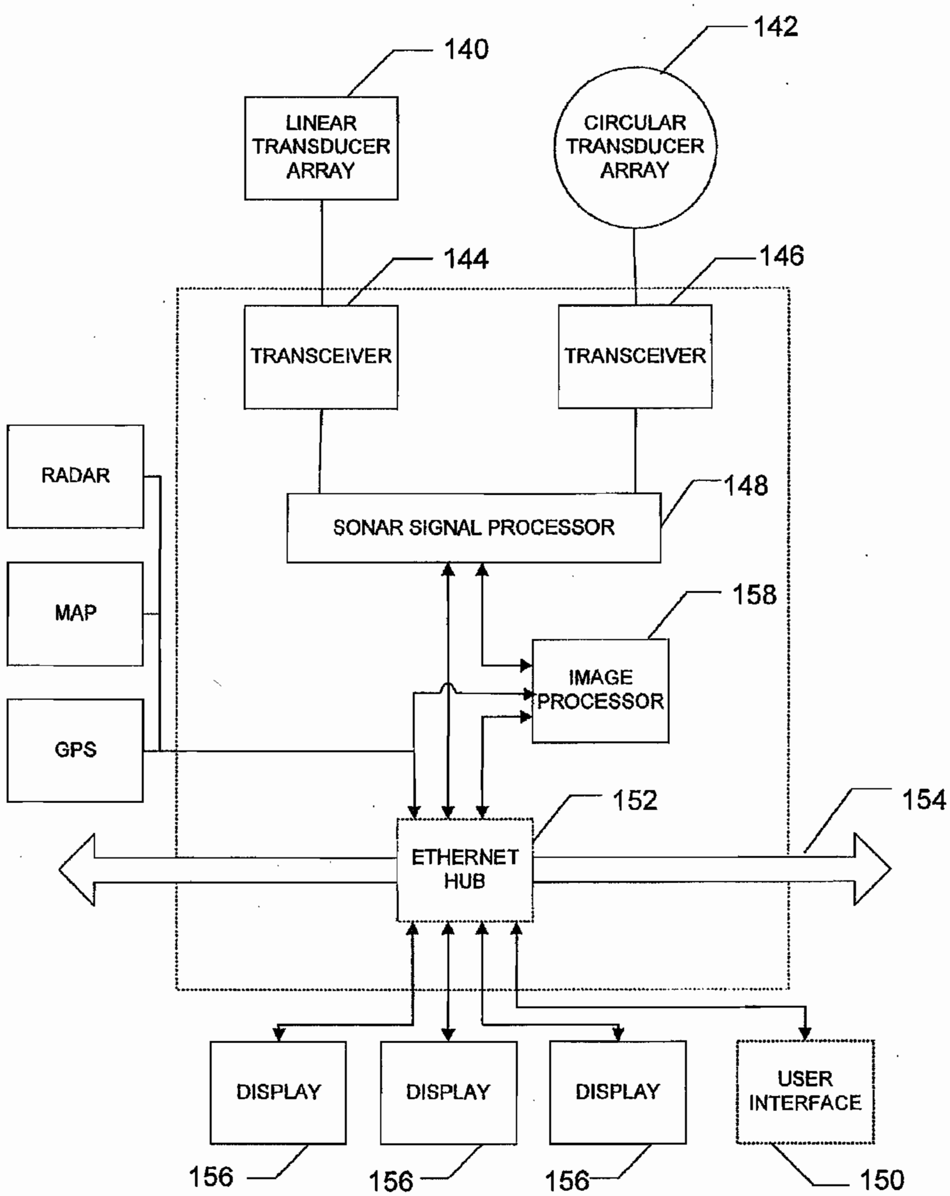


FIG. 13C.



140
142
LINEAR TRANSDUCER ARRAY
CIRCULAR TRANSDUCER ARRAY
144
146
TRANSCEIVER
TRANSCEIVER
RADAR
MAP
GPS
SONAR SIGNAL PROCESSOR
148
158
IMAGE PROCESSOR
152
154
ETHERNET HUB
DISPLAY
DISPLAY
DISPLAY
USER INTERFACE
156
156
156
150

FIG. 14.

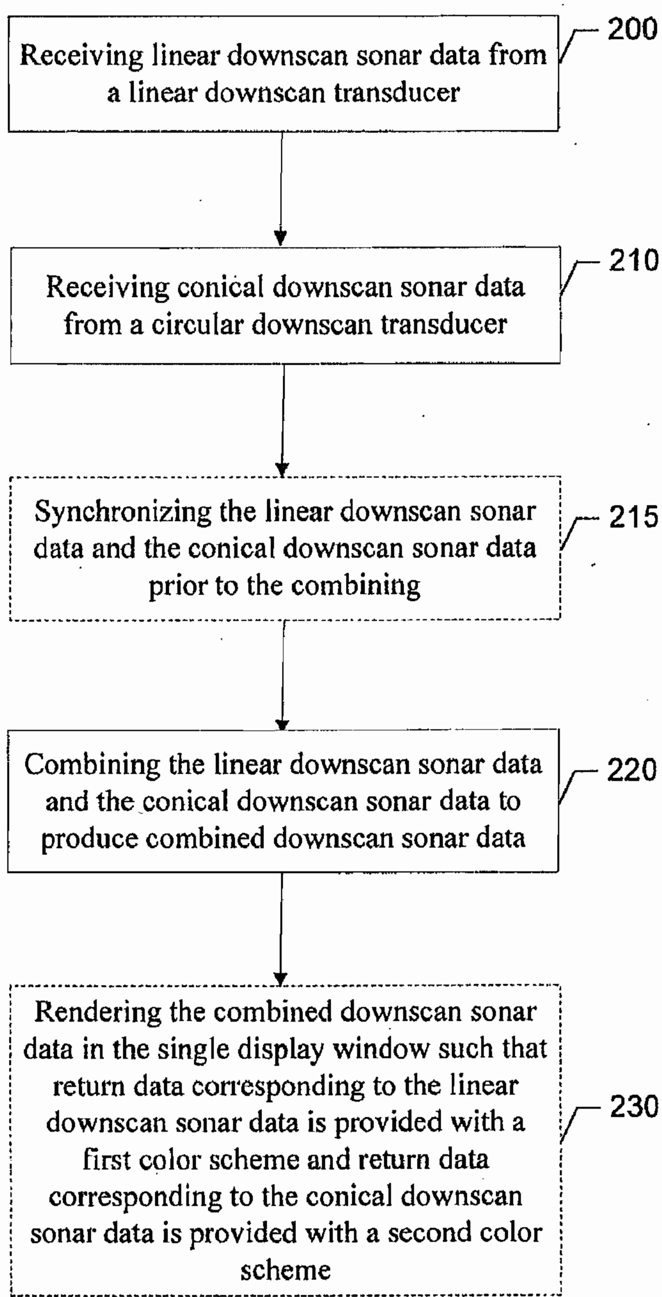

Receiving linear downscan sonar data from a linear downscan transducer
200
Receiving conical downscan sonar data from a circular downscan transducer
210
Synchronizing the linear downscan sonar data and the conical downscan sonar data prior to the combining
215
Combining the linear downscan sonar data and the conical downscan sonar data to produce combined downscan sonar data
220
Rendering the combined downscan sonar data in the single display window such that return data corresponding to the linear downscan sonar data is provided with a first color scheme and return data corresponding to the conical downscan sonar data is provided with a second color scheme
230

FIG. 15.

LINEAR AND CIRCULAR DOWNSCAN IMAGING SONAR

FIELD OF THE INVENTION

Embodiments of the present invention relate generally to sonar systems, and more particularly, to providing an ability to display images from both linear and circular downscan transducers.

BACKGROUND OF THE INVENTION

Sonar has long been used to detect waterborne or underwater objects. For example, sonar devices may be used to determine depth and bottom topography, detect fish or other waterborne contacts, locate wreckage, etc. In this regard, due to the extreme limits to visibility underwater, sonar is typically the most accurate way for individuals to locate objects underwater. Devices such as transducer elements, or simply transducers, have been developed to produce sound or vibrations at a particular frequency that is transmitted into and through the water and also to detect echo returns from the transmitted sound that return to the transducer after reflecting off an object. The transducers can convert electrical energy into sound energy and also convert sound energy (e.g., via detected pressure changes) into an electrical signal, although some transducers may act only as a hydrophone for converting sound energy into an electrical signal without having a transmitting capability. The transducers are often made using piezoelectric materials.

A typical transducer produces a beam pattern that emanates as a sound pressure signal from a small source such that the sound energy generates a pressure wave that expands as it moves away from the source. For instance, a circular transducer (e.g., a cylindrical shaped crystal with a circular face) typically creates a conical shaped beam with the apex of the cone being located at the source. Any reflected sound then returns to the transducer to form a return signal that may be interpreted as a surface of an object. Such transducers have often been directed in various directions from surfaced or submerged vessels in order to attempt to locate other vessels and/or the seabed for the purposes of navigation and/or target location.

Since the development of sonar, display technology has also been improved in order to enable better interpretation of sonar data. Strip chart recorders and other mechanical output devices have been replaced by, for example, digital displays such as LCDs (liquid crystal displays). Current display technologies continue to be improved in order to provide, for example, high quality sonar data on multi-color, high resolution displays having a more intuitive output than early sonar systems were capable of producing.

With display capabilities advancing to the point at which richly detailed information is able to be displayed, attention has turned back to the transducer in order to provide higher quality data for display. Furthermore, additional uses have been developed for sonar systems as transducer and display capabilities have evolved. For example, sonar systems have been developed to assist fishermen in identifying fish and/or the features that tend to attract fish. Historically, these types of sonar systems primarily analyzed the column of water beneath a watercraft with a cylindrical piezo element that produces a conical beam, known as a conical beam transducer or simply as a circular transducer referring to the shape of the face of the cylindrical element. However, with the advent of sidescan sonar technology, fishermen were given the capability to view not only the column of water beneath their vessel, but also view water to either side of their vessel.

Sidescan sonar can be provided in different ways and with different levels of resolution. As its name implies, sidescan sonar is directed to look to the side of a vessel and not below the vessel. In fact, many sidescan sonar systems (e.g., swath and bathymetry sonar systems) have drawn public attention for their performance in the location of famous shipwrecks and for providing very detailed images of the ocean floor, but such systems are costly and complex. Sidescan sonar typically generates a somewhat planar fan-shaped beam pattern that is relatively narrow in beamwidth in a direction parallel to the keel of a vessel deploying the sidescan sonar and is relatively wide in beamwidth in a direction perpendicular to the keel of the vessel. It may be provided in some cases using multibeam sonar systems. Such multibeam sonar systems are typically comprised of a plurality of relatively narrowly focused conventional circular transducer elements that are arrayed next to each other to produce an array of narrowly focused adjacent conical beams that together provide a continuous fan shaped beam pattern. FIG. **1** shows an example of a series of conventional (generally circular) transducer elements **10** arrayed in an arc to produce a multibeam sonar system. FIG. **2** shows a typical fan shaped beam pattern **12** produced by the multibeam sonar system of FIG. **1** as the beam pattern is projected onto the seabed.

However, multibeam sonar systems typically require very complex systems to support the plurality of transducers that are employed in order to form the multibeam sonar system. For example, a typical system diagram is shown in FIG. **3**, which includes a display **20** driven by a sonar signal processor **22**. The sonar signal processor **22** processes signals received from each of a plurality of transducers **26** that are fed to the sonar signal processor **22** by respective different transceivers **24** that are paired with each of the transducers **26**. Thus, conventional multibeam sonar systems tend to include a large number of transceivers and correspondingly introduce complexity in relation to processing the data such systems produce.

More recently, ceramic sidescan transducer elements have been developed that enable the production of a fan shaped sonar beam directed to one side of a vessel. Accordingly, the sea floor on both sides of the vessel can be covered with two elements facing on opposite sides of the vessel. These types of sidescan transducer elements are linear, rather than cylindrical, and provide a somewhat planar fan-shaped beam pattern using a single transducer to provide sidescan sonar images without utilizing the multibeam array described above. However, employment of these types of sidescan elements typically leaves the column of water beneath the vessel either un-monitored, or monitored using conical beam or circular transducers. In this regard, FIG. **4** illustrates an example of a conventional sidescan sonar with linear sidescan transducer elements oriented to produce fan-shaped beams **27** directed from opposite sides of the vessel and a conical beam **28** projecting directly below the vessel. These beams have conventionally been provided to have a conical shape by using conventional cylindrical transducers to produce depth information since sidescan transducers are typically not as useful for providing depth or water column feature information, such as fish targets. However, cylindrical transducers provide poor quality images for sonar data relating to the bottom structure directly below the vessel.

Accordingly, it may be desirable to develop a sonar system that is capable of providing an improved downscan imaging sonar.

BRIEF SUMMARY OF THE INVENTION

Accordingly, embodiments of the present invention employ a linear transducer, directed downward to receive high quality images relative to the water column and bottom features directly beneath the linear transducer and the vessel on which the linear transducer is employed and also employ a circular transducer to provide greater sensitivity with respect to detecting small objects in the water column. Embodiments of the present invention may then provide for a combination of the data from the linear transducer and the circular transducer to be displayed. As such, the advantages of each type of transducer may be combined to produce an improved downscan sonar display.

In one exemplary embodiment, a method for providing a combined linear and circular downscan sonar display is provided. The method may include receiving linear downscan sonar data from a linear downscan transducer, receiving conical downscan sonar data from a circular downscan transducer, and combining the linear downscan sonar data and the conical downscan sonar data to produce combined downscan sonar data.

In another exemplary embodiment, a computer program product for providing a combined linear and circular downscan sonar display is provided. The computer program product may include at least one computer-readable storage medium having computer-executable program code portions stored therein. The computer-executable program code portions may include program code instructions for receiving linear downscan sonar data from a linear downscan transducer, receiving conical downscan sonar data from a circular downscan transducer, and combining the linear downscan sonar data and the conical downscan sonar data to produce combined downscan sonar data.

In another exemplary embodiment, an apparatus for providing a combined linear and circular downscan sonar display is provided. The apparatus may include a sonar signal processor configured for receiving linear downscan sonar data from a linear downscan transducer, receiving conical downscan sonar data from a circular downscan transducer, and combining the linear downscan sonar data and the conical downscan sonar data to produce combined downscan sonar data.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING(S)

The patent or application file contains at least one drawing executed in color. Copies of this patent or patent application publication with color drawing(s) will be provided by the U.S. Patent and Trademark Office upon request and payment of the necessary fee.

Having thus described the invention in general terms, reference will now be made to the accompanying drawings, which are not necessarily drawn to scale, and wherein:

FIG. **1** is a diagram illustrating an example of a series of conventional transducer elements **10** arrayed to produce a multibeam sonar system;

FIG. **2** illustrates a fan shaped beam pattern produced by the conventional multibeam sonar system of FIG. **1** as the beam pattern is projected onto the seabed;

FIG. **3** is a block diagram of a conventional multibeam sonar system for the system shown in FIG. **1**;

FIG. **4** is a diagram illustrating a conventional sidescan sonar system;

FIG. **5** is a basic block diagram illustrating a sonar system according to an exemplary embodiment of the present invention;

FIG. **6**A is a diagram showing a perspective view of a linear downscan transducer and a circular downscan transducer within a single housing from a point above the housing according to an exemplary embodiment of the present invention;

FIG. **6**B is a perspective view from one side of the housing of FIG. **6**A at a point substantially perpendicular to a longitudinal axis of the housing according to an exemplary embodiment of the present invention;

FIG. **6**C is a perspective view from the front side of the housing of FIG. **6**A at a point looking straight down the longitudinal axis of the housing according to an exemplary embodiment of the present invention;

FIG. **7**A is a diagram showing a perspective view of a linear downscan transducer within a single housing from a point above the housing according to an exemplary embodiment of the present invention;

FIG. **7**B is a perspective view from one side of the housing of FIG. **7**A at a point substantially perpendicular to a longitudinal axis of the housing according to an exemplary embodiment of the present invention;

FIG. **7**C is a perspective view from the front side of the housing of FIG. **7**A at a point looking straight down the longitudinal axis of the housing according to an exemplary embodiment of the present invention;

FIG. **8**A is a diagram showing a perspective view of a linear downscan transducer array including two linear downscan transducers within a single housing from a point above the housing according to an exemplary embodiment of the present invention;

FIG. **8**B is a perspective view from one side of the housing of FIG. **8**A at a point substantially perpendicular to a longitudinal axis of the housing according to an exemplary embodiment of the present invention;

FIG. **8**C is a perspective view from the front side of the housing of FIG. **8**A at a point looking straight down the longitudinal axis of the housing according to an exemplary embodiment of the present invention;

FIG. **9**A illustrates an example of a top view of the beam overlap that may occur in situations where a linear downscan transducer and a circular downscan transducer are employed simultaneously according to an exemplary embodiment of the present invention;

FIG. **9**B shows side views of the same beam overlap shown in FIG. **9**A from the starboard side of a vessel and from ahead of the bow of the vessel according to an exemplary embodiment of the present invention;

FIG. **10** illustrates the provision of separate display windows for linear and circular downscan transducer data, respectively, according to an exemplary embodiment of the present invention;

FIG. **11** illustrates a flowchart showing how superposition of linear and conical downscan sonar data may be accomplished according to an exemplary embodiment of the present invention;

FIG. **12**A is an example image of conical downscan sonar data alone according to an exemplary embodiment of the present invention;

FIG. **12**B illustrates linear downscan sonar data displayed alone in an example image according to an exemplary embodiment of the present invention;

FIG. **12**C illustrates combined linear and conical downscan sonar data displayed in a single display window according to an exemplary embodiment of the present invention;

FIG. 13A is an example image of conical downscan sonar data alone according to an exemplary embodiment of the present invention;

FIG. 13B illustrates linear downscan sonar data displayed alone in an example image according to an exemplary embodiment of the present invention;

FIG. 13C illustrates combined linear and conical downscan sonar data displayed in a single display window according to an exemplary embodiment of the present invention;

FIG. 14 is a basic block diagram illustrating a sonar system according to an exemplary embodiment of the present invention; and

FIG. 15 is a flowchart illustrating a method of producing a combined linear and circular downscan image according to an exemplary embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Exemplary embodiments of the present invention now will be described more fully hereinafter with reference to the accompanying drawings, in which some, but not all embodiments of the invention are shown. Indeed, the invention may be embodied in many different forms and should not be construed as limited to the exemplary embodiments set forth herein; rather, these embodiments are provided so that this disclosure will satisfy applicable legal requirements. Like reference numerals refer to like elements throughout.

Conventionally, sonar transducers generally don't have overlapping coverage areas in order to minimize interference. Furthermore, since different types of transducers typically may operate with different frequencies and produce different data with corresponding different images, it has been considered impractical or undesirable to combine the output of different types of transducers into a single display. However, embodiments of the present invention overcome some of the technical challenges associated with combining data from different types of transducers and provide flexibility in providing a useful output of combined data to the user.

FIG. 5 is a basic block diagram illustrating a sonar system 30 for use with multiple exemplary embodiments of the present invention. As shown, the sonar system 30 may include a number of different modules or components, each of which may comprise any device or means embodied in either hardware, software, or a combination of hardware and software configured to perform one or more corresponding functions. For example, the sonar system 30 may include a sonar signal processor 32, a transceiver 34 and a transducer array 36 and/or numerous other peripheral devices such as one or more displays 38. One or more of the modules may be configured to communicate with one or more of the other modules to process and/or display data, information or the like from one or more of the modules. The modules may also be configured to communicate with one another in any of a number of different manners including, for example, via a network 40. In this regard, the network 40 may be any of a number of different communication backbones or frameworks including, for example, Ethernet, the NMEA 2000 framework or other suitable networks. However, in some embodiments, components may communicate directly with one another, or be in a common housing, and thus, no network may be provided.

The display 38 may be configured to display images and may include or otherwise be in communication with a user interface 39 configured to receive an input from a user. The display 38 may be, for example, a conventional LCD (liquid crystal display), a touch screen display or any other suitable display known in the art upon which images may be rendered. Although each display 38 of FIG. 5 is shown as being connected to the sonar signal processor 32 via the network and/or via an Ethernet hub, the display 38 could alternatively be in direct communication with the sonar signal processor 32 in some embodiments. Each display 38 may be configured to receive input data from the sonar signal processor 32 (or from an image processor or driving circuitry in communication with or forming a portion of the signal processor 32) and render (e.g., represent, display, present, or depict) the input data in one or more display windows on the display 38. Thus, for example, one or more of the displays 38 may be configured to render different windows that may each display a different type of data or view and, in some cases, more than one of the different windows may be displayed at a time. In this regard, for example, one window may display sonar data from a particular type of transducer while another display window shows sonar data from another type of transducer. In other cases, one window may display sonar data, while another window displays other data such as positioning data or radar data. Furthermore, in an exemplary embodiment of the present invention, one display window may actually display combined sonar data from two different types of transducers.

The user interface 39 may include, for example, a keyboard, keypad, function keys, mouse, scrolling device, input/output ports, touch screen, or any other mechanism by which a user may interface with the system. Moreover, in some cases, the user interface 39 may be a portion of one or more of the displays 38.

The transducer array 36 according to an exemplary embodiment may be provided in one or more housings that may provide for flexible mounting with respect to a hull of the vessel on which the sonar system 30 is employed. In this regard, for example, the housing(s) may be mounted onto the hull of the vessel or onto a device or component that may be attached to the hull (e.g., a trolling motor or other steerable device, or another component that is mountable relative to the hull of the vessel). The transducer array 36 may include one or more transducer elements positioned within the housing, as described in greater detail below, and each of the transducer elements may be configured to be directed to cover a respective area of the water column and/or bottom structure in the vicinity of the vessel. In an exemplary embodiment, the transducer elements of the transducer array 36 may include at least one linear transducer and at least one circular transducer. Moreover, in an exemplary embodiment, the transducer array may be oriented downward in order to monitor water and bottom features below the vessel. The transducer array 36 may be configured to both transmit and receive sound pressure waves. However, in some cases, the transducer array 36 could include separate elements for transmission and reception. The transducer array 36 is described in greater detail below, but further variations of the transducer array and other aspects related to the sonar module are described in U.S. patent application Ser. No. 12/460,139, entitled "Downscan Imaging Sonar" filed on even date herewith, the disclosure of which is incorporated herein by reference in its entirety.

In an exemplary embodiment, the sonar signal processor 32, the transceiver 34 and an Ethernet hub 42 or other network hub may form a sonar module 44. As such, for example, in some cases, the transducer array 36 may simply be placed into communication with the sonar module 44, which may itself be a mobile device that may be placed (but not necessarily mounted in a fixed arrangement) in the vessel to permit easy installation of one or more displays 38, each of which may be remotely located from each other and operable independent of each other. In this regard, for example, the Ethernet hub 42 may include one or more corresponding interface ports for placing the network **40** in communication with each display **38** in a plug-n-play manner. As such, for example, the Ethernet hub **42** may not only include the hardware needed to enable the displays **38** to be plugged into communication with the network **40** via the Ethernet hub **42**, but the Ethernet hub **42** may also include or otherwise be in communication with software modules for providing information to enable the sonar module **44** to communicate with one or more different instances of the display **38** that may or may not be the same model or type of display and that may display the same or different information. In other words, the sonar module **44** may store configuration settings defining a predefined set of display types with which the sonar module is compatible so that if any of the predefined set of display types are placed into communication with the sonar module **44**, the sonar module **44** may operate in a plug-n-play manner with the corresponding display types. Accordingly, the sonar module **44** may include a memory storing device drivers accessible to the Ethernet hub **42** to enable the Ethernet hub **42** to properly work with displays for which the sonar module **44** is compatible. The sonar module **44** may also be enabled to be upgraded with additional device drivers to enable expansion of the numbers and types of devices with which the sonar module **44** may be compatible. In some cases, the user may select a display type to check whether a the display type is supported and, if the display type is not supported, contact a network entity to request software and/or drivers for enabling support of the corresponding display type. In still other cases, particularly in situations in which there is no Ethernet hub **42** and/or network **40**, the sonar module **44** may include a single display **38**.

The sonar signal processor **32** may be any means such as a device or circuitry operating in accordance with software or otherwise embodied in hardware or a combination of hardware and software (e.g., a processor operating under software control or the processor embodied as an application specific integrated circuit (ASIC) or field programmable gate array (FPGA) specifically configured to perform the operations described herein, or a combination thereof) thereby configuring the device or circuitry to perform the corresponding functions of the sonar signal processor **32** as described herein. In this regard, the sonar signal processor **32** may be configured to analyze electrical signals communicated thereto by the transceiver **34** to provide sonar data indicative of the size, location, shape, etc. of objects detected by the sonar system **30**. In some cases, the sonar signal processor **32** may include a processor, a processing element, a coprocessor, a controller or various other processing means or devices including integrated circuits such as, for example, an ASIC, FPGA or hardware accelerator, that is configured to execute various programmed operations or instructions stored in a memory device. The sonar signal processor **32** may further or alternatively embody multiple compatible additional hardware or hardware and software items to implement signal processing or enhancement features to improve the display characteristics or data or images, collect or process additional data, such as time, temperature, GPS information, waypoint designations, or others, or may filter extraneous data to better analyze the collected data. It may further implement notices and alarms, such as those determined or adjusted by a user, to reflect depth, presence of fish, proximity of other watercraft, etc. Still further, the processor, in combination with suitable memory, may store incoming transducer data or screen images for future playback or transfer, or alter images with additional processing to implement zoom or lateral movement, or to correlate data, such as fish or bottom features to a GPS position or temperature. In an exemplary embodiment, the sonar signal processor **32** may execute commercially available software for controlling the transceiver **34** and/or transducer array **36** and for processing data received therefrom.

The transceiver **34** may be any means such as a device or circuitry operating in accordance with software or otherwise embodied in hardware or a combination of hardware and software (e.g., a processor operating under software control or the processor embodied as an ASIC or FPGA specifically configured to perform the operations described herein, or a combination thereof) thereby configuring the device or circuitry to perform the corresponding functions of the transceiver **34** as described herein. In this regard, for example, the transceiver **34** may include circuitry for providing transmission electrical signals to the transducer array **36** for conversion to sound pressure signals based on the provided electrical signals to be transmitted as a sonar pulse. The transceiver **34** may also include circuitry for receiving electrical signals produced by the transducer array **36** responsive to sound pressure signals received at the transducer array **36** based on echo or other return signals received in response to the transmission of a sonar pulse. The transceiver **34** may be in communication with the sonar signal processor **32** to both receive instructions regarding the transmission of sonar signals and to provide information on sonar returns to the sonar signal processor **32** for analysis and ultimately for driving one or more of the displays **38** based on the sonar returns.

FIG. **6** (which includes FIGS. **6A**, **6B** and **6C**) is a diagram illustrating a more detailed view of at least a portion of the transducer array **36** according to an exemplary embodiment. As shown in FIG. **6**, the transducer array **36** may include a housing **50** that may include one or more mounting holes **52** through which screws, rivets, bolts or other mounting devices may be passed in order to fix the housing **50** to a mounting bracket, a device attached to a vessel or to the hull of the vessel itself. However, in some cases, the housing **50** may be affixed by welding, adhesive, snap fit or other coupling means. The housing **50** may be mounted to a portion of the vessel, or to a device attached to the vessel, that provides a relatively unobstructed view of at least the column of water beneath the vessel. Thus, for example, the housing **50** may be mounted on or near the keel (or centerline) of the vessel, on a fixed or adjustable mounting bracket that extends below a depth of the keel (or centerline) of the vessel, or on a mounting device that is offset from the bow or stern of the vessel.

FIG. **6A** is a perspective view from above the housing **50**. Meanwhile, FIG. **6B** is a perspective view from one side of the housing **50** at a point substantially perpendicular to a longitudinal axis of the housing **50** and FIG. **6C** is a perspective view from the front side of the housing **50** at a point looking straight down the longitudinal axis of the housing **50**. As shown in FIGS. **6A-6C**, the transducer array **36** may include a linear downscan transducer **54** and a circular downscan transducer **56**. Each of the linear downscan transducer **54** and the circular downscan transducer **56** may be disposed within the housing **50** such that transmissions emanating from the linear downscan transducer **54** and the circular downscan transducer **56** are directed into the water column and toward bottom features substantially directly below the vessel. In other words, the linear downscan transducer **54** and the circular downscan transducer **56** are referred to as "downscan" transducers because each of the linear downscan transducer **54** and the circular downscan transducer **56** are directed downward relative to a surface of the body of water on which the vessel may operate.

In an exemplary embodiment, the linear downscan transducer **54** and the circular downscan transducer **56** may each be disposed to be in planes that are substantially parallel with each other and with a plane in which the longitudinal axis of the housing **50** lies. Generally speaking, the linear downscan transducer **54** and the circular downscan transducer **56** may also be displosed in line with the longitudinal axis of the housing **50**. Although shown in a particular order in FIGS. **6A-6C**, the ordering of the placement of the linear downscan transducer **54** and the circular downscan transducer **56** within the housing **50** may be reversed or varied in some examples. Furthermore, in some cases, the linear downscan transducer **54** and the circular downscan transducer **56** may each be located in their own respective separate housings rather than both being within a single housing.

In this regard, for example, in some cases the linear downscan transducer **54** may be within its own housing **50'** as shown in FIG. **7** (which includes FIGS. **7A**, **7B** and **7C**). Similarly, although not specifically shown, the circular downscan transducer **56** may be disposed within its own housing, such as a relatively cylindrically shaped housing that may be mounted near the housing **50'** of the linear downscan transducer **54**. As such, by way of comparison to FIG. **6**, FIGS. **7A** through **7C** illustrate diagrams of the linear downscan transducer **54** in the housing **50'** from various different perspectives. In this regard, FIG. **7A** is a perspective view from above the housing **50'**. Meanwhile, FIG. **7B** is a perspective view from one side of the housing **50'** at a point substantially perpendicular to a longitudinal axis of the housing **50'** and FIG. **7C** is a perspective view from the front side of the housing **50'** at a point looking straight down the longitudinal axis of the housing **50'**. As shown in FIGS. **7A-7C**, by employing only the linear downscan transducer **54**, the size of the housing **50'** may be reduced. In this regard, for example, particularly FIG. **7C** shows a reduction in the cross sectional size of the housing **50'** as compared to the cross sectional size of the housing **50** of FIG. **6C**. Thus, for example, the housing **50'** may introduce less drag than the housing **50**.

As indicated above, the transducer array **36** may include one or more of the linear downscan transducer **54** and one or more of the circular downscan transducer **56**. FIG. **8** (which includes FIGS. **8A**, **8B** and **8C**) illustrates an example where multiple linear downscan tranducers are included within a housing **50"** to illustrate a modification of the example shown in FIG. **7**. However, in some cases, multiple linear downscan transducers could be implemented in connection with the example of FIG. **6**. In other words, a single housing could include multiple linear downscan transducers and one or more circular downscan transducers.

The housing (e.g., housing **50**) may include a recessed portion defining containment volume for holding transducer elements (e.g., the linear downscan transducer element **54** and the circular downscan transducer element **56**). The recessed portion defining the containment volume may extend over a substantial portion of the length the housing **50**. To prevent cavitation or the production of bubbles due to uneven flow over the housing **50**, the housing **50** (and in particular the containment volume portion of the housing) may have a gradual rounded profile to permit laminar flow of water over the housing **50**. In some examples, one or more insulated cables may provide a conduit for wiring to communicatively couple the transducer elements of the transducer array **36** to the sonar module **44**.

In an exemplary embodiment, the linear downscan transducer **54** may be formed of a rectangular prism shaped crystal forming a linear transducer element. Thus, for example, the linear downscan transducer **54** may be substantially rectangular in shape and made from a piezoelectric material such as a piezoelectric ceramic material, as is well known in the art and may include appropriate shielding (not shown) as is well known in the art. The piezoelectric material being disposed in a rectangular arrangement provides for an approximation of a linear array having beamwidth characteristics that are a function of the length and width of the rectangular face of the transducer element of the linear downscan transducer **54** and the frequency of operation. In an exemplary embodiment, the linear downscan transducer **54** may be configured to operate in accordance with at least two operating frequencies. In this regard, for example, a frequency selection capability may be provided by the sonar module **44** to enable the user to select one of perhaps multiple frequencies of operation. In one example, one operating frequency may be set to about 800 kHz and another operating frequency may be set to about 455 kHz. Furthermore, the length of the transducer elements may be set to about 120 mm while the width is set to about 3 mm to thereby produce beam characteristics corresponding to a bearing fan of about 0.8 degrees by about 32 degrees at 800 kHz or about 1.4 degrees by about 56 degrees at 455 kHz. However, in general, the length and width of the linear downscan transducer **54** may be set such that the beamwidth of sonar beam produced by the linear downscan transducer **54** in a direction parallel to a longitudinal length (L) of the linear downscan transducer **54** is less than about five percent as large as the beamwidth of the sonar beam in a direction (w) perpendicular to the longitudinal length of the linear downscan transducer **54**. (See generally FIG. **9**.) It should be noted that although the widths of various beams are shown and described herein, the widths being referred to do not necessarily correspond to actual edges defining limits to where energy is placed in the water. As such, although beam patterns and projections of beam patterns are generally shown herein as having fixed and typically geometrically shaped boundaries, those boundaries merely correspond to the −3 dB (or half power) points for the transmitted beams. In other words, energy measured outside of the boundaries shown is less than half of the energy transmitted. Thus, the boundaries shown are merely theoretical half power point boundaries.

Although dual frequency operations providing a specific beam fan for each respective element for given lengths are described above, it should be understood that other operating ranges could alternatively be provided with corresponding different transducer element sizes and corresponding different beamwidth characteristics. Moreover, in some cases, the sonar module **44** may include a variable frequency selector, to enable an operator to select a particular frequency of choice for the current operating conditions. However, in all cases where the longitudinal length of the linear downscan transducer **54** is generally aligned with the centerline of the vessel and the linear downscan transducer **54** is oriented to transmit pulses into the water column below the vessel, the rectangular shape of the linear downscan transducer **54** provides for a narrow beamwidth in a direction substantially parallel to the centerline of the vessel and wide beamwidth in a direction substantially perpendicular to the centerline of the vessel. However, if the transducer array **36** is mounted in a different fashion or to a rotatable accessory on the vessel (e.g., a trolling motor mount), the fan-shaped beams produced will have the wide beamwidth in a direction substantially perpendicular to the longitudinal length of the housing **50** and a narrow beamwidth in a direction substantially parallel to the longitudinal length of the housing **50'** regardless of the orientation of the vessel. Thus, the sonar could also be oriented to provide fore and aft oriented fan-shaped beams or any other orientation relative to the vessel in instances where motion of the vessel is not necessarily in a direction aligned with the centerline of the vessel.

FIG. 9 (which includes FIGS. 9A and 9B) shows an illustration of the beam characteristics produced by an exemplary embodiment of the present invention. In this regard, FIG. 9A illustrates an example of a top view of the beam overlap that may occur in situations where the linear downscan transducer **54** and the circular downscan transducer **56** are employed simultaneously. FIG. 9B shows side views of the same beam overlap shown in FIG. 9A from the starboard side of a vessel (on the left side of the page) and from ahead of the bow of the vessel (on the right side of the page). As shown in FIG. 9A, there is overlap between a conical beam projection **60** showing an example coverage area of a beam produced by the circular downscan transducer **56** and a linear downscan beam projection **62** showing an example coverage area of a beam produced by the linear downscan transducer **54**. The differences between the beam patterns of the linear downscan transducer **54** and the circular downscan transducer **56** are further illustrated in FIG. 9B in which it can be seen that the beamwidth **64** of the beam produced by the circular downscan transducer **56** is substantially the same regardless of the side from which the beam is viewed. However, the beamwidth **66** of the beam produced by the linear downscan transducer **54** as viewed from the starboard side of the vessel is substantially smaller than the beamwidth **68** of the beam produced by the linear downscan transducer as viewed from ahead of the bow of the vessel. Moreover, the beamwidth **68** is wider than the beamwidth **64**, while the beamwidth **66** is narrower than the beamwidth **64**.

Due to the differences in beamwidth, particularly in the direction parallel to the centerline of the vessel, it may take several linear downscan transducer beams to cover the same area that is covered by a single circular downscan transducer beam. However, one difference between a typical linear downscan transducer and a typical circular downscan transducer is that linear downscan transducers typically provide each new beam without any (or very little) overlap with prior beams (at least with respect to boundaries of the beams as defined by the half power points of the beams). Due to the minimal overlapping of linear downscan transducer beams, objects that show up on a display of linear downscan data are typically relatively crisp and clear. Meanwhile, conical beams from a circular downscan transducer typically overlap each other. Thus, since return data may be received from objects over multiple scans, return data often appears to be blurred to some extent. For example, fish or other suspended objects often appear as "arches" on a display of circular downscan transducer data.

The above described differences between linear and circular downscan transducer beams provide display characteristics that some may consider advantageous for each respective display. For example, the relatively cleaner lines provided by a display of linear downscan transducer data may make it easier to see bottom features such as trees, boulders or other objects even to the point where tree limbs are clearly visible in some cases. Furthermore, suspended objects such as fish or schools of fish may appear more crisply on a display of linear downscan transducer data. However, due to the narrow beamwidth of the linear downscan transducer **54** in the direction of motion of the vessel, smaller objects may be more difficult to discern in some cases. Thus, display data corresponding to a circular downscan transducer may often be more sensitive to picking up objects, and particularly smaller objects, than data corresponding to a linear downscan transducer. Additionally, many users are very familiar with reading a display of circular downscan transducer data as it has been used for a long time, while linear downscan transducers are new, so it may initially be difficult for some users to read data from a linear downscan transducer.

Given the characteristics described above, it may be useful to incorporate characteristics from linear downscan transducer data with characteristics from circular downscan transducer data to provide users with a display that incorporates aspects of each. Thus, for example, certain characteristics that may be seen as being advantageous from each type of data may have potential for incorporation into a single display. Users may therefore be provided with a display that is, in some cases, easier to read and provides comprehensive information regarding the water column and bottom features directly below the vessel. Although it may be possible to provide a single display with one display window showing data corresponding to a linear downscan transducer in one portion of the display and another display window corresponding to a circular downscan transducer in another portion of the display (e.g., as shown in the example of FIG. **10**), it may in some cases be preferable to offer aspects of both sets of data within a single display window. In this regard, a single display window may be all that is practical for some smaller sized displays and, even on larger displays, users may prefer a more comprehensive display that provides combined data from both linear and circular downscan transducers in a single display window.

FIG. **10** illustrates the provision of separate display windows for linear and circular downscan transducer data, respectively. In this regard, display window **70** and display window **72** may each be provided on the same display (e.g., one of the displays **38**). Display window **70** shows data corresponding to a circular downscan transducer (e.g., the circular downscan transducer **56**). Meanwhile, display window **72** shows data corresponding to a linear downscan transducer (e.g., the linear downscan transducer **54**). As discussed above, the display of the different types of data in different display windows may not always be preferable or desirable. Accordingly, some exemplary embodiments of the present invention may provide for a combination of the circular downscan transducer data and the linear downscan transducer data into a single display window.

In an exemplary embodiment, the combination of circular downscan transducer data and linear downscan transducer data into a single display window may be accomplished by the sonar module **44**. To accomplish the incorporation of characteristics of both linear and circular downscan transducer data into a single display window, for example, the sonar module **44** may combine linear downscan sonar data from a linear downscan transducer with conical downscan sonar data from a circular downscan transducer. In an exemplary embodiment, the combination may be accomplished via the sonar signal processor **32**. As such, for example, the sonar signal processor **32** may be programmed (either via hardware or software or a combination thereof) to combine linear downscan sonar data and the conical downscan sonar data received from the linear downscan transducer **54** and the circular downscan transducer **56**, respectively. In some cases, a portion of the sonar signal processor **32** (e.g., an image processor or some other dedicated processor) may be configured to perform the combination. As such, for example, the sonar signal processor **32** is configured to receive linear downscan sonar data from a linear downscan transducer and receive conical downscan sonar data from a circular downscan transducer. The sonar signal processor **32** may then be configured to combine the linear downscan sonar data and the conical downscan sonar data to produce combined downscan sonar data displayable in a single display window.

As described above, and shown in FIG. 9, the linear downscan sonar data and the conical downscan sonar data that is ultimately combined may correspond to respective underwater regions that at least partially overlap. Moreover, due to the potential for asynchronous operation of the linear downscan transducer 54 and the circular downscan transducer 56, the sonar signal processor 32 may be further configured to synchronize the linear downscan sonar data and the conical downscan sonar data prior to the combining. Synchronization may be accomplished by sending a trigger signal at a predetermined interval. In this regard, for example, each sounding or transmission produced by either one of the linear downscan transducer 54 or the circular downscan transducer 56 may be the reference used to synchronize data corresponding to the other one of the linear downscan transducer 54 or the circular downscan transducer 56. The trigger may be operated in either direction and at any sounding interval or at any desired frequency of operation. In other words, for example, each sounding of a less frequently transmitting device may be used to trigger alignment with multiple returns of the more frequently transmitting device or a trigger may be sent every predetermined number of soundings of a more frequently transmitting device to trigger alignment with a smaller number of returns from a lower frequency transmitting device.

In an exemplary embodiment, the sonar signal processor 32 may be configured to produce the combined data for rendering at a display (e.g., one of the displays 38). The combined data may be a superposition of the linear downscan sonar data and the conical downscan sonar data. In some cases, the rendering of the combined data may include rendering base data corresponding to one of the linear downscan sonar data or the conical downscan sonar data and rendering overlay data corresponding to the other of the linear downscan sonar data or the conical downscan sonar data over the base data. In some situations, a level mask may be applied to the overlay data. In other words, for example, only overlay data that is above a predefined threshold may be rendered. In an exemplary embodiment, rather than overlaying data as described above, the sonar signal processor 32 may be configured to blend the linear downscan sonar data with the conical downscan sonar data and render the blended data. When blending is employed, the sonar signal processor 32 may be configured to apply a first weighting factor to the linear downscan sonar data to produce first weighted data and apply a second weighting factor to the conical downscan sonar data to produce second weighted data. In such situations, rendering the blended data may include combining the first weighted data and second weighted data into combined weighted data and rendering the combined weighted data.

FIG. 11 illustrates a flowchart showing how superposition of linear and conical downscan sonar data may be accomplished according to an exemplary embodiment. In this regard, as shown in FIG. 11, linear downscan sonar data from the linear downscan transducer 54 may be stored in columns (e.g., in a memory of or accessible to the sonar signal processor 32) at operation 100. Similarly, conical downscan sonar data may be stored in columns (e.g., in a memory of or accessible to the sonar signal processor 32) at operation 102. In some cases, the circular downscan transducer 56 may operate at a lower frequency than the linear downscan transducer 54, so in this example, each sounding of the circular downscan transducer 56 may be a trigger 104 for synchronization between the conical downscan sonar data and the linear downscan sonar data.

In this example, since multiple linear downscan sonar data columns correspond to each conical downscan sonar data column, the sonar signal processor 32 may query all columns of the stored linear downscan sonar data that have been stored since the last trigger as shown at operation 106. The queried columns, or segments of data, may then be merged into a single linear downscan sonar data column corresponding to its respective conical downscan sonar data column at operation 108. Merging of data may be accomplished by selecting a largest value for each corresponding segment of a plurality of linear downscan sonar data columns and storing the largest value for each segment to form a corresponding second data column. In an alternative embodiment, merging of data may be accomplished by averaging values for each corresponding segment of the plurality of linear downscan sonar data columns and storing an average value for each segment to form a corresponding second data column. The merged data may then be stored (e.g., in a memory of or accessible to the sonar signal processor 32) at operation 110.

At operation 112, the user may utilize the user interface to provide mode selection, sensitivity selection, color palette selection or other user inputs that may impact the rendering of the data. Mode selection could include selecting whether to render only the conical downscan sonar data in the display window, render only the linear downscan sonar data in the display window, or render the combined downscan sonar data in the display window. However, in some cases, the mode selection could also include selecting multiple windows to be simultaneously displayed such as the linear downscan sonar data on one side of the display and the conical downscan sonar data and/or combined data being displayed on another segment of the display. Mode selection could be used to select blending or level masking as described above. However, in some cases, level selection (e.g., for the mask or for blending) could be made as a sensitivity selection. For example, the user may select the predefined threshold of the level mask or may select to render blended data with conical downscan sonar data selected to receive a 70% weight and linear downscan sonar data weighted selected to receive a 30% weight. Color palette selection may be accomplished by providing color schemes from which the user may select to customize the display. For example, the user may select color coding to differentiate conical downscan sonar data from linear downscan sonar data and, within the color codings assigned to each type of data, intensity or color differences may further indicate the strength of sonar return received. Alternatively, the user may select cross-hatching, shades of gray or even black and white as color palette options to distinguish between linear downscan sonar data and conical downscan sonar data. As such, for example, the user interface may be used to control the sonar signal processor 32 with respect to rendering the combined downscan sonar data in the single display window such that return data corresponding to the linear downscan sonar data is provided with a first color scheme and return data corresponding to the conical downscan sonar data is provided with a second color scheme.

At operation 114, the conical downscan sonar data columns (e.g., the base data in this example) may be rendered and then at operation 116, the linear downscan sonar data columns (e.g., the overlay data) may be rendered over the conical downscan sonar data columns. The combined data may then be drawn to the display screen in the same display window at operation 118.

FIG. 12 (which includes FIGS. 12A, 12B and 12C) illustrates some example images that may be useful in explaining operation of an exemplary embodiment. In this regard, FIG. 12A is an image of conical downscan sonar data alone. FIG. 12B illustrates linear downscan sonar data alone. FIG. 12C illustrates combined linear and conical downscan sonar data. As shown in FIG. 12C, since the linear downscan sonar data is overlayed onto the conical downscan sonar data, there is no obscuring of either type of data. Instead, the sensitivity with respect to identifying small objects in the water column below the vessel is provided by the conical downscan sonar data and the clarity of bottom features is provided by the linear downscan sonar data. In this regard, for example, the trees so clearly visible in FIG. 12B are also shown in FIG. 12C to provide definition or further clarity with respect to these bottom features within the more blurry returns provided by the conical downscan sonar data. Specifically, in this example, the trees shown in FIG. 12B are shown in brown overlay in FIG. 12C over the red return data shown from FIG. 12A.

FIG. 13 (which includes FIGS. 13A, 13B and 13C shows another example. In this example, FIG. 13A is an image of conical downscan sonar data alone. FIG. 13B illustrates linear downscan sonar data alone. FIG. 13C illustrates combined linear and conical downscan sonar data. As shown in FIG. 13B, the linear downscan image may be provided on a majority of the display and other information may be provided over the linear downscan image. For example, frequency information (provided at the lower left portion of the display window in this example) and a depth scale (provided on the right edge of the display in this example) may be provided to assist the user in interpreting the image displayed. As such, boat position may be represented by the numeral **0** (e.g., on the right side), or some other desirable icon, for most recent sonar pings, and older sonar data may be presented on the left side of the screen to present a scrolling image as the boat (and transducer) move through the water over time.

FIG. 14 illustrates an exemplary sonar system incorporating linear and circular downscan transducer arrays **140**, **142**. The two transducer arrays may be in the same or separate housings and may include one or more transducers in each respective array. The arrays also typically utilize different operational frequencies. Such may also assist in minimizing interference. Similar to the system illustrated in FIG. 5, the transducers are operationally connected to the transceivers **144**, **146**, which configure the transducer outputs for receipt by a sonar signal processor **148**. The sonar signal processor **148** (which may be similar to the sonar signal processor **32** of FIG. 5) executes various programs stored or as may be selected by the user interface **150**. The Ethernet hub **152**, network **154**, displays **156** and user interface **150** operate as described for the corresponding components of FIG. 5. The image processor **158** may perform a variety of functions to optimize or customize the display images, including such features as split screen to show multiple different sonar images or data. Examples include individual and separate images of GPS, waypoints, mapping, nautical charts, GPS tracking, radar, etc., which are typically shown side-by-side or stacked. Additional examples include individual data boxes, such as speed, depth, water, temperature, range or distance scales, location or waypoint, latitude, longitude, time, etc. Still further examples include composite images that combine information from one or more of these sources, such as the images from the linear downstream and circular downstream transducers to overlay the images. For example, the traditional "fish arch" image representing a possible fish using a circular downscan sonar may be imposed over a small white circle or oval representing a possible fish using a linear downscan sonar. Still further, one image may be colorized to distinguish it visibly from data representing another image. As such, for example, the images may be combined using image blending or overlay techniques. Alternatively, individual images may be presented, or different images, simultaneously on different displays without overlay. Image data packets or streams may also have additional data associated therewith, such as time of day, location, temperature, speed, GPS, etc.

Notably, the example of FIG. 14 may be simplified in some embodiments. In this regard, the radar, map and GPS modules of FIG. 14 along with the Ethernet hub **152** may not be included in some embodiments. Moreover, in one example, an embodiment of the present invention may include essentially only processing circuitry to handle inputs from a linear and circular transducer array along with a display in a single device. As such, for example, all of the electronics for handling linear and circular transducer inputs may be included along with a display within a single box, without any Ethernet connection or other peripherals.

FIG. 15 is a flowchart of a system, method and program product according to an exemplary embodiment of the invention. It will be understood that each block or step of the flowchart, and combinations of blocks in the flowchart, can be implemented by various means, such as hardware, firmware, and/or software including one or more computer program instructions. For example, one or more of the procedures described above may be embodied by computer program instructions. In this regard, the computer program instructions which embody the procedures described above may be stored by a memory device of the sonar module and executed by a processor in the sonar module. As will be appreciated, any such computer program instructions may be loaded onto a computer or other programmable apparatus (i.e., hardware) to produce a machine, such that the instructions which execute on the computer or other programmable apparatus create means for implementing the functions specified in the flowchart block(s) or step(s). These computer program instructions may also be stored in a computer-readable memory that can direct a computer or other programmable apparatus to function in a particular manner, such that the instructions stored in the computer-readable memory produce an article of manufacture including instruction means which implement the function specified in the flowchart block(s) or step(s). The computer program instructions may also be loaded onto a computer or other programmable apparatus to cause a series of operational steps to be performed on the computer or other programmable apparatus to produce a computer-implemented process such that the instructions which execute on the computer or other programmable apparatus provide steps for implementing the functions specified in the flowchart block(s) or step(s).

Accordingly, blocks or steps of the flowchart support combinations of means for performing the specified functions, combinations of steps for performing the specified functions and program instruction means for performing the specified functions. It will also be understood that one or more blocks or steps of the flowchart, and combinations of blocks or steps in the flowchart, can be implemented by special purpose hardware-based computer systems which perform the specified functions or steps, or combinations of special purpose hardware and computer instructions.

As shown in FIG. 15, one embodiment of a method for providing a combined linear and circular downscan sonar display may include receiving linear downscan sonar data from a linear downscan transducer at operation **200** and receiving conical downscan sonar data from a circular downscan transducer at operation **210**. The method may further include combining the linear downscan sonar data and the conical downscan sonar data to produce combined downscan sonar data at operation **220**. In some cases, additional optional operations may be included, some of which are shown in dashed lines in FIG. 15. For example, the method may further include synchronizing the linear downscan sonar data and the conical downscan sonar data prior to the combining at operation **215**. In some cases, the method may further include rendering the combined downscan sonar data in the single display window such that return data corresponding to the linear downscan sonar data is provided with a first color scheme and return data corresponding to the conical downscan sonar data is provided with a second color scheme at operation **230**.

The above described functions may be carried out in many ways. For example, any suitable means for carrying out each of the functions described above may be employed to carry out embodiments of the invention. In one embodiment, all or a portion of the elements of the invention generally operate under control of a computer program product. The computer program product for performing the methods of embodiments of the invention includes a computer-readable storage medium, such as the non-volatile storage medium, and computer-readable program code portions, such as a series of computer instructions, embodied in the computer-readable storage medium.

Many modifications and other embodiments of the inventions set forth herein will come to mind to one skilled in the art to which these embodiments pertain having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the inventions are not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

That which is claimed:

1. A method comprising:

receiving linear downscan sonar data based on sonar returns from a series of fan-shaped beams produced sequentially by a linear downscan transducer mounted on a watercraft, the series of fan-shaped beams insonifying different fan-shaped regions of an underwater environment beneath the watercraft as the watercraft travels;

receiving conical downscan sonar data based on sonar returns from a generally conical beam produced by a second downscan transducer, wherein the conical beam is wider than each fan-shaped beam in a direction parallel to a longitudinal length of the linear downscan transducer;

combining the linear downscan sonar data and the conical downscan sonar data to produce combined downscan sonar data; and

rendering the combined downscan sonar data as at least one image on a display, the at least one image including a composite of images of the fan-shaped regions arranged in a progressive order corresponding to the travel of the watercraft.

2. The method of claim **1**, wherein receiving the linear downscan sonar data and receiving the conical downscan sonar data comprises receiving the linear downscan sonar data and the conical downscan sonar data corresponding to respective underwater regions that at least partially overlap.

3. The method of claim **1**, wherein combining the linear downscan sonar data and the conical downscan sonar data comprises producing the combined downscan sonar data to be displayable in a single display window.

4. The method of claim **1**, further comprising synchronizing the linear downscan sonar data and the conical downscan sonar data prior to the combining.

5. The method of claim **4**, wherein synchronizing the linear downscan sonar data and the conical downscan sonar data comprises utilizing a predetermined interval of linear downscan transmissions from the linear downscan transducer as a reference for synchronization with the conical downscan sonar data.

6. The method of claim **4**, wherein synchronizing the linear downscan sonar data and the conical downscan sonar data comprises utilizing a predetermined interval of downscan transmissions from the second downscan transducer as a reference for synchronization with the linear downscan sonar data.

7. The method of claim **4**, wherein synchronizing the linear downscan sonar data and the conical downscan sonar data comprises utilizing a predetermined time interval as a reference for synchronization.

8. The method of claim **1**, wherein the rendering step comprises rendering base data corresponding to one of the linear downscan sonar data or the conical downscan sonar data and rendering overlay data corresponding to the other of the linear downscan sonar data or the conical downscan sonar data over the base data.

9. The method of claim **8**, wherein rendering overlay data corresponding to the other of the linear downscan sonar data or the conical downscan sonar data over the base data comprises applying a level mask to the overlay data and rendering only data above a predefined threshold associated with the level mask as the overlay data.

10. The method of claim **1**, wherein combining the linear downscan sonar data and the conical downscan sonar data comprises blending the linear downscan sonar data with the conical downscan sonar data and rendering the blended data.

11. The method of claim **10**, wherein blending the linear downscan sonar data with the conical downscan sonar data comprises applying a first weighting factor to the linear downscan sonar data to produce first weighted data and applying a second weighting factor to the conical downscan sonar data to produce second weighted data and wherein rendering the blended data comprises combining the first weighted data and second weighted data into combined weighted data and rendering the combined weighted data.

12. The method of claim **1**, wherein combining the linear downscan sonar data and the conical downscan sonar data comprises:

forming first data columns of the conical downscan sonar data;

forming second data columns of the linear downscan sonar data corresponding to each of the first data columns; and

rendering base data from one of the first data columns or the second data columns and rendering at least a portion of overlay data from the other of the first data columns or the second data columns over the base data.

13. The method of claim **12**, wherein forming the second data columns comprises storing a plurality of linear downscan sonar data columns corresponding to each of the first data columns and merging the plurality of linear downscan sonar data columns to produce one second data column corresponding to each first data column.

14. The method of claim **13**, wherein merging the plurality of linear downscan sonar data columns to produce one second data column corresponding to each first data column comprises selecting a largest value for each corresponding segment of the plurality of linear downscan sonar data columns and storing the largest value for each segment to form a corresponding second data column.

15. The method of claim **13**, wherein merging the plurality of linear downscan sonar data columns to produce one second data column corresponding to each first data column comprises averaging values for each corresponding segment of the plurality of linear downscan sonar data columns and storing an average value for each segment to form a corresponding second data column.

16. The method of claim 1, wherein combining the linear downscan sonar data and the conical downscan sonar data comprises combining the linear downscan sonar data and the conical downscan sonar data based on a user selected sensitivity.

17. The method of claim 1, further comprising rendering the combined downscan sonar data in a single display window such that return data corresponding to the linear downscan sonar data is provided with a first color scheme and return data corresponding to the conical downscan sonar data is provided with a second color scheme.

18. The method of claim 17, wherein rendering the combined downscan sonar data comprises enabling user selection of a color palette for displaying return data corresponding to the linear downscan sonar data with a first color scheme and displaying return data corresponding to the conical downscan sonar data with a second color scheme.

19. The method of claim 1, further comprising enabling user selection of a rendering option corresponding to one of:

rendering only the conical downscan sonar data in a single display window;

rendering only the linear downscan sonar data in the single display window;

rendering only the combined downscan sonar data in the single display window;

rendering the conical downscan sonar data, the linear downscan sonar data and the combined downscan sonar data each in respective different display windows;

rendering the conical downscan sonar data and the linear downscan sonar data each in respective different display windows; or

rendering one of the conical downscan sonar data or the linear downscan sonar data with the combined downscan sonar data such that the combined downscan sonar data and the one of the conical downscan sonar data or the linear downscan sonar data are each provided in respective different display windows.

20. The method of claim 1, wherein the rendering step comprises creating linear downscan image data based on the linear downscan sonar data, creating conical downscan image data based on the conical downscan sonar data, and displaying both the linear downscan image data and the conical downscan sonar data for a same region beneath the watercraft.

21. The method of claim 20, wherein the linear downscan image data for said same region is displayed in a first window on a display and the conical downscan sonar data for said same region is displayed in a second window on the display.

22. The method of claim 20, wherein the linear downscan image data for said same region and the conical downscan sonar data for said same region are displayed overlaid on the display.

23. The method of claim 1, wherein the linear transducer is mounted on the watercraft with the longitudinal length of the linear transducer oriented substantially parallel to a fore-to-aft direction of the watercraft.

24. A computer program product comprising at least one non-transitory computer-readable storage medium having computer-executable program code portions stored therein, the computer-executable program code portions comprising:

program code instructions for receiving linear downscan sonar data based on sonar returns from a series of fan-shaped beams produced sequentially by a linear downscan transducer mounted on a watercraft, the series of fan-shaped beams insonifying different fan-shaped regions of an underwater environment beneath the watercraft as the watercraft travels;

program code instructions for receiving conical downscan sonar data based on sonar returns from a generally conical beam produced by a second downscan transducer, wherein the conical beam is wider than each fan-shaped beam in a direction parallel to a longitudinal length of the linear downscan transducer;

program code instructions for combining the linear downscan sonar data and the conical downscan sonar data to produce combined downscan sonar data; and

program code instructions for rendering the combined downscan sonar data as at least one image on a display, the at least one image including a composite of images of the fan-shaped regions arranged in a progressive order corresponding to the travel of the watercraft.

25. The computer program product of claim 24, wherein program code instructions for receiving the linear downscan sonar data and receiving the conical downscan sonar data include instructions for receiving the linear downscan sonar data and the conical downscan sonar data corresponding to respective underwater regions that at least partially overlap.

26. The computer program product of claim 24, wherein program code instructions for combining the linear downscan sonar data and the conical downscan sonar data includes instructions for producing the combined downscan sonar data to be displayable in a single display window.

27. The computer program product of claim 24, further comprising program code instructions for synchronizing the linear downscan sonar data and the conical downscan sonar data prior to the combining.

28. The computer program product of claim 27, wherein program code instructions for synchronizing the linear downscan sonar data and the conical downscan sonar data include instructions for utilizing a predetermined interval of linear downscan transmissions from the linear downscan transducer as a reference for synchronization with the conical downscan sonar data.

29. The computer program product of claim 27, wherein program code instructions for synchronizing the linear downscan sonar data and the conical downscan sonar data include instructions for utilizing a predetermined interval of downscan transmissions from the second downscan transducer as a reference for synchronization with the linear downscan sonar data.

30. The computer program product of claim 27, wherein program code instructions for synchronizing the linear downscan sonar data and the conical downscan sonar data includes instructions for utilizing a predetermined time interval as a reference for synchronization.

31. The computer program product of claim 24, wherein program code instructions for combining the linear downscan sonar data and the conical downscan sonar data include instructions for rendering base data corresponding to one of the linear downscan sonar data or the conical downscan sonar data and rendering overlay data corresponding to the other of the linear downscan sonar data or the conical downscan sonar data over the base data.

32. The computer program product of claim 31, wherein program code instructions for rendering overlay data corresponding to the other of the linear downscan sonar data or the conical downscan sonar data over the base data include instructions for applying a level mask to the overlay data and rendering only data above a predefined threshold associated with the level mask as the overlay data.

33. The computer program product of claim 24, wherein program code instructions for combining the linear downscan sonar data and the conical downscan sonar data include instructions for blending the linear downscan sonar data with the conical downscan sonar data and rendering the blended data.

34. The computer program product of claim 33, wherein program code instructions for blending the linear downscan sonar data with the conical downscan sonar data include instructions for applying a first weighting factor to the linear downscan sonar data to produce first weighted data and applying a second weighting factor to the conical downscan sonar data to produce second weighted data and wherein rendering the blended data comprises combining the first weighted data and second weighted data into combined weighted data and rendering the combined weighted data.

35. The computer program product of claim 24, wherein program code instructions for combining the linear downscan sonar data and the conical downscan sonar data include instructions for:

forming first data columns of the conical downscan sonar data;

forming second data columns of the linear downscan sonar data corresponding to each of the first data columns; and

rendering base data from one of the first data columns or the second data columns and rendering at least a portion of overlay data from the other of the first data columns or the second data columns over the base data.

36. The computer program product of claim 35, wherein program code instructions for forming the second data columns include instructions for storing a plurality of linear downscan sonar data columns corresponding to each of the first data columns and merging the plurality of linear downscan sonar data columns to produce one second data column corresponding to each first data column.

37. The computer program product of claim 36, wherein program code instructions for merging the plurality of linear downscan sonar data columns to produce one second data column corresponding to each first data column include instructions for selecting a largest value for each corresponding segment of the plurality of linear downscan sonar data columns and storing the largest value for each segment to form a corresponding second data column.

38. The computer program product of claim 36, wherein program code instructions for merging the plurality of linear downscan sonar data columns to produce one second data column corresponding to each first data column include instructions for averaging values for each corresponding segment of the plurality of linear downscan sonar data columns and storing an average value for each segment to form a corresponding second data column.

39. The computer program product of claim 24, wherein program code instructions for combining the linear downscan sonar data and the conical downscan sonar data include instructions for combining the linear downscan sonar data and the conical downscan sonar data based on a user selected sensitivity.

40. The computer program product of claim 24, further comprising program code instructions for rendering the combined downscan sonar data in the single display window such that return data corresponding to the linear downscan sonar data is provided with a first color scheme and return data corresponding to the conical downscan sonar data is provided with a second color scheme.

41. The computer program product of claim 40, wherein program code instructions for rendering the combined downscan sonar data include instructions for enabling user selection of a color palette for displaying return data corresponding to the linear downscan sonar data with a first color scheme and displaying return data corresponding to the conical downscan sonar data with a second color scheme.

42. The computer program product of claim 24, further comprising program code instructions for enabling user selection of a rendering option corresponding to:

rendering only the conical downscan sonar data in a single display window;

rendering only the linear downscan sonar data in the single display window;

rendering only the combined downscan sonar data in the single display window;

rendering the conical downscan sonar data, the linear downscan sonar data and the combined downscan sonar data each in respective different display windows;

rendering the conical downscan sonar data and the linear downscan sonar data each in respective different display windows; or

rendering one of the conical downscan sonar data or the linear downscan sonar data with the combined downscan sonar data such that the combined downscan sonar data and the one of the conical downscan sonar data or the linear downscan sonar data are each provided in respective different display windows.

43. An apparatus comprising a sonar signal processor configured to:

receive linear downscan sonar data based on sonar returns from a series of fan-shaped beams produced sequentially by a linear downscan transducer mounted on a watercraft, the series of fan-shaped beams insonifying different fan-shaped regions of an underwater environment beneath the watercraft as the watercraft travels;

receive conical downscan sonar data based on sonar returns from a generally conical beam produced by a second downscan transducer, wherein the conical beam is wider than each fan-shaped beam in a direction parallel to a longitudinal length of the linear downscan transducer;

combine the linear downscan sonar data and the conical downscan sonar data to produce combined downscan sonar data; and

render the combined downscan sonar data as at least one image on a display, the at least one image including a composite of images of the fan-shaped regions arranged in a progressive order corresponding to the travel of the watercraft.

44. The apparatus of claim 43, wherein the sonar signal processor is configured to receive the linear downscan sonar data and receiving the conical downscan sonar data by receiving the linear downscan sonar data and the conical downscan sonar data corresponding to respective underwater regions that at least partially overlap.

45. The apparatus of claim 43, wherein the sonar signal processor is configured to combine the linear downscan sonar data and the conical downscan sonar data by producing the combined downscan sonar data to be displayable in a single display window.

46. The apparatus of claim 43, wherein the sonar signal processor is further configured to synchronize the linear downscan sonar data and the conical downscan sonar data prior to the combining.

47. The apparatus of claim 46, wherein the sonar signal processor is configured to synchronize the linear downscan sonar data and the conical downscan sonar data by utilizing a predetermined interval of linear downscan transmissions from the linear downscan transducer as a reference for synchronization with the conical downscan sonar data.

48. The apparatus of claim 46, wherein the sonar signal processor is configured to synchronize the linear downscan sonar data and the conical downscan sonar data by utilizing a predetermined interval of downscan transmissions from the second downscan transducer as a reference for synchronization with the linear downscan sonar data.

49. The apparatus of claim 46, wherein the sonar signal processor is configured to synchronize the linear downscan sonar data and the conical downscan sonar data by utilizing a predetermined time interval as a reference for synchronization.

50. The apparatus of claim 43, wherein the sonar signal processor is configured to combine the linear downscan sonar data and the conical downscan sonar data by rendering base data corresponding to one of the linear downscan sonar data or the conical downscan sonar data and rendering overlay data corresponding to the other of the linear downscan sonar data or the conical downscan sonar data over the base data.

51. The apparatus of claim 50, wherein the sonar signal processor is configured to render overlay data corresponding to the other of the linear downscan sonar data or the conical downscan sonar data over the base data by applying a level mask to the overlay data and rendering only data above a predefined threshold associated with the level mask as the overlay data.

52. The apparatus of claim 43, wherein the sonar signal processor is configured to combine the linear downscan sonar data and the conical downscan sonar data by blending the linear downscan sonar data with the conical downscan sonar data and rendering the blended data.

53. The apparatus of claim 52, wherein the sonar signal processor is configured to blend the linear downscan sonar data with the conical downscan sonar data by applying a first weighting factor to the linear downscan sonar data to produce first weighted data and applying a second weighting factor to the conical downscan sonar data to produce second weighted data and wherein rendering the blended data comprises combining the first weighted data and second weighted data into combined weighted data and rendering the combined weighted data.

54. The apparatus of claim 43, wherein the sonar signal processor is configured to combine the linear downscan sonar data and the conical downscan sonar data by:

forming first data columns of the conical downscan sonar data;

forming second data columns of the linear downscan sonar data corresponding to each of the first data columns; and

rendering base data from one of the first data columns or the second data columns and rendering at least a portion of overlay data from the other of the first data columns or the second data columns over the base data.

55. The apparatus of claim 54, wherein the sonar signal processor is configured to form the second data columns by storing a plurality of linear downscan sonar data columns corresponding to each of the first data columns and merging the plurality of linear downscan sonar data columns to produce one second data column corresponding to each first data column.

56. The apparatus of claim 55, wherein the sonar signal processor is configured to merge the plurality of linear downscan sonar data columns to produce one second data column corresponding to each first data column by selecting a largest value for each corresponding segment of the plurality of linear downscan sonar data columns and storing the largest value for each segment to form a corresponding second data column.

57. The apparatus of claim 55, wherein the sonar signal processor is configured to merge the plurality of linear downscan sonar data columns to produce one second data column corresponding to each first data column by averaging values for each corresponding segment of the plurality of linear downscan sonar data columns and storing an average value for each segment to form a corresponding second data column.

58. The apparatus of claim 43, wherein the sonar signal processor is configured to combine the linear downscan sonar data and the conical downscan sonar data by combining the linear downscan sonar data and the conical downscan sonar data based on a user selected sensitivity.

59. The apparatus of claim 43, wherein the sonar signal processor is further configured to render the combined downscan sonar data in the single display window such that return data corresponding to the linear downscan sonar data is provided with a first color scheme and return data corresponding to the conical downscan sonar data is provided with a second color scheme.

60. The apparatus of claim 59, wherein the sonar signal processor is configured to render the combined downscan sonar data by enabling user selection of a color palette for displaying return data corresponding to the linear downscan sonar data with a first color scheme and displaying return data corresponding to the conical downscan sonar data with a second color scheme.

61. The apparatus of claim 59, wherein the sonar signal processor is configured to render the combined downscan sonar data by enabling user selection of a color palette for displaying return data corresponding to the linear downscan sonar data with a first shading or cross-hatching scheme and displaying return data corresponding to the conical downscan sonar data with a second shading or cross-hatching scheme.

62. The apparatus of claim 43, wherein the sonar signal processor is further configured to enable user selection of a rendering option corresponding to:

rendering only the conical downscan sonar data in a single display window;

rendering only the linear downscan sonar data in the single display window;

rendering only the combined downscan sonar data in the single display window;

rendering the conical downscan sonar data, the linear downscan sonar data and the combined downscan sonar data each in respective different display windows;

rendering the conical downscan sonar data and the linear downscan sonar data each in respective different display windows; or

rendering one of the conical downscan sonar data or the linear downscan sonar data with the combined downscan sonar data such that the combined downscan sonar data and the one of the conical downscan sonar data or the linear downscan sonar data are each provided in respective different display windows.

63. The apparatus of claim 43, wherein the sonar signal processor is part of a sonar module in a single housing.

64. The apparatus of claim 63, wherein the sonar module includes multiple operating frequencies.

65. The apparatus of claim 63, wherein the housing is mountable to a watercraft.

66. The apparatus of claim 63, wherein the sonar module includes a single transceiver serving multiple transducers.

67. The apparatus of claim 63, wherein the sonar module includes multiple linear transducers.

68. The apparatus of claim 63, wherein the sonar module includes multiple circular transducers.

69. The apparatus of claim **43**, further comprising a display configured to display images representing sonar signals.

70. The apparatus of claim **69**, wherein the display is configured to render different images on the same display.

71. The apparatus of claim **43**, wherein the linear downscan transducer provides one or more of depth, water column features and bottom data.

72. The apparatus of claim **43**, wherein the linear downscan transducer and the second downscan transducer are within a same housing.

73. The apparatus of claim **72**, wherein the housing has a streamlined shape.

74. The apparatus of claim **43**, wherein the linear downscan transducer and the second downscan transducer provide data simultaneously.

75. The apparatus of claim **43**, further comprising a display and a sonar module including the sonar signal processor, the display and the sonar module being within a same housing.

76. The apparatus of claim **75**, wherein the display is configured to render data from sources of data including at least one of the group of radar, GPS, digital mapping, time and temperature.

77. The apparatus of claim **75**, wherein a display format for the display is user selectable.

78. The apparatus of claim **43**, wherein the second transducer is circular.

79. The apparatus of claim **43**, further comprising a transducer assembly comprising said linear downscan transducer and said second downscan transducer disposed in a housing that is mountable to a watercraft, wherein said linear downscan transducer and said second downscan transducer are oriented to both insonify a same region beneath the watercraft.

80. The apparatus of claim **79**, wherein the linear downscan transducer is oriented to insonify a first region beneath the watercraft that is relatively narrow in a direction parallel to a longitudinal length of the linear downscan transducer and relatively wide in a direction transverse to the longitudinal length, and the second downscan transducer is oriented to insonify a second region beneath the watercraft that is wider than the first region in said direction parallel to the longitudinal length of the linear downscan transducer.

81. The apparatus of claim **80**, wherein the linear downscan transducer and the second downscan transducer are oriented such that the first and second regions at least partially overlap.

* * * * *

EXHIBIT B

US008305840B2

(12) **United States Patent**
Maguire

(10) **Patent No.: US 8,305,840 B2**
(45) **Date of Patent: Nov. 6, 2012**

(54) **DOWNSCAN IMAGING SONAR**

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G01S 15/00 (2006.01)

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(58) **Field of Classification Search** 367/88
See application file for complete search history.

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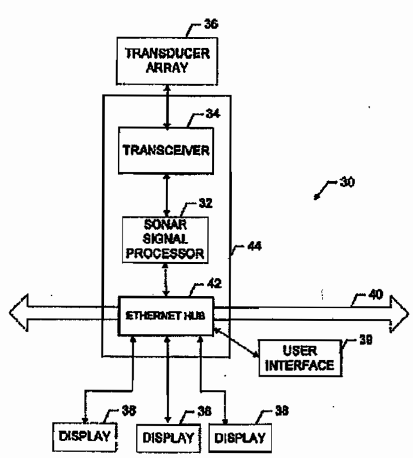
(57) **ABSTRACT**

A downscan imaging sonar utilizes a linear transducer element to provide improved images of the sea floor and other objects in the water column beneath a vessel. A transducer array may include a plurality of transducer elements and each one of the plurality of transducer elements may include a substantially rectangular shape configured to produce a sonar beam having a beamwidth in a direction parallel to longitudinal length of the transducer elements that is significantly less than a beamwidth of the sonar beam in a direction perpendicular to the longitudinal length of the transducer elements. The plurality of transducer elements may be positioned such that longitudinal lengths of at least two of the plurality of transducer elements are parallel to each other. The plurality of transducer elements may also include at least a first linear transducer element, a second linear transducer element and a third linear transducer element. The first linear transducer element may be positioned within the housing to project sonar pulses from a first side of the housing in a direction substantially perpendicular to a centerline of the housing. The second linear transducer element may be positioned within the housing to lie in a plane with the first linear transducer element and project sonar pulses from a second side of the housing that is substantially opposite of the first side. The third linear transducer element may be positioned within the housing to project sonar pulses in a direction substantially perpendicular to the plane.

73 Claims, 23 Drawing Sheets
(5 of 23 Drawing Sheet(s) Filed in Color)



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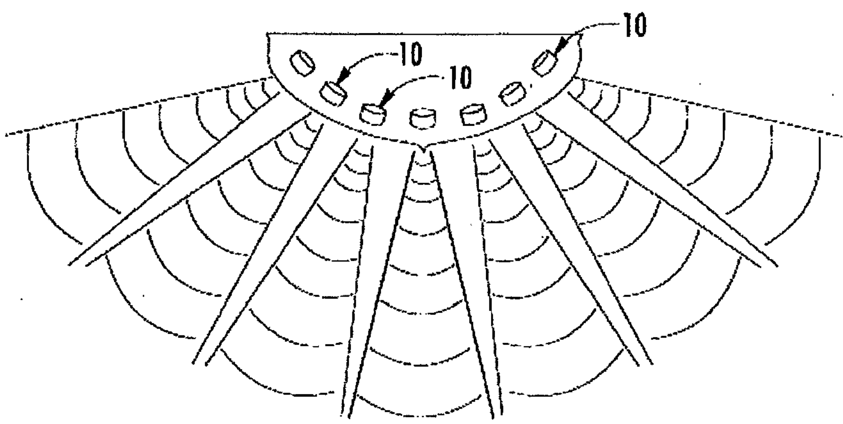


FIG. 1
(PRIOR ART)

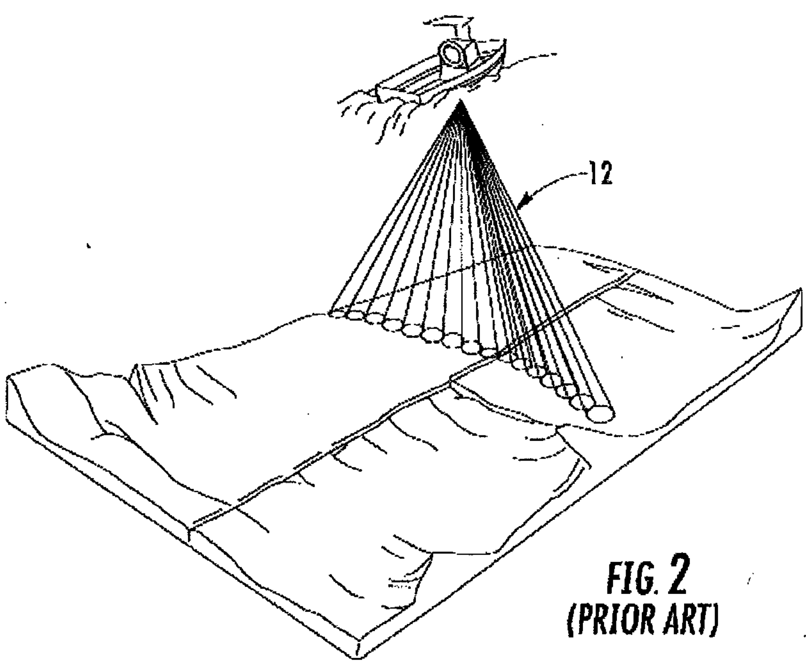


FIG. 2
(PRIOR ART)

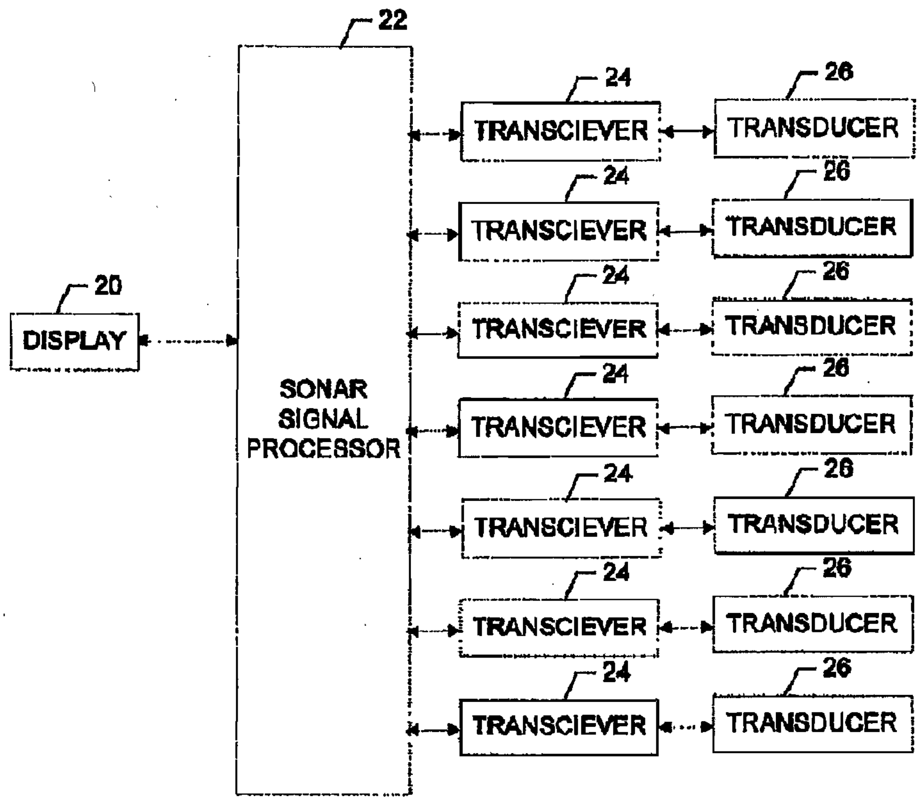


FIG. 3.
(Prior Art)

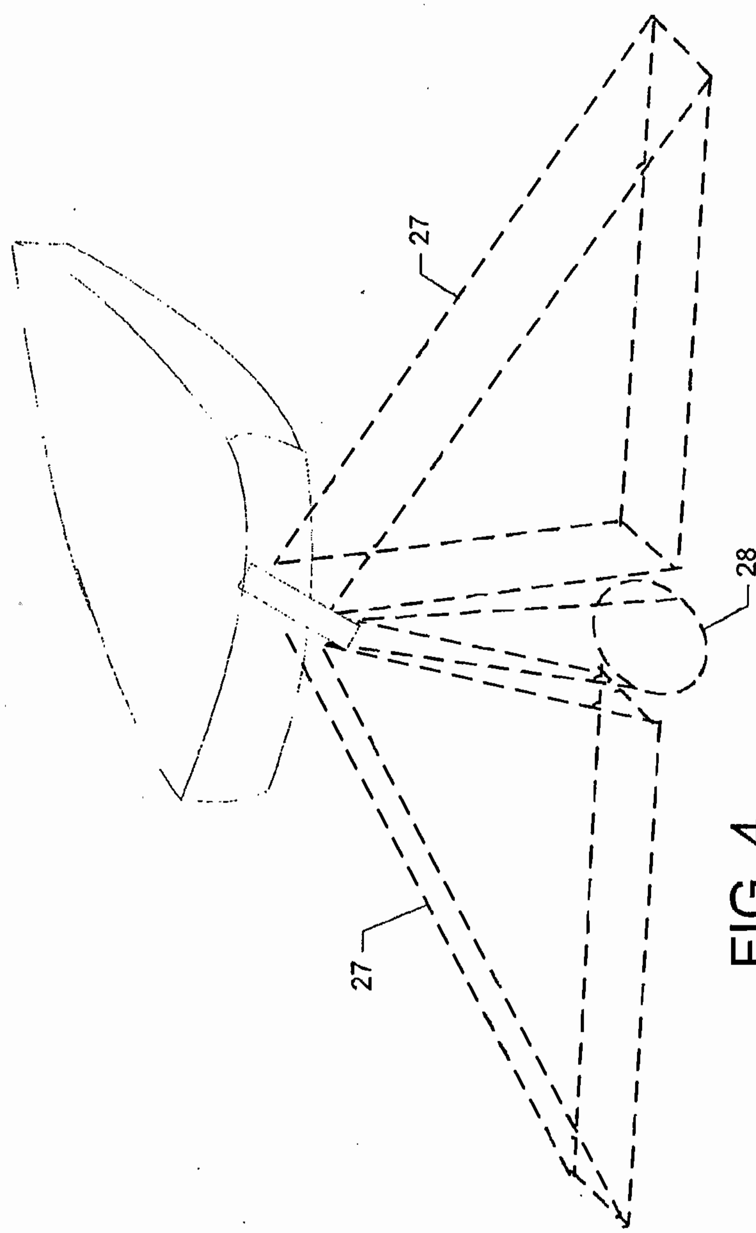
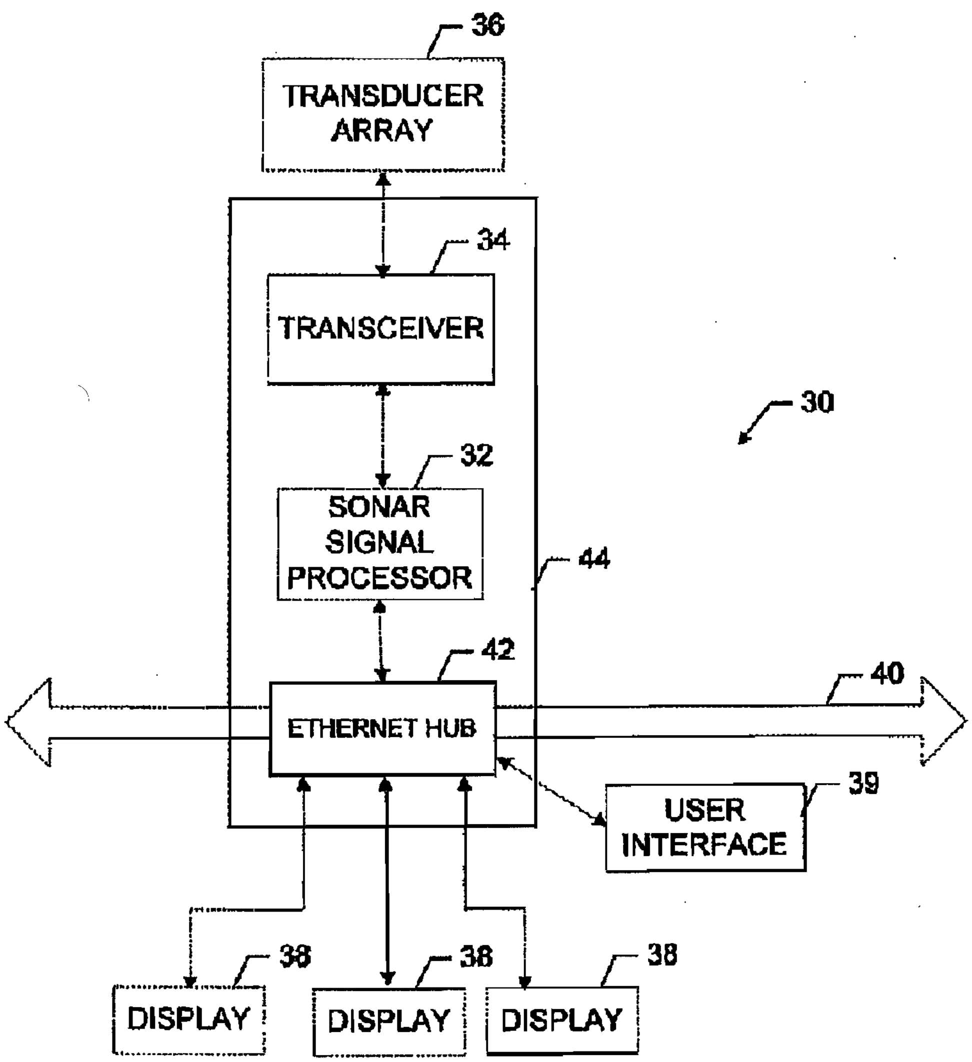


FIG. 4.
(Prior Art)


36
TRANSDUCER ARRAY
34
TRANSCEIVER
30
32
SONAR SIGNAL PROCESSOR
44
42
40
ETHERNET HUB
39
USER INTERFACE
38
38
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DISPLAY
DISPLAY
DISPLAY

FIG. 5.

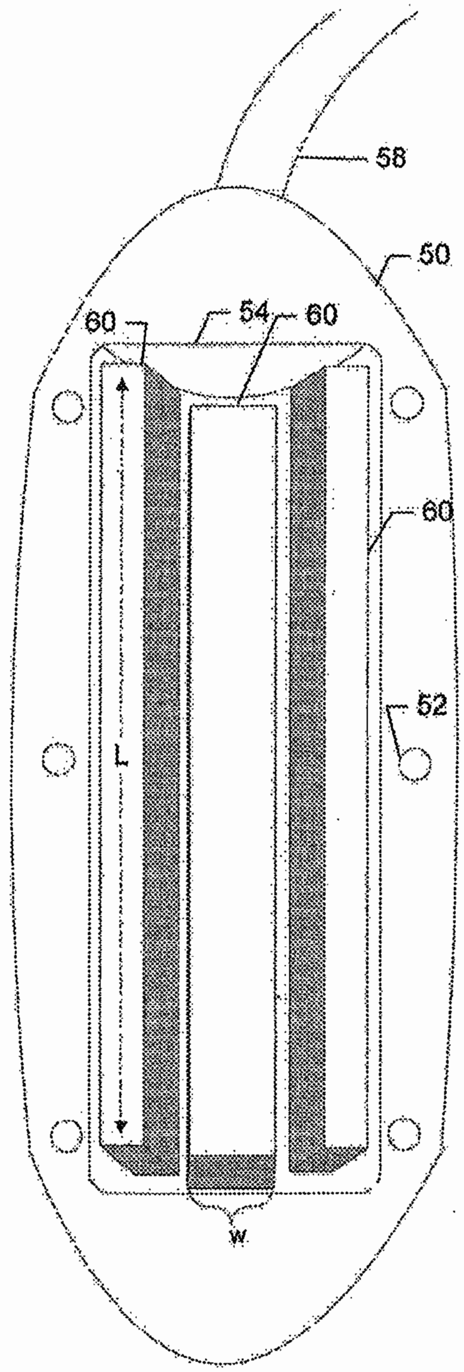


FIG. 6.

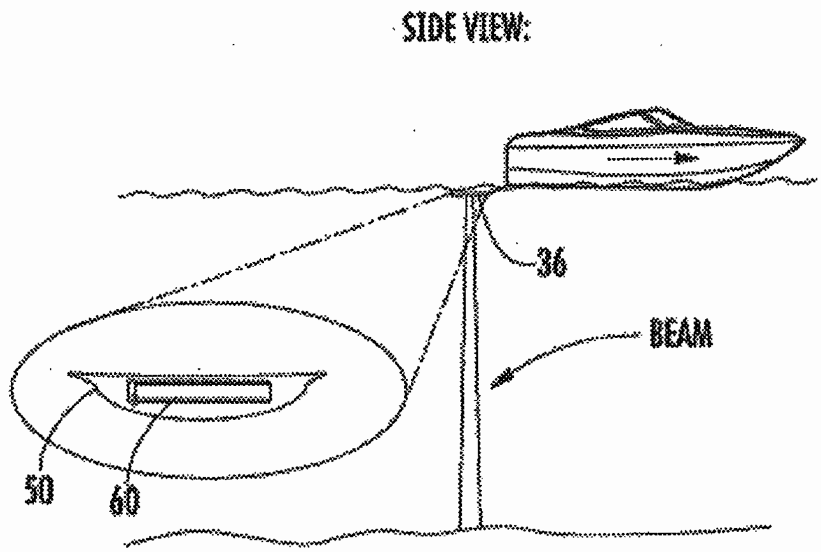

SIDE VIEW:
36
BEAM
50
60

FIG. 7A

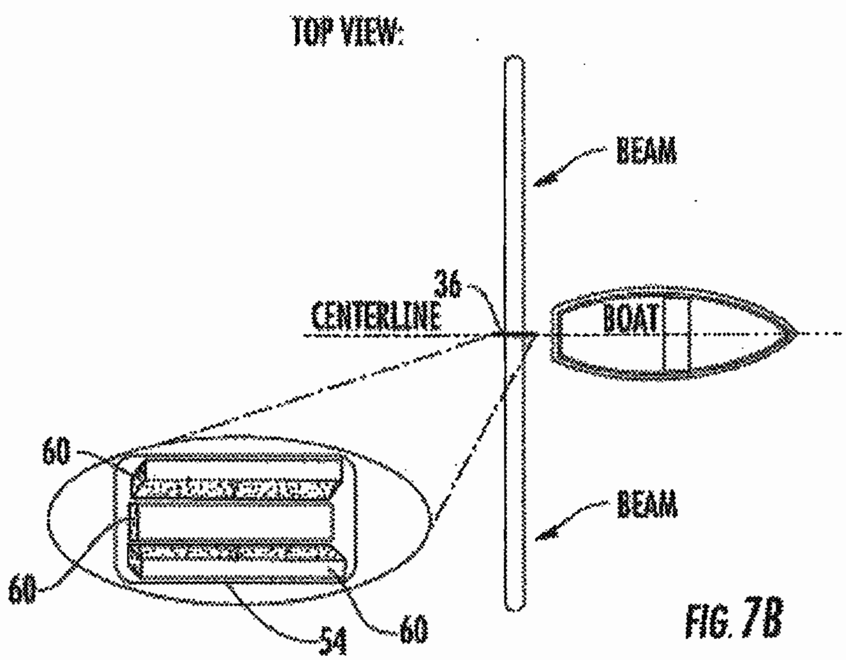

TOP VIEW:
BEAM
36
CENTERLINE
BOAT
60
60
BEAM
54
60

FIG. 7B

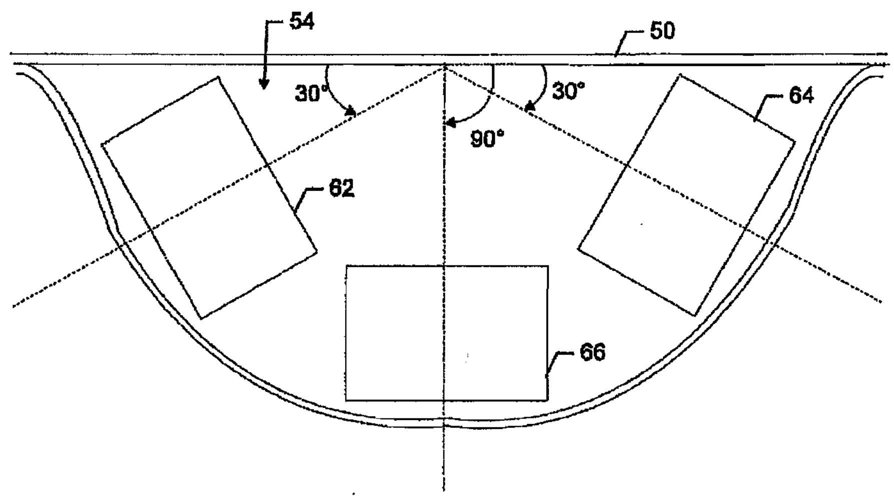


FIG. 8A.

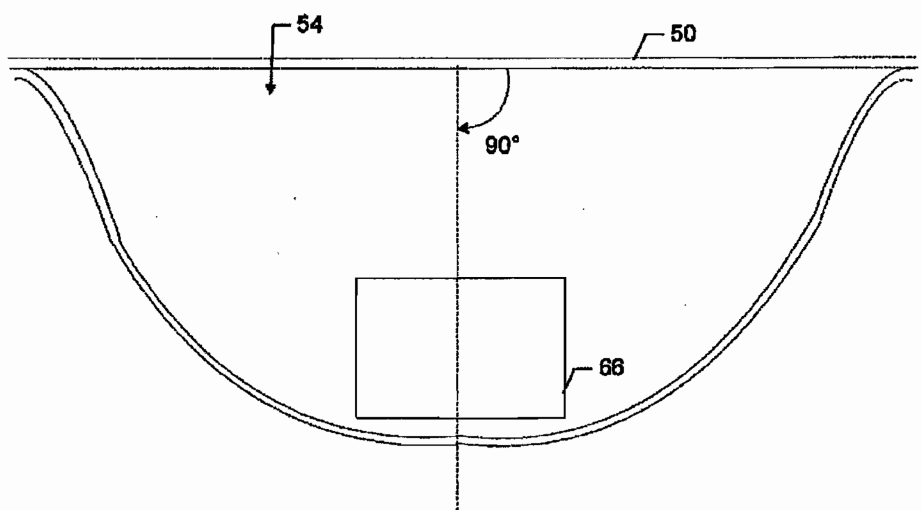


FIG. 8B.

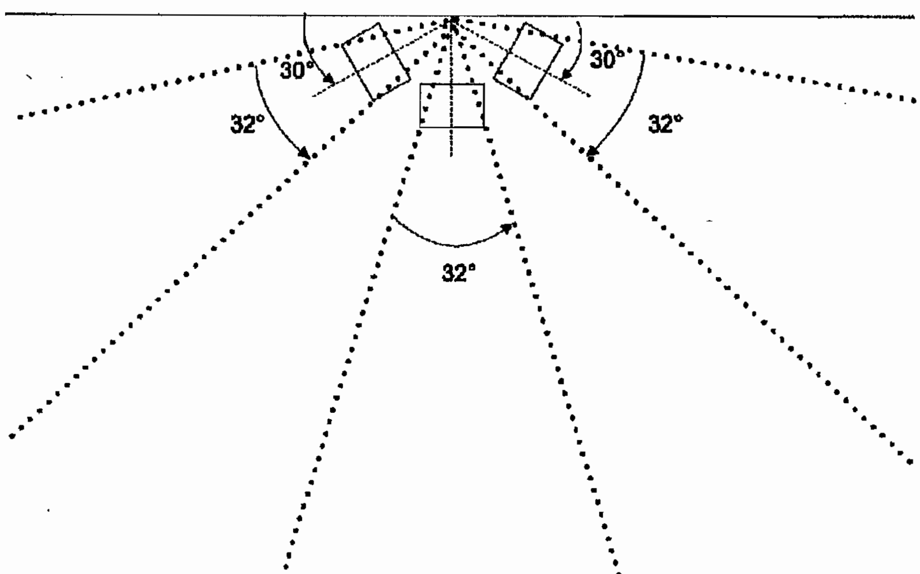


FIG. 9A.

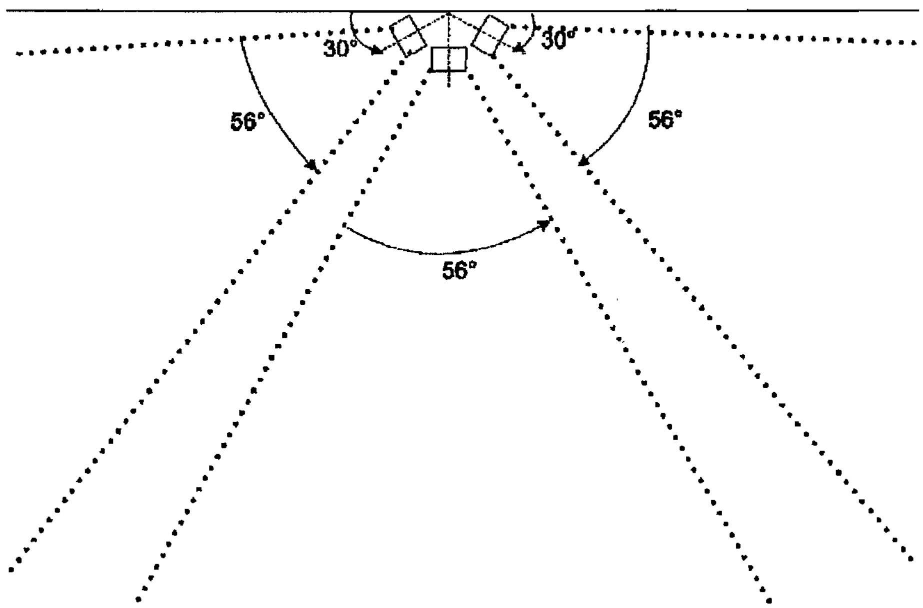


FIG. 9B.

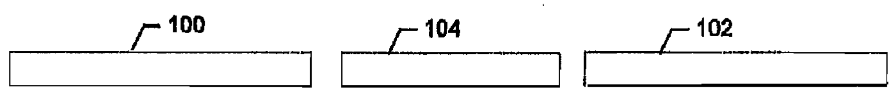


FIG. 10A.

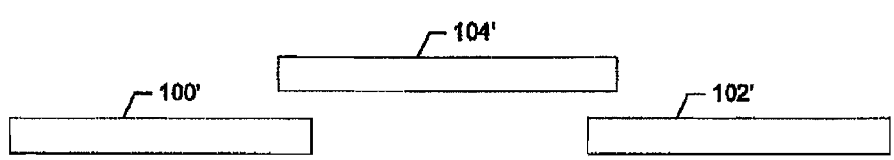


FIG. 10B.

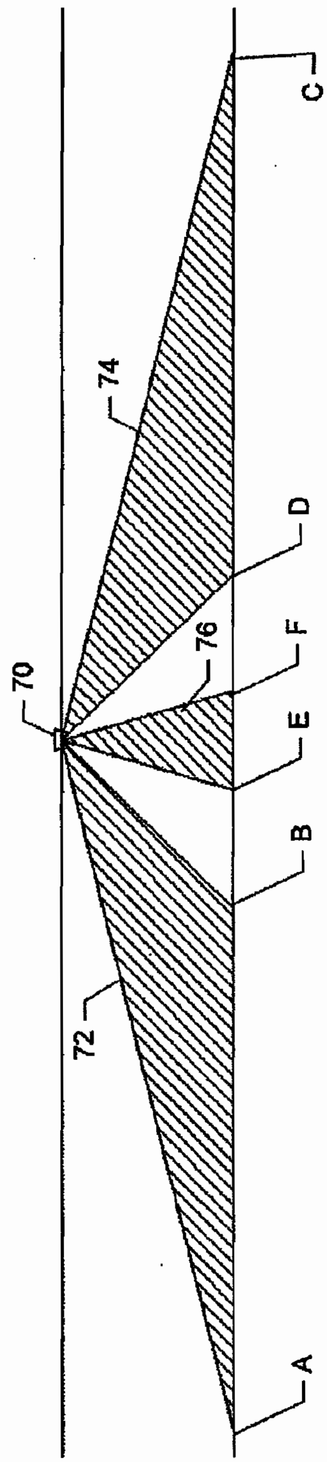


FIG. 11A.

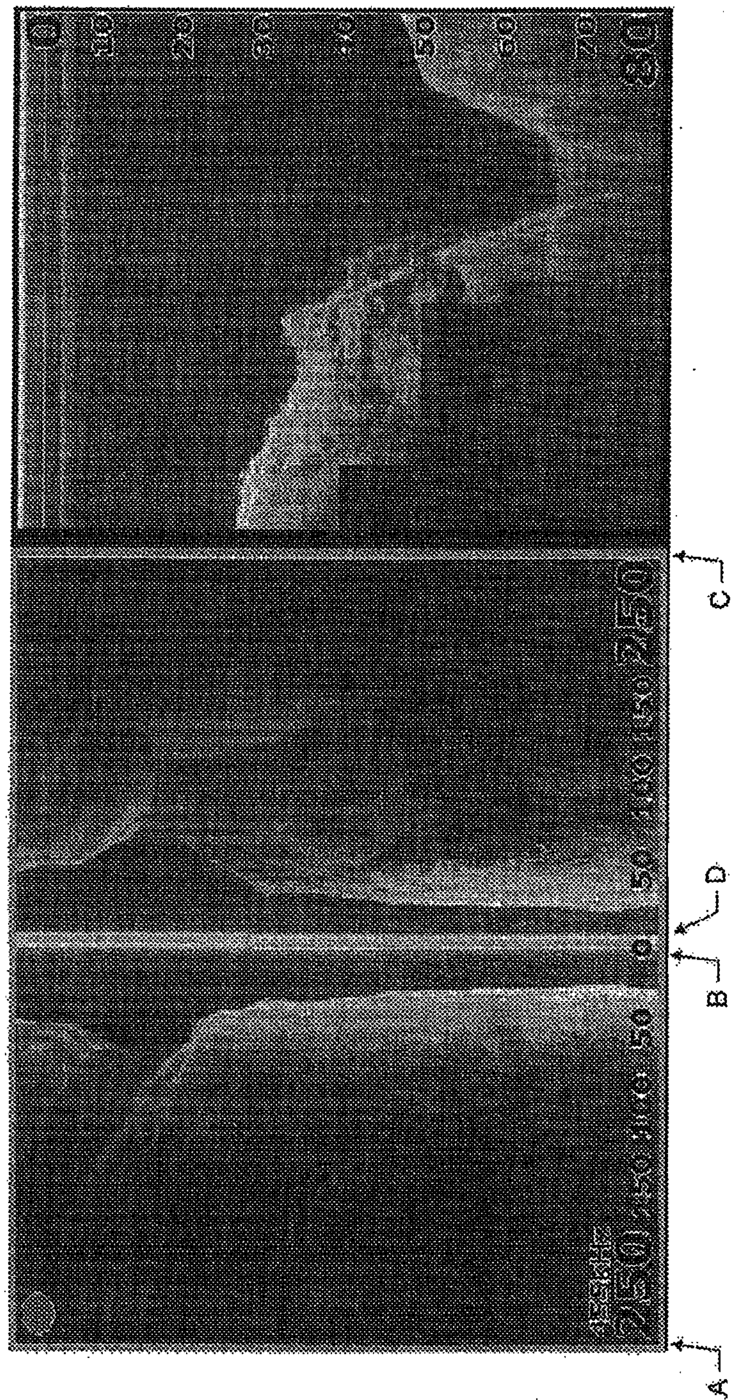


FIG. 11B.

FIG. 11C.

FIG. 12A.

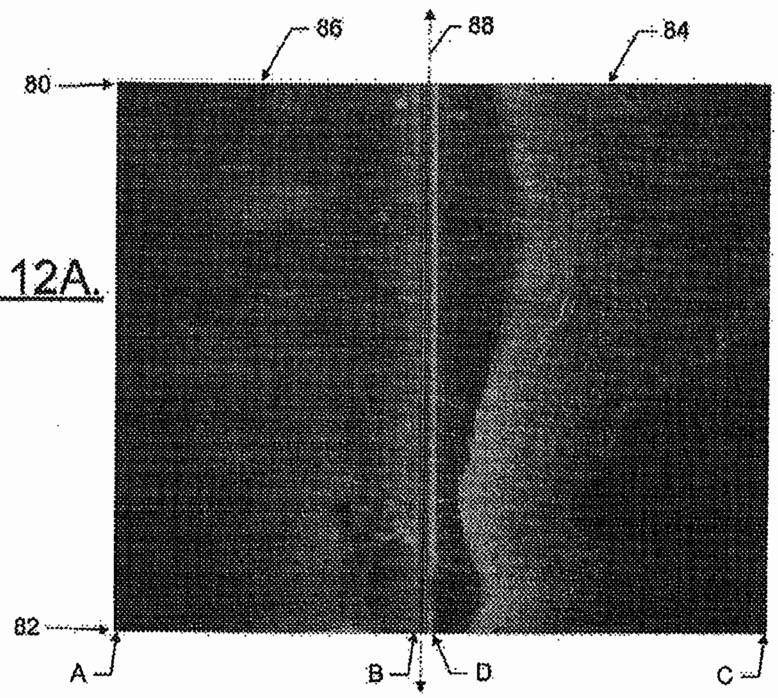
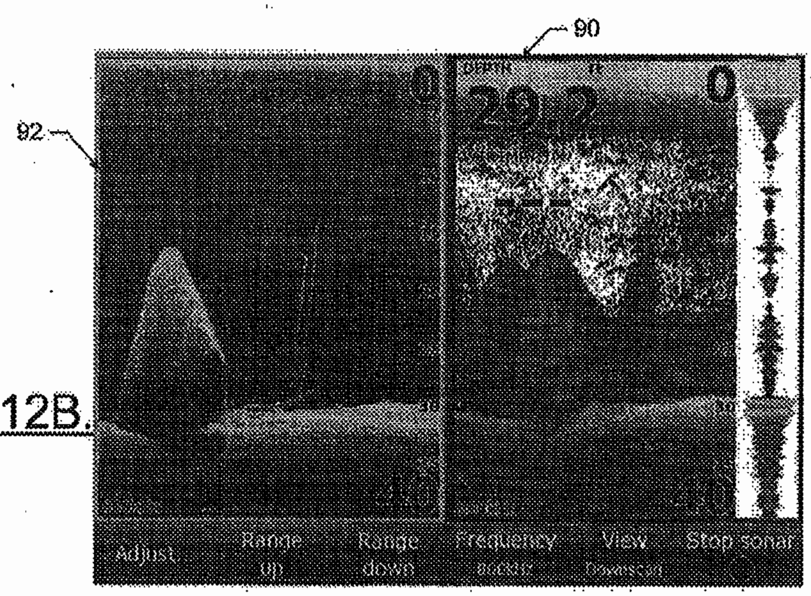


FIG. 12B.



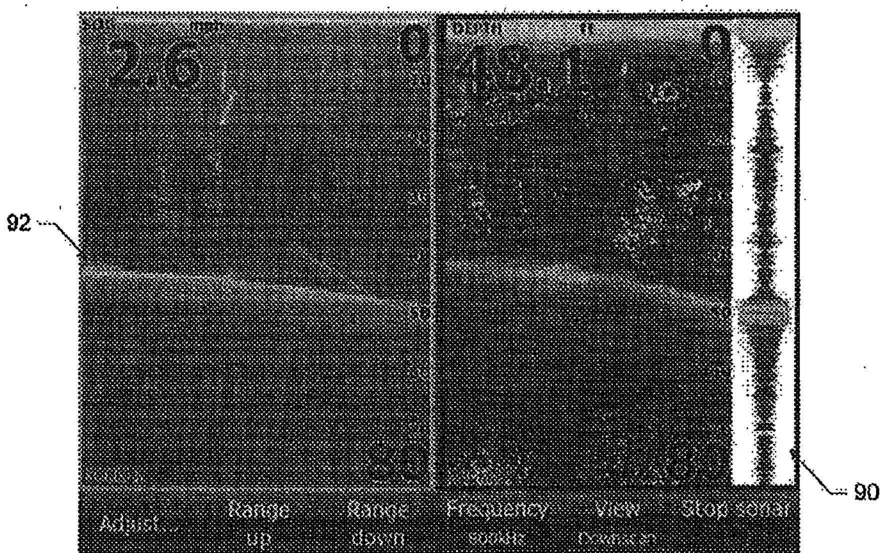


FIG. 12C.

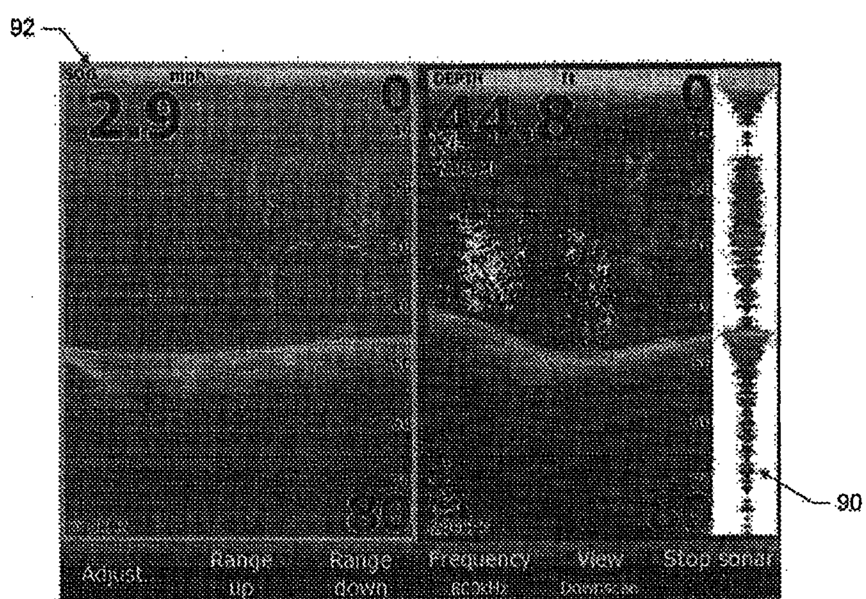


FIG. 12D.

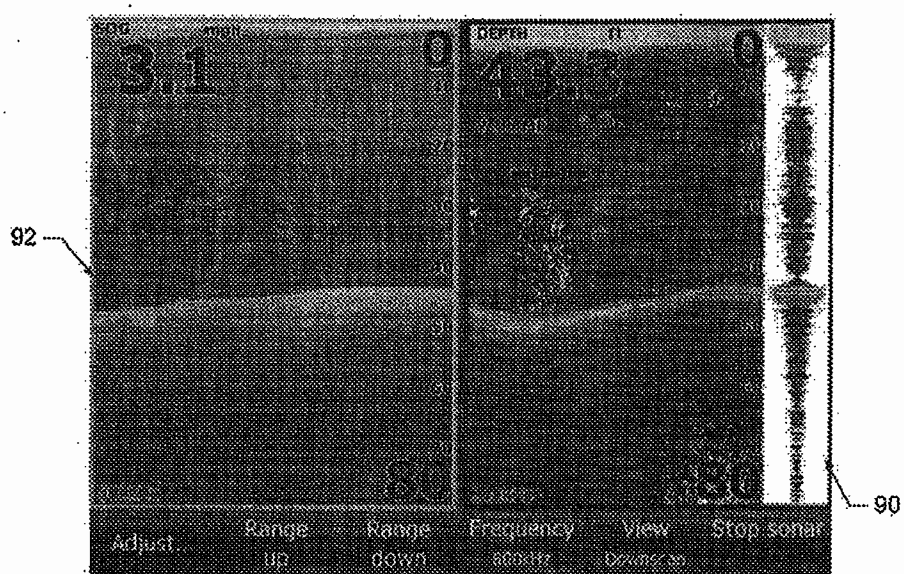


FIG. 12E.

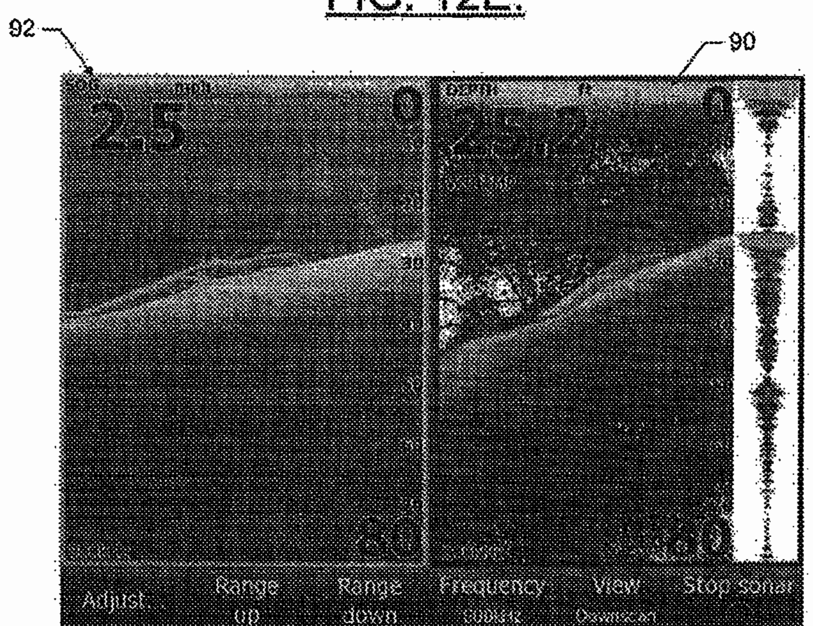


FIG. 12F.

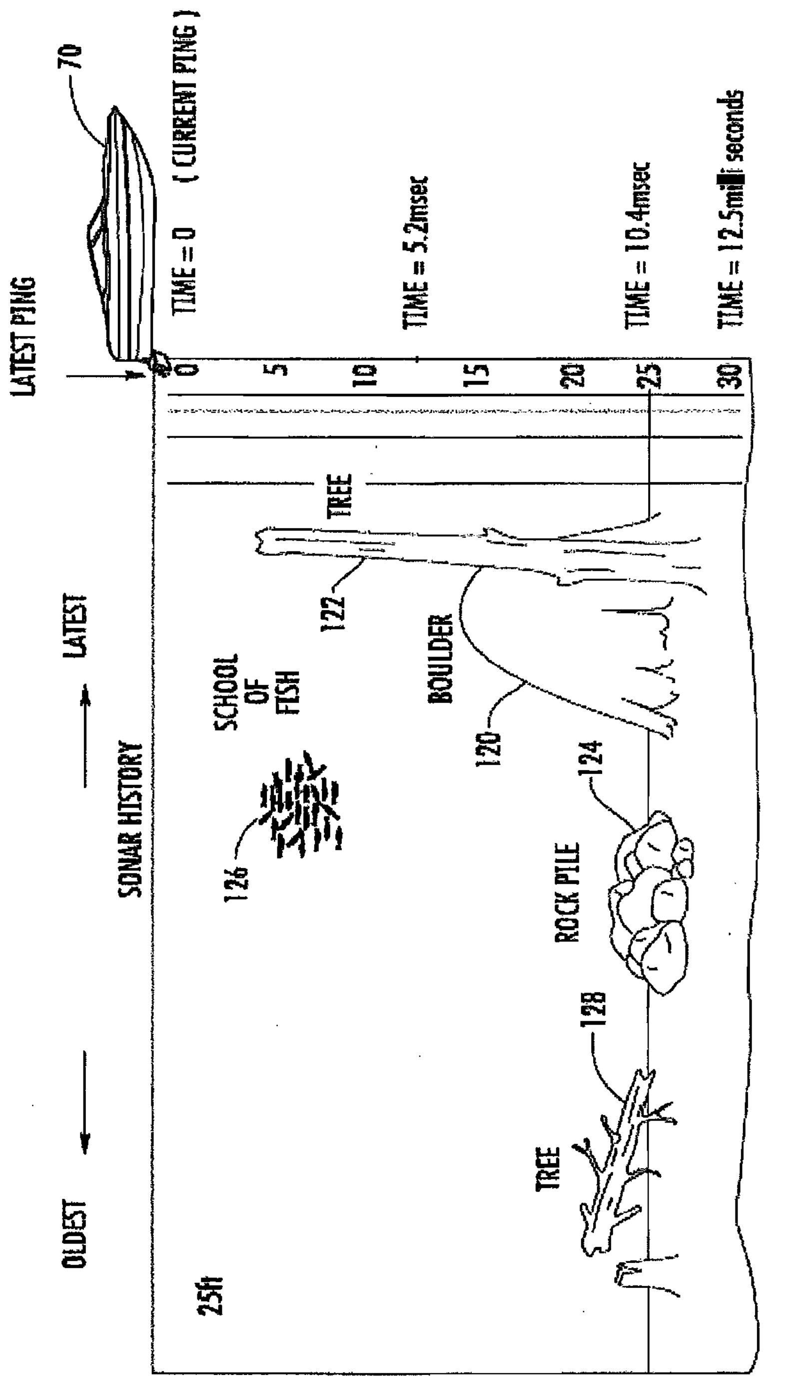

LATEST PING
70
TIME = 0 (CURRENT PING)
TIME = 5.2msec
TIME = 10.4msec
TIME = 12.5milli seconds
0
5
10
15
20
25
30
TREE
122
SCHOOL OF FISH
126
BOULDER
120
124
ROCK PILE
128
TREE
LATEST
SONAR HISTORY
OLDEST
25ft
SCROLLS

FIG. 13A

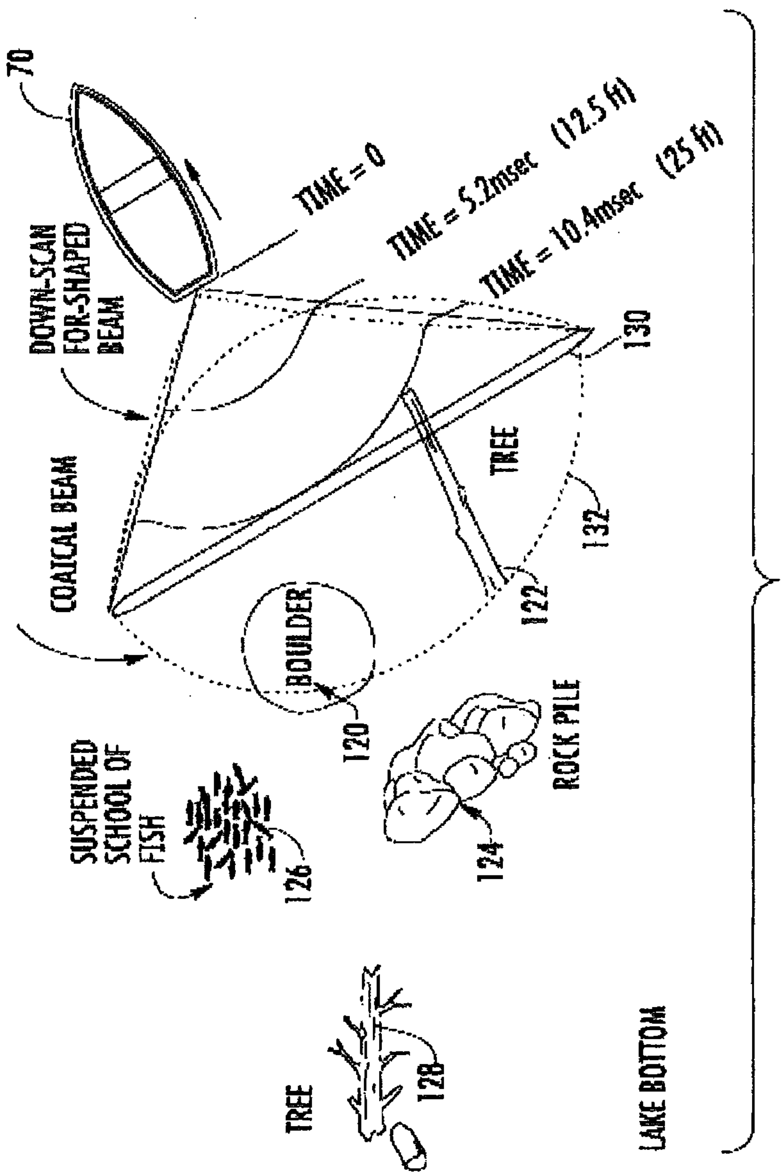

70
TIME = 0
TIME = 5.2msec (12.5 ft)
TIME = 10.4msec (25 ft)
DOWN-SCAN
FOR-SHAPED
BEAM
130
TREE
COAICAL BEAM
132
122
BOULDER
120
ROCK PILE
124
SUSPENDED
SCHOOL OF
FISH
126
TREE
128
LAKE BOTTOM

FIG. 13B

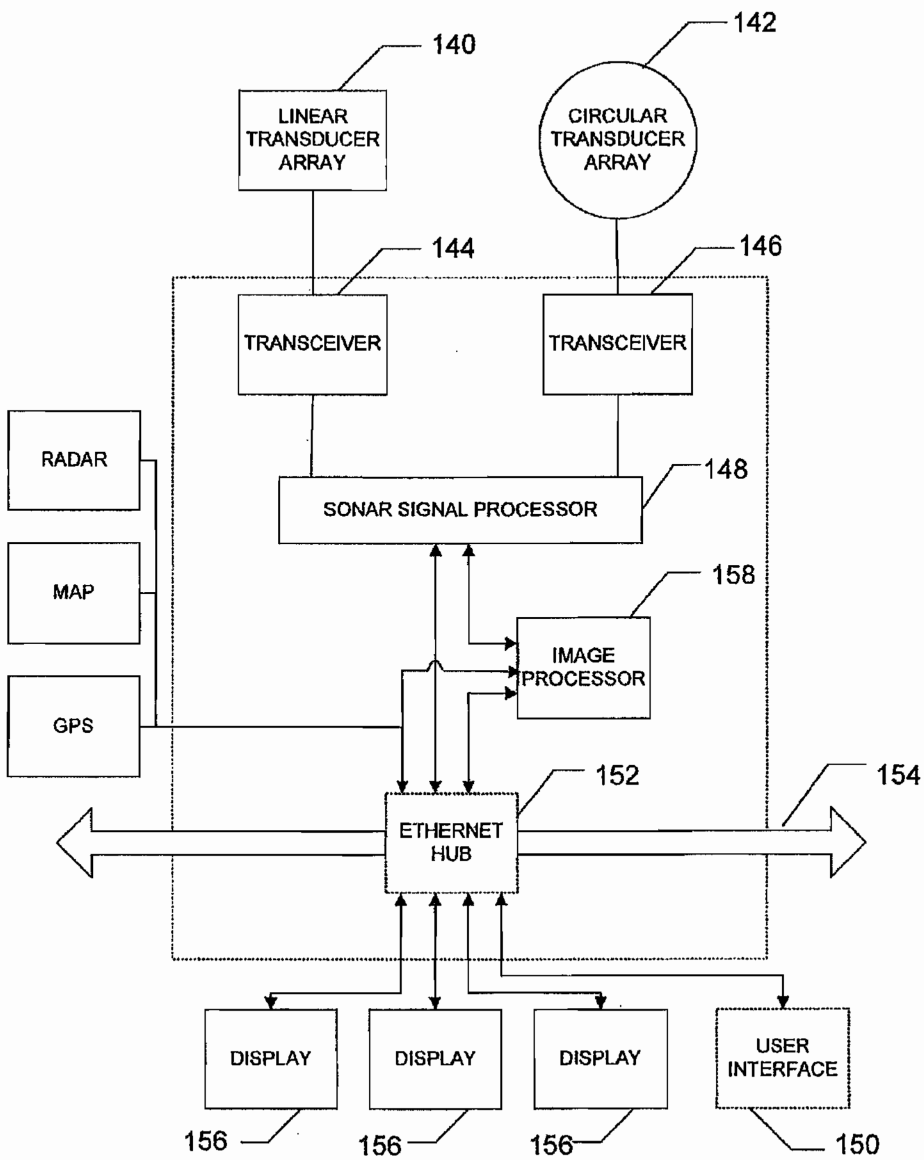

140
142
LINEAR TRANSDUCER ARRAY
CIRCULAR TRANSDUCER ARRAY
144
146
TRANSCEIVER
TRANSCEIVER
RADAR
148
SONAR SIGNAL PROCESSOR
MAP
158
IMAGE PROCESSOR
GPS
152
154
ETHERNET HUB
DISPLAY
DISPLAY
DISPLAY
USER INTERFACE
156
156
156
150

FIG. 14.

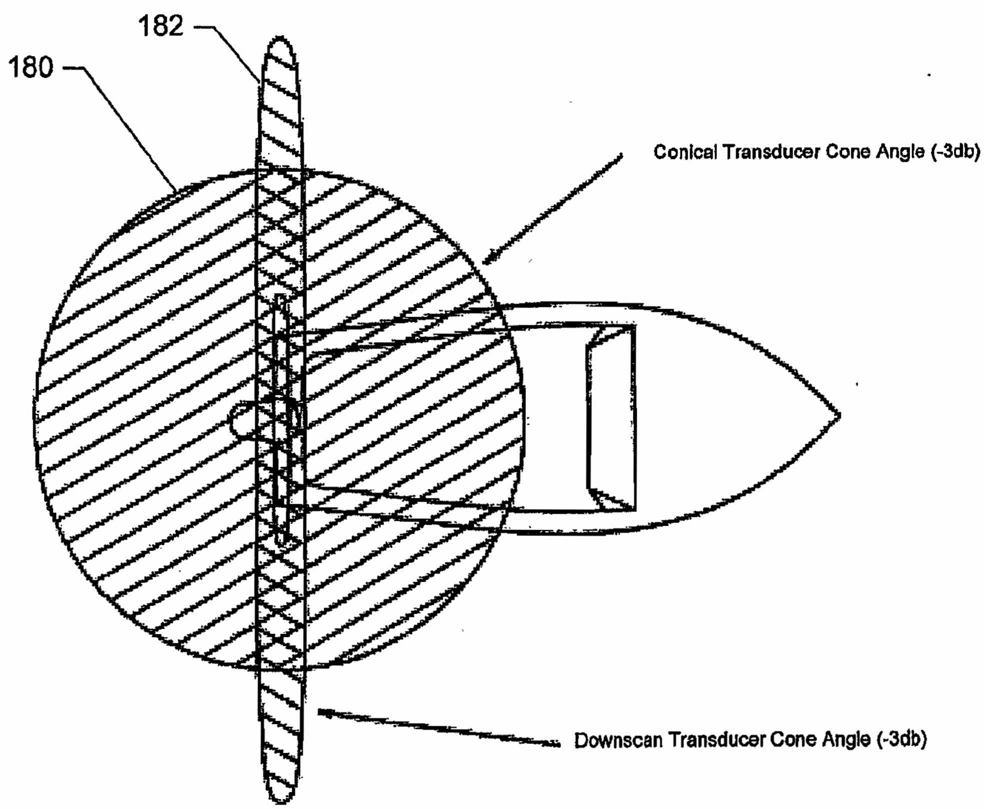

182
180
Conical Transducer Cone Angle (-3db)
Downscan Transducer Cone Angle (-3db)

FIG. 15A.

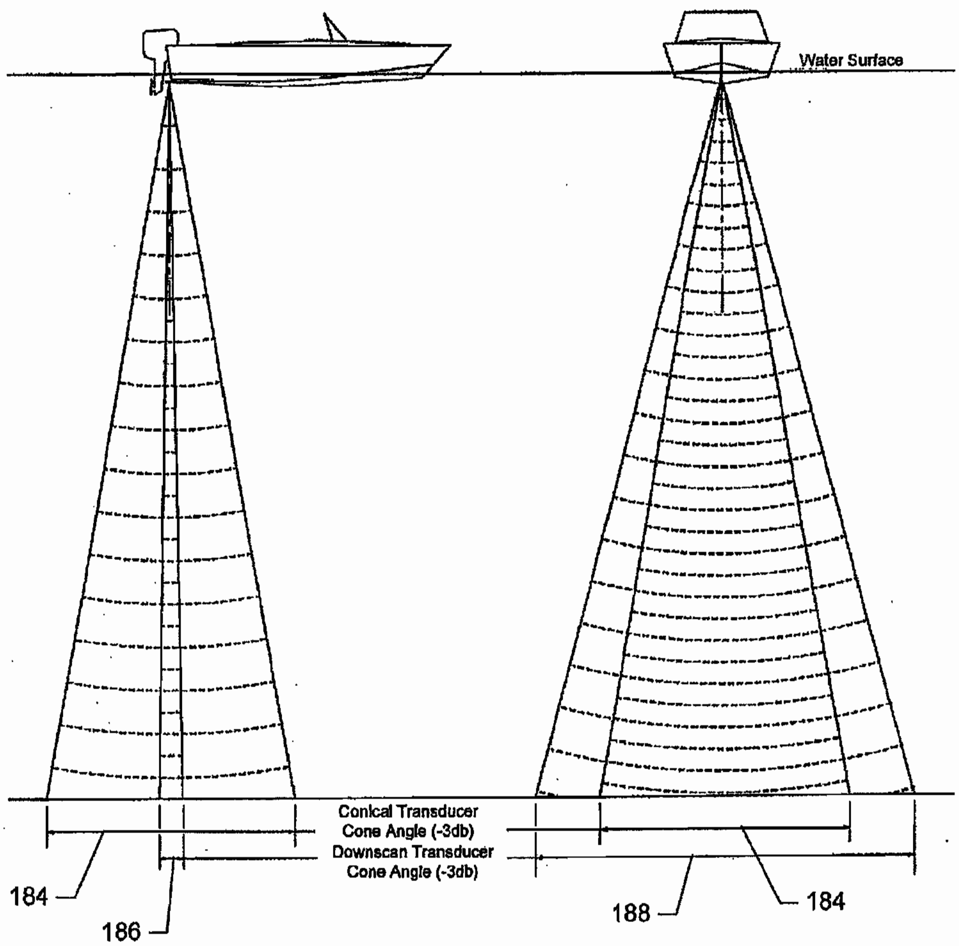
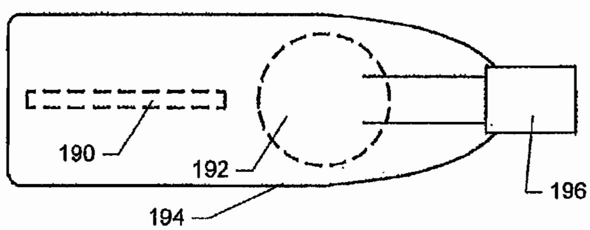

Water Surface
Conical Transducer Cone Angle (-3db)
Downscan Transducer Cone Angle (-3db)
184
186
188
184

FIG. 15B.

FIG. 16A.



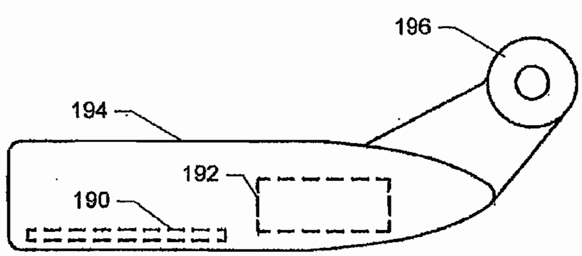


FIG. 16B.

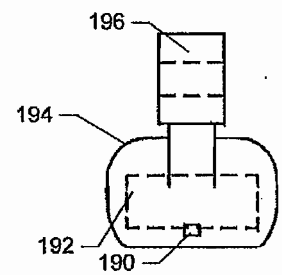
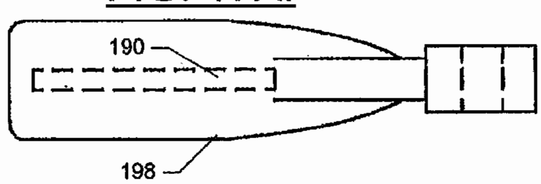


FIG. 16C.

FIG. 17A.



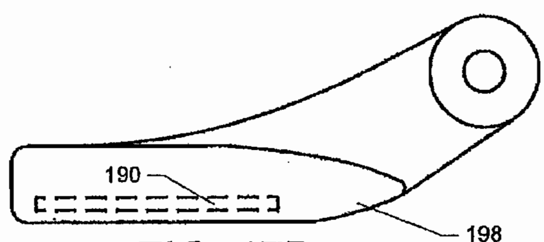


FIG. 17B.

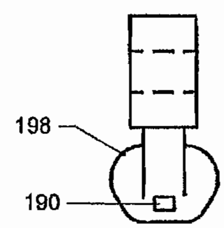


FIG. 17C.

DOWNSCAN IMAGING SONAR

FIELD OF THE INVENTION

Embodiments of the present invention relate generally to sonar systems, and more particularly, to providing a downscan imaging sonar using a linear transducer.

BACKGROUND OF THE INVENTION

Sonar has long been used to detect waterborne or underwater objects. For example, sonar devices may be used to determine depth and bottom topography, detect fish or other waterborne contacts, locate wreckage, etc. In this regard, due to the extreme limits to visibility underwater, sonar is typically the most accurate way for individuals to locate objects underwater. Devices such as transducer elements, or simply transducers, have been developed to produce sound or vibrations at a particular frequency that is transmitted into and through the water and also to detect echo returns from the transmitted sound that return to the transducer after reflecting off an object. The transducers can convert electrical energy into sound energy and also convert sound energy (e.g., via detected pressure changes) into an electrical signal, although some transducers may act only as a hydrophone for converting sound energy into an electrical signal without having a transmitting capability. The transducers are often made using piezoelectric materials.

A typical transducer produces a beam pattern that emanates as a sound pressure signal from a small source such that the sound energy generates a pressure wave that expands as it moves away from the source. For instance, a circular transducer (e.g., a cylindrical shaped crystal with a circular face) typically creates a conical shaped beam with the apex of the cone being located at the source. Any reflected sound then returns to the transducer to form a return signal that may be interpreted as a surface of an object. Such transducers have often been directed in various directions from surfaced or submerged vessels in order to attempt to locate other vessels and/or the seabed for the purposes of navigation and/or target location.

Since the development of sonar, display technology has also been improved in order to enable better interpretation of sonar data. Strip chart recorders and other mechanical output devices have been replaced by, for example, digital displays such as LCDs (liquid crystal displays). Current display technologies continue to be improved in order to provide, for example, high quality sonar data on multi-color, high resolution displays having a more intuitive output than early sonar systems were capable of producing.

With display capabilities advancing to the point at which richly detailed information is able to be displayed, attention has turned back to the transducer in order to provide higher quality data for display. Furthermore, additional uses have been developed for sonar systems as transducer and display capabilities have evolved. For example, sonar systems have been developed to assist fishermen in identifying fish and/or the features that tend to attract fish. Historically, these types of sonar systems primarily analyzed the column of water beneath a watercraft with a cylindrical piezo element that produces a conical beam, known as a conical beam transducer or simply as a circular transducer referring to the shape of the face of the cylindrical element. However, with the advent of sidescan sonar technology, fishermen were given the capability to view not only the column of water beneath their vessel, but also view water to either side of their vessel.

Sidescan sonar can be provided in different ways and with different levels of resolution. As its name implies, sidescan sonar is directed to look to the side of a vessel and not below the vessel. In fact, many sidescan sonar systems (e.g., swath and bathymetry sonar systems) have drawn public attention for their performance in the location of famous shipwrecks and for providing very detailed images of the ocean floor, but such systems are costly and complex. Sidescan sonar typically generates a somewhat planar fan-shaped beam pattern that is relatively narrow in beamwidth in a direction parallel to the keel of a vessel deploying the sidescan sonar and is relatively wide in beamwidth in a direction perpendicular to the keel of the vessel. It may be provided in some cases using multibeam sonar systems. Such multibeam sonar systems are typically comprised of a plurality of relatively narrowly focused conventional circular transducer elements that are arrayed next to each other to produce an array of narrowly focused adjacent conical beams that together provide a continuous fan shaped beam pattern. FIG. **1** shows an example of a series of conventional (generally circular) transducer elements **10** arrayed in an arc to produce a multibeam sonar system. FIG. **2** shows a typical fan shaped beam pattern **12** produced by the multibeam sonar system of FIG. **1** as the beam pattern is projected onto the seabed.

However, multibeam sonar systems typically require very complex systems to support the plurality of transducers that are employed in order to form the multibeam sonar system. For example, a typical system diagram is shown in FIG. **3**, which includes a display **20** driven by a sonar signal processor **22**. The sonar signal processor **22** processes signals received from each of a plurality of transducers **26** that are fed to the sonar signal processor **22** by respective different transceivers **24** that are paired with each of the transducers **26**. Thus, conventional multibeam sonar systems tend to include a large number of transceivers and correspondingly introduce complexity in relation to processing the data such systems produce.

More recently, ceramic sidescan transducer elements have been developed that enable the production of a fan shaped sonar beam directed to one side of a vessel. Accordingly, the sea floor on both sides of the vessel can be covered with two elements facing on opposite sides of the vessel. These types of sidescan transducer elements are linear, rather than cylindrical, and provide a somewhat planar fan-shaped beam pattern using a single transducer to provide sidescan sonar images without utilizing the multibeam array described above. However, employment of these types of sidescan elements typically leaves the column of water beneath the vessel either un-monitored, or monitored using conical beam or circular transducers. In this regard, FIG. **4** illustrates an example of a conventional sidescan sonar with linear sidescan transducer elements oriented to produce fan-shaped beams **27** directed from opposite sides of the vessel and a conical beam **28** projecting directly below the vessel. These conical beams have conventionally been provided using conventional cylindrical transducers to produce depth information since sidescan transducers are typically not as useful for providing depth or water column feature information, such as fish targets. However, cylindrical transducers provide poor quality images for sonar data relating to the structure on the bottom or in the water column directly below the vessel.

Accordingly, it may be desirable to develop a sonar system that is capable of providing an improved downscan imaging sonar.

BRIEF SUMMARY OF THE INVENTION

Accordingly, embodiments of the present invention employ a linear transducer, directed downward to receive high quality images relative to the water column and bottom features directly beneath the linear transducer and the vessel on which the linear transducer is employed. Some other embodiments, in addition to the use of a linear transducer directed downward, also employ at least one sidescan transducer element (e.g., a linear transducer oriented away from the side of the vessel) to ensonify (e.g., emit sonar pulses and detect echo returns) the sea floor on the sides of a vessel. Accordingly, better quality sonar images may be provided for the water column and bottom features beneath the vessel, of a quality that was unavailable earlier. Moreover, embodiments of the present invention may simplify the processing involved in producing high quality sonar images.

In one exemplary embodiment, a transducer array is provided. The transducer array may include a housing and a linear transducer element. The housing may be mountable to a watercraft capable of traversing a surface of a body of water. The linear transducer element may be positioned within the housing and may have a substantially rectangular shape configured to produce a sonar beam having a beamwidth in a direction parallel to longitudinal length of the linear transducer element that is significantly less than a beamwidth of the sonar beam in a direction perpendicular to the longitudinal length of the transducer element. The linear transducer element may also be positioned within the housing to project sonar pulses in a direction substantially perpendicular to a plane corresponding to the surface.

In another exemplary embodiment, a transducer array is provided. The transducer array may include a plurality of transducer elements and each one of the plurality of transducer elements may include a substantially rectangular shape configured to produce a sonar beam having a beamwidth in a direction parallel to longitudinal length of the transducer elements that is significantly less than a beamwidth of the sonar beam in a direction perpendicular to the longitudinal length of the transducer elements. The plurality of transducer elements may be positioned such that longitudinal lengths of at least two of the plurality of transducer elements are parallel to each other. The plurality of transducer elements may also include at least a first linear transducer element, a second linear transducer element and a third linear transducer element. The first linear transducer element may be positioned within the housing to project sonar pulses from a first side of the housing in a direction generally perpendicular to a centerline of the housing. The second linear transducer element may be positioned within the housing to lie in a plane with the first linear transducer element and project sonar pulses from a second side of the housing that is generally opposite of the first side. The third linear transducer element may be positioned within the housing to project sonar pulses in a direction generally perpendicular to the plane.

In another exemplary embodiment, a sonar system is provided. The sonar system may include a transducer array and a sonar module. The transducer array may include a plurality of transducer elements and each one of the plurality of transducer elements may include a substantially rectangular shape configured to produce a sonar beam having a beamwidth in a direction parallel to longitudinal length of the transducer elements that is significantly less than a beamwidth of the sonar beam in a direction perpendicular to the longitudinal length of the transducer elements. The plurality of transducer elements may be positioned such that longitudinal lengths of at least two of the plurality of transducer elements are parallel to each other. The plurality of transducer elements may also include at least a first linear transducer element, a second linear transducer element and a third linear transducer element. The first linear transducer element may be positioned within the housing to project sonar pulses from a first side of the housing in a direction generally perpendicular to a centerline of the housing. The second linear transducer element may be positioned within the housing to lie in a plane with the first linear transducer element and project sonar pulses from a second side of the housing that is generally opposite of the first side. The third linear transducer element may be positioned within the housing to project sonar pulses in a direction generally perpendicular to the plane. The sonar module may be configured to enable operable communication with the transducer array. The sonar module may include a sonar signal processor configured to process sonar return signals received via the transducer array, and a transceiver configured to provide communication between the transducer array and the sonar signal processor.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING(S)

The patent or application file contains at least one drawing executed in color. Copies of this patent or patent application publication with color drawing(s) will be provided by the U.S. Patent and Trademark Office upon request and payment of the necessary fee.

Having thus described the invention in general terms, reference will now be made to the accompanying drawings, which are not necessarily drawn to scale, and wherein:

FIG. **1** is a diagram illustrating an example of a series of conventional transducer elements **10** arrayed to produce a multibeam sonar system;

FIG. **2** illustrates a fan shaped beam pattern produced by the conventional multibeam sonar system of FIG. **1** as the beam pattern is projected onto the seabed;

FIG. **3** is a block diagram of a conventional multibeam sonar system for the system shown in FIG. **1**;

FIG. **4** is a diagram illustrating a conventional sidescan sonar system;

FIG. **5** is a basic block diagram illustrating a sonar system according to an exemplary embodiment of the present invention;

FIG. **6** is a diagram illustrating a more detailed view of a transducer array according to an exemplary embodiment of the present invention;

FIG. **7**A illustrates a side view showing a beam pattern produced by the transducer array according to an exemplary embodiment of the present invention;

FIG. **7**B illustrates a top view showing a beam pattern produced by the transducer array according to an exemplary embodiment of the present invention;

FIG. **8**A is a diagram illustrating a cross section of components in a containment volume of a housing according to an exemplary embodiment of the present invention;

FIG. **8**B is a diagram illustrating a cross section of components in a containment volume of a housing according to another exemplary embodiment of the present invention;

FIG. **9**A shows an example of beam coverage for an 800 kHz operating frequency in one exemplary embodiment of the present invention;

FIG. **9**B shows an example of beam coverage for a 455 kHz operating frequency in one exemplary embodiment of the present invention;

FIG. **10**A illustrates a projection, onto a substantially flat sea bed, of the beam pattern of an exemplary transducer array providing gaps between fan shaped beams produced by a transducer array in which transducer elements are positioned to provide coplanar beams with gaps therebetween according to an exemplary embodiment of the present invention;

FIG. 10B illustrates a projection, onto a substantially flat sea bed, of the beam pattern of an exemplary transducer array providing gaps between the fan shaped beams produced by a transducer array in which the transducer elements are positioned to provide gaps with planar separation therebetween according to another exemplary embodiment of the present invention;

FIG. 11A shows an example of a view of the beam coverage associated with the exemplary embodiment of FIG. 9A in which the beam coverage is extended to the bottom of a flat bottomed body of water according to an exemplary embodiment of the present invention;

FIG. 11B illustrates example sidescan images that may be produced based on data from sidescan beams shown in FIG. 11A according to an exemplary embodiment of the present invention;

FIG. 11C illustrates example linear downscan images that may be produced based on data from linear downscan beams shown in FIG. 11A according to an exemplary embodiment of the present invention;

FIG. 12A illustrates example sidescan images that may be produced based on data from sidescan beams;

FIG. 12B illustrates a side-by-side comparison of images produced by a downscan linear transducer element according to an exemplary embodiment and a corresponding conical downscan image;

FIG. 12C illustrates another side-by-side comparison of images produced by a downscan linear transducer element according to an exemplary embodiment and a corresponding conical downscan image;

FIG. 12D illustrates still another side-by-side comparison of images produced by a downscan linear transducer element according to an exemplary embodiment and a corresponding conical downscan image;

FIG. 12E illustrates yet another side-by-side comparison of images produced by a downscan linear transducer element according to an exemplary embodiment and a corresponding conical downscan image;

FIG. 12F illustrates yet still another side-by-side comparison of images produced by a downscan linear transducer element according to an exemplary embodiment and a corresponding conical downscan image;

FIG. 13A is a diagram illustrating an example of a sea bottom structure viewed through a linear downscan transducer element according to an exemplary embodiment;

FIG. 13B is a diagram illustrating an example of a fan shaped beam from a linear downscan transducer compared to a conical beam from a cylindrical transducer for the sea bottom structure illustrated in FIG. 13A according to an exemplary embodiment;

FIG. 14 is a basic block diagram illustrating a sonar system according to an exemplary embodiment of the present invention;

FIG. 15A illustrates an example of a top view of the beam overlap that may occur in situations where a linear downscan transducer and a circular downscan transducer are employed according to an exemplary embodiment of the present invention;

FIG. 15B shows side views of the same beam overlap shown in FIG. 15A from the starboard side of a vessel and from ahead of the bow of the vessel according to an exemplary embodiment of the present invention;

FIG. 16A is a diagram showing a perspective view of a linear downscan transducer and a circular downscan transducer within a single housing from a point above the housing according to an exemplary embodiment of the present invention;

FIG. 16B is a perspective view from one side of the housing of FIG. 16A at a point substantially perpendicular to a longitudinal axis of the housing according to an exemplary embodiment of the present invention;

FIG. 16C is a perspective view from the front side of the housing of FIG. 16A at a point looking straight down the longitudinal axis of the housing according to an exemplary embodiment of the present invention;

FIG. 17A is a diagram showing a perspective view of a linear downscan transducer within a single housing from a point above the housing according to an exemplary embodiment of the present invention;

FIG. 17B is a perspective view from one side of the housing of FIG. 17A at a point substantially perpendicular to a longitudinal axis of the housing according to an exemplary embodiment of the present invention; and

FIG. 17C is a perspective view from the front side of the housing of FIG. 17A at a point looking straight down the longitudinal axis of the housing according to an exemplary embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Exemplary embodiments of the present invention now will be described more fully hereinafter with reference to the accompanying drawings, in which some, but not all embodiments of the invention are shown. Indeed, the invention may be embodied in many different forms and should not be construed as limited to the exemplary embodiments set forth herein; rather, these embodiments are provided so that this disclosure will satisfy applicable legal requirements. Like reference numerals refer to like elements throughout.

FIG. 5 is a basic block diagram illustrating a sonar system 30 for use with multiple exemplary embodiments of the present invention. As shown, the sonar system 30 may include a number of different modules or components, each of which may comprise any device or means embodied in either hardware, software, or a combination of hardware and software configured to perform one or more corresponding functions. For example, the sonar system 30 may include a sonar signal processor 32, a transceiver 34 and a transducer array 36 and/or numerous other peripheral devices such as one or more displays 38. One or more of the modules may be configured to communicate with one or more of the other modules to process and/or display data, information or the like from one or more of the modules. The modules may also be configured to communicate with one another in any of a number of different manners including, for example, via a network 40. In this regard, the network 40 may be any of a number of different communication backbones or frameworks including, for example, Ethernet, the NMEA 2000 framework or other suitable networks.

The display 38 may be configured to display images and may include or otherwise be in communication with a user interface 39 configured to receive an input from a user. The display 38 may be, for example, a conventional LCD (liquid crystal display), a touch screen display, or any other suitable display known in the art upon which images may be rendered. Although each display 38 of FIG. 5 is shown as being connected to the sonar signal processor 32 via the network and/or via an Ethernet hub, the display 38 could alternatively be in direct communication with the sonar signal processor 32 in some embodiments, or the display 38, sonar signal processor 32 and user interface 39 could be in a single housing. The user interface 39 may include, for example, a keyboard, keypad, function keys, mouse, scrolling device, input/output ports, touch screen, or any other mechanism by which a user may interface with the system. Moreover, in some cases, the user interface 39 may be a portion of one or more of the displays 38.

The transducer array 36 according to an exemplary embodiment may be provided in one or more housings that provide for flexible mounting with respect to a hull of the vessel on which the sonar system 30 is employed. In this regard, for example, the housing may be mounted onto the hull of the vessel or onto a device or component that may be attached to the hull (e.g., a trolling motor or other steerable device, or another component that is mountable relative to the hull of the vessel), including a bracket that is adjustable on multiple axes, permitting omnidirectional movement of the housing. The transducer array 36 may include one or more transducer elements positioned within the housing, as described in greater detail below, and each of the transducer elements may be configured to be directed to cover a different area such that one transducer element covers one side of the vessel with a fan shaped beam, another transducer element covers the opposite side of the vessel with a fan shaped beam, and the third fan shaped beam covers a region between the other transducer elements directed below the vessel. In an exemplary embodiment, each of the transducer elements of the transducer array 36 may be substantially identical in terms of construction and therefore may be different only by virtue of the orientation of the respective transducer elements. The transducer array 36 may be configured to both transmit and receive sound pressure waves. However, in some cases, the transducer array 36 could include separate elements for transmission and reception. The transducer array 36 is described in greater detail below in reference to FIG. 6.

In an exemplary embodiment, the sonar signal processor 32, the transceiver 34 and an Ethernet hub 42 or other network hub may form a sonar module 44. As such, for example, in some cases, the transducer array 36 may simply be placed into communication with the sonar module 44, which may itself be a mobile device that may be placed (but not necessarily mounted in a fixed arrangement) in the vessel to permit easy installation of one or more displays 38, each of which may be remotely located from each other and operable independent of each other. In this regard, for example, the Ethernet hub 42 may include one or more corresponding interface ports for placing the network 40 in communication with each display 38 in a plug-n-play manner. As such, for example, the Ethernet hub 42 may not only include the hardware needed to enable the displays 38 to be plugged into communication with the network 40 via the Ethernet hub 42, but the Ethernet hub 42 may also include or otherwise be in communication with software modules for providing information to enable the sonar module 44 to communicate with one or more different instances of the display 38 that may or may not be the same model or type of display and that may display the same or different information. In other words, the sonar module 44 may store configuration settings defining a predefined set of display types with which the sonar module is compatible so that if any of the predefined set of display types are placed into communication with the sonar module 44, the sonar module 44 may operate in a plug-n-play manner with the corresponding display types. Accordingly, the sonar module 44 may include a memory storing device drivers accessible to the Ethernet hub 42 to enable the Ethernet hub 42 to properly work with displays for which the sonar module 44 is compatible. The sonar module 44 may also be enabled to be upgraded with additional device drivers to enable expansion of the numbers and types of devices with which the sonar module 44 may be compatible. In some cases, the user may select a display type to check whether a the display type is supported and, if the display type is not supported, contact a network entity to request software and/or drivers for enabling support of the corresponding display type.

The sonar signal processor 32 may be any means such as a device or circuitry operating in accordance with software or otherwise embodied in hardware or a combination of hardware and software (e.g., a processor operating under software control or the processor embodied as an application specific integrated circuit (ASIC) or field programmable gate array (FPGA) specifically configured to perform the operations described herein, or a combination thereof) thereby configuring the device or circuitry to perform the corresponding functions of the sonar signal processor 32 as described herein. In this regard, the sonar signal processor 32 may be configured to analyze electrical signals communicated thereto by the transceiver 34 to provide sonar data indicative of the size, location, shape, etc. of objects detected by the sonar system 30. In some cases, the sonar signal processor 32 may include a processor, a processing element, a coprocessor, a controller or various other processing means or devices including integrated circuits such as, for example, an ASIC, FPGA or hardware accelerator, that is configured to execute various programmed operations or instructions stored in a memory device. The sonar signal processor may further or alternatively embody multiple compatible additional hardware or hardware and software items to implement signal processing or enhancement features to improve the display characteristics or data or images, collect or process additional data, such as time, temperature, GPS information, waypoint designations, or others, or may filter extraneous data to better analyze the collected data. It may further implement notices and alarms, such as those determined or adjusted by a user, to reflect depth, presence of fish, proximity of other watercraft, etc. Still further, the processor, in combination with suitable memory, may store incoming transducer data or screen images for future playback or transfer, or alter images with additional processing to implement zoom or lateral movement, or to correlate data, such as fish or bottom features to a GPS position or temperature. In an exemplary embodiment, the sonar signal processor 32 may execute commercially available software for controlling the transceiver 34 and/or transducer array 36 and for processing data received therefrom. Further capabilities of the sonar signal processor 32 and other aspects related to the sonar module are described in U.S. patent application Ser. No. 12/460,093, entitled "Linear and Circular Downscan Imaging Sonar" filed on even date herewith, the disclosure of which is incorporated herein by reference in its entirety.

The transceiver 34 may be any means such as a device or circuitry operating in accordance with software or otherwise embodied in hardware or a combination of hardware and software (e.g., a processor operating under software control or the processor embodied as an ASIC or FPGA specifically configured to perform the operations described herein, or a combination thereof) thereby configuring the device or circuitry to perform the corresponding functions of the transceiver 34 as described herein. In this regard, for example, the transceiver 34 may include circuitry for providing transmission electrical signals to the transducer array 36 for conversion to sound pressure signals based on the provided electrical signals to be transmitted as a sonar pulse. The transceiver 34 may also include circuitry for receiving electrical signals produced by the transducer array 36 responsive to sound pressure signals received at the transducer array 36 based on echo or other return signals received in response to the transmission of a sonar pulse. The transceiver 34 may be in communication with the sonar signal processor 32 to both receive instructions regarding the transmission of sonar signals and to provide information on sonar returns to the sonar signal processor **32** for analysis and ultimately for driving one or more of the displays **38** based on the sonar returns.

FIG. **6** is a diagram illustrating a more detailed view of the transducer array **36** according to an exemplary embodiment. As shown in FIG. **6**, the transducer array **36** may include a housing **50** that may include mounting holes **52** through which screws, rivets, bolts or other mounting devices may be passed in order to fix the housing **50** to a mounting bracket, a device attached to a vessel or to the hull of the vessel itself. However, in some cases, the housing **50** may be affixed by welding, adhesive, snap fit or other coupling means. The housing **50** may be mounted to a portion of the vessel, or to a device attached to the vessel, that provides a relatively unobstructed view of both sides of the vessel. Thus, for example, the housing **50** may be mounted on or near the keel (or centerline) of the vessel, on a fixed or adjustable mounting bracket that extends below a depth of the keel (or centerline) of the vessel, or on a mounting device that is offset from the bow or stern of the vessel. The housing **50** may include a recessed portion defining containment volume **54** for holding transducer elements **60**. The recessed portion defining the containment volume may extend away from the hull of the vessel on which the housing **50** is mounted and therefore protrude into the water on which the vessel operates (or in which the vessel operates in a case where the transducer array **36** is mounted to a tow fish). To prevent cavitation or the production of bubbles due to uneven flow over the housing **50**, the housing **50** (and in particular the containment volume portion of the housing) may have a gradual, rounded or otherwise streamlined profile to permit laminar flow of water over the housing **50**. In some examples, an insulated cable **58** may provide a conduit for wiring to communicatively couple the transducer elements **60** to the sonar module **44**.

Each of the transducer elements **60** may be a linear transducer element. Thus, for example, each of the transducer elements **60** may be substantially rectangular in shape and made from a piezoelectric material such as a piezoelectric ceramic material, as is well known in the art and may include appropriate shielding (not shown) as is well known in the art. The piezoelectric material being disposed in a rectangular arrangement provides for an approximation of a linear array having beamwidth characteristics that are a function of the length and width of the rectangular face of the transducer elements and the frequency of operation. In an exemplary embodiment, the transducer elements **60** may be configured to operate in accordance with at least two operating frequencies. In this regard, for example, a frequency selection capability may be provided by the sonar module **44** to enable the user to select one of at least two frequencies of operation. In one example, one operating frequency may be set to about 800 kHz and another operating frequency may be set to about 455 kHz. Furthermore, the length of the transducer elements may be set to about 120 mm while the width is set to about 3 mm to thereby produce beam characteristics corresponding to a bearing fan of about 0.8 degrees by about 32 degrees at 800 kHz or about 1.4 degrees by about 56 degrees at 455 kHz. However, in general, the length and width of the transducer elements **60** may be set such that the beamwidth of sonar beam produced by the transducer elements **60** in a direction parallel to a longitudinal length (L) of the transducer elements **60** is less than about five percent as large as the beamwidth of the sonar beam in a direction (w) perpendicular to the longitudinal length of the transducer elements **60**. (See generally FIGS. 7A, 7B, 9A, 9B.) It should be noted that although the widths of various beams are shown and described herein, the widths being referred to do not necessarily correspond to actual edges defining limits to where energy is placed in the water. As such, although beam patterns and projections of beam patterns are generally shown herein as having fixed and typically geometrically shaped boundaries, those boundaries merely correspond to the −3 dB (or half power) points for the transmitted beams. In other words, energy measured outside of the boundaries shown is less than half of the energy transmitted. Thus, the boundaries shown are merely theoretical half power point boundaries.

Although dual frequency operations providing a specific beam fan for each respective element for given lengths are described above, it should be understood that other operating ranges could alternatively be provided with corresponding different transducer element sizes and corresponding different beamwidth characteristics. Moreover, in some cases, the sonar module **44** may include a variable frequency selector, to enable an operator to select a particular frequency of choice for the current operating conditions. However, in all cases where the longitudinal length of the transducer elements **60** is generally aligned with the centerline of the vessel, the rectangular shape of the transducer elements **60** provides for a narrow beamwidth in a direction substantially parallel to the centerline of the vessel and wide beamwidth in a direction substantially perpendicular to the centerline of the vessel. However, if the transducer array **36** is mounted in a different fashion or to a rotatable accessory on the vessel (e.g., a trolling motor mount), the fan-shaped beams produced will have the wide beamwidth in a direction substantially perpendicular to the longitudinal length of the transducer elements **60** and a narrow beamwidth in a direction substantially parallel to the longitudinal length of the transducer elements **60**. Thus, the sonar could also be oriented to provide fore and aft oriented fan-shaped beams or any other orientation relative to the vessel in instances where motion of the vessel is not necessarily in a direction aligned with the centerline of the vessel.

FIGS. **7A** and **7B** show side and top views, respectively, illustrating the beam characteristics produced by an exemplary embodiment of the present invention. In this regard, FIG. **7A** illustrates a side view showing the transducer array **36** mounted to a bracket that extends from the aft end of the centerline of the vessel (e.g., boat). As shown in FIG. **7A**, the beam produced by the transducer array **36** is relatively narrow in the direction substantially parallel to the centerline of the vessel if the transducer elements are aligned for a generally coplanar beam. FIG. **7A** also includes a cutaway view of the transducer array **36** to show the orientation of the transducer elements **60** in context relative to the vessel according to this example. Meanwhile, FIG. **7B** shows a top view of the beam produced by the transducer assembly **36** if the transducer elements are aligned for a generally coplanar beam. As shown in FIG. **7B**, the beam produced by the transducer array is relatively wide in the direction substantially perpendicular to the centerline of the vessel thereby producing a fan-shaped beam pattern extending out to both sides and also covering the water column beneath the vessel, as described below. FIG. **7B** also includes a cutaway view of the transducer array **36** to show the orientation of the transducer elements **60** in context relative to the vessel according to this example.

FIG. **8A** is a diagram illustrating a cross section of components in the containment volume **54** according to an exemplary embodiment. In particular, FIG. **8A** illustrates the arrangement of the linear transducer elements **60** within the containment volume **54**. The transducer elements **60**, which may include a port side element **62** positioned to scan substantially to the port side of the vessel, a starboard side element **64** positioned to scan substantially to the starboard side of the vessel, and a downscan element **66** positioned to scan substantially below the vessel. As shown in FIG. **8**A, in an exemplary embodiment, both the port side element **62** and the starboard side element **64** may be oriented to face slightly below a surface of the water on which the vessel travels. In one example, both the port side element **62** and the starboard side element **64** may be oriented such that the widest dimension of the beamwidth of each respective element is centered at 30 degrees below a plane substantially parallel to the surface of the water. Meanwhile, the downscan linear element **66** may be positioned such that the widest dimension of the beamwidth of the downscan element **66** is centered at 90 degrees below the plane substantially parallel to the surface of the water. In other words, the downscan element **66** has the central portion of its fan shape aimed straight down. The containment volume **54** may include electrical connections (not shown) to communicate with the transceiver **34** and supports, struts, rods or other supporting structures to secure each of the linear transducer elements **60** in their respective orientations. The transducer elements **60** may be held in place or otherwise affixed to the supporting structures via adhesive or any other suitable joining material and the angles at which the transducer elements **60** are affixed relative to each other and to the housing **50** may vary as necessary or as desired.

FIG. **8**B is a diagram illustrating a cross section of components in the containment volume **54** according to an alternative exemplary embodiment. In this regard, FIG. **8**B illustrates the arrangement of one linear transducer element **60** within the containment volume **54**. The transducer element **60** according to this exemplary embodiment is a single linear transducer (e.g., downscan element **66**) positioned to scan substantially below the vessel. As shown in FIG. **8**B, the downscan element **66** may be positioned such that the widest dimension of the beamwidth of the downscan element **66** is centered at 90 degrees below the plane substantially parallel to the surface of the water. In other words, the downscan element **66** has the central portion of its fan shape aimed substantially straight down. As discussed above, the containment volume **54** may include electrical connections (not shown) to communicate with the transceiver **34** and supports, struts, rods or other supporting structures to secure the downscan element **66** in its respective orientation. The linear downscan element **66** may be held in place or otherwise affixed to the supporting structures via adhesive or any other suitable joining material such that transmissions produced by the downscan element **66** exit the housing **50** substantially at a 90 degree angle with respect to the plane of the face of the downscan element **66** from which the transmissions emanate.

FIG. **9**A shows an example of beam coverage for an 800 kHz operating frequency in one exemplary embodiment. As such, the beamwidth (e.g., width between the half power points) of each of the three linear transducer elements **60** is about 32 degrees. FIG. **9**B shows an example of beam coverage for a 455 kHz operating frequency in one exemplary embodiment, thereby providing about 56 degrees of beamwidth for each of the three linear transducer elements **60**. Accordingly, in each of the exemplary embodiments of FIGS. **9**A and **9**B, the three fan-shaped segments together produce a discontinuous fan shaped beam. The discontinuity may be minimized in some instances by selection of transducer element dimensions and operating frequencies selected to minimize the size of the gaps (e.g., zones with sonar beam coverage outside of beam coverage area as defined by the half power points of the beams) between the beams of the transducer elements. Alternatively, the physical orientation of the transducer elements **60** with respect to each other could be changed in order to minimize the size of the gaps. However, it should be noted that in most cases some gap should be maintained in order to prevent interference between the beam patterns emanating from the linear transducer elements **60**. Although the fan-shaped segments of an exemplary embodiment may all lie in the same plane, it may be desirable to alter the orientation of one or more of the transducer elements **60** such that a corresponding one or more of the fan-shaped segments is outside of the plane of the other fan-shaped segments. The gap could therefore be provided via planar separation of the fan-shaped segments rather than by providing separation between the segments within the same plane.

In this regard, FIG. **10**A illustrates a projection, onto a substantially flat sea bed, of the beam pattern of an exemplary transducer array providing gaps between the boundaries of the projections as defined by the half power points defining fan shaped beams produced by a transducer array in which the transducer elements **60** are positioned to provide coplanar beams with gaps therebetween according to an exemplary embodiment. As such, a first transducer element beam projection **100**, a second transducer element beam projection **102** and a third transducer element beam projection **104** are all shown lying in the same plane in FIG. **10**A. Meanwhile, FIG. **10**B illustrates a projection, onto a substantially flat sea bed, of the beam pattern of an exemplary transducer array providing gaps between the fan shaped beams produced by a transducer array in which the transducer elements **60** are positioned to provide gaps with planar separation therebetween according to another exemplary embodiment. Thus, the first transducer element beam projection **100'**, the second transducer element beam projection **102'** and the third transducer element beam projection **104'** are shown lying in different planes in FIG. **10**B. Notably, in each of FIG. **10**A and **10**B, the view is shown from the top looking down onto the sea bed and the beam projections are not necessarily to scale.

FIG. **11**A shows an example of a view of the beam coverage associated with the embodiment of the example shown in FIG. **9**A in which the beam coverage is extended to the bottom of a flat bottomed body of water. The illustration of FIG. **11**A shows a view looking at the stern of a vessel **70** as the vessel **70** is driving away from the viewer (e.g., into the page). According to this example, a port sidescan beam **72** (e.g., that may be produced by port sidescan element **62**) extends out to the port side of the vessel **70** providing coverage of the bottom from point A to point B. Meanwhile, a starboard sidescan beam **74** (e.g., that may be produced by starboard sidescan element **64**) extends out to the starboard side of the vessel **70** from point C to point D. Additionally, a downscan beam **76** (e.g., that may be produced by downscan element **66**) extends directly below the vessel **70** from point E to point F. As shown in FIG. **11**A, the coverage areas defined between points A and B and points C and D are substantially larger than the coverage area defined between points E and F. Based on the increased bottom coverage, the display provided responsive to data received in the sidescan beams **72** and **74** will be different than the display provided responsive to data received in the downscan beam **76**. FIGS. **11**B and **11**C show examples of images that may correspond to the beam coverage areas shown in FIG. **11**A. In this regard, for example, FIG. **11**B illustrates possible images that could correspond to the region defined between points A and B and points C and D (e.g., sidescan images), while FIG. **11**C illustrates a possible image that may correlate to the coverage area between points E and F (e.g., a linear downscan image).

FIGS. **12**A through **12**F show examples of images that may be produced by embodiments of the present invention to illustrate differences between the display produced by a linear downscan element of an embodiment of the present invention of the vessel, and a downscan element **66** positioned to scan substantially below the vessel. As shown in FIG. **8**A, in an exemplary embodiment, both the port side element **62** and the starboard side element **64** may be oriented to face slightly below a surface of the water on which the vessel travels. In one example, both the port side element **62** and the starboard side element **64** may be oriented such that the widest dimension of the beamwidth of each respective element is centered at 30 degrees below a plane substantially parallel to the surface of the water. Meanwhile, the downscan linear element **66** may be positioned such that the widest dimension of the beamwidth of the downscan element **66** is centered at 90 degrees below the plane substantially parallel to the surface of the water. In other words, the downscan element **66** has the central portion of its fan shape aimed straight down. The containment volume **54** may include electrical connections (not shown) to communicate with the transceiver **34** and supports, struts, rods or other supporting structures to secure each of the linear transducer elements **60** in their respective orientations. The transducer elements **60** may be held in place or otherwise affixed to the supporting structures via adhesive or any other suitable joining material and the angles at which the transducer elements **60** are affixed relative to each other and to the housing **50** may vary as necessary or as desired.

FIG. **8**B is a diagram illustrating a cross section of components in the containment volume **54** according to an alternative exemplary embodiment. In this regard, FIG. **8**B illustrates the arrangement of one linear transducer element **60** within the containment volume **54**. The transducer element **60** according to this exemplary embodiment is a single linear transducer (e.g., downscan element **66**) positioned to scan substantially below the vessel. As shown in FIG. **8**B, the downscan element **66** may be positioned such that the widest dimension of the beamwidth of the downscan element **66** is centered at 90 degrees below the plane substantially parallel to the surface of the water. In other words, the downscan element **66** has the central portion of its fan shape aimed substantially straight down. As discussed above, the containment volume **54** may include electrical connections (not shown) to communicate with the transceiver **34** and supports, struts, rods or other supporting structures to secure the downscan element **66** in its respective orientation. The linear downscan element **66** may be held in place or otherwise affixed to the supporting structures via adhesive or any other suitable joining material such that transmissions produced by the downscan element **66** exit the housing **50** substantially at a 90 degree angle with respect to the plane of the face of the downscan element **66** from which the transmissions emanate.

FIG. **9**A shows an example of beam coverage for an 800 kHz operating frequency in one exemplary embodiment. As such, the beamwidth (e.g., width between the half power points) of each of the three linear transducer elements **60** is about 32 degrees. FIG. **9**B shows an example of beam coverage for a 455 kHz operating frequency in one exemplary embodiment, thereby providing about 56 degrees of beamwidth for each of the three linear transducer elements **60**. Accordingly, in each of the exemplary embodiments of FIGS. **9**A and **9**B, the three fan-shaped segments together produce a discontinuous fan shaped beam. The discontinuity may be minimized in some instances by selection of transducer element dimensions and operating frequencies selected to minimize the size of the gaps (e.g., zones with sonar beam coverage outside of beam coverage area as defined by the half power points of the beams) between the beams of the transducer elements. Alternatively, the physical orientation of the transducer elements **60** with respect to each other could be changed in order to minimize the size of the gaps. However, it should be noted that in most cases some gap should be maintained in order to prevent interference between the beam patterns emanating from the linear transducer elements **60**. Although the fan-shaped segments of an exemplary embodiment may all lie in the same plane, it may be desirable to alter the orientation of one or more of the transducer elements **60** such that a corresponding one or more of the fan-shaped segments is outside of the plane of the other fan-shaped segments. The gap could therefore be provided via planar separation of the fan-shaped segments rather than by providing separation between the segments within the same plane.

In this regard, FIG. **10**A illustrates a projection, onto a substantially flat sea bed, of the beam pattern of an exemplary transducer array providing gaps between the boundaries of the projections as defined by the half power points defining fan shaped beams produced by a transducer array in which the transducer elements **60** are positioned to provide coplanar beams with gaps therebetween according to an exemplary embodiment. As such, a first transducer element beam projection **100**, a second transducer element beam projection **102** and a third transducer element beam projection **104** are all shown lying in the same plane in FIG. **10**A. Meanwhile, FIG. **10**B illustrates a projection, onto a substantially flat sea bed, of the beam pattern of an exemplary transducer array providing gaps between the fan shaped beams produced by a transducer array in which the transducer elements **60** are positioned to provide gaps with planar separation therebetween according to another exemplary embodiment. Thus, the first transducer element beam projection **100'**, the second transducer element beam projection **102'** and the third transducer element beam projection **104'** are shown lying in different planes in FIG. **10**B. Notably, in each of FIG. **10**A and **10**B, the view is shown from the top looking down onto the sea bed and the beam projections are not necessarily to scale.

FIG. **11**A shows an example of a view of the beam coverage associated with the embodiment of the example shown in FIG. **9**A in which the beam coverage is extended to the bottom of a flat bottomed body of water. The illustration of FIG. **11**A shows a view looking at the stern of a vessel **70** as the vessel **70** is driving away from the viewer (e.g., into the page). According to this example, a port sidescan beam **72** (e.g., that may be produced by port sidescan element **62**) extends out to the port side of the vessel **70** providing coverage of the bottom from point A to point B. Meanwhile, a starboard sidescan beam **74** (e.g., that may be produced by starboard sidescan element **64**) extends out to the starboard side of the vessel **70** from point C to point D. Additionally, a downscan beam **76** (e.g., that may be produced by downscan element **66**) extends directly below the vessel **70** from point E to point F. As shown in FIG. **11**A, the coverage areas defined between points A and B and points C and D are substantially larger than the coverage area defined between points E and F. Based on the increased bottom coverage, the display provided responsive to data received in the sidescan beams **72** and **74** will be different than the display provided responsive to data received in the downscan beam **76**. FIGS. **11**B and **11**C show examples of images that may correspond to the beam coverage areas shown in FIG. **11**A. In this regard, for example, FIG. **11**B illustrates possible images that could correspond to the region defined between points A and B and points C and D (e.g., sidescan images), while FIG. **11**C illustrates a possible image that may correlate to the coverage area between points E and F (e.g., a linear downscan image).

FIGS. **12**A through **12**F show examples of images that may be produced by embodiments of the present invention to illustrate differences between the display produced by a linear downscan element of an embodiment of the present invention and either a sidescan or a conventional circular downscan transducer element. In this regard, FIG. **12A** illustrates an example image that may be produced based on data from the sidescan beams **72** and **74**. For this example, assume the top of the display (identified by arrow **80**) shows the most recent data (e.g., corresponding to the vessel's current position) and the bottom of the display (identified by arrow **82**) shows the oldest data. Additionally, the right side of the display **84** may correspond to the starboard sidescan beam **74** while the left side of the display **86** corresponds to the port sidescan beam **72**. Brighter pixels illustrated in FIG. **12A** correspond to return data received in the corresponding sidescan beams. In this regard, data closest to dashed line **88** corresponds to the data gathered near point B (for the left side of the display **86**) and near point D (for the right side of the display **84**) and data at the left edge of the display corresponds to data gathered near point A while data at the right edge of the display corresponds to data gathered near point C over the time period from the position of arrow **82** to the position of arrow **80**. Thus, well over 50% of the display of FIG. **12A** (and in many cases 100%) is utilized to show data corresponding to bottom features, e.g. the topography of and structures attached to the bottom, that have provided return data from the sidescan beams **72** and **74**. By comparison only a small portion (e.g., less than 20%) of the display shows any water column features, e.g., data from the water column between the vessel **70** and the portions of the bottom covered by each respective sidescan beam. The sidescan beams **72** and **74** also fail to provide depth data. Still further, the sidescan beams fail to provide depth data or bottom feature data or water column data for that portion of the bottom beneath the vessel, e.g., that portion between reference points B and D and the vessel **70** in FIG. **11**.

FIGS. **12B** through **12F** show on the right side (e.g., right display **90**) of each figure, exemplary screen shots of a conventional circular downscan transducer image that corresponds to the display (e.g., the left side of each figure (left display **92**)) produced by the linear downscan element of an embodiment of the present invention (e.g., downscan element **66**). In this regard, the left display of FIG. **12B** shows a boulder on the left, two tree trunks rising up from the bottom near the center of the display, and, possibly, several fish (white spots) near the lower right. The corresponding same features can be vaguely determined from the right display **90** (i.e., the circular downscan display), but the images are much less clear. Similarly, FIGS. **12C**, **12D** and **12E** clearly show very detailed images of trees rising vertically from the bottom in the left display **92**, while such features are very difficult to distinguish on the right display **90**. FIG. **12F** clearly shows a downed tree and at least two vertical trees nearby in the left display **92**, whereas the same features are difficult to discern in the right display **90**.

The exemplary linear downscan image on the left side of FIG. **12B** includes a numerical depth scale 0-40 on the right side, with sonar reflection data being represented on the display screen at the time-dependent depth using known sonar imaging practices. Boat position is represented by the numeral 0, or some other desirable icon, for the most recent sonar pings, and the oldest sonar pings are presented by the left side of the screen, presenting a scrolling image as the boat (and transducer) move across the water surface over time. The far right column reflects the intensity of the return echo received at the circular downscan transducer, plotted adjacent the 0-40 depth scale.

Accordingly, by placing a linear transducer in a downward oriented position, a much improved image quality is achieved for bottom data and structures attached to it or rising above it relative to the conventional circular downscan sonar. In this regard, while sidescan images are valued for their ability to provide detailed images of laterally distant bottom features, they are unable to provide depth data or bottom data or water column data below the vessel. A linear downscan element provides the unexpected advantage of providing detailed images of the water column below the vessel (e.g., upwardly extending submerged trees, fish, etc.), as well as details of the features of the bottom or structures resting on or rising above the bottom (e.g., rocks, crevices, submerged trees, sunken objects, etc.), and a depth indication that can be registered (e.g., feet or meters). For example, again referring to the left image of FIG. **12B**, the mass of bright pixels at about 30 feet (as indicated by the numbers in increments of five feet that extend down the right edge of the left display **92**) represent bottom feature data and are indicative of the depth at which the bottom is encountered. The bottom feature data may also, in some cases, indicate the type of bottom (e.g., rocky, muddy, hard, soft, flat, sloped, smooth, rough, etc.). Thus, sonar returns associated with the bottom in a linear downscan display are not only indicative of bottom features, but are also indicative of depth and water column data. However, the bottom feature data represents a relatively small percentage of the overall display area. Due to the relatively small percentage of display area that is devoted to bottom feature data, a relatively large percentage of the display area may be devoted to other data, e.g., data representing the water column above the bottom). Thus, for example, as shown in FIG. **12B**, water column features are represented by data including a boulder and trees extending from the bottom along with any suspended objects (e.g., schools of bait fish, individual large fish, etc.), thermoclines, and other features may be displayed in greater detail along with the indication of bottom depth. Meanwhile, even in situations where the zoom level of the display is not set such that the lake or sea bottom is near the lowest portion of the display (such as in FIG. **12C**), the bottom features only account for a small percentage of the display area, while the water column features account for more than 50% and the area below the lake or sea bottom is essentially featureless.

FIGS. **12B** through **12F** each show far less than 50% (and typically less than 20%) of the display being utilized to show data corresponding to bottom features, and do so for the water column beneath the vessel. As shown, a linear transducer positioned as a downscan element (e.g., downscan element **66**) according to an exemplary embodiment, is capable of providing far more information regarding the water column itself rather than merely the bottom features or depth. Thus, water column data can be received and displayed representing schools of fish, individual fish and certain structural features in the water column directly below the vessel **70**. Additionally, as shown in FIGS. **12B** through **12F**, a linear transducer positioned as a downscan element is also capable of producing depth data. In this regard, whereas a sidescan image produces relatively high quality images of bottom features (see for example, FIG. **12A**), it is unable to produce useful depth data or water column data. A downscan image produced by a linear transducer according to an exemplary embodiment of the present invention produces depth data along with bottom feature data and water column data.

FIG. **13A** provides an example of a display of the bottom structure as viewed through use of a linear downscan sonar element (e.g., downscan element **66**) of an exemplary embodiment of the present invention. FIG. **13B** shows the vessel **70** and various bottom features viewed from above. The bottom features include a boulder **120**, a vertical tree **122**, a rock pile **124**, a school of fish **126** and a fallen, horizontal tree **128**. FIG. **13**B also shows a linear transducer downscan fan-shaped sonar beam **130** projected onto the bottom as compared to a circular transducer downscan conical beam **132** projected onto the bottom. As can be appreciated from the corresponding example display provided in FIG. **13**A, since the linear downscan beam **130** has a narrow aspect in one direction and a broad aspect in the other, the amount of data received and therefore processed for display is less with respect to each feature for which a return is received than for the conical beam **132**. There is typically no overlap in coverage from each outgoing sound wave to the next (ping to ping) in the linear downscan beam **130** whereas there will be such overlap in the conical beam **132**. Thus, while data corresponding to the conical beam **132** is processed, it produces blurred images due to the additional return data received. The linear downscan beam **130** is able to produce "cleaner" images that more accurately illustrate feature data that reflects what objects are in the water column and on the bottom beneath the vessel. Note, however, that there can be at least partial overlap in the bottom topography that is sonified by the linear and circular trausducer, as shown in FIG. **13**B.

By providing the downscan element **66** as a linear transducer element of the same type and construction as one or both of the port side linear element **62** and the starboard side linear element **64**, embodiments of the present invention provide vivid images of the column of water over which the vessel passes in addition to providing vivid images of the water column on both sides of the vessel, which is provided by conventional sidescan sonar systems that either neglect the column of water beneath the vessel or only scan such region with a conical beam from a transducer element having a cylindrical shape that is not capable of providing the level of detail provided by embodiments of the present invention. Moreover, embodiments of the present invention provide high quality images of the column of water over which the vessel passes without the high degree of complexity and cost associated with a multibeam system.

FIG. **14** illustrates an exemplary sonar system incorporating linear and circular downscan transducers **140**, **142**. The two transducers may be in the same or separate housings. They typically uitlize different operational frequencies. Such may also assist in minimizing interference. Similar to the system illustrated in FIG. **5**, the transducers are operationally connected to the transceivers **144**, **146**, which configure the transducer outputs for receipt by the sonar signal processor **148**. The sonar signal processor executes various programs stored or as may be selected by the user interface **150**. The Ethernet hub **152**, network **154**, displays **156** and user interface **150** operate as described for the corresponding components of FIG. **5**. The image processor **158** may perform a variety of functions to optimize or customize the display images, including such features as split screen to show multiple different sonar images or data. Examples include individual and separate images of GPS, waypoints, mapping, nautical charts, GPS tracking, radar, etc., which are typically shown side-by-side or stacked. Additional examples include individual data boxes, such as speed, depth, water, temperature, range or distance scales, location or waypoint, latitude, longitude, time, etc. Still further examples include composite images that combine information from one or more of these sources, such as the images from the linear downstream and circular downstream transducers to overlay the images. For example, the traditional "fish arch" image representing a possible fish using a circular downscan sonar may be imposed over a small white circle or oval representing a possible fish using a linear downscan sonar. Still further, one image may be colorized to distinguish it visibly from data representing another image. As such, for example, the images may be combined using image blending or overlay techniques. Alternatively, individual images may be presented, or different images, simultaneously on different displays without overlay. Image data packets or streams may also have additional data associated therewith, such as time of day, location, temperature, speed, GPS, etc.

Notably, the example of FIG. **14** may be simplified in some embodiments. In this regard, the radar, map and GPS modules of FIG. **14** along with the Ethernet hub **152** may not be included in some embodiments. Moreover, in one example, an embodiment of the present invention may include essentially only processing circuitry to handle inputs from a linear and circular transducer array along with a display in a single device. As such, for example, all of the electronics for handling linear and circular transducer inputs may be included along with a display within a single box, without any Ethernet connection or other peripherals.

FIG. **15**A illustrates an example of a top view of the beam overlap that may occur in situations where a linear downscan transducer and a circular downscan transducer are employed simultaneously. FIG. **15**B shows side views of the same beam overlap shown in FIG. **15**A from the starboard side of a vessel (on the left side of the page) and from ahead of the bow of the vessel (on the right side of the page). As shown in FIG. **15**A, there is overlap between a conical beam projection **180** showing an example coverage area of a beam produced by the circular downscan transducer and a downscan beam projection **182** showing an example coverage area of a beam produced by the linear downscan transducer. The differences between the beam patterns of the linear and circular downscan transducers are further illustrated in FIG. **15**B in which it can be seen that the beamwidth **184** of the beam produced by the circular downscan transducer is substantially the same regardless of the side from which the beam is viewed. However, the beamwidth **186** of the beam produced by the linear downscan transducer as viewed from the starboard side of the vessel is substantially smaller than the beamwidth **188** of the beam produced by the linear downscan transducer as viewed from ahead of the bow of the vessel. Moreover, the beamwidth **188** is wider than the beamwidth **184**, while the beamwidth **186** is narrower than the beamwidth **184**.

FIGS. **16**A through **16**C illustrate diagrams of a linear downscan transducer **190** and a circular downscan transducer **192** within a single streamlined housing **194** from various different perspectives. In this regard, FIG. **16**A is a perspective view from above the housing **194**. Meanwhile, FIG. **16**B is a perspective view from one side of the housing **194** at a point substantially perpendicular to a longitudinal axis of the housing **194** and FIG. **16**C is a perspective view from the front side of the housing **194** at a point looking straight down the longitudinal axis of the housing **194**. As shown in FIGS. **16**A-**16**C, the linear downscan transducer **190** and the circular downscan transducer **192** may each be disposed to be in planes that are substantially parallel with each other and with a plane in which the longitudinal axis of the housing **194** lies. Generally speaking, the linear downscan transducer **190** and the circular downscan transducer **192** may also be displosed in line with the longitudinal axis of the housing **194**. Although shown in a particular order in FIGS. **16**A-**16**C, the ordering of the placement of the linear downscan transducer **190** and the circular downscan transducer **192** within the housing **194** may be reversed in some examples. Furthermore, in some cases, the linear downscan transducer **190** and the circular downscan transducer **192** may each be located in their own respective separate housings rather than both being within a single housing. FIGS. **16A-16C** also illustrate an example of a mounting device **196** for mounting the housing **194** to a vessel.

By way of comparison, FIGS. **17A** through **17C** illustrate diagrams of a single linear downscan transducer **190** a housing **198** from various different perspectives. In this regard, FIG. **17A** is a perspective view from above the housing **198**. Meanwhile, FIG. **17B** is a perspective view from one side of the housing **198** at a point substantially perpendicular to a longitudinal axis of the housing **198** and FIG. **17C** is a perspective view from the front side of the housing **198** at a point looking straight down the longitudinal axis of the housing **198**. As shown in FIGS. **17A-17C**, by employing only the linear downscan transducer **190** the size of the housing **198** may be reduced. In this regard, for example, particularly FIG. **17C** shows a reduction in the cross sectional size of the housing **198** as compared to the cross sectional size of the housing **194** of FIG. **16C**. Thus, for example, the housing **198** may introduce less drag than the housing **194**.

Many modifications and other embodiments of the inventions set forth herein will come to mind to one skilled in the art to which these embodiments pertain having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the inventions are not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

That which is claimed:

1. A sonar assembly for imaging an underwater environment beneath a watercraft traveling on a surface of a body of water, the sonar assembly comprising:

a housing mountable to the watercraft;

a single linear downscan transducer element positioned within the housing, the linear downscan transducer element having a substantially rectangular shape configured to produce a fan-shaped sonar beam having a relatively narrow beamwidth in a direction parallel to a longitudinal length of the linear downscan transducer element and a relatively wide beamwidth in a direction perpendicular to the longitudinal length of the transducer element, the linear downscan transducer element being positioned with the longitudinal length thereof extending in a fore-to-aft direction of the housing;

wherein the linear downscan transducer element is positioned within the housing to project fan-shaped sonar beams in a direction substantially perpendicular to a plane corresponding to the surface of the body of water, said sonar beams being repeatedly emitted so as to sequentially insonify different fan-shaped regions of the underwater environment as the watercraft travels; and

a sonar signal processor receiving signals representative of sonar returns resulting from each of the fan-shaped sonar beams and processing the signals to produce sonar image data for each fan-shaped region and to create an image of the underwater environment as a composite of images of the fan-shaped regions arranged in a progressive order corresponding to the travel of the watercraft.

2. The sonar assembly of claim **1**, wherein the linear downscan transducer element is configured to operate at a selected one of at least two selectable operating frequencies.

3. The sonar assembly of claim **1**, wherein the selectable operating frequencies include about 455 kHz and 800 kHz.

4. The sonar assembly of claim **1**, wherein the beamwidth of the linear downscan transducer element is about 0.8 degrees by about 32 degrees or about 1.4 degrees by about 56 degrees.

5. The sonar assembly of claim **1**, wherein the linear downscan transducer element is configured to communicate with a single transceiver.

6. The sonar assembly of claim **1**, wherein a length of a rectangular face of the linear downscan transducer element is about 120 mm and a width of the rectangular face of the linear downscan transducer element is about 3 mm.

7. The sonar assembly of claim **1**, wherein the housing is mountable to the watercraft such that the fan-shaped beam extends from one side of the watercraft to an opposite side of the watercraft.

8. The sonar assembly of claim **1**, wherein the housing has a streamlined shape.

9. The sonar assembly of claim **1**, wherein the beamwidth in the direction parallel to a longitudinal length of the linear downscan transducer element is less than about five percent as large as the beamwidth of the sonar beam in the direction perpendicular to the longitudinal length of the linear downscan transducer element.

10. The sonar assembly of claim **1**, wherein the linear downscan transducer element is configured to provide data displayable as sonar data images in which images corresponding to data received via the linear downscan transducer element provide data regarding bottom features over less than fifty percent of a display screen when displayed.

11. The sonar assembly of claim **1**, wherein the linear downscan transducer element is configured to provide data displayable as sonar data images in which images corresponding to data received via the linear downscan transducer element provide data regarding bottom features over less than twenty percent of a display screen when displayed.

12. The sonar assembly of claim **1**, wherein the linear downscan transducer element is configured to provide data displayable as sonar data images in which images corresponding to data received via the linear downscan transducer element provide data indicative of bottom depth.

13. The sonar assembly of claim **1**, wherein the linear downscan transducer element is configured to provide data displayable as sonar data images in which images corresponding to data received via the linear downscan transducer element provide data indicative of water column features.

14. The sonar assembly of claim **1**, wherein the linear downscan transducer element is configured to provide data displayable as sonar data images indicative of bottom data.

15. The sonar assembly of claim **1**, wherein the linear downscan transducer element is configured to provide data displayable as sonar data images indicative of two or more of depth data water column data and bottom data.

16. The sonar assembly of claim **1**, further comprising a circular transducer element positioned to project conical sonar pulses in a direction substantially perpendicular to the plane corresponding to the surface.

17. The sonar assembly of claim **16**, wherein the linear downscan and circular transducer elements are in the same housing.

18. The sonar assembly of claim **16**, wherein the linear downscan transducer and circular transducer elements are positioned to project fan-shaped and conical sonar beams that at least partially overlap.

19. The sonar assembly of claim **16**, wherein the sonar signal returns from the circular transducer element and linear downscan transducer element provide generally simultaneous data.

20. The sonar assembly of claim 1, wherein the linear downscan transducer element is configured to emit fan-shaped sonar beams as well to receive echo returns and convert sound energy of the echo returns into electrical signals.

21. The sonar assembly of claim 1, wherein the housing is mounted to the watercraft.

22. The sonar assembly of claim 1, wherein the linear downscan transducer element is configured to produce a generally planar fan-shaped beam.

23. A sonar system for imaging an underwater environment beneath a watercraft traveling on a surface of a body of water, the sonar system comprising:

a single linear downscan transducer element positioned within a housing that is mountable to the watercraft, the linear downscan transducer element having a substantially rectangular shape configured to produce a fan-shaped sonar beam having a relatively narrow beamwidth in a direction parallel to longitudinal length of the linear downscan transducer element and a relatively wide beamwidth in a direction perpendicular to the longitudinal length of the transducer element, the linear downscan transducer element being positioned with the longitudinal length thereof extending in a fore-to-aft direction of the housing;

wherein the linear downscan transducer element is positioned to project fan-shaped sonar beams in a direction substantially perpendicular to a plane corresponding to the surface of the body of water, said sonar beams being repeatedly emitted so as to sequentially insonify different fan-shaped regions of the underwater environment as the watercraft travels;

a sonar module configured to enable operable communication with the linear downscan transducer element, the sonar module including:

a sonar signal processor to process sonar return signals, and

at least one transceiver configured to provide communication between the linear downscan transducer element and the sonar signal processor;

the sonar signal processor receiving signals representative of sonar returns resulting from each of the fan-shaped sonar beams and processing the signals to produce sonar image data for each fan-shaped region and to create an image of the underwater environment as a composite of images of the fan-shaped regions arranged in a progressive order corresponding to the travel of the watercraft.

24. The sonar system of claim 23, wherein the sonar module further comprises an Ethernet hub in communication with the signal processor.

25. The sonar system of claim 23, wherein the sonar module is provided within a separate housing.

26. The sonar system of claim 23, further comprising at least one visual display presenting the image.

27. The sonar system of claim 26, wherein the display and the sonar module are in the same housing.

28. The sonar system of claim 26, wherein at least one display of the plurality of displays is enabled to simultaneously provide different images representing different information from the processed sonar return signals.

29. The sonar system of claim 23, wherein the sonar module further comprises configuration settings defining a predefined set of display images that may be presented.

30. The sonar system of claim 23, wherein the linear downscan transducer element is configured to operate at a selected one of at least two selectable operating frequencies.

31. The sonar system of claim 23, wherein the selectable operating frequencies include about 455 kHz and 800 kHz.

32. The sonar system of claim 23, wherein the housing is mountable to the watercraft such that the fan-shaped beam extends from one side of the watercraft to an opposite side of the watercraft.

33. The sonar system of claim 23, wherein the sonar signal processor is configured to display images of sonar data in which images corresponding to data received via the linear downscan transducer element provide data regarding bottom features over less than fifty percent of a display screen when displayed.

34. The sonar system of claim 23, wherein the sonar signal processor is configured to display images of sonar data corresponding to data received via the linear downscan transducer element representing bottom data.

35. The sonar system of claim 23, wherein the sonar signal processor is configured to display images of sonar data corresponding to data received via the linear downscan transducer element representing water column data.

36. The sonar system of claim 23, wherein the sonar signal processor is configured to display images of sonar data corresponding to data received via the linear downscan transducer element representing depth data.

37. The sonar system of claim 23, wherein the sonar signal processor is configured to display images of sonar data corresponding to data received via the linear downscan transducer element representing two or more of depth data, water column data and bottom data.

38. The sonar system of claim 23, wherein the sonar signal processor is configured to display images of sonar data corresponding to data received via the linear downscan transducer element representing data vertically below the linear transducer element.

39. The sonar system of claim 23, further comprising a circular transducer element producing a conical downscan beam.

40. The sonar system of claim 39, wherein the fan-shaped sonar beams from the linear downscan transducer element and the sonar pulses from the circular transducer element insonify areas of the bottom that at least partially overlap.

41. The sonar system of claim 39, wherein the sonar signal returns from the circular transducer element and linear downscan downscan element provide generally simultaneous data.

42. The sonar system of claim 23, further comprising a circular transducer element producing a conical downscan beam from within the housing.

43. The sonar system of claim 23, further comprising sources of data from at least one of the group of radar, GPS, digital mapping, time and temperature.

44. The sonar system of claim 43, wherein a display format for display of the data is in a user selectable format.

45. The sonar system of claim 23, wherein the linear downscan transducer element is configured to emit fan-shaped sonar beams as well to receive echo returns and convert sound energy of the echo returns into electrical signals.

46. The sonar system of claim 23, further comprising a display in communication with the sonar module.

47. The sonar system of claim 46, wherein the sonar module and display communicate with each other via a network.

48. The sonar system of claim 46, further comprising at least one additional display in communication with the sonar module.

49. The sonar system of claim 46, further comprising a user interface in communication with the sonar module and configured to receive an input from a user.

50. The sonar system of claim **49**, wherein the display, the sonar signal processor, and the user interface are all contained in a single housing.

51. The sonar system of claim **49**, wherein the user interface is part of the display.

52. The sonar system of claim **46**, wherein the linear downscan transducer element, the transceiver, and the display respectively comprise at least two separate modules.

53. The sonar system of claim **46**, wherein the sonar signal processor is further configured to implement signal processing or enhancement to improve display characteristics.

54. The sonar system of claim **46**, wherein the sonar signal processor is further configured to process GPS information.

55. The sonar system of claim **46**, wherein the sonar signal processor is further configured to process waypoint designations.

56. The sonar system of claim **46**, wherein the sonar signal processor is further configured to process time data.

57. The sonar system of claim **46**, wherein the sonar signal processor is further configured to process temperature data.

58. The sonar system of claim **46**, wherein the sonar signal processor is further configured to implement a notice or alarm regarding depth.

59. The sonar system of claim **46**, wherein the sonar signal processor is further configured to implement a notice or alarm regarding presence of fish.

60. The sonar system of claim **46**, wherein the sonar signal processor is further configured to implement a notice or alarm regarding proximity of other watercraft.

61. The sonar system of claim **46**, wherein the processor, in combination with a memory, stores incoming transducer data or screen images for future playback or transfer.

62. The sonar system of claim **46**, wherein the sonar signal processor is further configured to perform additional processing to implement zoom.

63. The sonar system of claim **46**, wherein the sonar signal processor is further configured to perform additional processing to correlate sonar data to a GPS position.

64. The sonar system of claim **23**, wherein the housing containing the linear downscan transducer element is mounted to the watercraft.

65. The sonar system of claim **23**, wherein the housing containing the linear downscan transducer element is mounted on an intermediate structure that in turn is mounted to the watercraft.

66. The sonar system of claim **23**, wherein the housing containing the linear downscan transducer element has a streamlined profile.

67. The sonar system of claim **23**, wherein the housing containing the linear downscan transducer element is mounted on an accessory on the watercraft enabling the fan-shaped beam to assume various orientations with respect to the watercraft.

68. The sonar system of claim **23**, further comprising a display in communication with the sonar module, and wherein the system is configured to indicate a position of the watercraft on the display.

69. The sonar system of claim **23**, further comprising a display in communication with the sonar module, and wherein the system is configured to indicate water depth on the display.

70. The sonar system of claim **23**, further comprising a second transducer positioned and configured to produce a conical sonar beam directed downwardly from the watercraft, wherein the system further includes a display in communication with the sonar module, and wherein the system is configured to indicate on the display an intensity of a return echo received from the conical sonar beam.

71. The sonar system of claim **70**, wherein the linear downscan transducer element and the second transducer are both contained in the housing.

72. The sonar system of claim **70**, wherein the linear downscan transducer element and the second transducer operate at different respective frequencies.

73. A sonar imaging apparatus comprising:

a housing mountable to a watercraft that traverses a surface of a body of water, the watercraft defining a center plane that extends from fore to aft and that is perpendicular to the surface of the body of water;

a linear transducer element positioned within the housing, the linear transducer element being configured to produce a fan-shaped sonar beam having a longitudinal beamwidth in a direction parallel to a longitudinal length of the linear transducer element that is significantly less than a transverse beamwidth of the sonar beam in a direction perpendicular to the longitudinal length of the transducer element;

wherein the housing is configured for mounting to the watercraft such that the longitudinal length of the linear transducer element is parallel to said center plane, and

wherein the transverse beamwidth of the sonar beam is sufficiently wide in relation to a direction in which the linear transducer element is aimed such that the transverse beamwidth spans from a port side of said center plane to a starboard side of said center plane, said fan-shaped sonar beam being repeatedly emitted so as to sequentially insonify different fan-shaped regions of an underwater environment beneath the watercraft as the watercraft travels across the surface of the water; and

a sonar signal processor receiving signals representative of sonar returns resulting from each of the fan-shaped sonar beams and processing the signals to produce sonar image data for each fan-shaped region and to create an image of the underwater environment as a composite of images of the fan-shaped regions arranged in a progressive order corresponding to the travel of the watercraft.

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