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3 SYSTEM FOR PROVIDING AN ESTIMATE OF

4 THE LOCATION OF AN UNDERSEA OBJECT

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6 STATEMENT OF GOVERNMENT INTEREST

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

11

12 BACKGROUND OF THE INVENTION

13 (1) Field of the Invention

14 The present invention relates to a sonar system and, more
15 particularly, to a system that provides a sonar operator with
16 the most likely range of the target of interest.

17 (2) Description of the Prior Art

18 Sonar systems are used for analyzing acoustic energy to
19 determine the identification of the acoustic energy and the
20 location of the source of acoustic energy, whether the source be
21 a ship or a school of fish.

22 Sonar systems are known and some of which are described in
23 U.S. Patents 5,065,371; 5,184,330; 5,537,380; and 5,657,296.

1 Further, systems for analyzing geographic data by interactively
2 displaying selected properties to an operator are known, and one
3 such system is disclosed in U.S. Patent 4,467,461.

4 Sonar systems may have a range of the day display. The
5 traditional range of the day display provided to a sonar
6 operator is a single "best" estimate of the detection range to a
7 threat of interest or acoustic source and is based on expected
8 own ship, target, environmental, and operator selectable sonar
9 parameters. Sonar systems having such a range of display
10 include military legacy SONAR systems AN/BQQ-5, AN/BSY-1,
11 AN/BSY-2, AN/SQQ-89, as well as, commercial fish finding sonars.
12 The estimate is provided in a non-interactive manner by use of
13 static estimates determined by the sonar operator.

14 It is desired that the estimate of range to an expected
15 acoustic energy source or threat submarine be provided in an
16 enhanced interactive manner. The prior art range estimate can
17 also be enhanced by providing a graphical tool that allows the
18 sonar operator the flexibility of varying critical own ship,
19 environmental, and operator parameters, in "what if" scenarios
20 with each "what if" scenario leading to an improved estimate.

1 The system provides range estimates to targets of interest and
2 counter detection ranges based on operator interaction with a
3 range of day display. The system provides the sonar operator
4 with interactive sessions allowing for a back-and-forth dialogue
5 between the sonar operator and the system itself.

6 The system providing for the interactive dialogue generates
7 range contours determined by the probability of the detection of
8 the undersea object. The system comprises a computer, a
9 display, and input means. The computer has a plurality of ports
10 and is responsive to application programs. The display is
11 operatively connected to some of the ports of the computer. The
12 input means is also operatively connected to some of the ports
13 of said computer. The sonar operator can use the input means
14 for selection of parameters that are directed into the computer
15 and manipulated by application programs having a computational
16 model. The selectable parameters comprise own ship's
17 parameters, target parameters, environmental parameters, and
18 operator parameters. The application programs manipulate the
19 parameters in accordance with the computational model to
20 generate at least one contour having a predetermined probability
21 of detection and causing at least one contour to be rendered on
22 the display.

SUMMARY OF THE INVENTION

It is a first object of the present invention to provide a system that allows the operator to visualize the process for detecting undersea objects and improves the sonar operator's ability to find schools of fish or submarines in a shorter time.

It is another object of the present invention to provide for range contours related to different levels of probability of detection, target aspect angle, different depths, and different operational conditions.

It is yet another object of the present invention to provide for range contours in various rendering by utilizing different shapes and color scales to more definitively define the range contour.

It is still a further object of the present invention to utilize a real time linkage to satellite communication systems that provide information associated with an existing surface traffic, existing surface traffic noises, or weather, all such information being used to provide more realistic sonar performance predictions.

Accordingly, it is the general purpose and object of the present invention to provide a system that presents to a sonar or ship operator the most likely range to a target of interest.

1 BRIEF DESCRIPTION OF THE DRAWINGS

2 A more complete understanding of the invention and many of
3 the attendant advantages thereto will be readily appreciated as
4 the same becomes better understood by reference to the following
5 detailed description when considered in conjunction with the
6 accompanying drawings wherein corresponding reference characters
7 indicate corresponding parts throughout the several views of the
8 drawings and wherein:

9 FIG. 1 is a block diagram of the present invention;

10 FIG. 2 illustrates the computation model associated with
11 the application programs of the present invention;

12 FIG. 3 illustrates operator selectable parameters utilized
13 for the computation model of the present invention to determine
14 the probability of detection, range of interest and counter
15 detection range; and

16 FIG. 4 is composed of FIGS. 4A, 4B, 4C, and 4D which
17 cumulatively illustrate the graphics involved with a situation
18 of comparing two own ship's depths to two interrelated target
19 aspects.

1 DESCRIPTION OF THE PREFERRED EMBODIMENTS

2 With reference to the drawing, there is shown in FIG. 1, a
3 block diagram of the system 10 used on board a ship providing
4 for an interactive dialogue with a sonar operator. The
5 interactive dialogue allows the sonar operator to detect the
6 presence and location of a target of interest and to generate
7 range contours determined by probabilities of detection. The
8 system comprises a computer 12 having a plurality of ports and
9 responsive to application programs of the present invention.
10 The system further comprises a display 14 connected to some of
11 the ports of the computer 12 and a input device 15, also
12 connected to some of the ports of the computer 12, which may be
13 a mouse, a track ball, a touch screen or some other pointing
14 device that allows the operator selection for input to the
15 computer 12. Utilizing input device 15, the operator selects
16 parameters representative of real time ship database 16
17 parameters, an environmental and target database 18, and
18 operator inputs 20.

19 The real time ship database parameters 16 comprise
20 latitude, longitude, depth, date, time, course, speed, array
21 heading, array depth, ambient noise level of the environment,

1 depth of the bottom below the ship, and the ship's radiated
2 noise.

3 The environmental and target database 18 comprises target
4 parameters consisting of depth, aspect, speed, spectral
5 characteristics, and radiated noise. The environmental and
6 target database 18 further comprises environmental parameters
7 which include sea state, sound velocity profile, and shipping
8 density. In addition, the environmental and target database 18
9 includes threat data, sonar receiver operating characteristics,
10 sonar array characteristics of directivity index (DI), array
11 self noise (LE), ambient noise (NL), sonar system processing
12 gain (NRD), and own ship radiated noise. NRD is the minimum
13 detectable signal given a sonar processing gain which includes
14 passive narrow band and passive broad band.

15 The operator inputs 20 primarily comprises selection of the
16 probability of detection as further described below. The
17 operator inputs 20 also include "what-if" slider bars allowing
18 the operator to examine the effects of changes in own ship
19 speed, own ship depth and other controllable factors. These
20 controllable factors include: assumed own ship speed; assumed
21 own ship depth; operational array; ambient noise level; assumed
22 target depth; assumed target; assumed target spectrum; assumed

1 target speed; assumed target radiated noise; and sonar system
2 identification.

3 The system 10 further comprises a satellite communication
4 linkage 22 that allows the satellite, in a manner known in the
5 art, to supply information comprising existing surface traffic
6 targets, existing surface traffic noise, and existing surface
7 weather. All of this information is utilized by the present
8 inventor to improve sonar predictions to be described.

9 The computer 12 operates in response to application
10 programs 28, which may be further described with reference
11 to FIG. 2. FIG. 2 illustrates application programs 28 which
12 primarily consist of sonar equation 30 and an acoustic
13 propagation model 32. The sonar equation 30 receives inputs
14 from functional units 16, 18, and 20 shown in FIG. 1.

15 The sonar equation 30 may be expressed by the below
16 equation (1):

$$17 \qquad \qquad \qquad \text{FOM} = \text{SL} - (\text{NL} - \text{DI} + \text{NRD}) \qquad (1)$$

18 where FOM is the figure of merit,

19 SL is the target source level,

20 NL is the ambient noise array self noise,

1 DI is the array directivity index, and NRD is the minimum
2 detectable signal given sonar processing gain and is
3 sometimes referred to as recognition differential.

4 The sonar equation (1) is well known and further details
5 thereof may be found in the text entitled "Principles of
6 Undersea Sound for Engineers," Chapter 2 pages 16-28, of Robert
7 J. Urlick, published by McGraw Hill Inc., copyrighted 1967, and
8 incorporated by reference herein. It should be noted that the
9 text of R.J. Urlick replaces the term NRD with the term DT more
10 fully described therein as "detection threshold."

11 The sonar equation (1) yields FOM quantities 36 which are
12 representative of the transmission loss at the instant when the
13 sonar equation is satisfied, the FOM gives an immediate
14 indication of range at which the target can be detected. The
15 FOM quantities 36 are routed to the acoustic propagation model
16 32 which, as indicated by arrowed 34, also receives ship's
17 measured sound velocity profile and environmental data including
18 sea state, as well as historical data including previously
19 measured sound velocity profiles and bottom depths.

20 The acoustic propagation model 32 is well known and further
21 details thereof may be found in the text entitled "Sonar and
22 Underwater Sound," Chapter 2, pages 9-33, of Albert W. Cox,

1 published by D.C. Heath and Company, copyrighted 1974, and
2 herein incorporated by reference. The acoustic propagation
3 model 32 yields functions 38, 40, and 42 that respectively
4 represent the probability of detection (Pd), range to threat,
5 and counter detection range.

6 In operation, the system 10 provides the sonar operator
7 with the ability to generate "what if" scenarios, wherein the
8 sonar operator has an interactive dialogue with the system 10.
9 With such scenarios, real time ship data is used to set the
10 initial conditions for the system 10 from which the operator can
11 provide operator inputs 20. The environmental and target
12 database 18 brings in parameters that are not available from the
13 real time ship database 16 system, as well as information on the
14 threat of interest. The primary element of the computational
15 model of FIG. 2 is the sonar equation (1) that derives the FOM
16 quantities 36. The elements of the FOM quantity vary by
17 variation in various inputs, and the final FOM quantities are
18 applied to the acoustical propagation model 32. The outputs of
19 the acoustic propagation model 32 are the probability of
20 detection (Pd) 38, range to threat 40, and the counter detection
21 range 42. The interactive back-and-forth dialogue between the
22 operator and the system 10 and thus, the "what if" scenario, can

1 be further described with reference to FIG. 3 illustrating
2 operator selectable parameters 44, each of which has a reference
3 number and a general classification.

4 In operation, the operator selections are made with a track
5 ball or pointing device previously described with reference to
6 input device 15 of FIG. 1. The selection of these parameters
7 are responded to by the computational model (sonar equation (1)
8 and the acoustic propagation model) developing at least one, but
9 preferably four range contours, each having a predetermined
10 probability of detection, and these range contours are rendered
11 on display means 14, with a typical display array being shown in
12 FIG. 4.

13 FIG. 4 is composed of FIGS. 4A, 4B, 4C, and 4D. FIG. 4
14 shows a situation of comparing two own ship's depth and against
15 two target aspects. Each of the renditions shown in FIGS. 4A,
16 4B, 4C, and 4D is labeled depth/aspect, and it is preferred that
17 all of the plots related to the present invention carry the
18 depth/target aspect labeling.

19 For the scenario of FIG. 4, FIG. 4A represents range
20 contours of the associated ship having a Depth 1 and dealing
21 with a target having an Aspect 1. FIG. 4B represents range
22 contours of the associated ship having a Depth 1 (same as FIG.

1 4A) and dealing with target having an Aspect 2. FIG. 4C
2 represents range contours of the associated ship having a Depth
3 2 and dealing with a target having an Aspect 1. Finally, FIG.
4 4D represents range contours of the associated ship having a
5 Depth 2 (same as FIG. 4C) and dealing with a target having an
6 Aspect 2.

7 In another example, the operator can select up to three
8 parameter scenarios for additional plots, each plot being a
9 function of the probability of detection (Pd). The inputs from
10 sources 16, 18, and 20 are directed in to the application
11 programs 28, in particular, the computational model shown in
12 FIG. 2.

13 The computational model manipulates the environmental data,
14 threat data, and own ship's characteristic data. The
15 environmental data consists of historical data for particular
16 operational areas or recent sound velocity profiles (SVP) taken
17 on board a vessel, such as a submarine in which system 10 finds
18 application. The threat data commonly consists of spectral and
19 radiated noise of the expected threat to be encountered. The
20 real time ship database 16 commonly consists of sonar array
21 information such as, self noise characteristics, array gain, and
22 signal processing gain.

1 With reference to FIGS. 2 and 3, the computational model is
2 initialized with the environmental and threat database 18 based
3 on date/time 48, latitude 52 and longitude 56. Current sound
4 velocity profile parameters may also be used, if available. The
5 expected threat data 46 is also loaded by and is based on
6 operator selection. The detection array used with the sonar may
7 be either a spherical hull or towed array and such information
8 54 is also selected by the operator. The operator may then
9 select contour plot label, Depth 1/Aspect 1 and select current
10 own ship's depth 60 and speed 58 and noise environment 64. The
11 target parameters are selected by the operator next. The
12 target's depth 70, aspect 72 and speed 74 are selected by the
13 operator. The target radiated noise 76 tracks those settings
14 (depth, aspect and speed), but the operator is allowed to change
15 the target's radiated noise 76 based upon current updated
16 information.

17 The operator can utilize the contents of FIG. 4 to
18 determine the probability of detection of a target. FIG. 4,
19 which includes FIGS. 4A, 4B, 4C, and 4D, has an axis 78 and an
20 origin 82. First, second, third and fourth contour plots are
21 respectively displayed in FIGS. 4A, 4B, 4C, and 4D, each having
22 contours defined by reference numbers 82, 84 and 86 which are

1 referenced to the axis 78 and to the origin 80. The reference
2 number 86 is being used twice to define the main region and
3 broken-away portions thereof. Although contours 82, 84 and 86
4 are the same in FIGS. 4A-4D it is anticipated that they will
5 vary by Aspect and Depth or by the chosen parameters.

6 After all the selections have been made by the operator, a
7 first contour plot FIG. 4A will be displayed. Then three
8 contours will be shown for preselected probabilities. Targets
9 located within first contour 82, defined by reference numbers 80
10 and 82 as seen, for example in FIG. 4A, have a greater than 90%
11 probability of detection. Targets located between the first
12 contour 82 and the second contour 84 have a 75% probability of
13 detection. Targets located between the second contour 84 and
14 the third contour 86 have a 50% probability of detection.

15 Once the operator is presented with four contours, the
16 operator can change the probability of detection (Pd) by
17 selecting a contour (FIG. 4A) and changing its probability of
18 the detection (Pd) value 68. The three remaining plots, FIGS.
19 4B, 4C, and 4D can now be used as a "what if" situation in which
20 the operator is allowed to optimize the detection range. The
21 operator continues the interactive sessions with a back-and-

1 forth dialogue with system 10 until the optimum detection range
2 is ascertained and is shown on the display of FIG. 4A.

3 It should now be appreciated that the practice of the
4 present invention provides the sonar operator with the most
5 likely range of the target of interest. The range is estimated
6 based on own ships parameters (i.e., latitude, longitude, depth,
7 date/time and speed), target parameters (i.e., depth, aspect,
8 speed, spectral characteristics and radiated noise),
9 environmental data (i.e., sea state, sound velocity profile, and
10 shipping density) and operator parameters (i.e., probability of
11 detection). The sonar operator can utilize "what if" scenarios
12 for generating a range of contours and ascertaining the most
13 probable range for the target of interest.

14 Although the above description utilized concentric
15 contours, shown in FIG. 4 for three probabilities, a continuous
16 color plot could also be used with a color scale on the side.
17 In lieu of the concentric contours, concentric volumes could be
18 used to show continuous variation with, for example, depth or
19 aspect. Automatic searching could also be done to create
20 optimum operating conditions. Further, as previously mentioned,
21 the system 10 includes a satellite communication linkage that
22 allows for the application programs of the present invention to

1 be provided with existing surface traffic noises, or weather,
2 each contributing and aiding in providing more realistic x
3 versus y sonar predictions.

4 Further, a single display with "drill down" (known in the
5 art) capability could also be provided, as well as a display of
6 x versus y in lieu of the circular display could be used.

7 Further, a relative bearing display in lieu of a true N-S-E-W
8 display could be used. In addition, automatic alerts and
9 contour detection ranges could be shown by monitoring own ship's
10 radiated noise events and displaying range differences between
11 the ship and the target.

12 It will be understood that various changes in the details,
13 steps and arrangements of parts, which have been herein
14 described and illustrated in order to explain the nature of the
15 invention, may be made to those skilled in the art within the
16 principle and scope of the invention.

17

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3 SYSTEM FOR PROVIDING AN ESTIMATE OF

4 THE LOCATION OF AN UNDERSEA OBJECT

5

6 ABSTRACT OF THE DISCLOSURE

7 A system is disclosed that provides a sonar operator with
8 the most likely range to a target of interest. The system
9 generates and displays a contour based on ship's parameters,
10 target parameters, environmental data, and operator parameters.
11 The sonar operator can vary many of the parameters in "what if"
12 scenarios so as to generate groups of contours for preselected
13 probabilities of detection. Contours can be used to show the
14 actions that should be taken to ensure a favorable outcome.

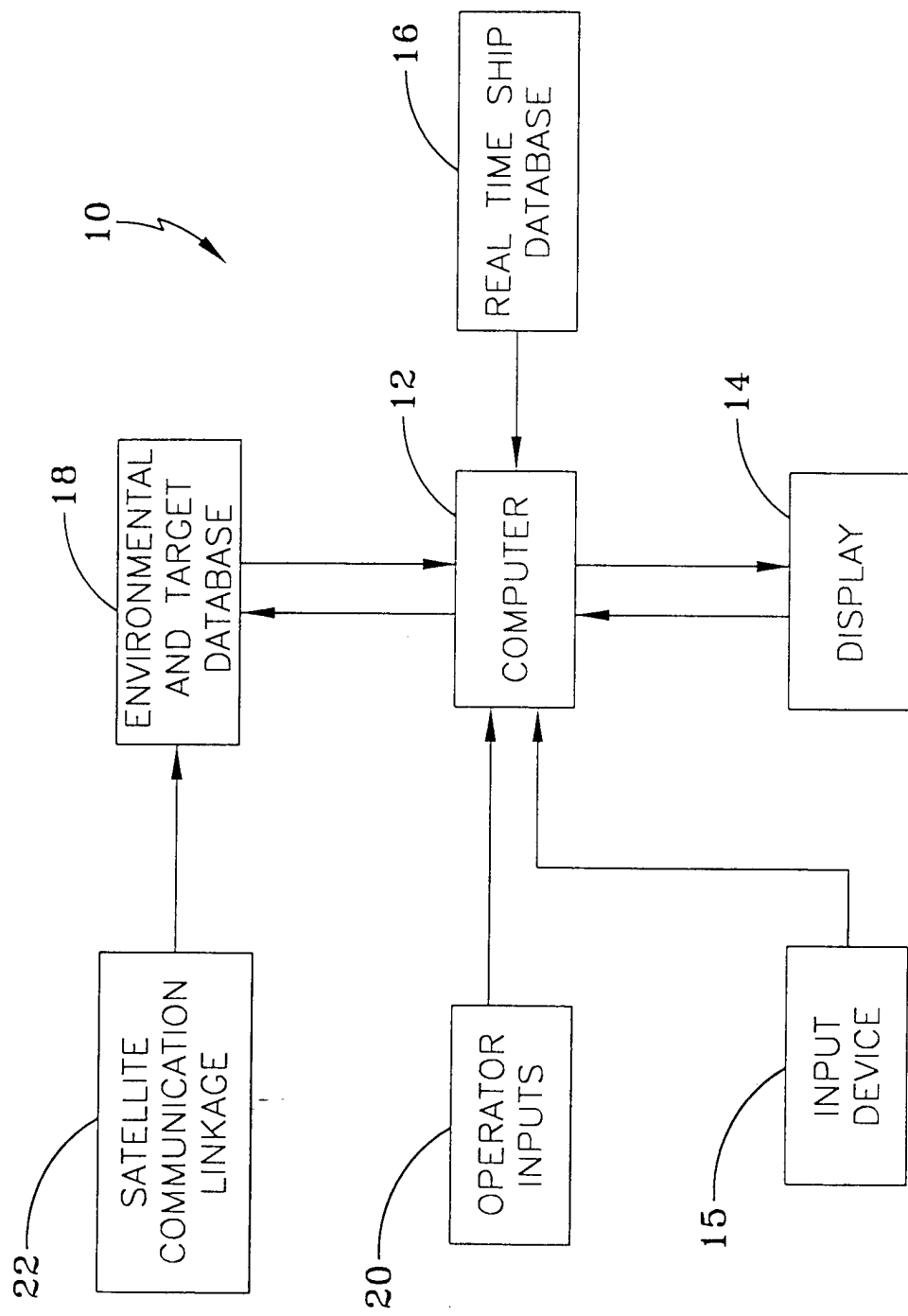


FIG. 1

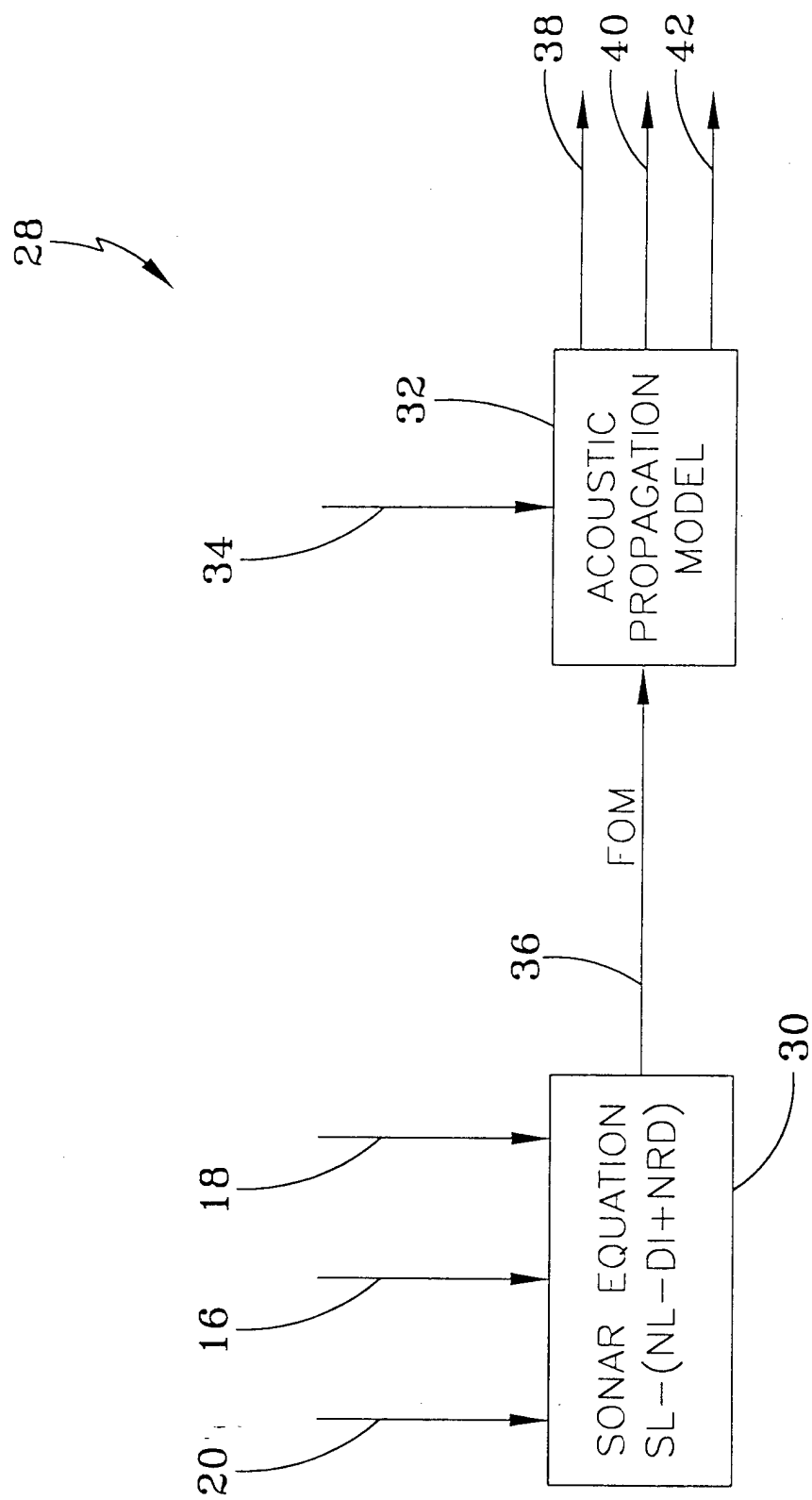


FIG. 2

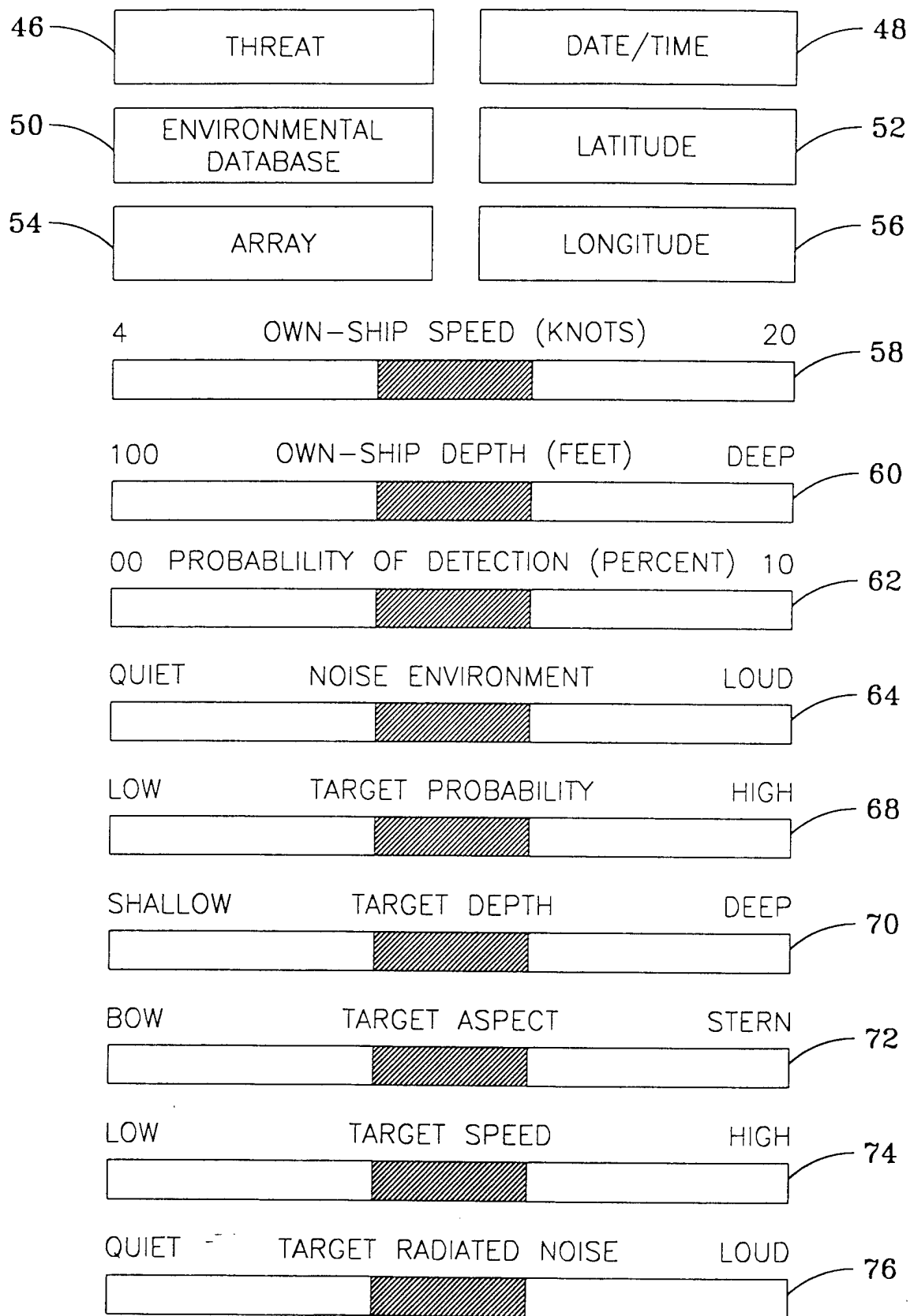


FIG. 3

DEPTH 1/ASPECT 1

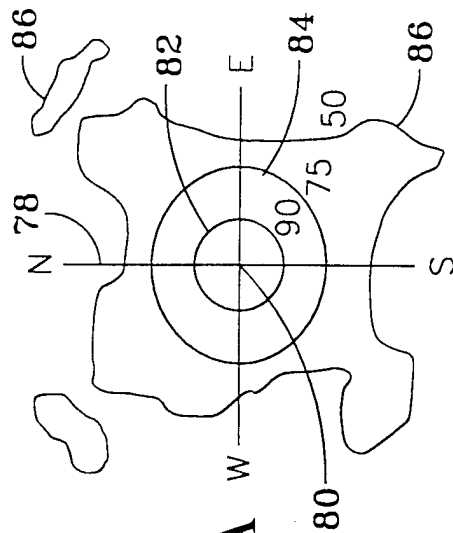


FIG. 4A

DEPTH 1/ASPECT 2

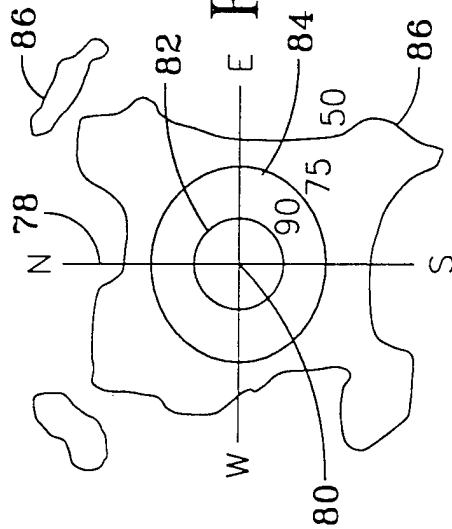


FIG. 4B

DEPTH 2/ASPECT 1

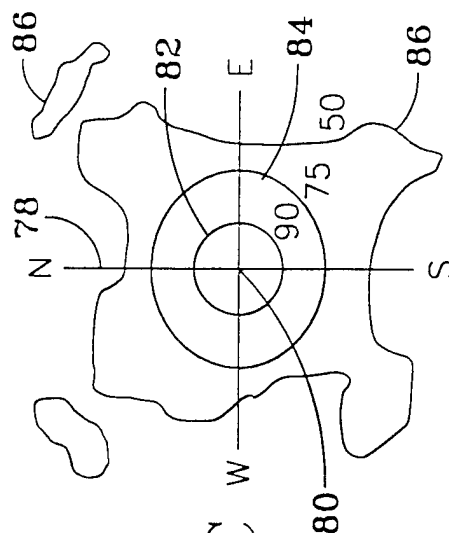


FIG. 4C

DEPTH 2/ASPECT 2

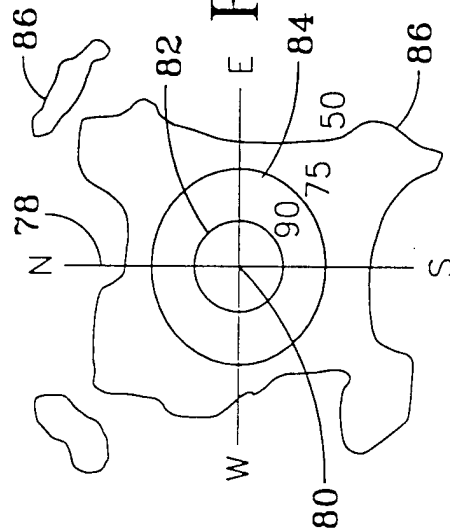


FIG. 4D