Jan. 10, 1933. H. HECHT ET AL 1,893,741

ARRANGEMENT FOR DIRECTIONAL TRANSMISSION AND RECEPTION WITH A PLURALITY OF OSCILLATORS

Filed Jan. 9, 1929 4 Sheets-Sheet 1

Fig. 1.

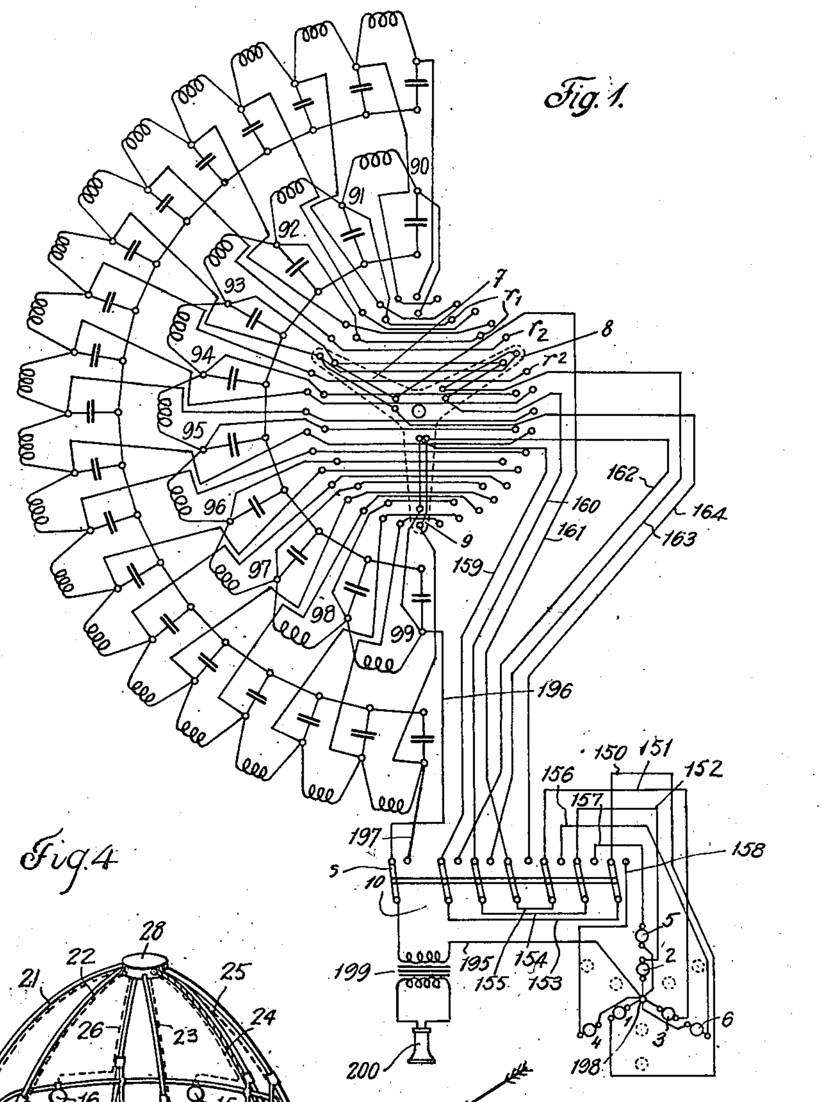

Fig. 4

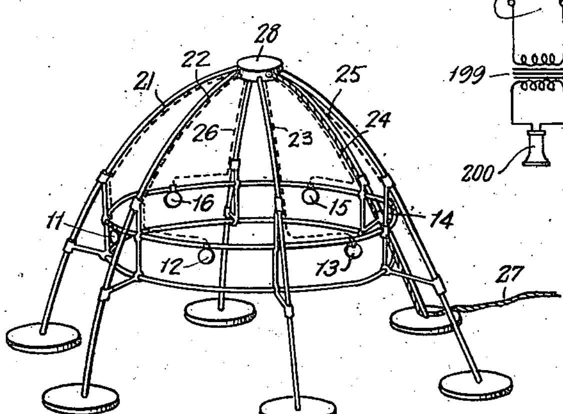

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Fig. 7.

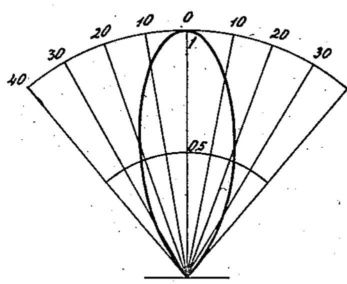


Fig. 8.

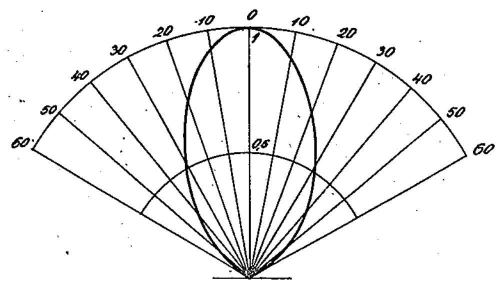


Fig. 9b.

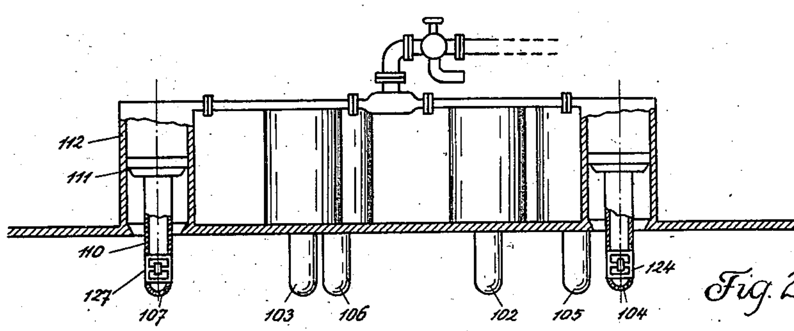


Fig. 2

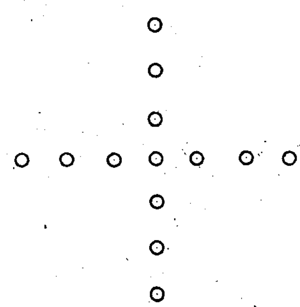


Fig. 9c.

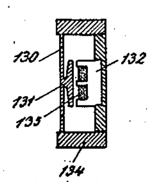
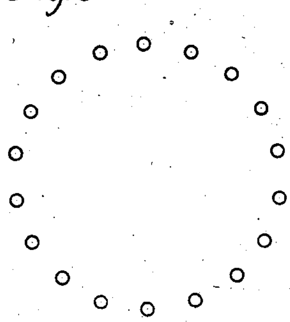


Fig. 3



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ARRANGEMENT FOR DIRECTIONAL TRANSMISSION AND RECEPTION WITH A PLURALITY OF OSCILLATORS

Filed Jan. 9, 1929 4 Sheets-Sheet 3

Fig. 5.

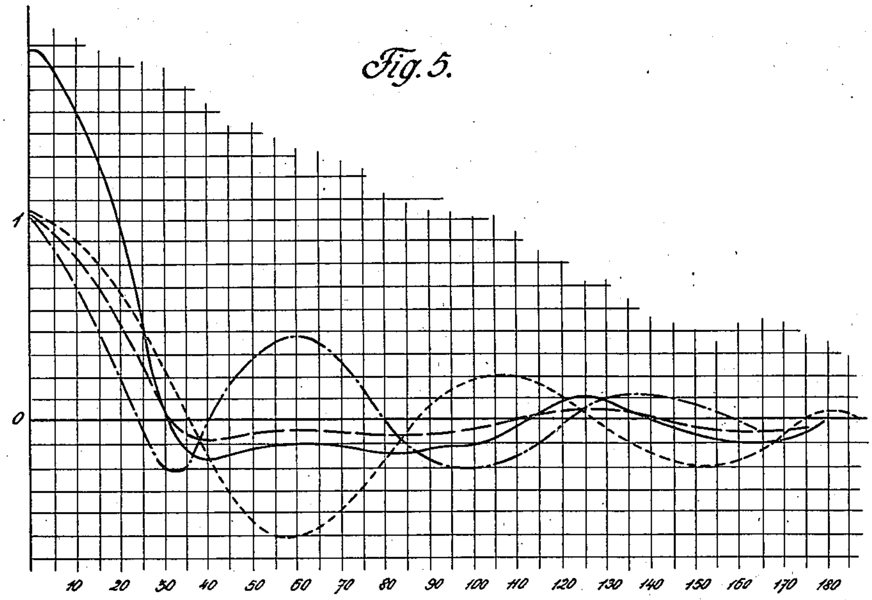
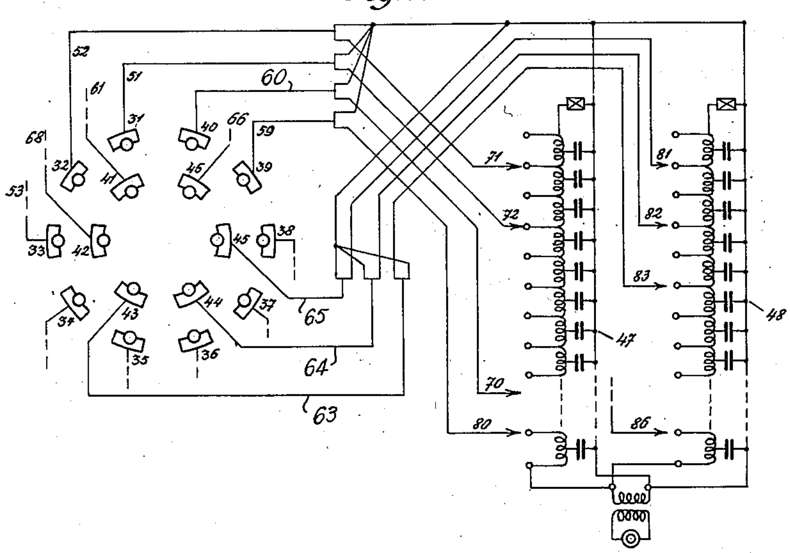


Fig. 6.



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ARRANGEMENT FOR DIRECTIONAL TRANSMISSION AND RECEPTION WITH A PLURALITY OF OSCILLATORS

Filed Jan. 9, 1929 4 Sheets-Sheet 4

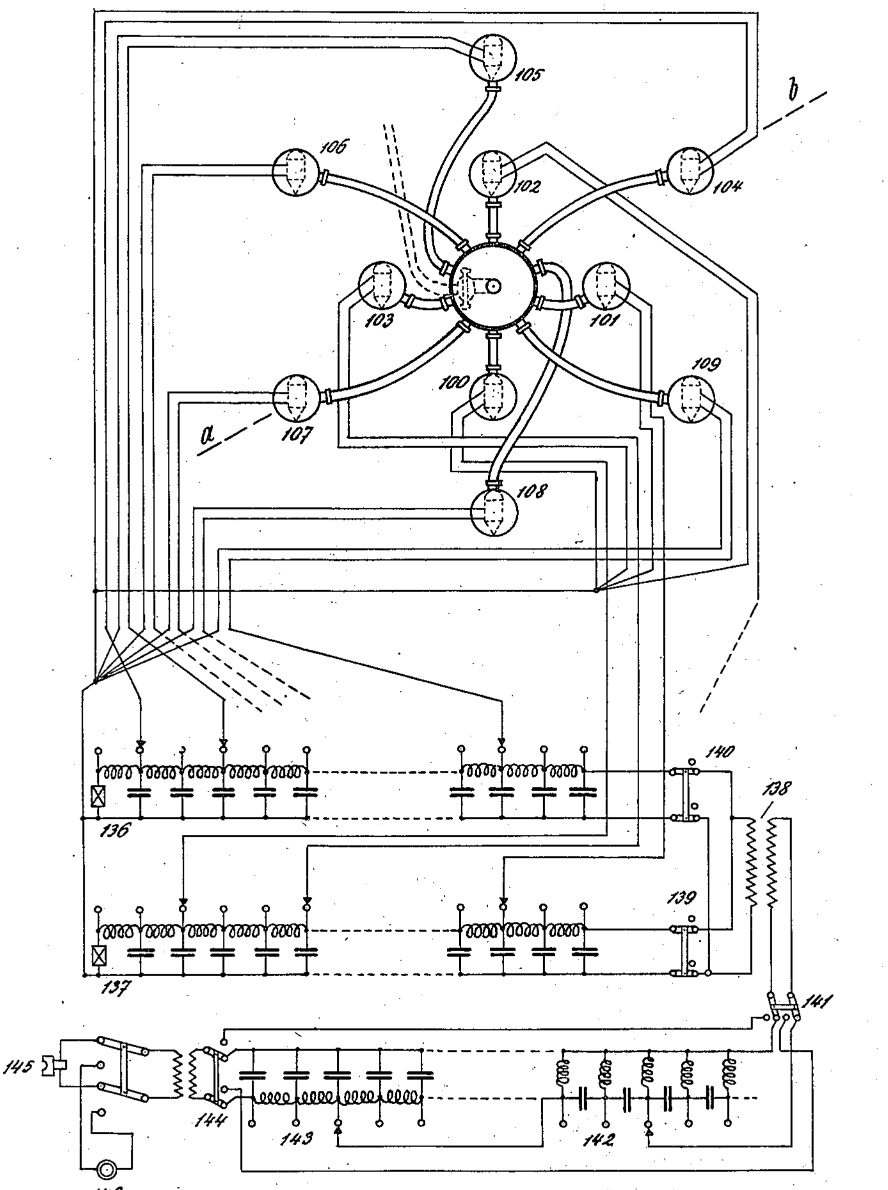

Fig. 9a.

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UNITED STATES PATENT OFFICE

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ARRANGEMENT FOR DIRECTIONAL TRANSMISSION AND RECEPTION WITH A PLURALITY OF OSCILLATORS

Application filed January 9, 1929, Serial No. 331,286, and in Germany January 14, 1928.

In the numerous proposals hitherto submitted for directional transmission and reception with a plurality of oscillators (for example, subaqueous sound transmitters or receivers) apart from rotatable arrangements, a line of oscillators which are connected with a compensator has generally been sufficient.

By "compensator" we understand, broadly speaking, a device for introducing suitable time retardation in the relative flow of energy—for instance sound or electric wave energy—through several energy consumers or producers for the purpose of bringing about a desired phase relation between the individual energy effects produced in said consumers or producers by the energy flow. Devices of this character are today well known instrumentalities, in particular in the acoustic and electric signalling art. By employing such time retardation in the energy flow, it is possible for instance in energy consumers or receivers, which for outside reasons do not happen to individually receive energy simultaneously, to bring about a simultaneous energy effect in all of them by retarding through compensators the flow in those which receive their energy too early. How such compensators, for instance in the form of electric filter circuits, may be particularly usefully employed in directional wave energy transmission or reception is also well known in the art.

Rotatable arrangements such as aforementioned are, at least for longer waves (audible sound frequencies), only of small interest for practical use on account of their clumsy size and frequently also on account of the inadequacy of the arrangement in the operation. Fixed single row arrangements with compensator, particularly those in a straight line, have, however, a number of serious disadvantages. One of these is the bipolarity. With a straight row of receivers, for example, it is not possible on the occurrence of a sound maximum to ascertain whether the sound source is on the one or the other side of the row. It is then necessary always to use several rows and carry out several observations, whether by separating the two rows by means of shading bodies or arranging them at an angle to one another. A second disadvantage is the limited freedom from disturbance. A horizontal row of receivers picks up sound, including also irregular disturbances, with the same maximum tone strength from a space which is formed by the rotation of the direction opening angle with its vertex in the center of the row of receivers about the latter as axis that is, also from above and from below, which, for example, in such receiving arrangements on ships is very disturbing on account of the reception of the noises of the observer's own ship. A third disadvantage when using a straight row of oscillators in connection with a compensator is the non-uniform accuracy, with which the direction of impulses arriving can be determined according to their angle of inclination to the row. The increase of the inaccuracy from incidence at right angles to brushing incidence is approximately 1 to 6 in a straight-line arrangement. Finally, in arrangements of this type, an ambiguity of the direction determination almost always occurs on account of the fact that, with certain positions of the compensator, secondary maxima up to the strength of the main maximum occur which may resemble sound from sources or transmitters apparently located at points where none are in fact.

According to the invention, all these disadvantages are avoided by means of a distribution of the oscillators, which are distributed in fixed relative position to one another, over a surface and which, for the purpose of emitting sound or of searching for the direction of arriving sound, are connected with compensators. In this case it is very important that in such groups only so-called single wave oscillators are used, i. e. for instance, if acoustical oscillators are concerned, only apparatus the tuning of which depends merely upon, for instance, the qualities of the diaphragm alone, because, if oscillators consisting of a plurality of coupled oscillatory structures are applied in each oscillator the exactitude of coordination of phases can not be obtained sharply enough and sharpness being a feature which cannot be dispensed with for the group effect.

Though the oscillators may be arranged in a plane at the corners of any shape polygon, a most advantageous arrangement is obtained if the oscillators are arranged at the corners of a polygon, which are located on a circle, and if the oscillators are located substantially equal distances from each other. Accordingly, where reference is made hereinafter in the claims to the oscillators being arranged in a circle, we mean to imply their arrangement at the corners of a polygon inscribed in a circle, this being the more specific form of the broader idea of the arrangement in a polygon irrespective of whether all of its corners are located exactly on a circle. This arrangement in general applies not only to fixed installations with compensators, but also to installations without a compensator, which have to be moved for determining or varying the direction.

As is well-known, the transmitting or directional sharpness of a directional installation consisting of several locally separated oscillators depends upon the ratio $d:\lambda$, wherein d indicates the greatest distance of the receivers from one another, λ the wave length of the frequency substantially to be received or the frequency to which the oscillators of the installation are substantially tuned. By transmitting or receiving directional sharpness is meant the angle within which the position of the sound source sought can be determined with certainty or outside of which no appreciable amounts of energy are emitted. In the case of only two oscillators, d is the distance of the latter from one another. In the case of a row of more than two oscillators arranged in a straight line, d is the distance between the outermost oscillators, with oscillators arranged in a circle, d is the diameter of the circle. d has the latter meaning here.

The number n of oscillators which are inserted between the outermost oscillators of the group is decisive for the value, the number and the position of the secondary maxima, but not for the transmitting or directional sharpness. With oscillator arrangements in circles, this number is the number of oscillators in the circle.

Now, we have found through mathematical investigation (see Electrische Nachrichten Technik, published by Weidmann, Berlin, 1929, vol 6, #5, pp. 165–181), that an increase of this number n only up to a certain limit results in a decrease in the value of the secondary maxima and particularly of the first one. For oscillators arranged in a circle at uniform distances apart, the relationship

$$n \geqq 2\left(1+\frac{\pi d}{\lambda}\right)$$

is true for the least number of oscillators depending upon the diameter d and the wave-length λ, in which the smallest values of the secondary maxima are obtained. While, on one hand, a smaller number than this may lead to the formation of the greatest disturbing secondary maxima, a considerable increase of the same right above this value no longer results in any improvement worthy of mention.

For diminishing or annihilating these secondary disturbing maxima there exist a number of means which can be applied singly or in combination. As first of these means may be mentioned filter circuits which choke the oscillations, causing these secondary maxima.

As is well-known, the existence of secondary maxima in arrangements for the determination of direction according to the interference method depends upon the distance of the oscillators from each other. For the sake of simplicity it may be assumed first that a pair of receivers is turned about the center of the line connecting the two receivers in a plane in which a source of sound lies emitting a broad range of frequencies. It is found that in turning the receiving arrangement out of the medium position the intensity of sound decreases to the limit position (90°) only for such frequencies for which the distance between the two receivers is equal to or smaller than one half of the wave-length. For smaller wave lengths the received energy increases towards the limit position until with a frequency whose wave length is equal to the distance between the two receivers in the limit position again phase equality and therefor a new maximum appears. Such secondary maxima are repeated with increasing frequencies in increasing number.

All secondary maxima may be avoided by inserting between receivers and indicator (telephone) an electrical or mechanical filter circuit throttling all frequencies the wave-length of which is nearly equal to or smaller than twice the distance between the receivers. Small amounts of a first secondary maximum are tolerable because they differ substantially from the main maximum in their intensity. Therefore it is sufficient to put the lowest limit frequency into the vicinity of this value; but in all cases it must lie clearly below the frequency the wave-length of which is equal to the whole distance between the receivers. This applies for arrangements to be tuned as well as for arrangements with electrical or acoustical compensation.

It is true and may be proven by calculation that by the exemption from higher frequencies a single and unipolar main maximum can be obtained, but the sharpness of direction determination decreases, i. e. the relativ broadness of the main maximum increases.

Therefore the invention comprises further a method and an arrangement of direction determination in which the before-mentioned disadvantage is avoided. According to the invention the direction determination is carried out so that at first the position of the source of sound is roughly found with filter circuits, i. e. with only one main maximum and that afterward the filter circuits are switched off and the direction is determined exactly. For this purpose two arrangements are not necessary provided care is taken that the filter circuits can be switched off for the exact determination.

At the same time the filter circuits which, as is well-known, are adapted to eliminate definite ranges of frequencies of a complex wave, are a good means for throttling out disturbances such as are caused by shocks and blows, for instance in a ship in the form of mechanical vibrations or by atmospheric disturbances or disturbing senders in the form of electrical vibrations.

Another method of eliminating secondary maxima which may be applied alone or in combination with the means described is the following: The amplitude of the different maxima of a circular group (main maximum and secondary maximum) can be shown in right-angled co-ordinates by means of a Bessel function of the character of the dotted line or dot-and-dash line in Fig. 5, each of which corresponds to one of two circular groups of different diameter and different number of oscillators. The phase of the oscillation is given in the curve by a positive or negative ordinate value. It is seen that it is possible to find groups, the maxima of which are located partly opposite one another. The means of the invention for diminishing or for almost completely removing the secondary maxima, consists in combining two groups with each other, the secondary maxima of which are approximately equal as regards the amplitude but as far as possible opposite to one another as regards the phase, and in allowing them to work on the same receiving apparatus. The full line curve in Fig. 5 shows the result, the curve with long dashes shows the same on the return to the ordinate 1. The most disturbing and greatest secondary maxima close to the main maximum are greatly diminished. If that does not occur to an equal degree with the more distantly located and smaller secondary maxima, it would not impair the value of the invention, since these latter maxima are easily distinguished, in the case of reception, by the experienced listener, for example, by the timbre, as secondary maxima and not as a new source of disturbance), but in any case they are so small, that they no longer disturb observation and direction determination. In practice, the decrease of the greatest secondary maximum in the case of two circular groups is less than 1% of the energy of the main maximum, whilst, with only one circular group, it is equal to or greater than 16%.

In first approximation a very useful effect can be obtained with one circular group and a single oscillator in the interior, appropriately in the center, the single oscillator being in the sense of the invention a compensating group.

Of course, other groups of oscillators may also be allowed to act on the same indicator, in the same sense and with a similar effect, for the purpose of compensating the secondary maxima. In the same way, more than two independent groups may be combined with one another.

In the following the invention is described more clearly with reference to the drawings showing systems of oscillators located in a plane, in which drawings

Fig. 1 shows two systems of oscillators at the corners of two triangles with compensator.

Fig. 2 a system of oscillators located in two crossed straight rows.

Fig. 3 an arrangement of oscillators in a circle.

Fig. 4 an arrangement of oscillators according to Fig. 3 mounted on a fixed frame to be placed upon the bottom of the sea.

Fig. 5 shows two single diagrams and the combined diagram of two circle systems of oscillators.

Fig. 6 an arrangement and wiring diagram of combined circle systems of oscillators diagrammatically.

Figs. 7 and 8 show direction characteristics of combined circle arrangements, and

Figs. 9*a*, *b* and *c* a complete installation for a ship with two circle arrangements of oscillators according to Fig. 6 and with filter circuits for the directional emission and reception of sound.

Fig. 1 shows, if at first only one group of oscillators is considered, the simplest form of a surface arrangement with three oscillators relatively placed at the corners of an equilateral triangle. The oscillators are indicated by 1, 2, 3. The compensator is so constructed that, corresponding to the triad of oscillators, three contact arms 7, 8, 9 slide on the path of the connecting contacts, the angular relationship of which arms corresponds to the distribution of the oscillators on the circle. Such an arrangement may, however, also be unsymmetrical. All the elements of the compensator with this arrangement are utilized twice because each of them is connected to two contacts of the contact path.

The detail arrangement of the wiring shown in Fig. 1 is as follows. One terminal of each of the oscillators 1, 2, 3, respectively, 4, 5, 6 is connected to the common point 198. This point is connected by way of conductor 195 with the primary coil of the telephone transformer 199, whose secondary coil is connected to the telephone receiver 200. The other terminal of the primary transformer coil is connected to the pivotal point of switch arm s of multiple switch 10, which arm operates on two contact points to which one of the ends of the inner and outer compensator chains are connected by conductors 196 and 197. In Fig. 1 the secondary transformer coil is shown connected to the inner compensator chain. The other terminals of the inner oscillator group 1, 2, 3 are respectively connected by way of the conductors 150, 151, 152 to some of the fixed contact points of switch 10 and thence are connected through the arms of this switch and by way of conductors 153, 154, 155 to the conductors 159, 160 and 161, which lead to the compensator. These last-mentioned conductors are flexible where they terminate at the compensator so that the compensator arms 7, 8 and 9 can rotate. The three arms 7, 8 and 9 of this compensator which are angularly spaced apart the same distance as the oscillators (namely in this case 120°), carry insulated contact elements, (not visible in Fig. 1) which cooperate with the circular row of contacts r_1, in which the inner compensator elements terminate. The particular position of the three-armed rotatable compensator element 7, 8, 9 as shown in Fig. 1 corresponds with a position in which a sound wave passes over the group of oscillators 1, 2, 3 in the direction of the double feathered arrow. With such a direction of the sound wave the oscillators 2 and 3 are encountered first by the sound and must, therefore, have in their circuit connection with the telephone the same number of compensator chain elements, whereas the oscillator 1 which is last encountered by the sound must have no compensator element in circuit with the telephone. It will be apparent from Fig. 1 that accordingly the contact arms 7 and 8 whose leads are connected with oscillators 2 and 3 are both resting on the fixed contact studs of the compensator which lead to the point 93 of the inner compensator chain, so that accordingly six chain links are in circuit, counting from chain end 99, at which the primary of the telephone transmitter is connected as aforementioned. In this case the contact arm 9 which leads to oscillator 1 is directly connected to the point 99 of the chain and, with no chain link in circuit, is connected thence directly by way of conductor 196 and switch s to the primary of transformer 199. It will be apparent that in such an arrangement, if the sound beams striking the oscillator group should turn an angle of 120° to the right or to the left, the contact bridge 7, 8, 9 of the compensator must be turned through the same angle correspondingly to the left or right in order to produce a maximum sound intensity in the telephone. For the intermediate angular positions the contact bridge 7, 8, 9 must be turned into corresponding intermediate positions and thus in each case a suitable number of compensator chain links are switched in circuit with each of the three oscillators, so that always the maximum sound intensity is produced in the telephone whenever the oscillators are completely compensated relatively to each other. If instead of only three oscillators arranged 120° apart a larger number is used, of course the number of conductors and arms at the rotatable compensator bridge must be correspondingly increased.

The outer circle of oscillators 4, 5 and 6 in Fig. 1 is correspondingly connected with the outer circle of the compensator chain, the center of the three oscillators being connected by conductor 195 directly to one terminal of the telephone transformer primary, and the other terminals of these oscillators being connected by way of conductors 156, 157, 158, to some of the fixed terminals of switch 10, through which latter they are connected to the conductors 162, 163, 164 leading to the portions of the three-armed contact bridge 7, 8 and 9, which cooperate with the outer circle r_2 of the fixed contacts, and which in turn lead to the individual outer chain elements. The beginning of the outer compensator chain is directly connected by way of conductor 197 to one of the terminals of switch 10 with which the arm s cooperates, so that when the latter is thrown onto this contact the beginning of the chain becomes connected to the other terminal of the primary of telephone transformer 199. This occurs when the entire switch 10 is thrown to the right in order to bring the outer circle of oscillators 4, 5, 6 into operation with the telephone 200.

In such arrangements it is possible that, in the case of a fixed base and variable compensator, the secondary maxima always remain below a prescribed amount of the main maximum, for example, always below 0.25 of the main maximum. There is a diameter D of the circle circumscribing the triangle in which the above requirement is satisfied, that is to say, in which the greatest secondary maximum is exactly 0.25 of the main maximum. A main maximum of definite sharpness for bearing determination belongs to this plane. The directional sharpness scarcely alters with the azimuth of the angle of incidence. Its greatest fluctuation lies near 0° and 60° angle of incidence and is only approximately 1:1.4 while with the straight line it lies at 0° and 90° angle of incidence and deviates approximately 1:6. If the diameter of the triangle is smaller, then the secondary maxima become smaller, the directional sharpness, however, less; if the diameter is larger, then the directional sharpness becomes greater, the secondary maxima, however, become greater than the prescribed amount.

If the receivers are arranged in such a way that no secondary maximum is greater than 0.25 of the main maximum, the directional sharpness may not satisfy many requirements of practice. A second larger triangle can then be used for the more accurate bearing determination, the receivers of which have the numbers 4, 5, 6.

The small triangle serves for firmly establishing clearness, the second for accurate bearing determination.

Instead of the triangular arrangements of Fig. 1, other arrangements also can be used with advantage, thus, for example, those of the cross bases Fig. 2 or of the circle Fig. 3.

The case of the crossed bases shows the difference between the new method and the old one in a very characteristic manner. Even in the old method which works with line arrangements, two crossed bases are used for the unipolar direction determination, at which two different measurements are made, however, in succession of time. In the new method, on the contrary, the two bases are constantly connected and thus, by means of a single observation and without disturbing reverse switching, give a correct direction determination with almost constant directional sharpness and greatly increased freedom from disturbance. The circle arrangement (Fig. 3) is the most ideal arrangement if the smallest fluctuation of the directional sharpness with the greatest directional sharpness, the greatest clearness and the greatest freedom from disturbance are required. In the case of the circle arrangement it is quite easy to see without calculation that the diameter of the circles gives the directional sharpness and the sequence of the receivers on the circle, that is to say, the number of receivers gives clearness. If it is desired to make the directional sharpness and clearness great, then it is necessary to arrange a large number of receivers in a large circle. It is obvious, that, for reasons of symmetry, the distribution of the individual receivers on the circle is appropriately a uniform one.

The compensator for the circle of oscillators can, in principle, be constructed exactly like the one for the triangle, however, with as many contact arms as there are oscillators.

The compensator for several groups, for example, for several concentric circles or several concentric polygons as used for example for preliminary bearing determination and for exact bearing determination, is in principle so constructed that for each figure a special filter is provided, the sub-division of which corresponds to the desired degree of accuracy and the lag value of which corresponds to the distances between the receivers (diameter of circle). Moreover switching mechanisms 10 must be provided, which, according to choice, allows the groups of receivers and the corresponding filters to be connected together selectively and to the telephone. The compensator has two filters, the inner one of which corresponds to the inner circle and the outer one to the outer circle. The latter is, corresponding to the increased directional sharpness, divided more finely and has the greater lag value, since in the outer circle, the distance between the oscillators is greater. Each filter has its corresponding contact path and its corresponding arms (conductor) on the sliding contact. Sliding arms, oscillators and telephone are taken through a change-over switch which allows the outer filter to be connected with the larger and the inner filter with the smaller group of receivers.

Fig. 4 shows in diagrammatic representation an arrangement of six receivers in a circle which is conceived to be arranged on a frame on the bottom of the sea. The oscillators are 11, 12, 13, 14, 15, 16. They are connected through the cables 21, 22, 23, 24, 25, 26 with the cable box 28 and through the cable 27 with the transmitting station located on land and containing the compensator. The frame, which carries the receiver has the form of a dome as smooth as possible on the outside in order to prevent the accidental dragging of the arrangement by nets and the like.

Fig. 5 is discussed already in the introduction to the description.

A combined circular group with associated compensator is illustrated in Fig. 6 in purely diagrammatic form. The oscillators, ten in the outer and six in the inner group, are indicated by 31 to 40 and 41 to 46 respectively. The double conductors from the oscillators to the compensator are shown partly as simple dashes. The compensator consists of two artificial retardation lines or groups of lines 47 and 48, each of which is allotted to a group, 47 to the outer and 48 to the inner group. The wires connecting the outer group with 47 are 51 to 60 and those connecting the inner group with 48 are 61 to 66. On the one hand they are connected to the common neutral conductor 49 of the compensator, and on the other hand, led over sliding contacts 71 to 80 or 81 to 86, which slide over corresponding contact studs, to which the individual links of the compensator are conducted. In the example shown, the impulses of all the receivers run over the same artificial line with a lag corresponding to their distance apart. Of course, a special artificial line can also be provided for each oscillator. In the same way instead of the compensator with open artificial lines, as is shown, a circular compensator may be used with as many artificial lines as groups used. Finally, all the oscillators may also be connected through the same artificial line which, according to various laws, must of course, be subdivided corresponding to the distances between the oscillators of the different groups and where each group must be allotted its special path of sliding contacts. Such an arrangement would be realized from Fig. 6 if the artificial line 47 were so subdivided that the number of sections for the two groups is commensurable and if a correspondingly different number of sections of the artificial lines is connected to each of the sliding paths.

In Fig. 7 the characteristic of a combination consisting of two groups of six and ten oscillators is illustrated in the plane.

In Fig. 8 finally is shown the characteristic in the plane for a group of eight oscillators in a circle and one in the center.

Figs. 9*a*, *b* and *c* illustrate the invention in the form of a ship's installation for directional reception and emission of sound. Fig. 9*a* shows a diagrammatical top plan view of the arrangement as far as the oscillators and their carriers are concerned, while the connections are shown in the simplest possible form. The two oscillator arrangements are 100 to 103 for the four oscillators of the inner circle and 104 to 109 for the six oscillators of the outer circle. Each oscillator is mounted in a running out gear which can be brought out through the bottom of the ship. This can be seen more clearly in Fig. 9*b* corresponding to a section along *a*—*b* in Fig. 9*a*. The running out gears consist of a sword-like body 110 which slides in a tube 112 with its piston 111. The running out gears are moved hydraulically or pneumatically, but may also be pushed out mechanically or electromechanically. In Fig. 9*b* besides can be seen the gears 102, 103, 105 and 106. The oscillators are shown diagrammatically at 124 and 127. More clearly an oscillator is illustrated in Fig. 9*c*. Corresponding to the rule of the one-wave principle it contains only one vibratory structure, the diaphragm 130, which is fabricated as a whole together with the casing 134. The diaphragm carries the magnet armature 131 facing the magnet field 132 within the oscillator with its coil 133. In the example of Fig. 9*c* is shown a permanent magnetic field, but in the same way may be used a magnetic field polarized with direct current. Instead of electromagnetic oscillators electrodynamic ones may serve with coils vibrating in a direct current field. The inner circle of oscillators is connected to the compensator 137 and the outer to compensator 136, both of which are switched in parallel to the transformer 138. The circle arrangements may also be alternately connected to the transformer 138 by means of the switches 139 and 140. Behind the transformer 138 the groups may be switched at will directly or over the artificial line circuits 142 and 143 to the telephone 145 or the alternator 146. The two artificial line circuits are of a different kind, 142 is composed of capacities in series and inductances in parallel, 143 of inductances in series and capacities in parallel for the purpose of eliminating higher or lower ranges of frequencies. Besides these circuits are variable in their length.

For finding out the direction of noises of ships or of under water noise generally one will make use of submarine sound receivers which are located either fixed or movable above (in submarines) or below (on surface vessels) the ship's body free towards all directions. For obtaining true results with these methods the condition must be fulfilled that oscillators are used which receive and emit vibrations with correct phase and intensity, for instance electromagnetic or electrodynamic oscillators. For the emission or reception of electrical wave energy antennæ of well-known kind can be applied, but it will be necessary for a clear effect of the predetermined working of the arrangement to take antennæ or oscillators which in themselves have no directional characteristic.

We claim:—

1. An arrangement for directional communication of sound wave energy, consisting of one indicator, a group of oscillators (three or more) distributed over a plane in parallel to the direction of the wave propagation, an adjustable compensator for rendering coincident impulses of all oscillators at only one definite position corresponding to a definite direction of the sound beam, and electrical connections for connecting all oscillators over different points of said compensator to said indicator at the same time for bringing about the aforesaid coincidence.

2. An arrangement for determining the directional maximum effect in communication of wave energy, comprising one indicator, a plurality of oscillators (three or more) distributed in a polygon over a plane in parallel to the direction of the wave propagation, a compensator, and electrical connections for connecting all oscillators over different points of said compensator to said indicator at the same time for suitably adjusting the relative lag between the individual oscillator currents flowing through said indicator, to produce a maximum energy effect in the latter.

3. An arrangement for determining the directional maximum effect in communication of wave energy comprising one indicator, a plurality of one-wave oscillators (three or more) distributed in a polygon over a plane, in parallel to the direction of the wave propagation, a compensator, and electrical connections for connecting all oscillators over different points of said compensator to said indicator at the same time for suitably adjusting the relative lag between the individual oscillator currents flowing through said indicator, to produce a maximum energy effect in the latter.

4. An arrangement for determining the directional maximum effect in communication of wave energy comprising one indicator, a

plurality of oscillators (three or more) distributed over a circle, a compensator, and electrical connections for connecting all oscillators over different points of said compensator to said indicator at the same time for suitably adjusting the relative lag between the individual oscillator currents flowing through said indicator, to produce a maximum energy effect in the latter.

5. An arrangement for determining the directional maximum effect in communication of wave energy comprising one indicator, a plurality of oscillators (three or more) distributed over a circle and spaced equal distances apart, a compensator, and electrical connections for connecting all oscillators over different points of said compensator to said indicator at the same time for suitably adjusting the relative lag between the individual oscillator currents flowing through said indicator, to produce a maximum energy effect in the latter.

6. An arrangement for determining the directional maximum effect in communication of wave energy comprising one indicator, a plurality of groups of oscillators, the groups comprising each a plurality of oscillators distributed in polygons over a plane in parallel to the direction of the wave propagation, a compensator, and electrical connections for connecting all oscillators of each group over suitable points of said compensator to said indicator at the same time by which connections opposite phases of secondary energy maxima in said groups are combined for the purpose of eliminating the effect of the secondary maxima upon said indicator.

7. An arrangement for determining the directional maximum effect in communication of wave energy comprising one indicator, a plurality of groups of oscillators, the groups comprising each a plurality of oscillators distributed in concentric equilateral polygons over a plane in parallel to the direction of the wave propagation, a compensator, and electrical connections for connecting all oscillators of each group over suitable points of said compensator to said indicator at the same time by which connections opposite phases of secondary energy maxima in said groups are combined for the purpose of eliminating the effect of the secondary maxima upon said indicator.

8. An arrangement for determining the directional maximum effect in communication of wave energy comprising one indicator, a plurality of groups of oscillators, the groups comprising each a plurality of oscillators distributed in concentric equilateral polygons over a plane, a compensator comprising switching means for suitably connecting the oscillator of each group to adjust the relative time lag between the individual oscillator currents to produce a maximum indicating effect of the combined oscillator of each group, and electrical connections for connecting all oscillators of each group through said compensator to said indicator at the same time by which connections opposite phases of secondary energy maxima in said groups are combined for the purpose of eliminating the effect of the secondary maxima upon said indicator.

9. An arrangement for determining the directional maximum effect in communication of wave energy comprising one indicator, a plurality of groups of oscillators, the groups comprising each a plurality of oscillators distributed in concentric equilateral polygons over a plane, a compensator comprising switching means for suitably connecting the oscillator of each group to adjust the relative time lag between the individual oscillator currents to produce a maximum indicating effect of the combined oscillator of each group, and electrical connections for connecting at will the said groups through said compensator alternately or at the same time to said indicator whereby through the alternate connection of the groups the energy maximum of each group is ascertained in the indicator, and by the simultaneous connection of all groups opposite phases of secondary energy maxima of the connected groups can be combined and their individual effects be eliminated from the indicator in order to produce a sharp maximum energy effect in the latter.

10. An arrangement for determining the directional maximum effect in communication of wave energy comprising one indicator, a plurality of groups of oscillators arranged in concentric polygonal form and in polygons of different size, a compensator comprising time lag circuits subdivided into different elements corresponding to the distances between the oscillators in the different groups, and switching means between the different groups and the indicator adapted to connect alternately or simultaneously the said groups through said compensator to the indicator whereby through the alternate connection of the groups the energy maximum of each group is ascertained in the indicator, and by the simultaneous connection of all groups opposite phases of secondary energy maxima of the connected groups can be combined and their individual effects be eliminated from the indicator in order to produce a sharp maximum energy effect in the latter.

11. An arrangement for determining the directional maximum effect in communication of wave energy comprising a plurality of groups of oscillators distributed over a plane, one indicator at the operator's station, compensating means between said indicator and the different groups of oscillators, and suitable connections between the groups and

said indicator for connecting the different groups partly in opposite sense through said compensating means to said indicator whereby opposite phases of secondary energy maxima in said two groups can be combined for the purpose of eliminating the effect of the secondary maxima upon said indicator.

12. An arrangement for determining the directional maximum effect in communication of wave energy comprising a plurality of groups of oscillators in a plane, the oscillators of the different groups being located upon concentric circles of different size, one indicator at the operator's station, compensating means between said indicator and the different groups of oscillators corresponding with regard to their compensating range to the size of the different circles for adjusting the relative time lag between the individual oscillator currents of each group, to produce a maximum energy indicating effect of the combined oscillators of each group, and suitable connections between the said groups and said indicator for connecting the different groups to said indicator partly in opposite sense whereby opposite phases of secondary energy maxima in said two groups can be combined for the purpose of eliminating the effect of the secondary maxima upon said indicator.

13. An arrangement for determining the directional maximum effect in communication of wave energy comprising a plurality of groups of oscillators distributed over a plane, one indicator at the operator's station, variable compensating means between said indicator and the different groups of oscillators for adjusting the relative time lag between the individual oscillator currents of each group, to produce a maximum energy indicating effect of the combined oscillators of each group, suitable connections between the groups and said indicator for connecting the different groups to the indicator partly in opposite sense whereby opposite phases of secondary energy maxima in said two groups can be combined for the purpose of eliminating the effect of the secondary maxima upon said indicator, and compensator variation means adapted to produce in the indicator coincidence of the impulse received by the oscillators at a given position of the source of wave energy.

14. An arrangement for determining the directional maximum effect in wave communication comprising a plurality of oscillators (three or more) distributed over a polygon in a plane, one indicator at the operator's station and variable synchronizing elements for the wave energy disposed between the oscillators and said indicator and adapted to synchronize the wave energy of all oscillators simultaneously for producing a maximum effect in the indicator at the synchronization point.

15. An arrangement for determining the directional maximum effect in wave communication comprising a plurality of oscillators distributed over a circle in a plane, one indicator at the operator's station, and a compensator inserted between the oscillators and said indicator, adapted to synchronize the wave energy of all oscillators, the ratio between the number n of oscillators to the diameter of the circle being at least

$$n=2\left(1+\frac{\pi d}{\lambda}\right).$$

16. An arrangement for determining the directional maximum effect in wave communication comprising a plurality of oscillators (three or more) distributed over a polygon in a plane, one indicator at the operator's station, synchronizing means between said indicator and the oscillators for adjusting the relative time lag between the individual oscillator currents of each group, to produce a maximum energy indicating effect of the combined oscillators of each group, and throttling means between the indicator and the oscillators for eliminating definite ranges of waves.

17. An arrangement for determining the directional maximum effect in wave communication comprising a plurality of oscillators (three or more), one indicator at the operator's station, synchronizing means between said indicator and the oscillators for adjusting the relative time lag between the individual oscillator currents of each group, to produce a maximum energy indicating effect of the combined oscillators of each group, and throttling means between the indicator and the oscillators for eliminating definite ranges of waves.

18. An arrangement for determining the directional maximum effect in reception of wave energy comprising a plurality of one-wave oscillators (three or more) distributed over a polygon in a plane, one indicator, variable synchronizing circuit elements disposed between the oscillators and the indicator for adjusting the relative time lag between the individual oscillator currents of each group, to produce a maximum energy indicating effect of the combined oscillators of each group, and filter circuits between said oscillators and the indicator adapted to eliminate definite ranges of waves.

19. An arrangement for determining the directional maximum effect in wave communication comprising a plurality of oscillators (three or more) distributed over a polygon in a plane, one indicator at the operator's station, synchronizing circuit elements disposed between the indicator and the oscillators for adjusting the relative time lag between the individual oscillator currents of each group, to produce a maximum energy indicating effect of the combined oscillators

of each group, throttling means between the indicator and the oscillators for eliminating definite ranges of waves and switching means for switching in and out at will the said throttling means.

20. An arrangement for determining the directional maximum effect in reception of wave energy comprising a plurality of one-wave oscillators (three or more) distributed over a polygon in a plane, one indicator, variable synchronizing circuit elements disposed between the oscillators and the indicator for adjusting the relative time lag between the individual oscillator currents of each group, to produce a maximum energy indicating effect of the combined oscillators of each group, filter circuits between the oscillators and the indicator adapted to eliminate definite ranges of waves, and switching means for switching in and out at will the said filter circuits.

21. An arrangement for determining the directional maximum effect in reception of wave energy comprising a plurality of oscillators distributed over a polygon in a plane and connected simultaneously to one indicator, variable synchronizing circuit elements disposed between the oscillators and the indicator for adjusting the relative time lag between the individual oscillator currents of each group, to produce a maximum energy indicating effect of the combined oscillators of each group, and filter circuits of different kind between the oscillators and the indicator adapted to eliminate different ranges of waves.

22. Arrangement according to claim 21 having variable filter circuits.

In testimony whereof we affix our signatures.

HEINRICH HECHT.
HEINRICH STENZEL.