

May 11, 1937.

W. KUNZE

2,079,620

DIRECTION FINDING

Filed Feb. 21, 1931

2 Sheets-Sheet 1

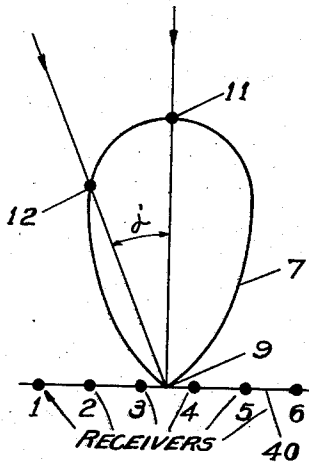


Fig. 1

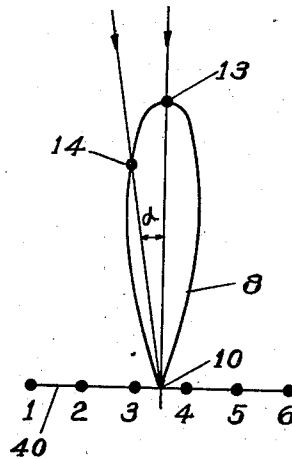


Fig. 2

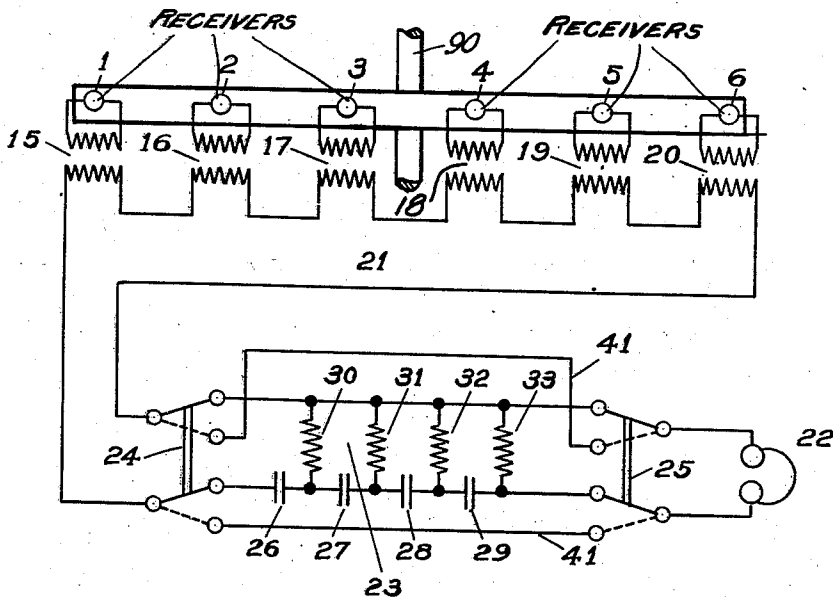


Fig. 3

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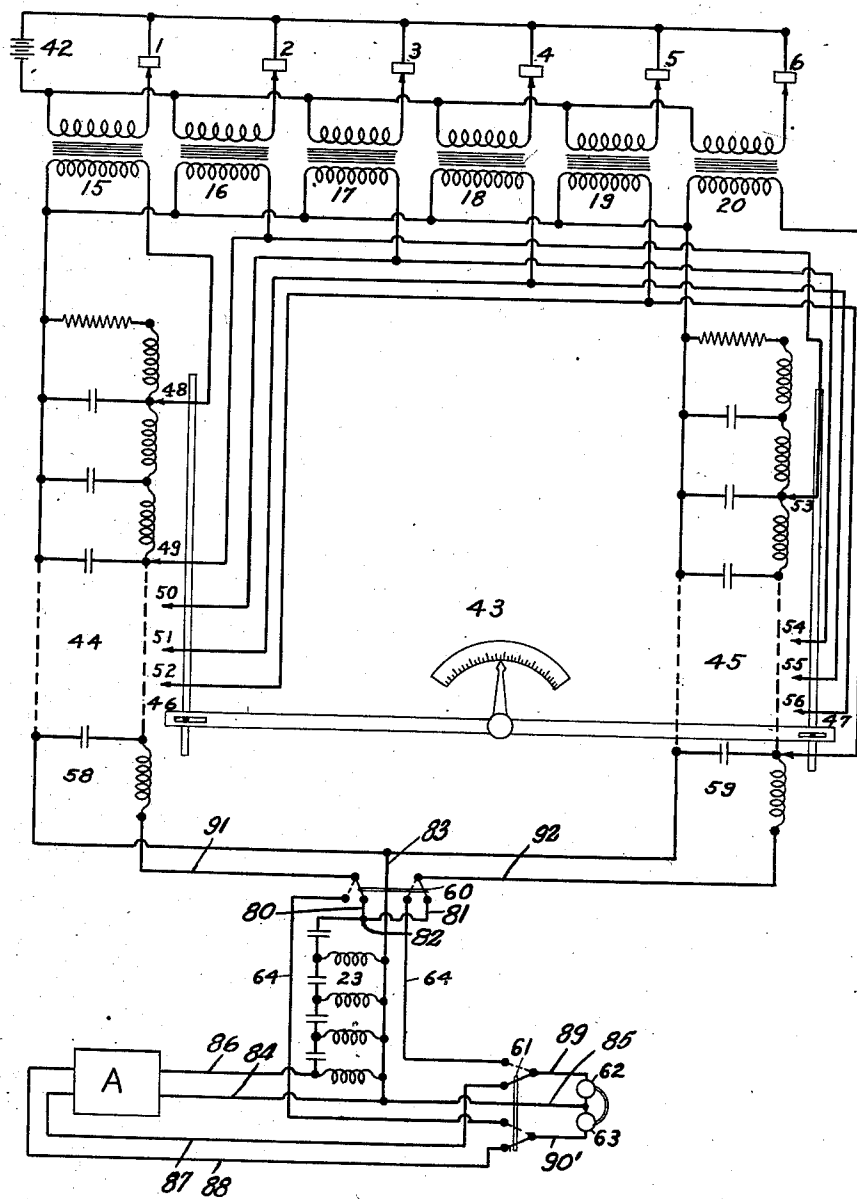


Figure 4

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UNITED STATES PATENT OFFICE

2,079,620

DIRECTION FINDING

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10 Claims. (Cl. 177—386)

The present invention relates to the art of determining the direction of a source of compressional waves, and more particularly to sound waves propagated in air or water medium in which a group of sound receivers are used and in which the sound energy arriving at each receiver is brought into the same phase at the indicating device. In arrangements of this nature it is common practice in the art to use a group of electrically responsive acoustic receiving devices spaced apart in a definite geometric configuration and conduct the electric energy created by the sound waves arriving at each receiver through retardation lines to a pair of telephone devices or an indicator. In such apparatus the retardation lines form a so-called electric compensator in which a switch mechanism is provided to compensate for a variation of the direction of the wave front arriving at the receivers. In this way it is possible to turn the compensator switch mechanism until the receivers are compensated for any particular direction of the wave front. When the receivers are so compensated that the wave front for which they are adjusted corresponds to the actual wave front of the sound being received, a maximum sound intensity is present in the telephones or listening devices.

In the past in such apparatus two methods of compensation have generally been used, one in which the observer notes the position of the binaural image and the other in which the observation is made by observing the maximum sound intensity.

In systems employing the so-called binaural method the receivers of one group are connected with one telephone going to one of the ears of the observer and the receivers of the other group are connected to a second telephone going to the other ear of the observer.

With the maximum method, on the other hand, the receivers are all connected to both telephones so that the same mixed sound wave arrives at both ears of the observer. According to experiments which I have observed certain advantages are presented in the use of the maximum method and certain other advantages are presented in the use of the binaural method.

The combination of these advantages in a single device for the purpose of determining the direction of a source of sound or compressional wave is the subject matter of the present invention.

In particular, in listening to a number of vessels in the same field, where the direction of the ves-

sels from the listening ship is approximately in the same line, or nearly the same line, it is almost impossible to distinguish the different vessels and set upon each separately with the maximum method. The sounds of the two vessels blend together over the angle between the two vessels from the listening source and it is practically impossible to obtain a true setting of the maximum intensity of the sound from any one of the vessels. This might naturally be expected since the sound is actually distributed over an angle subtending the line of the two vessels from the listening source. In these cases the binaural method of listening often proves very advantageous since the sound image of each vessel is independent and separable from each other, and although other disturbing sounds may be present, there will be a distinct shift from a lateral to a central image of one group of sounds even though the other group are present in the same field.

I have found, however, that by the use of a highpass filter the field of each individual vessel may be considerably narrowed and if the other vessel is not within this narrow range, a setting by the maximum method may be made. Where, however, the two vessels are positioned in the same narrow field according to my invention the filter is dispensed with and the binaural method used.

In view of the fact that the elimination of the lower frequency sounds sharpens the maximum intensity, it is possible by this method to obtain a much more accurate setting and observation of the direction of the source of sound waves. In employing this feature it is possible to listen, first, without the use of a filter in which case sounds of all frequencies reach the ears of the observer of the indicating device, and it is then possible, after the character of the vessel has been determined by listening to the natural sounds, to cut out all the sounds of the lower frequencies and accurately determine the direction of the source with only the higher frequencies. I have found in some cases that the use of a filter diminishes the sound intensity arriving at the indicating device. This is perhaps particularly true where the greater part of the sound source is made of sounds of lower frequencies from that which the filter passes. In such cases an amplifier is used in connection with the filter to bring up the sounds to normal value.

The filter used in the present invention may be one which passes frequencies above eight hundred cycles, but I prefer in most cases to use a high-pass filter which has a higher cut-off, for in-

stance, at fifteen hundred cycles. It is very difficult to obtain a binaural setting for frequencies above fifteen hundred cycles, and in this range, therefore, the maximum-minimum method is most effective.

The present invention will be described in particular in connection with the drawings in which Fig. 1 illustrates the sound intensity field with both low and high frequencies present, Fig. 2 illustrates the sound intensity field with the use of a high-pass filter, Fig. 3 shows schematically a circuit arrangement and Fig. 4 shows a modification of the circuit shown in Fig. 3.

In Fig. 1 the line 40, having dots 1, 2, 3, 4, 5 and 6, indicates the receivers arranged along this line on the dots just mentioned. The curve 7 in this case shows the relative intensities with which sound is received coming from a direction in the same plane as the plane of the paper. For instance, a sound coming from the direction of the line 9, 12 will have an intensity corresponding to the vector value of the length 9, 12. A sound coming from the direction 9, 11 will have the intensity corresponding to the vector length 9, 11.

In Fig. 2 where the curve 8 corresponds to the curve 7 with the exception that the lower frequencies have been cut out by the filter, the line 10, 14 shows the relative intensity of the sound received from a direction of 10, 14. Comparing Figs. 1 and 2, if the vector lengths 10, 13 and 10, 14 are the same as the vector lengths 9, 11 and 9, 12, respectively, the figures indicate that in the case of Fig. 1 for the decrease in the same intensity of sound the angle is α' while in Fig. 2 this same angle is α . In the case of Fig. 2 the intensity drops off quickly with small variations in angles, whereas in Fig. 1 it drops off much more slowly.

With the use of high-frequency filters, there is often present secondary or auxiliary maximum in the shape of small lobes similar to the lobes of 8 in Fig. 2. These lobes are apt to cause an ambiguity of direction and this is overcome in the present application by the use of the binaural method as a check to eliminate these ambiguities. The binaural image will only be produced with the maximum lobe so that if the compensator is set on a secondary lobe, this will easily be determined by switching to the binaural method which will indicate whether a binaural image is or is not obtained.

In Fig. 3 there is shown a group of six receivers illustrated diagrammatically by 1, 2, 3, 4, 5 and 6 corresponding to the same numerals in Figs. 1 and 2. If the group of receivers 1 to 6, inclusive, are rotated about an axis 90 so that their line is made to coincide with the wave front of the approaching sound, the electrical energy in the circuit 21 connected to the receivers 1 to 6, inclusive, through the transformers 15 to 20, inclusive, respectively, will be impressed upon the telephone 22 either through the filter indicated as 23 or over the straight transmission line 41. The filter 23 comprises the inductances 30 to 33, inclusive, in shunt and the capacity 26 to 29, inclusive, in series between each shunted inductance. Switches 24 and 25 are provided to throw the filter or the transmission line in between the telephone 22 and the receiving circuit 21.

In Fig. 4 the complete arrangement of the circuit in which a compensator using either the binaural or the maximum-minimum method and a filter and an amplifier associated together is shown. In this figure the receivers are indicated

with the numerals 1, 2, 3, 4, 5 and 6 and may be the same receivers as indicated in the other figures. The receivers may be of the electromagnetic or microphonic type and supplied by a battery 42. The receivers are connected with the compensator 43 through the transformers 15 to 20, inclusive. The compensator shown at 43 is composed of two retardation lines 44 and 45. The energy from the receivers 1 to 5, inclusive, are passed through the retardation line 44 and the energy from the receivers 2 to 6, inclusive, are passed through the transmission line 45. In this system, therefore, the effective binaural base is a distance between two adjacent receivers. The system just described is chosen because this will give a sufficient binaural base to be used in checking the true maximum from auxiliary maximum and also in aiding the determination of the direction of a source of sound when the two vessels are in the same field.

A proper switch mechanism is provided, as indicated by 46 and 47, to adjust the contacts 48, 49, 50, 51, 52 and corresponding contacts 53, 54, 55, 56 and 57 at various points along the respective lines 44 and 45 so that the energies from the five receivers on the left and the energies from the five receivers on the right are brought into the same phase at the lower ends 58 and 59, respectively, of the retardation lines 44 and 45.

A pair of double pole, double-throw switches 60 and 61 are provided for changing from the binaural method of listening without the filter 23 and amplifier A to the maximum method of listening which includes the filter 23 and the amplifier A in front of the telephones 62 and 63. The amplifier A is connected to the circuit at the end of the filter 23 and has its output connected to one pair of contacts of the switch 61. The other pair of contacts of the switch 61 are connected directly to the transmission line 64, 64 which are connected to a pair of contacts on the switch 60. By means of the transmission lines 64, when the poles of the switch 61 and 60 are thrown to the left, the telephone 63 is connected to the retardation line 44 and the telephone 62 to the retardation line 45. Under these circumstances the telephone 63 is operated by the left group of sound receivers while the telephone 62 is operated by the right group of sound receivers. When the switches 60 and 61 are thrown to the right, both telephones 62 and 63 are thrown in parallel and are operated by both retardation lines and both groups of receivers.

When the switch 60 is thrown to the right, both retardation lines 44 and 45 are connected through the short leads 80 and 81 to the input point 82 of the filter. It will be noted that the common 83 is at all times permanently connected on one side to the amplifier as at 84 and on the other side to the common lead to the right and left headphones 62 and 63. The output lead 86 of the filter with the common 84 form the input to the amplifier. The output to the amplifier, leads 87 and 88, are connected when the switch 61 is in the position shown in Fig. 4 to the head telephone pieces 62 and 63 through the leads 89 and 90, respectively. In this arrangement just described both the filter and the amplifier are in circuit and the two telephones are connected in parallel, both receiving the same input and therefore providing only a maximum indication. With the switch 60 shown to the left and the switch 61 in its upward position, the individual outputs of the lines 44 and 45

are impressed by means of the leads 91 and 92 on the right lead 64 and the left lead 64, respectively. The leads 64 conduct the impulses through the switch 61 to the telephone head pieces 62 and 63 by means of the leads 89 and 90. The common 83 remains as before connected to the common to the two telephones. In this position the telephone 63 is connected to the retardation line 44, and the telephone 62 to the line 45, and a binaural listening is therefore possible.

In the method employed in the present case, the operator can either listen, first, by the binaural method or by the maximum method. If he listens by the maximum method, he preferably may use the filter 23 and the amplifier A to amplify the high-frequency sounds which may be somewhat weak if they are not the predominant frequencies from the listening source. In order thereafter to determine whether any ambiguity of direction exists, he may throw the switches 60 and 61 to the left and check his observation by the binaural method.

This is perhaps the preferable manner of operating the present system although it is possible and perhaps under certain circumstances desirable to employ the binaural method when the vessel to be observed is in the vicinity of another vessel. In this case the binaural method may alone be employed or the binaural in combination with the maximum method may be employed as described just above.

There are a number of advantages in first determining the approximate direction of the source of sound without the use of a filter and then using the filter in the final steps. Since without the use of the filter the true character of the sound is more clearly observable, it is possible frequently in cases where more than one sound is in the listening field to concentrate on one of the sounds for an approximate setting and then complete the observation by a more accurate adjustment on the sound which is first observed. In this way even though two sounds are somewhat near together as, for instance, when two ships are within the listening range of the apparatus within a few degrees of one another, it is frequently possible to make an accurate determination of the position of one eliminating the position of the other.

In addition to this, however, a further advantage is obtained in making an approximate determination initially without the use of a filter. While the filter itself sharpens the maximum image to a considerable degree, it provides, however, a number of secondary or auxiliary maxima which might sometimes be mistaken for the chief maximum if the compensator is set with the filter initially used. Omitting the filter initially, the chief maximum can be readily determined within a number of degrees, and then using the filter, this maximum can be observed very accurately.

In addition there is a further utility in observing the sound initially without the use of a filter. While most vessels in so-called submarine multispot listening radiate sounds of practically all frequencies, still it sometimes happens that certain frequencies are not produced. If a vessel did not emit much high frequency sound, the use of a filter initially would make it appear that no source was within the listening range and it may, therefore, be difficult at first to detect the source. In this case the initial observation is quite important. It is also true that frequently the

maximum with a filter on account of its sharpness will be passed over in making an observation. The maximum without the filter being quite broad furnishes a good initial observation for beginning the accurate determination of the direction of the source.

Having now described my invention, I claim:

1. In combination, a plurality of spaced receivers, a pair of telephone receivers, a compensator for bringing the sound received at said receivers into substantially the same phase to produce a maximum sound intensity at the telephone, a filter and an amplifier adapted to be associated therewith at the output of said compensator, and means connecting said filter and amplifier in circuit after the compensator, and said telephone receivers as a single unit in the circuit after the other elements when the filter and amplifier are used and connecting said telephone receivers individually at the said output when the filter and amplifier are not used.

2. In combination, a plurality of spaced receivers, a compensator, means for using said compensator for the binaural or maximum-minimum method, a high pass filter, a pair of telephone receivers connected to said compensator, and means for connecting the filter in circuit before said telephone receivers in using the maximum-minimum method and omitting the filter in using the binaural method.

3. In combination, a plurality of spaced receivers, a compensator, means for using said compensator for the binaural or maximum-minimum method, a high pass filter and amplifier associated therewith at the output of said compensator, a pair of telephone receivers, and means for connecting the filter and amplifier in circuit between the compensator and said telephone receivers in using the maximum-minimum method and omitting the filter and amplifier in using the binaural method.

4. In combination, a compressional wave pick-up system including a plurality of spaced pick-up units and a telephone means associated therewith, means for adjusting said system to bring the energy at the telephone means into substantially the same phase and create thereby an observable intensity maximum and means for filtering out the lower wave frequencies from the received energy whereby the maximum observation may be sharpened.

5. A method of increasing the accuracy of determining the direction of a source of mixed sound waves which consists in receiving the waves at a plurality of points spaced from one another, translating the waves so received into corresponding electrical impulses of the same frequency and character, conducting said translated waves to a common point, variably retarding the progress of the waves to said common point until said waves are brought in the same observable phase, filtering the waves brought to the common point to pass only the higher frequencies picked up from the source whereby the accuracy of determination of the phase coincidence may be more accurately observed.

6. A method of increasing the accuracy of determining the direction of a source of mixed sound waves which consists first in receiving the sound waves at a plurality of points spaced apart one from the other, transmitting the energy so received to a common point, variably retarding the time of transmission of the energy to the common point until all of the energies have approxi-

mately the same observable time phase, filtering the energy after retardation to eliminate the lower frequencies from the source that is being observed and further adjusting the retarding of the impulses to make a more accurate observation of the direction of the source.

7. A method of increasing the accuracy of determining the direction of a source of mixed sound waves which consists in receiving sound at a plurality of points spaced apart one from the other, transmitting the energy picked up at all of said points to a common center, variably retarding energy so picked up until a maximum intensity of energy is observed, filtering out the lower sound frequencies of the source listened to after the energy has been retarded and varying the retardation until a sharper maximum is obtained.

8. A method of increasing the accuracy of determining the direction of a source of mixed sound waves which consists first in receiving the sound waves at a plurality of points spaced apart one from the other, transmitting the energy so received to a common point, variably retarding the time of transmission of the energy to the common point until all of the energies have approximately the same observable time phase, filtering the energy after retardation to eliminate the lower frequencies from the source that is being observed and further adjusting the retarding of the impulses to make a more accurate observation of the direction of the source, the filter being adapted to filter out frequencies below a value not sub-

stantially less than 800 cycles arriving from the source of sound.

9. A method of increasing the accuracy of determining the direction of a source of mixed sound waves which consists in receiving the sound at a plurality of points spaced one from the other, conducting the energy received at the spaced points to a common center, variably retarding the time of such conduction until the energies produce at the central point an observable maximum, filtering out the lower sound frequencies of the source received and adjusting the retardation for a sharper maximum, then listening at the central point by the binaural method to determine whether a true maximum has been obtained.

10. A method of increasing the accuracy of determining the direction of a source of mixed sound waves which consists first in receiving the sound waves at a plurality of points spaced apart one from the other, transmitting the energy so received to a common point, variably retarding the time of transmission of the energy to the common point until all of the energies have approximately the same observable time phase, filtering the energy after retardation to eliminate the lower frequencies from the source that is being observed and further adjusting the retarding of the impulses to make a more accurate observation of the direction of the source, the filter filtering out all frequencies below 1500 cycles whereby the frequencies of the sound source above this value are observed.

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