Feb. 3, 1948. E. E. TURNER, JR 2,435,253

SYSTEM FOR SOUND RANGING

Original Filed May 13, 1940 2 Sheets-Sheet 1

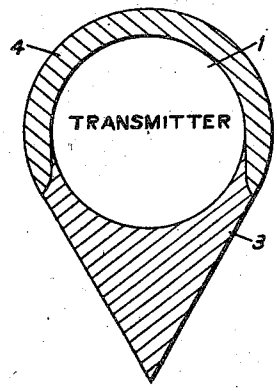


Fig. 4.

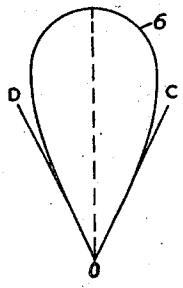


Fig. 5A.

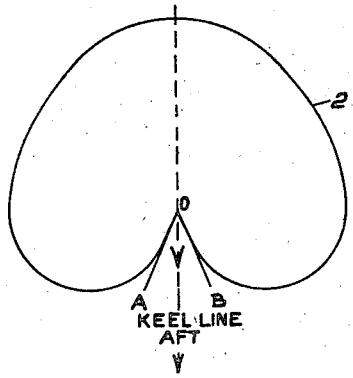


Fig. 5.

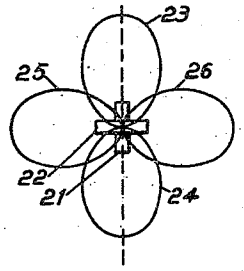


Fig. 6.

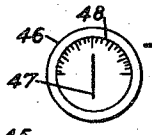


Fig. 7.

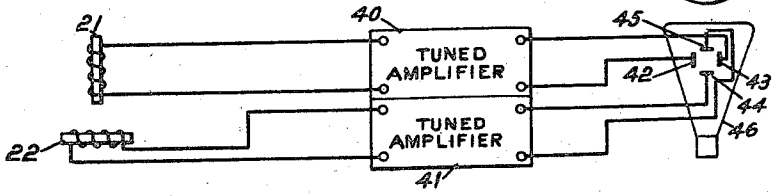


Fig. 1.

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SYSTEM FOR SOUND RANGING

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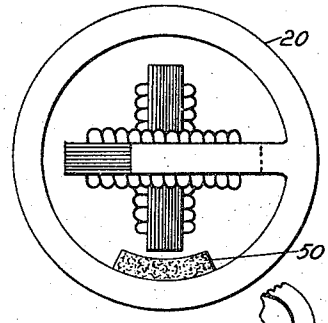


Fig. 3.

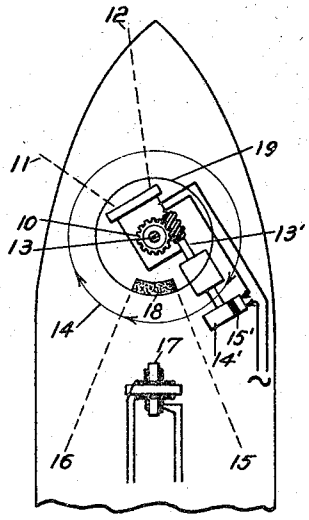


Fig. 8.

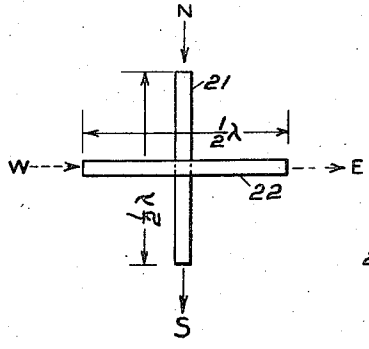


Fig. 9.

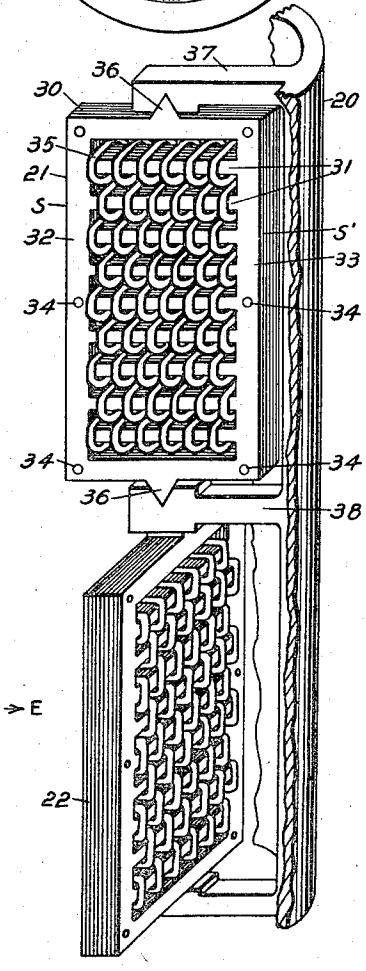


Fig. 2.

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Patented Feb. 3, 1948 2,435,253

UNITED STATES PATENT OFFICE

2,435,253

SYSTEM FOR SOUND RANGING

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Original application May 13, 1940, Serial No. 334,774. Divided and this application February 17, 1943, Serial No. 476,244

7 Claims. (Cl. 177—386)

1

The present application is a division of application Serial No. 334,774, filed May 13, 1940, now Patent No. 2,411,910.

The present invention relates to a sound ranging system and more particularly to one employing continuous waves and is particularly applicable to high frequencies of the order of 4000 to 5000 cycles per second and higher and may particularly be applied in or near the supersonic range for signaling and sound ranging in water or other heavy dense media.

The method of sound ranging presently employed in general does not permit rapid observation of foreign objects or obstacles in the vicinity of the observing or listening vessel. Usually in this type of work a supersonic beam is employed which sends out a ray of sound only in one direction and therefore makes it necessary for the observer to search each direction independently in some successive step-by-step manner. If, for instance, the range to be searched in water is 5000 yards, the echo from an object of this distance will take six seconds to return so that if this is the range which is being observed and if it is further assumed that the beam is approximately 15°, for a 360° sector one set of observations would take approximately 144 seconds or longer. It is highly desirable for many purposes to reduce this time if possible. More rapid observations of obstacles in the vicinity of the vessel are necessary not only for effective collision prevention with other moving vessels, but also for purposes of military observations such as the detection of submarines, mines or torpedoes.

The criterion in the avoiding of collision between any two obstacles is the constancy of the direction of approach. If two vessels are always moving towards each other with the same angular direction between them, a collision is bound to occur. If, on the other hand, this angle is constantly changing, the vessels will not collide. The present system employs in general this principle and it may be applied either to intermittent or continuous observations by the use of direction determination by means of the principles of phase displacements in the fundamental signaling frequency.

Without further enumerating or describing the features and advantages of the present invention, the invention will be fully and completely described in the specification below in connection with the drawings illustrating an embodiment of the same in which Fig. 1 shows diagrammatically the receiving system as a whole; Fig. 2 shows in fragmentary perspective a receiving apparatus;

2

Fig. 3 shows a top view of the device shown in Fig. 2; Fig. 4 shows the transmitting device partly in section; Fig. 5 shows the intensity curve in a horizontal projection of the radiation of the transmitter shown in Fig. 4; Fig. 5A shows the horizontal projection of an intensity curve by a beam projector; Fig. 6 shows the intensity curve of the device indicated in Fig. 2 in a horizontal projection; Fig. 7 shows a top view of the element of Fig. 1 directly below it; Fig. 8 shows schematically the layout in relation to a vessel of the system; and Fig. 9 shows a directional diagram for the receiver of Figs. 2 and 3.

In the system any type of transmitter may be employed which is capable of sending out the desired compressional wave with the intensity pattern either of Fig. 5 or 5A. If that of Fig. 5A is used, the beam must be rotated. In Fig. 4 the central unit 1 may be any high frequency transmitter as, for instance, a magnetostriction oscillator, a piezoelectric crystal quartz oscillator or a Rochelle salt or magnetic oscillator. The desired beam pattern of the oscillator 1 of Fig. 4 is indicated in Fig. 5 where the oscillator is not rotated, the curve 2 indicating the horizontal intensity curve with reference to a vessel. It will be noted that this curve is referred to the keel line of the vessel on which the apparatus is installed and is in the form of a cardioid with a blind spot or direction between the lines OA and OB aft towards the stern of the vessel in which angle the receiver is installed. This intensity curve may be obtained either by the construction of the oscillator or transmitter itself or it may be produced by screening by means of the sound screen 3 which is so placed with respect to the transmitter 1 to prevent radiation in the aft portion of the ship. The whole structure of Fig. 4 may be installed in a well or sea-chest within the vessel and be projected below the keel of the vessel so that it will be free to transmit its compressional waves in all directions.

If desired, in the present system the intensity or radiation pattern of Fig. 5 may be varied according to the direction in which listening is desired to be effected. If desired, the casing surrounding the transmitter 1 including the shell 4 as well as the sound insulating means 3 may be fixed in a stationary position and the transmitter 1, which may be given a form of a directive beam as above stated and as shown in Fig. 5A by the intensity curve 6, may be rotatable within the housing by means within the vessel. In this way the beam as shown by the curve 6 will be rotated around in the desired listening sector.

The width of such beam may be made to have the desired angular opening as between the lines OC and OD or as further illustrated in Fig. 8 between the lines 11 and 12 by proper design of the transmitter itself and the beam may be rotated at any slow speed of the order of one or two revolutions per second.

In the present system, therefore, the transmitter 1 may be either stationary or rotary and further may operate continuously or discontinuously as will be seen from the description below.

In the system as schematically shown in Fig. 8, the transmitter or projector 10 projects a beam or pencil of compressional waves within the angle formed by the lines 11 and 12. This projector 10 may be rotated by means of the shaft 13 through the drive 13' through the whole 360°, as indicated by the circle 14, sending continuously through the keying commutator 14' its beam except within the aft sector formed by the lines 15 and 16 when the circuit to the projector 10 is broken by the insulating segment 15' in which sector the projector will be silent. The purpose of this is to acoustically shield the receiver 17 which, of course, may also be shielded by acoustic insulation 18 positioned within the housing 19 in which the projector 10 rotates. In this way the direct signal will not be picked up by the receiving unit 17. The receiving unit 17 is indicated in Figs. 2 and 3 and comprises a suitable housing 20 supporting two directional receiving units 21 and 22, respectively, each of which has a horizontal intensity pattern for reception in the shape of a figure 8 as indicated in Fig. 6.

The unit shown in Figs. 2 and 3 must be directional in the present system from the point of view of the phase relationship with respect to the compressional wave. The unit 21 of Fig. 2 is composed of a group of thin laminations 30 of magnetostrictive material. These laminations are in the shape of a grill with a great number of parallel stems or bars 31, 31, each terminating in end plates 32, 33. These laminations are all held together either by means of the coil 35 which is shown as alternately threading in and out between successive bars or by means of the pins 34, 34 holding the laminations together in the edge plates or surfaces 32, 33. In place of making the coil 35 in the form of a single winding threading alternately back and forth between successive bars, individual coils for each of the bars 31 may be used. The whole block of laminations when assembled together is supported in their mid section by means of the inverted V-shaped projection 36 which is formed by the inverted V-shaped projection at the end of each of the laminations and which, therefore, form a wedge when the laminations are assembled in the block, which wedge is supported by the brackets 37 and 38 which extend from the casing 20 of the unit.

The unit 22 is similar to 21 except that it is positioned in a direction normal to the unit 21 and therefore the V-shaped support of this unit in the bracket 38 must run normal to the V-shaped support for the wedge 36. The units 21 and 22 operate at a frequency to which the system is resonant.

The laminations are designed so that the stems 31 with their end masses provided by means of the side plates 32 and 33 operate as a one-half wave length system with the stems 31 substantially narrow as compared with the width and length of the elements 32 and 33 the masses of which are proportionately effectively carried by the stems 31 making up the half wave length oscillating element. In this way the stems 31 act similarly to a loaded rod with equal loads at each end of the stem. The resonance of the system should be a one-half wave length resonance with no substantial mass in the stem 31 itself so that practically the stem acts as a pure elastic member.

The system further must be so loaded by the loads of the elements 32 and 33 that the distance between the outer edges S and S' is nearly or exactly one-half wave length in the medium in which the unit is to act as a receiver or transmitter since it may so be used. It will be noted, therefore, that, for instance, in the water medium the magnetostriction elements must be loaded to compensate for the difference in velocities of sound in nickel with that in water. Inasmuch as the velocity of sound in nickel is about three times as high as that in water, the system must be loaded to bring the normal one-half wave length of nickel in a uniform rod by means of loading to the corresponding one-half wave length in water.

With the design of the system as previously described the unit of Figs. 2 and 3 will be directive in the shape indicated in Fig. 6. This is illustrated in Fig. 9. If sound is approaching from the NS direction and the unit 21 is one-half wave length long as referred to the medium, the energy picked up by each face will be moving in opposite directions with the result that there is a maximum of compression or expansion in the stems 31 of the unit 21. Therefore, for sound approaching in the horizontal longitudinal direction of the unit, the unit 21 will pick up maximum sound energy. However, in the position which the unit 22 has in relation to this sound wave, the whole unit will be acted upon similarly with the result that no motion of the unit will take place. Therefore for sound approaching normal or transverse to the unit 22, as for instance, from the NS direction, no sound energy will be picked up. Consideration of the explanation in relation to Fig. 9 will show that in Fig. 6 the figure-eight curve composed of the curves 25 and 26 belong to the unit 22 while the curves 23 and 24 belong to the unit 21. Considering the radiating faces small as compared to the wave length, it may be shown that the intensity pattern is expressed by the equation

$$r=\sin\left(\frac{\pi}{2}\cos D\right)$$

where spacing between radiating faces is one-half wave length. In the equation, r is the polar vector and D the polar angle, both taken from the origin.

The unit above described directly ties in to a cathode ray tube or a tube of a similar nature to indicate directly the direction of the source of an approaching sound wave. In this case each unit 21 and 22 has its energy impressed upon separate tuned amplifiers 40 and 41, respectively, the outputs of which each operates respectively a pair of plates 42, 43 and 44, 45 of a cathode ray tube 46. As the oscillations picked up by the units 21 and 22 are harmonic in character, a cathode ray tube would produce straight line indication for two circular figure-eight patterns. While the patterns in Fig. 6 are not circles, nevertheless even without compensation they are substantially near to the shape of circles so that a clear indication can be obtained. Compensation may be introduced to flatten down the patterns of Fig. 6 to even more circular form if necessary. This may be done by making the output of the amplifiers pure harmonics, or by the addition of magnetic

field control on the electron beam, or in any well-known manner. An indication as a line 47, as shown in Fig. 7, may be referred on the face of the tube 46 to a scale 48 so that the angular direction of the source may be determined. In order to eliminate the double directional effect particularly in the aft direction if desired, a sound screen or acoustic insulating means may be used directly aft in the casing 20 of the receiver as illustrated by the sound screen or insulation 50.

In the present system it will be noted that the receiver is active simultaneously in all directions. With this system, therefore, a signal could be sent out in all directions, if desired, or a beam could be rotated in the desired listening range, for instance, 180° from starboard through forward to port on a vessel. If such rotation took place in one-half second, a complete sound ranging of the entire sector for a distance of 5000 yards would take place in six seconds.

The units 21 and 22 are preferably elongated vertically and may in this dimension be a number of wave lengths so that a large amount of energy can be picked up and noise other than from a horizontal direction may be eliminated. This result will follow, since a long vertically placed receiver is horizontally directive. The thickness of the laminated stack must, however, be small as compared to the wave length in the compressional medium of the compressional energy to be received to establish the desired pattern as set forth in Fig. 6.

Having now described my invention, I claim:

1. A submarine signaling system comprising, in combination, a pickup unit composed of two similar elements arranged substantially at right angles to each other, each of said elements having pickup surfaces positioned at points one half wave length apart in the signaling medium at the signaling frequency, cathode ray tube indicating means having two pairs of parallel plates at right angles to each other, and means operatively connecting each of said elements to one pair of said parallel plates.

2. A submarine signaling system comprising, in combination, a sound pickup unit composed of similar elements arranged substantially at right angles to each other, each of said elements comprising one-half wave length system both in the signaling medium and in the element itself at the signaling frequency and cathode ray tube indicating means operatively connected to said elements for indicating the direction of a sound source picked up by said units.

3. A submarine signaling system comprising, in combination, a sound pickup unit composed of similar elements arranged substantially at right angles to each other, each of said elements comprising one-half wave length system both in the signaling medium and in the element itself at the signaling frequency and cathode ray tube indicating means operatively connected to said elements for indicating the direction of a sound source picked up by said units, each of said pickup units having a circular group intensity pattern at right angles to the other.

4. A system for sound ranging on a vessel comprising, in combination, means for producing a sound beam, means for rotating said beam from a direction in the aft section of the vessel around in the forward direction to the aft section on the other side of the vessel leaving a section in the aft portion of the vessel where no sound beam is transmitted, a sound pickup unit having a polar sensitivity characteristic curve in the shape of two figure 8 curves at right angles to each other, cathode ray tube means for observing, with said sound pickup unit, the sound echo received from a distant object located in the sector through which the sound beam sweeps, and for indicating the direction of said echo as picked up by said pickup means.

5. A submarine signaling system comprising, in combination, means for transmitting sound in a polar pattern characteristic having a general cardioid-shaped curve and a receiving system positioned in the silent zone of the cardioid curve, said receiving system comprising a pair of directive receiving units indicating sound components at right angles with each other and a cathode ray indicator operatively connected thereto to indicate the direction of a received impulse emanating from an object in the path of the sound waves propagated by said transmitter.

6. A submarine signaling system comprising, in combination, means for transmitting sound in a polar pattern characteristic having a general cardioid-shaped curve and a receiving system positioned in the silent zone of the cardioid curve, and means included in said receiving system for indicating the direction of a source of sound reflected from an object in the path of the sound waves propagated by said transmitting means.

7. In a system for directive determination of a source of sound energy reflected from an object, means for projecting a sound wave, means for rotating said projector of said sound wave about a vertical axis and continually producing sound thereby except in a sector indicated as a dead zone, a receiving system positioned in said dead zone, said receiving system adapted to receive sound reflections in components at right angles to each other, and means for indicating the direction of sound reflected from an object in the path of the sound waves propagated by said projecting means and picked up by said receiving system.

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