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AN ACOUSTIC MULTIFUNCTIONAL STANDARD CALIBRATION METHOD

STATEMENT OF GOVERNMENT INTEREST

[0001] The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefore.

CROSS REFERENCE TO OTHER RELATED APPLICATIONS

[0002] Not applicable.

BACKGROUND OF THE INVENTION

(1) Field of the Invention

[0003] The present invention relates to acoustic transmitter devices and in particular to a method for using a deployable, small package acoustic transmitter device, which serves as a standard acoustic source for on-vessel, in-mission field calibration purposes.

(2) Description of the Prior Art

[0004] Individual acoustic hydrophone elements for sonar arrays are typically calibrated one by one before being assembled into an array for deployment on a marine vessel. Once

such arrays are in service, on-vessel array calibration is a challenging and costly process. Furthermore, after years of service, sonar array performance degrades for many reasons, such as due to environmental effects. To quantify array degradation, an independent standard acoustic source is needed for on-vessel array detection and tracking, which can not only act as a multi-configurable acoustic source, but also, in conjunction with a receiver decoder, can provide the true ray-path range from the independent standard acoustic source to the marine vessel for in-mission sonar passive ranging systems calibration.

[0005] For this reason, what is needed is a deployable, small package acoustic transmitter device, which serves as a standard multi-configurable acoustic source for on-vessel, in-mission field array detection, tracking, and calibration.

SUMMARY OF THE INVENTION

[0006] It is a general purpose and objective of the present invention to provide an independent standard acoustic source for on-vessel array detection and tracking.

[0007] It is a further objective for said acoustic source to not only act as a multi-configurable acoustic source, but to function in conjunction with a receiver decoder, to provide the true ray-path range from the source to the vessel for in-mission sonar passive ranging systems calibration.

[0008] These objectives are accomplished by a method employing a disposable, launchable, multifunctional acoustic transmitter device similar to an expendable bathythermograph. The primary functions of this acoustic transmitter device are to transmit a predefined acoustic signal at a selectable depth over a certain period of time with time coded information embedded within the acoustic signal for range information via time-of-flight calculations.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] A more complete understanding of the invention and many of the attendant advantages thereto will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in conjunction with the accompanying drawings wherein:

[0010] FIG. 1 is an illustration of the of the acoustic transmitter device of the present invention transmitting signals at a distance from a receiving array; and

[0011] FIG. 2 is an illustration of the deployment of the acoustic transmitter device for the purpose of determining true range and calibration.

DETAILED DESCRIPTION OF THE INVENTION

[0012] Referring now to FIG. 1 there is illustrated an acoustic transmitter device 10 of the present invention comprised of a calibration source device for on-vessel, in mission acoustic array sensitivity and performance calibrations. The acoustic transmitter device 10 is deployed a distance **d** from a receiving array 12 joined to a marine vessel (not shown), and transmits a selection of predefined standard acoustic signals 14 to ensonify at least one acoustic receiver in the receiving array 12. The acoustic transmitter device 10 can be used in a standalone fashion, to transmit and to stay at a predefined depth for a certain period of time, or to change depth during transmit operation at a selectable rate. It can also be reconfigured to record own ship projected acoustic signals. The acoustic transmitter device 10 can be a small package device (in a preferred embodiment a three foot long cylinder shape) similar in dimensions and deployment to an expendable bathythermograph (XBT), deployable by a submerged vessel's three-inch launcher, surface ship, helicopter, or other convenient launch methods. It is capable of transmitting predefined acoustic signals 14 to certain accuracy. It generates a predefined acoustic source level signal 14. It is capable of encoding required information (such as time to determine true range) into the predefined acoustic signals 14. It is able to maintain or traverse at a predefined water depth or change depth at a predefined rate. It is capable of

transferring or recording data prior to launch. It can be reconfigured to record data vice project acoustic signals. It can be controlled and powered (i.e., on/off) by a remote controlled trigger signal. It is capable of either a self destruct (sink) mode or a float (for retrieval) mode after completion of acoustic signal transmissions.

[0013] The operational concept of the acoustic transmitter device 10 of the present invention is illustrated in FIG. 1. The encoded time information is generated from a synchronized clock (not shown). It can also be from an electric radio frequency (RF) signal or by a global positioning satellite (GPS) signal, if the acoustic transmitter device 10 can establish a wireless data link to a surface buoy antenna (not shown). The time code capability requires that both the acoustic transmitter device 10 and the receiving array 12 have synchronized clocks. The acoustic transmitter device 10 transmits a predefined source signal 14. It then periodically transmits (in addition to its continuing acoustic signal) a time coded signal. The timing information from the time coded signal received by the receiving array 12 is decoded by a computer (not shown) that calculates (through signal processing) the duration that the time coded signal traveled in the water. Based on a separately input sound speed, the acoustic ray path slant range is also calculated by the computer. Based on the information received at the receiving array 12, standard methods known in the art are then

available for use to accurately calibrate an on-vessel receiving array 12.

[0014] Referring to FIG. 2, illustrating geometric locations of the deployable acoustic transmitter device 10 and the on-vessel receiving arrays 12, an acoustic transmitter device 10 at $\vec{r}_s$ is deployed at a distance $|\vec{d}_i|$ from the i th receiving array 12, where i equals 1 to N . The vector $\vec{r}_i$ is the position vector of the i th on-vessel acoustic receiving array. For a homogeneous medium, the following equations hold:

$$\begin{cases} |\vec{d}_i| = |\vec{r}_s - \vec{r}_i| \\ t_i = |\vec{d}_i| / c \\ \tau_{ij} = (|\vec{d}_i| - |\vec{d}_j|) / c \end{cases} \quad i, j = 1, 2, \dots, N, \quad (1)$$

[0015] In the above equation (1), c is the propagation sound speed of the medium, t_i and τ_{ij} are the signal travel time to the i th array and the difference of the propagation time between i th and j th receiving arrays respectively. Due to the timestamp coded transmitter signal, the duration of the propagation time for the distance between the acoustic transmitter device 10 and the i th receiver 12 is measureable. However, the exact coordinates of x_s , y_s and z_s for the acoustic transmitter device 10 also need to be determined. These quantities are subject to the following N governing equations:

$$\left\{ \begin{array}{l} |\vec{d}_1| = \sqrt{(x_s - x_1)^2 + (y_s - y_1)^2 + (z_s - z_1)^2} \\ |\vec{d}_2| = \sqrt{(x_s - x_2)^2 + (y_s - y_2)^2 + (z_s - z_2)^2} \\ \bullet \\ \bullet \\ |\vec{d}_i| = \sqrt{(x_s - x_i)^2 + (y_s - y_i)^2 + (z_s - z_i)^2} \\ \bullet \\ \bullet \\ |\vec{d}_N| = \sqrt{(x_s - x_N)^2 + (y_s - y_N)^2 + (z_s - z_N)^2} \end{array} \right. , \quad (2)$$

where the three unknown variables of x_s , y_s and z_s can be over determined.

[0016] In the case where the position of the i th sensor or array coordinates of x_i , y_i and z_i are to be calibrated, the following iteration of equations is used:

$$\left\{ \begin{array}{l} |\tau_{1,i}| = \frac{|\vec{d}_1| - |\vec{d}_i|}{c} = \frac{1}{c} \left(\sqrt{(x_s - x_1)^2 + (y_s - y_1)^2 + (z_s - z_1)^2} - \sqrt{(x_s - x_i)^2 + (y_s - y_i)^2 + (z_s - z_i)^2} \right) \\ |\tau_{2,i}| = \frac{|\vec{d}_2| - |\vec{d}_i|}{c} = \frac{1}{c} \left(\sqrt{(x_s - x_2)^2 + (y_s - y_2)^2 + (z_s - z_2)^2} - \sqrt{(x_s - x_i)^2 + (y_s - y_i)^2 + (z_s - z_i)^2} \right) \\ \bullet \\ \bullet \\ |\tau_{i-1,i}| = \frac{|\vec{d}_{i-1}| - |\vec{d}_i|}{c} = \frac{1}{c} \left(\sqrt{(x_s - x_{i-1})^2 + (y_s - y_{i-1})^2 + (z_s - z_{i-1})^2} - \sqrt{(x_s - x_i)^2 + (y_s - y_i)^2 + (z_s - z_i)^2} \right) \\ |\tau_{i+1,i}| = \frac{|\vec{d}_{i+1}| - |\vec{d}_i|}{c} = \frac{1}{c} \left(\sqrt{(x_s - x_{i+1})^2 + (y_s - y_{i+1})^2 + (z_s - z_{i+1})^2} - \sqrt{(x_s - x_i)^2 + (y_s - y_i)^2 + (z_s - z_i)^2} \right) \\ \bullet \\ \bullet \\ |\tau_{N,i}| = \frac{|\vec{d}_N| - |\vec{d}_i|}{c} = \frac{1}{c} \left(\sqrt{(x_s - x_N)^2 + (y_s - y_N)^2 + (z_s - z_N)^2} - \sqrt{(x_s - x_i)^2 + (y_s - y_i)^2 + (z_s - z_i)^2} \right), \end{array} \right. \quad (3)$$

where the $N-1$ governing equations are available for three unknown solutions of x_i , y_i and z_i , and i can vary from 1 to N . The

calculation of the above-stated series of equations/iterations (1), (2) and (3) are performed by a computer (not shown).

[0017] For better calibration accuracies, more than one acoustic transmitter device 10 can be deployed. Once the locations of both the acoustic transmitter device 10 $\vec{r}_s$ and the on-vessel receiver 12 $\vec{r}_i$ have been calibrated, the acoustic calibrations for the on-vessel arrays for the transmitter voltage sensitivity, the receiving voltage sensitivity and the beam patterns can be further performed by following the methodologies known in the art of sonar signal processing. (See for example A. Lee Van Buren, "Procedure for the in situ calibration of Sonar transducers," J. Acoustic Society of America, 90, 48 - 52, 1991, or Robert J. Urick, *Principles of underwater sound*, McGraw-Hill Book Company, 3rd ed, 1983, p53).

[0018] The advantage of the present invention over the prior art is that the new calibration method defined above offers benefits to most phases of sonar array performance assessments and calibrations. It offers the potential to reduce the cost of the present costly ranging calibration methods. It also offers an effective way to calibrate own-vessel sonar systems to verify sonar array design and performance in locations and environments of interest. It provides improvements with periodic sonar array calibrations for maximum sonar array performance and improved maintenance inputs.

[0019] In light of the above, it is therefore understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

AN ACOUSTIC MULTIFUNCTIONAL STANDARD CALIBRATION METHOD

ABSTRACT OF THE DISCLOSURE

A method for using a deployable, small package acoustic transmitter device is taught, which serves as a standard acoustic source for on-vessel, in-mission field calibration purposes. The method involves deploying an acoustic transmitter device underwater to provide a predefined acoustic energy source for sonar array detection as well as periodic time-coded acoustic signal pulses for tracking and calibration of passive ranging.

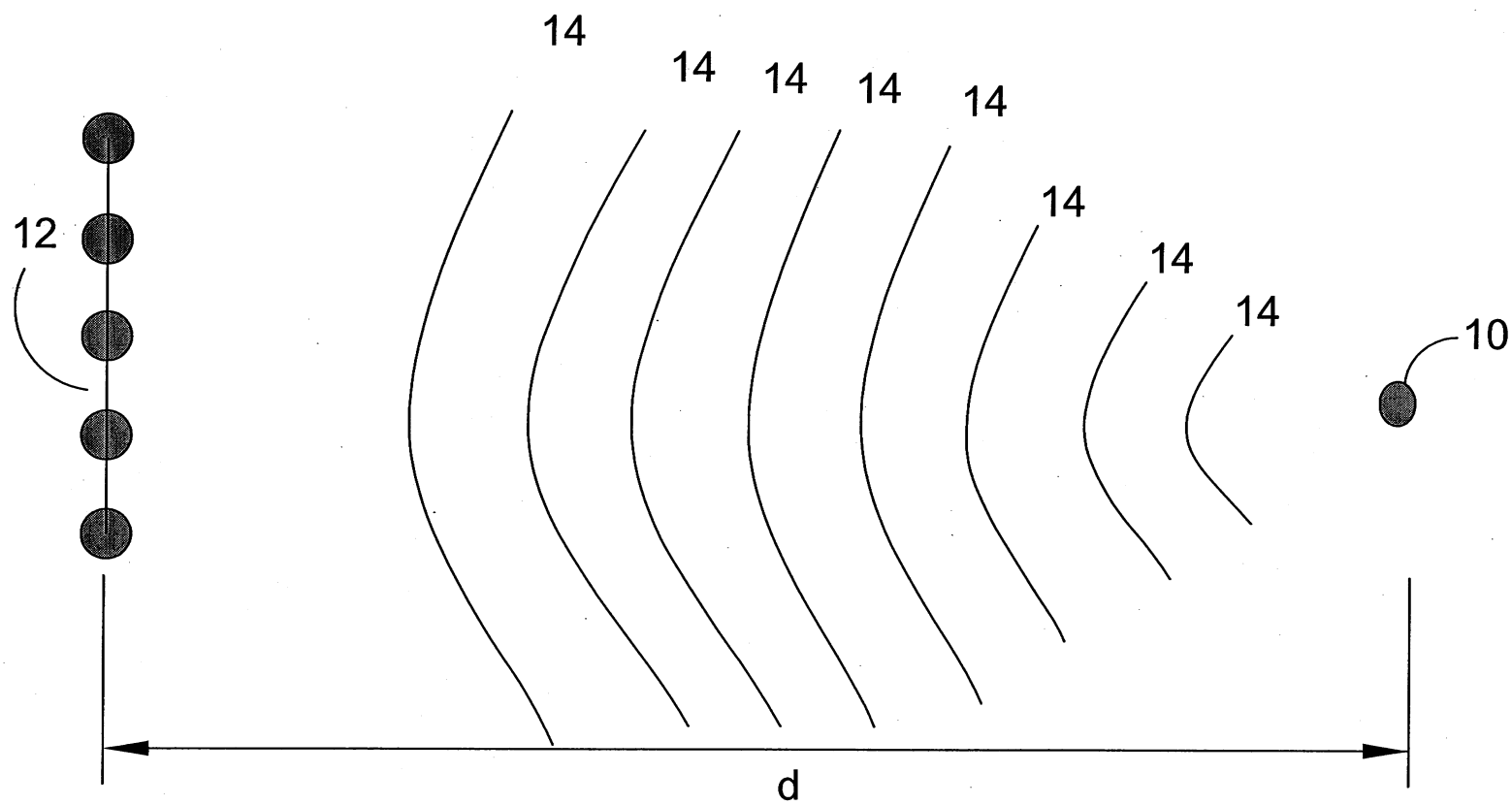


FIG. 1

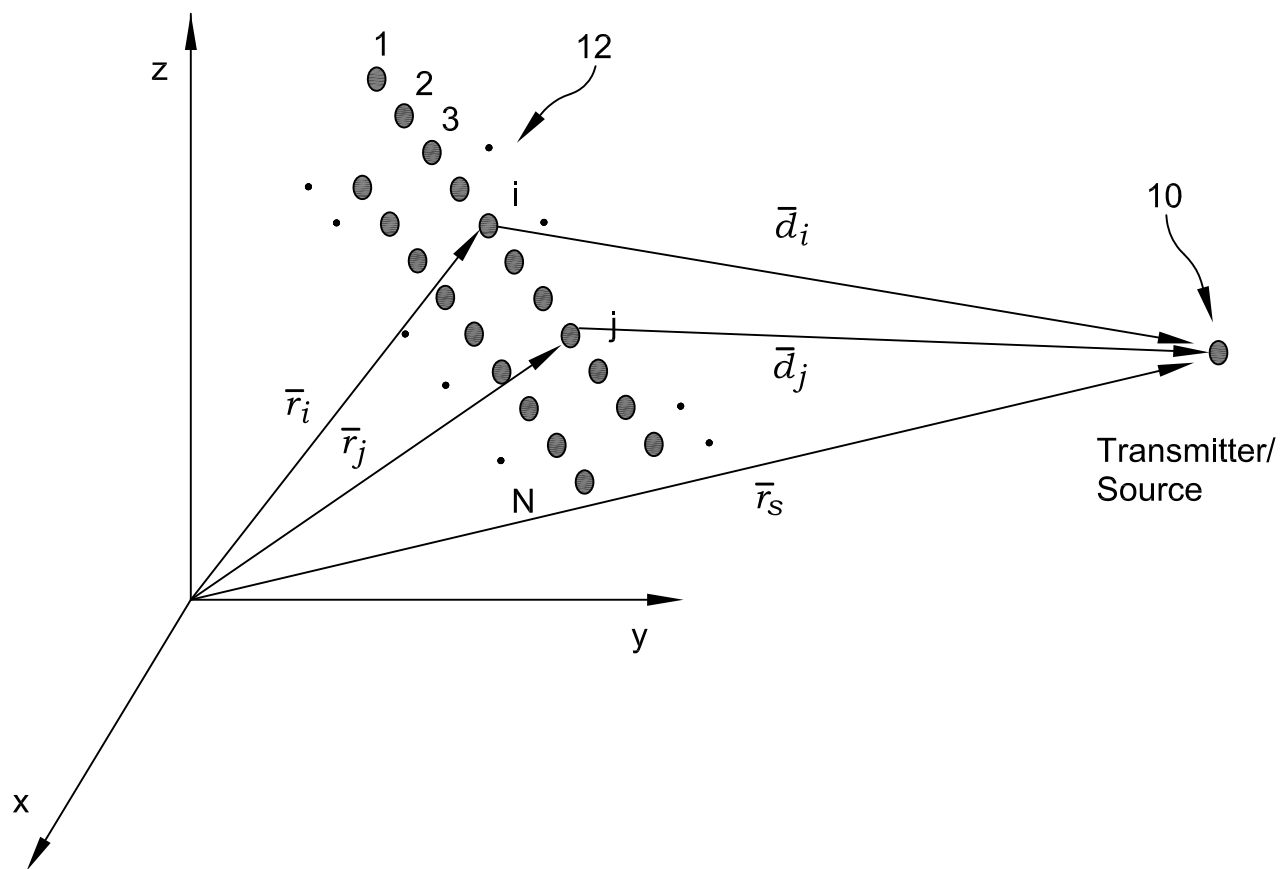


FIG. 2