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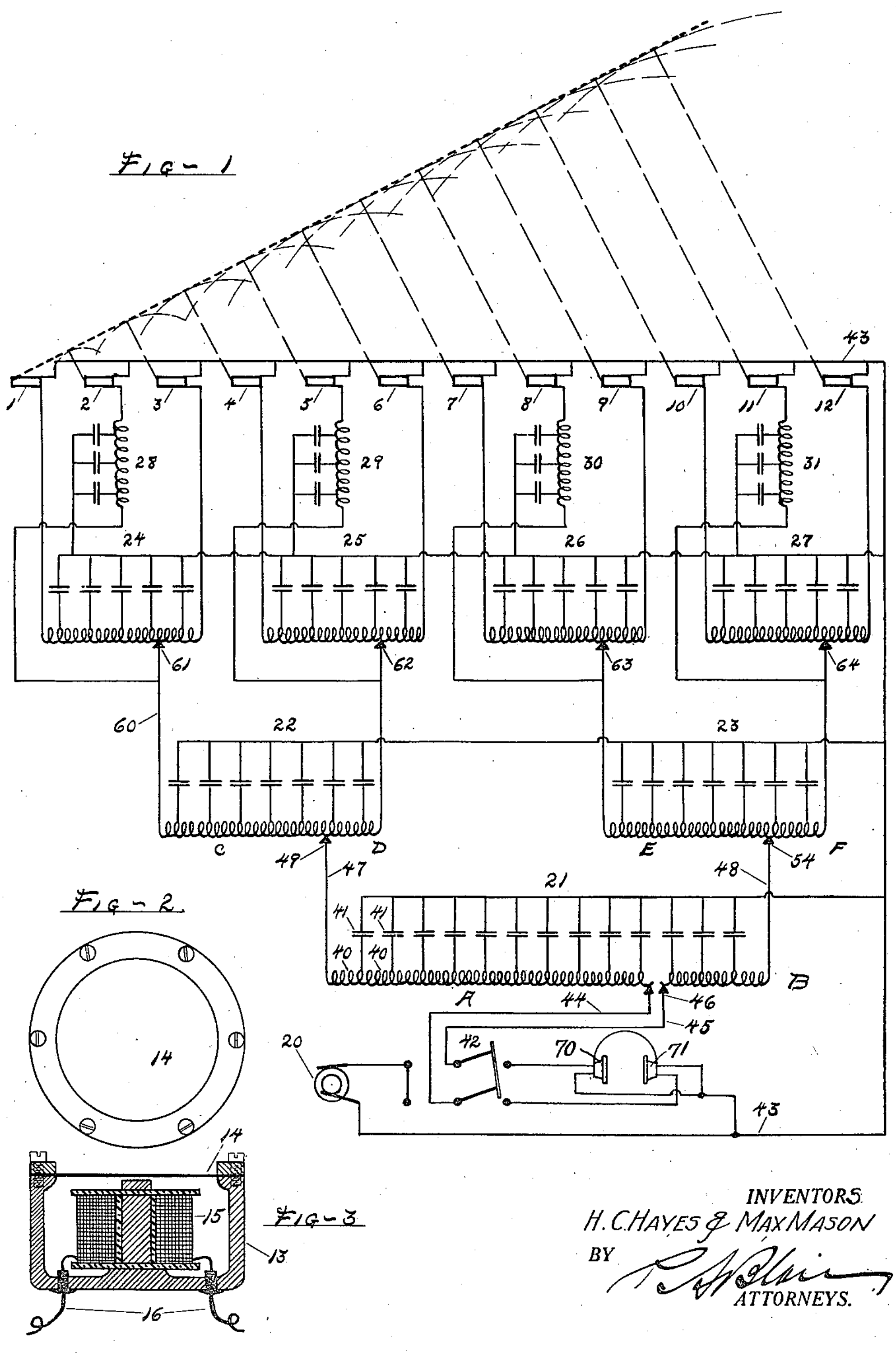

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HARVEY C. HAYES AND MAX MASON, OF NEW LONDON, CONNECTICUT, ASSIGNORS TO SUBMARINE SIGNAL COMPANY, OF PORTLAND, MAINE, A CORPORATION OF MAINE.

DIRECTIVE SOUND TRANSMISSION.

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The present invention relates to directive sound transmission. The object of the invention is to transmit sounds, and particularly submarine sounds, in a definite desired direction. This is accomplished by the employment of a plurality of sound transmitting sources which are disposed in a predetermined spaced relation and from which are sent out sounds having predetermined phase relations.

In the drawings in which we have illustrated diagrammatically one form of apparatus in which the invention may be embodied, Fig. 1 is a schematic diagram showing a plurality of sound transmitters and connections for exciting them to produce a desired phase relationship. Fig. 2 is an elevation of one of the magnetophones employed as sound transmitters, and Fig. 3 is a sectional view of the magnetophones.

Referring to the embodiment of the invention illustrated in the drawings, twelve sound transmitters are shown disposed in a straight line. For submarine sound work these transmitters are located under water, either at a shore station or on the side or the keel of a ship. Such sound transmitters are of course made water proof. A convenient form of sound transmitter for this purpose is a magnetophone such as shown in Figs. 2 and 3. This magnetophone comprises a water tight casing 13 having a soft iron diaphragm 14, the outer surface of which is exposed to the water. The diaphragm 14 is vibrated by means of a magnet 15 enclosed in the casing 13 and supplied with an alternating current of the desired frequency thru insulated lead wires 16.

In the illustrated embodiment of the invention, magnetophones numbered 1 to 12 inclusive are disposed so as to occupy a fixed position with relation to the shore in the case of a shore station or to the ship in case they are mounted on a ship. The direction in which the sound is transmitted is determined by suitably adjusting the phase relation between the several magnetophones. The current for exciting the magnetophones is generated by an alternating current generator 20 having the desired audible frequency, preferably in the neighborhood of 1000 cycles per second. The current from the generator 20 is distributed to the magnetophones thru loaded lines, arranged similarly to the loaded lines of the electric compensator employed by the Navy for directive sound reception. The wiring diaphragm of such a distributing system is shown schematically in Fig. 1. It consists of a plurality of loaded lines indicated by reference numerals 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, and 31. Each loaded line consists of inductances in series shunted by capacities in parallel. For convenience in construction, the loaded lines are made up of a plurality of units, each unit comprising an inductance 40 and capacity 41. The effect of such a loaded line is to retard the electric current pulsations traveling over it. By introducing more of these loaded line units between the generator 20 and any one of the magnetophones, the phase of the current at such magnetophone is lagged behind that of another magnetophone receiving current thru fewer of the loaded line units.

Referring to the wiring diaphragm shown in Fig. 1; when the switch 42 is thrown to the left, one side of the generator 20 is connected thru the lead 43 to the magnetophones in parallel. The other side of the generator is connected thru two leads 44 and 45 to a switching device 46. This switching device is arranged to interrupt the loaded line 21 and to divide it into two sections A and B. The number of units of the sections A and B may be varied by the switching device, so that any desired number may be put in series with the lead 44 while the remaining sections are put in series with lead 45. The ends of the line 21 are connected thru leads 47 and 48 to the loaded lines 22 and 23 respectively, the ends of leads 47 and 48 being provided with contact points which make connections at any points along the loaded lines 22 and 23 respectively. The current flowing thru the lead 47 and entering the loaded line 22 will divide, passing to the left and right along the sections of this line indicated by reference letters C and D respectively. By moving the contact point 49 the number of units in the sections C and D may be varied as desired. Similarly the current is divided thru loaded line 23, passing thru the two sections of this line indicated by reference letters E and F respectively.

The end of section C of the loaded line 22 is connected to lead 60 which has two branches, one terminating in a contact point 61 movable along the loaded line 24 and the other passing thru the loaded line 28 to the magnetophone 2. The loaded line 28 has one half of the retarding effect of the loaded line 24, so that when the contact point 61 is in the middle of the loaded line 24 the magnetophones 1, 2, and 3 are in phase with each other. They may be, however, thrown out of phase by moving the contact point 61 along the loaded line 24. The other end of the loaded line 22 is similarly connected to the magnetophones 4, 5 and 6 thru the loaded lines 25 and 29. One end of the loaded line 23 is similarly connected to magnetophones 7, 8, and 9 thru loaded lines 26 and 30, and the other end of the loaded line 23 is connected to the magnetophones 10, 11 and 12 thru the loaded lines 27 and 31. Suitable contact switches 62, 63, and 64 are provided for the loaded lines 25 to 27 having the same operation as the contact switch 61 has on the loaded line 24. The several switches 46, 49, 54, 61, 62, 63 and 64 are connected together so as to be operated in unison and to make contact in properly related points along the loaded lines. The rotary switch employed by the Navy is suitable for this purpose. Such a switch is well known to those skilled in the hydrophone art and the structural details are not here specifically described. This type of rotary switch is illustrated and described in copending application of George W. Pierce for electric compensators, Serial No. 306,689½.

Instead of having the form of switch diagrammatically indicated at reference numeral 46 which interrupts the line 21, a form of switch like that shown on 49 or 50 may be employed which would simply make contact along the several units of the line 21 allowing the current to divide thru the two sections A and B. It is preferable to use the type of switch indicated by reference numeral 46 which divides the loaded line 21 because by using this type of switch, the distributing system may be used as an electric compensator for the determination of the direction of a sound received by the magnetophones, which will operate as sound receivers as well as sound transmiters. The switch 42, is a double throw switch by means of which the two leads 44 and 45 may be connected to the two receivers 70 and 71 of a telephone head set, and the system may be used as a listening system giving both the binaural and maximum effect, as will be readily understood by anyone skilled in the hydrophone art.

The electrical constants of the units in the several loaded lines and the number of units in each line are computated so that for any setting of the compensator switch, there will be the same phase difference between the successive equally spaced transmitters. For example when the compensator switch is turned so that the several component switches make contact with the middles of the several loading lines, the sounds generated at the several magnetophones will all be in exact phase with each other. When, however, the compensator switch is turned from the middle connections along the loaded lines, for example, to the right as shown in Fig. 1, the electric impulses at the magnetophone 1 will have the same phase difference or lag behind the electric impulses at the magnetophone 2, as electric impulses at the magnetophone 2 have behind those at the magnetophone 3, and so on along the line of magnetophones.

In order to minimize reflections at the junction points made at the switch contacts indicated at 49, 54, 61, 62, 63 and 64, the loaded lines are computated so that the impedance of the section of one line is approximately equal to the impedance of the divided circuit thru the loaded line which it feeds. For example, the impedance of section B of the line 21 should approximate the impedance of the branch circuits thru the sections E and F of line 23. Similarly the impedance of the section F of the line 23 should approximate the impedance of the three branch circuits thru the loaded lines 27 and 31. This relation cannot be exactly realized but should be approximated as far as possible. The value of the electrical constants of the several loaded lines and their units is computated by the same formulæ as employed in computing the constants of electric compensator, such for example as developed and used by the Navy Department at the Naval Experimental Station, New London, Connecticut. These formulæ are well known to those skilled in the hydrophone art and for the sake of brevity are not given here at length. They are set forth in detail in the co-pending application of George W. Pierce for electrical compensation, Serial No. 306,689½.

The predetermined phase relation between the sound waves radiated from the several sound transmitters 1 to 12 inclusive produces a wave front having a maximum intensity in a definite direction. For example, if the sound waves generated at the transmitters are all in phase, the energy of the wave front will have a maximum for directions perpendicular to the line of transmitters and the energy will fall off rapidly at either side of this perpendicular direction, because of interference between the sound waves, according to well known Huygens principle of wave propagation. If on the other hand there is a phase difference between sounds sent out from the successive transmitters, the sound energy will be transmitted at its maximum in a direction inclined to the perpendicular to the line of transmitters. This is indicated in Fig. 1, in which the electrical connections are shown so that there is a predetermined time lag between the waves sent out from the several transmitters counting from right to left. In this case the wave front will have a general conical outline, the wave travelling in a direction inclined to the left as indicated in the drawing. By turning the compensator switch, the phase differences between the sounds sent out from the several receivers may be varied at will so as to vary the direction in which the sound is directed. The sharpness of the sound beam will depend, of course, upon the wave length, and the number and spacing of the receivers. In general the shorter the wave length the sharper the maximum in the direction in which it is desired to direct the sound.

The compensator switch may be angularly calibrated in the same way as the compensator switch is usually calibrated for directional sound reception, so that the operator by setting the compensator switch may immediately determine the angular direction in which the sound is to be sent out. The compensator may be used as a receiving system by throwing switch 42 to the two receivers 70 and 71 of the telephone head set. The setting of the compensator will in this case give the angular bearing of the sound received according to the well known operation of the electric compensator.

While we have shown our invention as embodied in an electrically operated sound generating system, the invention may be embodied in other sound generating systems. While it is preferred to have the several transmitters excited from a common source, they may be otherwise excited provided the desired phase relationship is obtained; and while it is preferred to have the several receivers disposed in a straight line, they may be otherwise disposed as for example around the circumference of a circle as disclosed in the co-pending patent of Harvey C. Hayes on "Determination of wave energy direction, Serial No. 322,222."

It is to be understood therefore that the invention is not limited to its preferred embodiment but may be otherwise embodied within the scope of the following claims.

We claim:

1. Directional sound transmitting apparatus comprising a plurality of transmitters disposed in a straight line and having their effective faces in the same plane and facing in the same direction, means for electrically generating therein sounds of the same frequency and of a variable phase relation and means for varying progressively said relation from one end to the other of said line.

2. Directional sound transmitting apparatus comprising a plurality of sound transmitters located in the same straight line and having their faces in the same plane facing in the same direction, and excited from a common source of energy, and means for varying the phase relation of the movements of the faces of said transmitters.

3. Directional sound transmitting apparatus comprising a plurality of sound transmitters disposed in a straight line and having their effective faces in the same plane and facing in the same direction, a common source of energy for exciting the several transmitters and connections between the transmitters and the source of energy having provision for imposing predetermined time lags progressively on the energy supplied to the respective transmitters.

4. Directional sound transmitting apparatus comprising a plurality of sound transmitters arranged in the same line and having their effective faces in the same plane and facing in the same direction, means for exciting such transmitters to generate sound waves of the same frequency and means for varying the phase of the excitation at the several transmitters in a predetermined and progressive manner whereby the impulses from all the transmitters will be in phase in a plane front of predetermined direction.

5. Directional sound transmitting apparatus comprising a plurality of transmitters located in a substantially straight line having their faces in the same plane and facing in the same direction, an electric generator for exciting the several transmitters and loaded lines interposed between the generator and the several transmitters, said loaded lines being adapted to vary the phase relation between said transmitters progressively from one end of the line thereof to the other.

6. Directional sound transmitting apparatus comprising a plurality of sound transmitters located in a substantially straight line having their faces in the same plane and facing in the same direction, an alternating current generator for exciting the several transmitters and means for introducing variable and progressive but relatively predetermined time lags in the connections between the generator and the several transmitters.

7. A directional sound transmitting apparatus comprising a plurality of transmitters having their transmitting faces located in a straight line and having their effective faces in the same plane and facing in the same direction, an alternator for exciting the several transmitters to produce an audible sound and loaded lines interposed between the alternator and the several transmitters adapted to cause currents excited by said alternator to act progressively upon said transmitters.

HARVEY C. HAYES.
MAX MASON.