

July 21, 1959

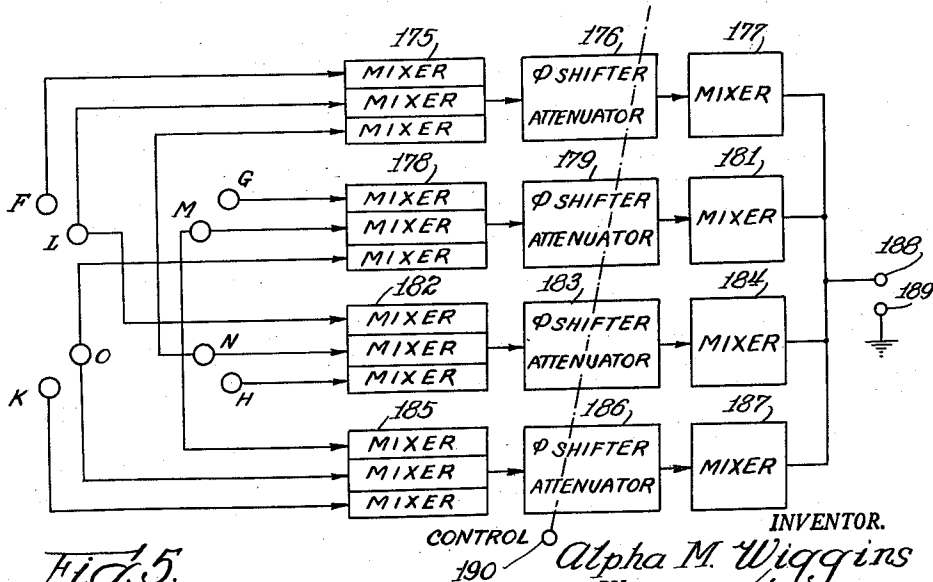
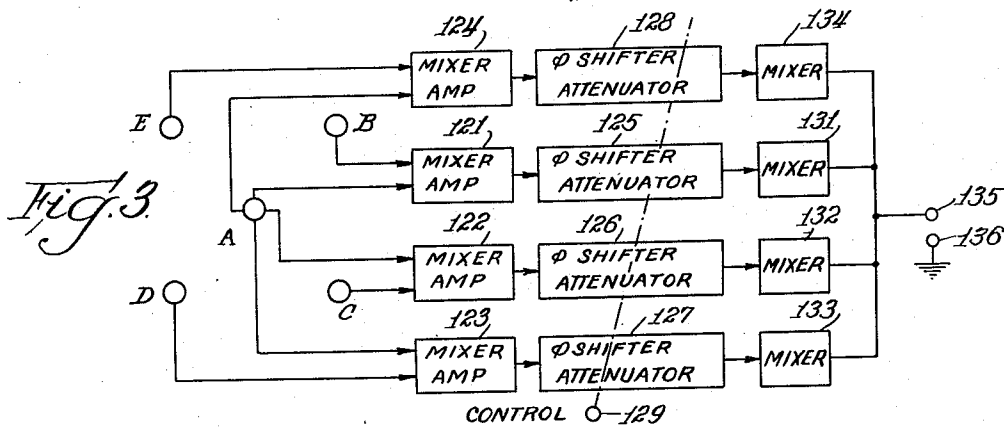
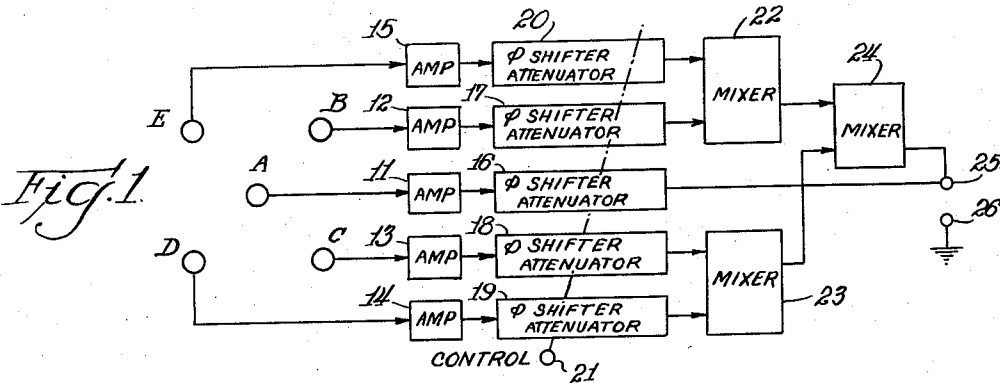
A. M. WIGGINS

2,896,189

HIGHER ORDER PRESSURE GRADIENT MICROPHONE SYSTEM
HAVING ADJUSTABLE POLAR RESPONSE PATTERN

Filed Feb. 8, 1952

4 Sheets-Sheet 1



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July 21, 1959

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HIGHER ORDER PRESSURE GRADIENT MICROPHONE SYSTEM
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4 Sheets-Sheet 2

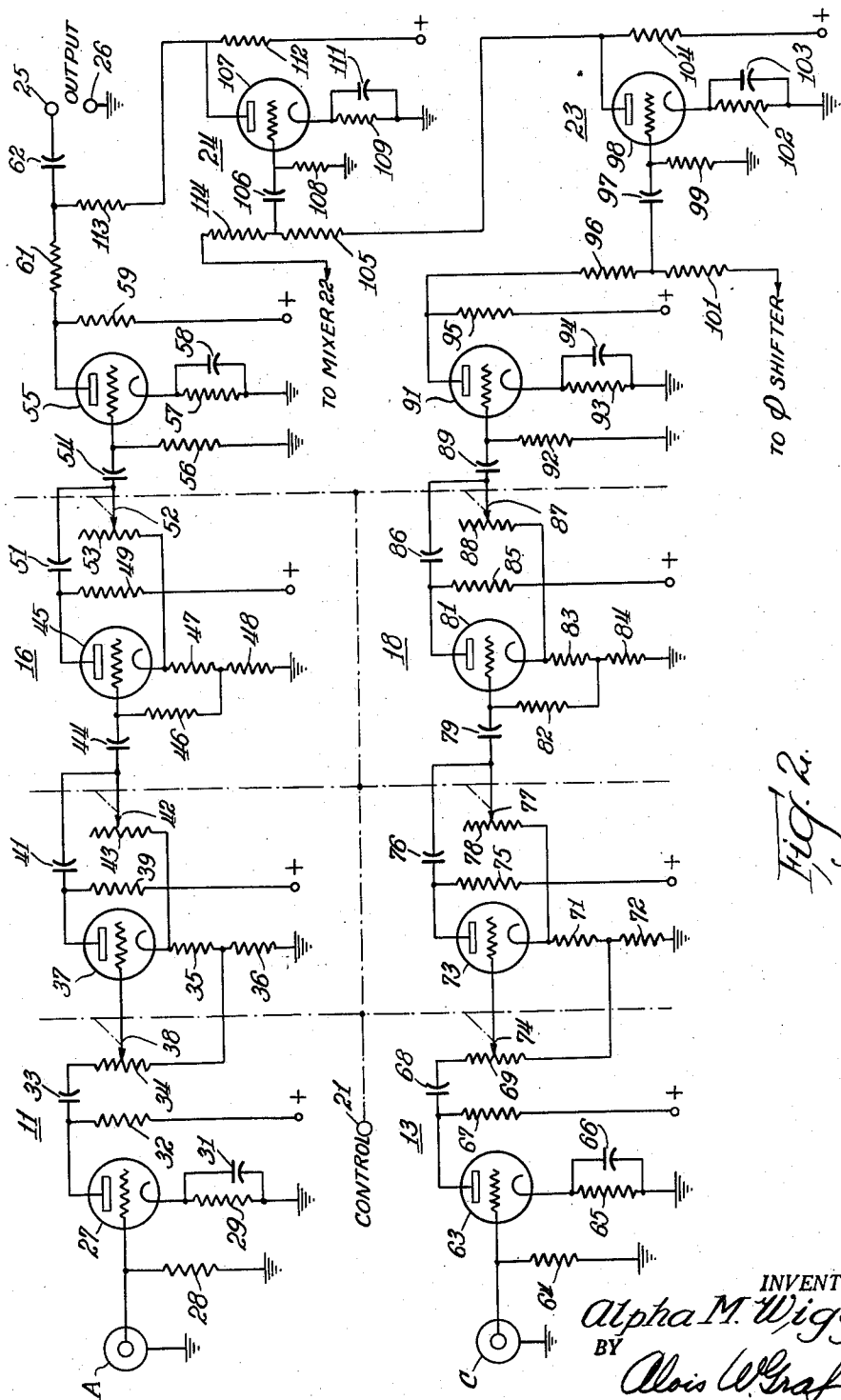


Fig. 2.

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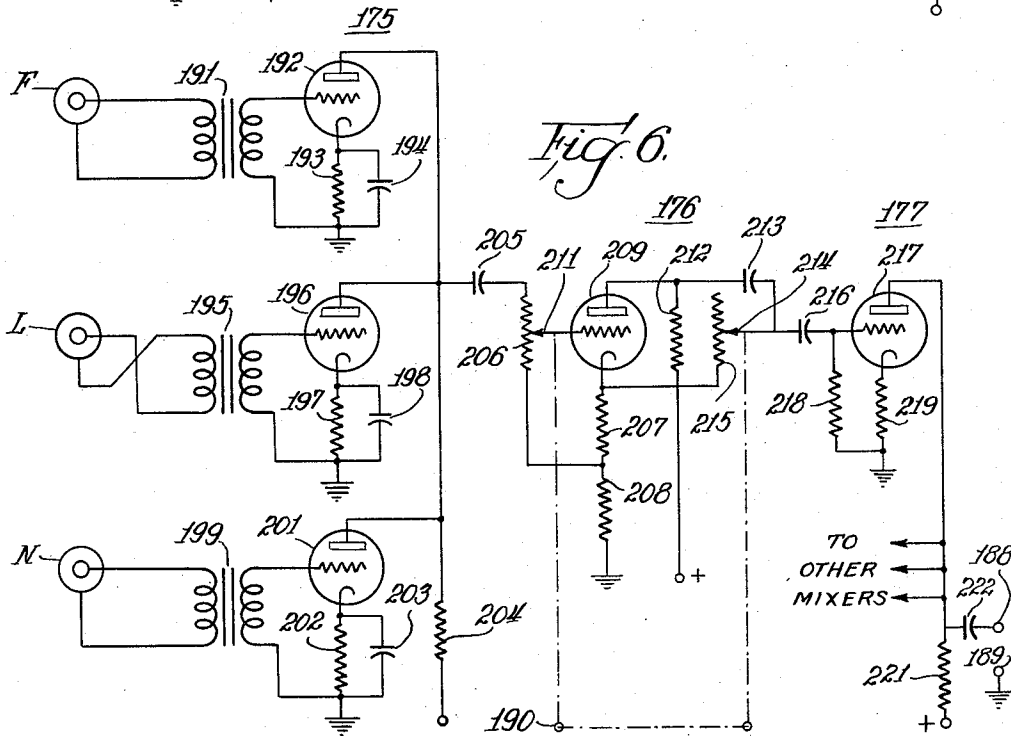
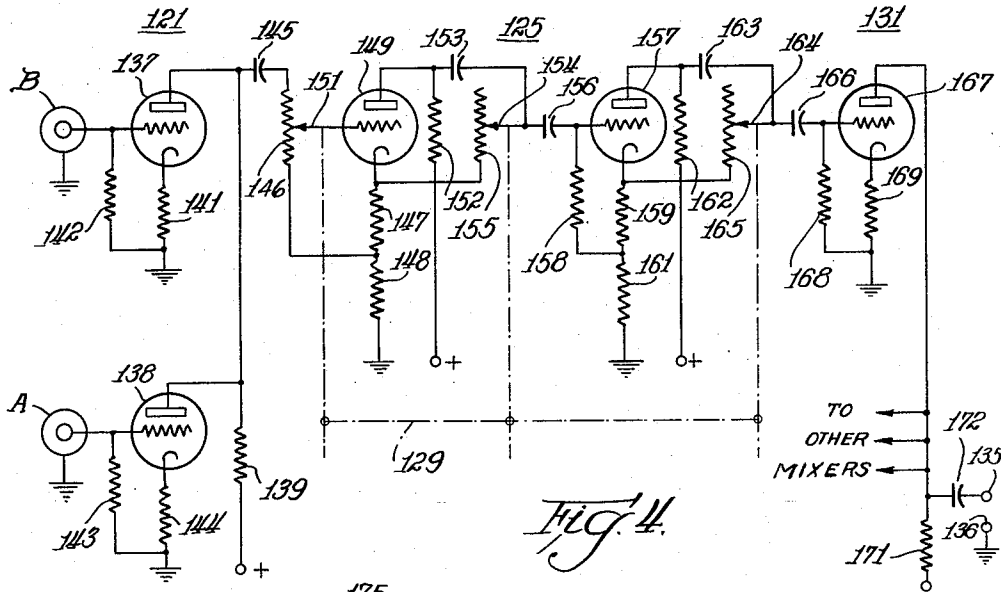
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4 Sheets-Sheet 3



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4 Sheets-Sheet 4

Fig. 7

$\cos \theta$

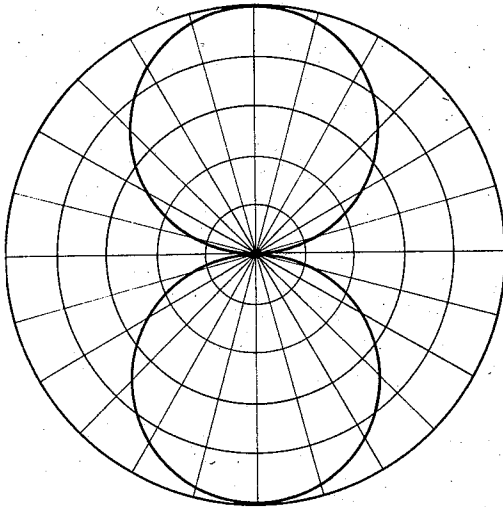
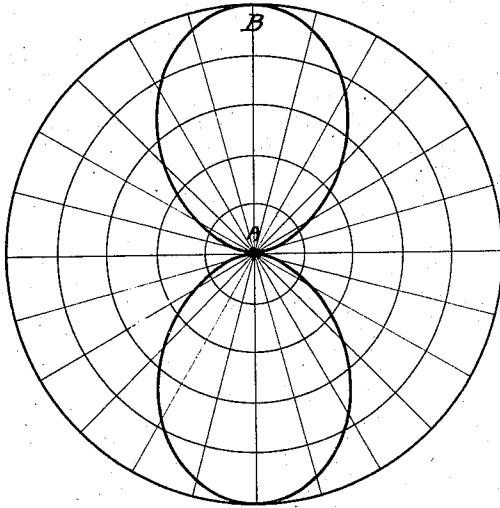


Fig. 8

$\cos^2 \theta$



$(1 + \cos \theta) \cos \theta$

B

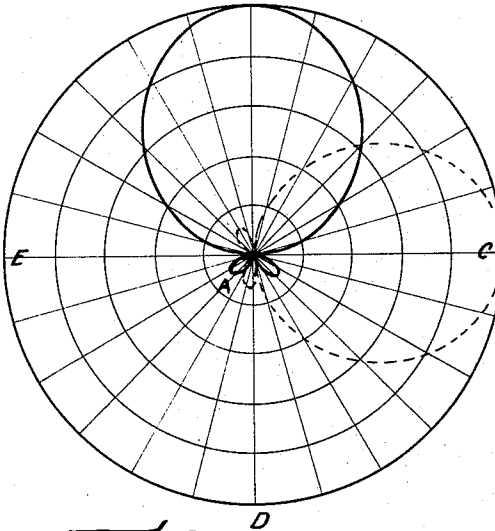


Fig. 9

$(a + b \cos \theta) \cos \theta$

B

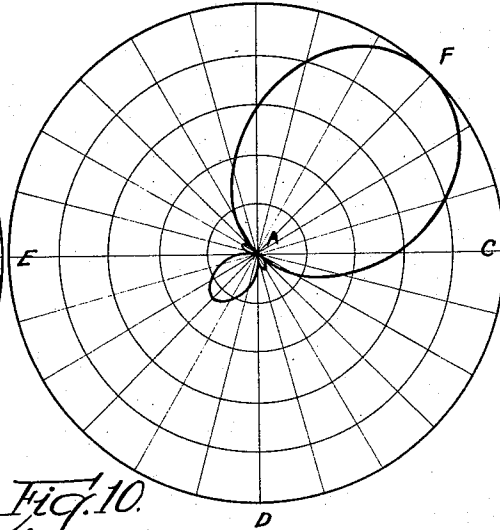


Fig. 10

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HIGHER ORDER PRESSURE GRADIENT MICROPHONE SYSTEM HAVING ADJUSTABLE POLAR RESPONSE PATTERN

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Application February 8, 1952, Serial No. 270,564

8 Claims. (Cl. 340—6)

The present invention relates to a higher order pressure gradient microphone system wherein the polar response pattern may be oriented as desired, either continuously or to a particular direction.

It frequently is desired to provide a microphone system for determining with accuracy the direction of a source of sound with respect to a point or to obtain an indication of the movement of a sound source. Heretofore, this generally has been accomplished by a relatively large heavy apparatus which is mechanically loaded for scanning. Such apparatus is rather expensive and requires a control mechanism which will produce movement of the apparatus at a steady rate without introducing undesired responses or noise into the microphone system.

It, therefore, would be desirable to provide a microphone system having a highly directional polar pattern which could be shifted or rotated as desired by the use of electrical circuit means thereby obviating the necessity for elaborate mechanical apparatus. In accordance with the present invention, it is proposed to arrange microphones in a pattern and to utilize electrical circuit means to differentially combine selected components from the several microphones to produce a highly directional polar pattern of desired orientation.

It, therefore, is an object of the present invention to provide a highly directional polar pattern in a higher order pressure gradient microphone system.

Another object of the present invention is to provide a higher order pressure gradient microphone system wherein the polar response pattern may be shifted as desired.

A further object of the invention is to provide a higher order pressure gradient microphone system arranged to utilize a directional polar pattern for scanning without mechanically moving the microphones.

Still another object of the invention is to provide a higher order pressure gradient microphone system to determine with accuracy the direction of a source of sound with respect to a point.

Still another object of the invention is to provide a pressure gradient microphone system of higher order to obtain an indication of the movement of a sound source.

Still another object of the invention is to provide a microphone system utilizing a plurality of microphones arranged in a pattern to obtain an adjustable pressure gradient polar response pattern.

These and other objects of the invention subsequently will become apparent by reference to the following description taken in conjunction with the accompanying drawings wherein:

Figure 1 is a block diagram of one higher order pressure gradient microphone system for obtaining an adjustable polar response pattern;

Figure 2 is a circuit diagram illustrating certain details of the system of Figure 1;

Figure 3 is another circuit diagram for a system for obtaining results similar to that obtained by the system shown in Figure 1;

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Figure 4 is a circuit diagram illustrating certain details of the system shown in Figure 3;

Figure 5 is another circuit diagram for obtaining a still higher order pressure gradient microphone system;

Figure 6 is a circuit diagram illustrating certain details of the system shown in Figure 5; and

Figures 7, 8, 9 and 10 are polar diagrams to aid in explaining the operation of the present invention.

Referring to Figure 1 of the drawings there is shown in the circuit diagram a plurality of microphones A, B, C, D and E arranged in a pattern. Preferably for the convenience of constructing the system and explaining the operation thereof these microphones are arranged at points in a symmetrical or geometrical figure. Thus the microphones B, C, D and E appear at the corners of a square whereas the microphone A is located at the intersection of the diagonals of the square. These microphones are arranged at a distance from each other bearing a selected relation to the wave lengths of the principal frequencies to which they are expected to respond. It will be appreciated that for certain purposes the construction and operation of the system contemplated can be simplified by selecting a frequency response band covering the principal sounds which are to be detected.

Each of the microphones A, B, C, D and E is connected to its respective amplifier 11, 12, 13, 14 and 15, the output of which is connected to the respective phase shifter and attenuator 16, 17, 18, 19 and 20. Each of the phase shifters and attenuators 16 to 20 is provided with one or more variable or adjustable circuit elements arranged to be operated in accordance with a common control mechanism 21. The control mechanism is not necessarily a unit control of all of these devices, but may be a servo system or sequence operation system so that at various times in a cycle of operation different amounts of phase shift and different degrees of attenuation are produced so that output voltage components of desired magnitude may be obtained.

Two of the phase shifters 17 and 21 are connected to a mixer 22. Similarly two other phase shifters and attenuators 18 and 19 are connected to a mixer 23. Thus, it will be seen that the four corner microphones B, C, D and E supply energy to the mixers 22 and 23. The outputs of the mixers 22 and 23 are combined in a mixer 24 which is connected to one of the output terminals 25, the other output terminal being connected to the ground. The phase shifter and attenuator 16 serving the microphone A has its output connected to the output terminal 25.

Before endeavoring to offer further explanation of the purpose and operation of the block diagram system shown in Figure 1, reference may be had to Figure 2 which illustrates certain circuit details. In Figure 2, there is shown the amplifier 11 which may be a triode vacuum tube 27 having its grid provided with a grounded resistor 28. The grid is also connected to a microphone jack A. The cathode of the vacuum tube 27 is provided with a grounded bias resistor 29 shunted by a bypass capacitor 31. Suitable anode potential is supplied to the vacuum tube 27 through an anode coupling resistor 32. The anode of the vacuum tube 27 is connected through a coupling capacitor 33 to one end of a voltage divider resistor or potentiometer 34 having its other terminal connected to the common junction between two cathode resistors 35 and 36 of a vacuum tube 37. The grid of the vacuum tube 37 is connected to an adjustable contact 38 of the voltage divider resistor 34. The vacuum tube 37 and its associated circuits is a part of the phase shifter and attenuator 16 shown in Figure 1, and the vacuum tube 11 and its associated circuits constitute the amplifier 11 of Figure 1. Suitable anode potential is

supplied to the vacuum tube 37 through an anode coupling resistor 39.

The anode of the vacuum tube 37 is connected to a coupling capacitor 41 which is connected to an adjustable contact 42 of a resistor 43 having one end connected to the cathode of the vacuum tube 37. The adjustable contact 42 is connected to a coupling capacitor 44 connected to the grid of a vacuum tube 45. The grid of the vacuum tube 45 is provided with a grid resistor 46 having one end connected between the common junction of two cathode resistors 47 and 48. Suitable anode potential is supplied to the anode of vacuum tube 45 through an anode coupling resistor 49. The anode of the vacuum tube 45 is connected to a coupling capacitor 51 which is connected to the adjustable contacts 52 of a resistor 53 having one end connected directly to the cathode of the vacuum tube 45. The adjustable contact 52 is connected to a coupling capacitor 54 which is connected to the grid of a vacuum tube 55. The vacuum tube 55 is provided with a grid resistor 56 connected to ground. The cathode of the vacuum tube 55 has a cathode biasing resistor 57 connected to ground which is by-passed by a capacitor 58. Suitable anode potential is provided for the vacuum tube 55 through an anode coupling resistor 59. The anode of the vacuum tube 55 is connected through a loading resistor 61 and a coupling capacitor 62 to the output terminal 25.

A microphone jack C is connected to the grid of a vacuum tube 63 having a grid resistor 64 connected to ground. The cathode is biased by a cathode resistor 65 which is by-passed by a capacitor 66. Anode potential is supplied to the vacuum tube 63 through an anode coupling resistor 67. The vacuum tube 63 and its associated circuits constitute the amplifier 13 shown in Figure 1.

The anode of the vacuum tube 63 is connected to a coupling capacitor 68 connected to one end of a voltage divider resistor 69 having its other end connected to the common junction between the cathode resistors 71 and 72 of a vacuum tube 73. The adjustable contact 74 of the resistor 69 is connected to the grid of the vacuum tube 73. Anode potential from a suitable source is supplied through an anode coupling resistor 75. The anode of the vacuum tube 73 is connected to a coupling capacitor 76 which is connected to an adjustable contact 77 of a resistor 78 having one terminal connected directly to the cathode of the vacuum tube 73. The adjustable contact 77 of the resistor 78 is connected through a coupling capacitor 79 to the grid of a vacuum tube 81. The grid of the vacuum tube 81 is provided with a grid resistor 82 having one end connected to the common junction between cathode resistors 83 and 84 of the vacuum tube 81. The anode is connected through a coupling capacitor 86 to an adjustable contact 87 of a resistor 88 having one end connected directly to the cathode of the vacuum tube 81.

The adjustable contact 87 of a resistor 88 is connected through a coupling capacitor 89 to the grid of a vacuum tube 91. The grid of the vacuum tube 91 is provided with a grid resistor 92 connected to ground. The cathode of the vacuum tube 91 is provided with a cathode bias resistor 93 which is by-passed by a capacitor 94. Suitable anode potential is supplied through an anode coupling resistor 95 to the vacuum tube 91.

The anode of the vacuum tube 91 is connected through a loading resistor 96 to a coupling capacitor 97 which is connected to the grid of a mixer tube 98. The grid of the mixer tube is provided with a grid resistor 99. The coupling capacitor 97 is connected to another loading resistor 101 which is connected to the phase shifter and attenuator 19 of the microphone D of Figure 1. It will be noted that the vacuum tubes 73, 81 and 91 together with their associated circuits constitute the phase shifter and attenuator 18 of Figure 1.

The cathode of the vacuum tube 98 is provided with a bias resistor 102 which is by-passed by a capacitor 103.

Anode potential is supplied to the vacuum tube 98 through an anode coupling resistor 104. The anode of the vacuum tube 23 is connected through a loading resistor 105 to a coupling capacitor 196 which is connected to the grid of a vacuum tube 107. The grid of the vacuum tube is provided with a grid resistor 108. The cathode of the vacuum tube 107 is provided with a grounded bias resistor 109 which is bypassed by a capacitor 111. Anode potential is supplied to the vacuum tube 107 through an anode coupling resistor 112. The anode of the vacuum tube 107 is connected through a loading resistor 113 to the juncture between the coupling capacitor 62 and the loading resistor 61. The grid of the vacuum tube 106 is connected through the capacitor 107 to a loading resistor 114 which in turn is connected to the mixer 22 of Figure 1. The vacuum tube 107 and its associated circuits constitutes the mixer 24 of Figure 1.

Since, however, the microphones B, C, D and E each have a circuit associated therewith similar to the circuit appearing in Figure 2 between the microphone jack C and the coupling capacitor 97 of the circuit of the mixer tube 98, it is not deemed necessary to show all the remaining circuits. The phase shifter and attenuator for the microphone C has adjustable contacts 74, 77 and 87 operating on their associated resistors and connected to be controlled by the control mechanism 21. Similarly the phase shifter 16 of the microphone A has adjustable contacts 38, 49 and 52 which likewise are controlled by the control mechanism or system 21.

It is well known that a pressure gradient microphone system may be constructed from two adjacent pressure microphones by placing them in tandem with their signal generating systems connected in opposition. This results in a first order pressure gradient microphone arrangement having polar response pattern generally corresponding to that shown in Figure 7.

A second order gradient microphone system can be obtained by using pressure microphones A, B and D of Figure 1. The output voltages of the microphones B and D are connected in series. Twice the output voltage of the microphone A is subtracted from this combined output. The resultant polar response characteristic will be similar to that shown in Figure 8 which curve is $\cos 2\theta$. It will be noted that the response characteristic has a maximum response in two directions from the point A. The response characteristic can be changed to a unidirectional one by introducing a phase shift in the outputs of the microphones B and D. An electrical phase shifting network whose phase shift is proportional to frequency is connected to the output of the microphone D to produce a lead in phase equal to the lead in phase produced from sound travelling from the position of the microphone D to the microphone B. A similar phase shifting circuit is connected to the microphone B to produce a lag in phase equal to the lag in phase produced by sound travelling the distance between the microphones A and B. The resultant polar response characteristic is represented by a polar curve shown in Figure 9 which is $(1 + \cos \theta) \cos \theta$.

From the foregoing it becomes apparent that another unidirectional response can be obtained from the microphones EAC at right angles to that obtained from the microphones BAD. This is shown by the dotted line representation in Figure 9. By suitable control of the amplitude of the voltage components derived from each microphone output and the phase shifting circuit with respect to the microphones B, C, D and E a similar polar response curve can be obtained, as illustrated by Figure 9; which will have its maximum pick up at any selected angle as determined by the amount of phase shift introduced by the various circuits and the magnitudes of the voltage components derived from the outputs of the several microphones.

When microphones B and D are connected differentially and microphones D and A are also connected dif-

ferentially through a phase shift network to microphones B and D, the equation for the polar pattern of the combination will be $(a+b \cos \theta) \cos \theta$; wherein a and b are factors dependent on the amount of phase shift. When this phase shift is equal to the phase shift produced by sound travelling between the microphone combinations BD and DA, factors a and b become equal to one. From this combination a polar pattern

$$(1+\cos \theta) \cos \theta$$

as shown in Figure 9 results. The difference between this condition and a partial phase shift is illustrated by the representation of the response characteristic in Figure 10. It will be noted that this is a unidirectional response which gives a result comparable to that shown in Figure 9. This, therefore, indicates that a certain latitude in the control of the several phase shift circuits shown in Figure 1 is possible and yet a unidirectional polar response characteristic can be obtained which may be shifted through 360° .

Reference may now be had to Figure 3 which shows another block diagram of an arrangement for obtaining response characteristics similar to that obtained by the system shown in Figure 1. For convenience in comparing this arrangement with that shown in Figure 1, five microphones again have been utilized at the locations A, B, C, D and E. The microphones B, C, D and E are connected respectively to mixer amplifiers 121, 122, 123 and 124. The microphone A is connected to each of these four mixer amplifiers. Each of these mixer amplifiers 121 through 124 is connected to one of the phase shifters 125, 126, 127 and 128 which are subject to a control 129. These phase shifters and attenuators 125 to 128 are connected through mixers 131 through 134 to the output terminal 135, the other output terminal 136 being connected to ground.

Since the circuit arrangement for each of the microphones B, C, D and E is the same it will be necessary only to illustrate the circuit arrangement for one of these microphones as shown in Figure 4. From this it will be seen that the mixer amplifier 121 has two tubes 137 and 138 having their anodes connected together and having a common anode coupling resistor 139 which in turn is connected to a suitable source of anode potential. The cathode of the vacuum tube 137 is connected to a bias resistor 141 which in turn is connected to ground. The grid of the vacuum tube 137 is connected to a grid resistor 142 which also is connected to ground. The grid of the vacuum tube 137 is connected to the microphone jack B.

The vacuum tube 138 has its grid connected to the microphone jack A and to a grid resistor 143 which is connected to ground. The cathode of the vacuum tube 138 is connected to a bias resistor 144 which is also connected to ground. The anodes of the vacuum tubes 137 and 138 are connected to a coupling capacitor 145 which is connected to one terminal of a resistor 146 having its other terminal connected to the juncture between cathode biasing resistors 147 and 148 of a vacuum tube 149. One end of the cathode resistor 148 is connected to ground. The grid of the vacuum tube 149 is connected to an adjustable contact 151 of a resistor 146. Suitable anode potential is supplied to the vacuum tube 149 through the anode coupling resistor 152. The anode of the vacuum tube 149 is connected to a coupling capacitor 153 which is connected to an adjustable contact 154 of a resistor 155 which has one end connected directly to the cathode of the vacuum tube 149.

The adjustable contact 154 of the resistor 155 is connected through a coupling capacitor 156 to the grid of a vacuum tube 157. The grid of the vacuum tube 157 has a grid resistor 158 which is connected to the juncture between cathode biasing resistors 159 and 161 which are connected between ground and the cathode 157.

Anode potential is supplied to the vacuum tube 157 from the anode source through a coupling resistor 162. The anode is connected through a coupling capacitor 163 to the adjustable contact 164 of a resistor 165 having one end connected directly to the cathode of the vacuum tube 157. The vacuum tubes 149 and 157 constitute the phase shifter and attenuator 125 of Figure 3.

The adjustable contact 164 of the resistor 165 is connected through a coupling capacitor 166 to the grid of a vacuum tube 167. The grid is also connected to a grid resistor 168 having one end connected to ground. A cathode biasing resistor 169 is connected between ground and the vacuum tube 167. The anode of the vacuum tube 167 is connected to the anodes of three similar tubes of mixers 132, 133 and 134. The vacuum tube 167 and its associated circuits constitutes the mixer 131 of Figure 3. All of these mixers have a common anode coupling resistor 171 and they are connected to a coupling capacitor 172 which is connected to one of the output terminals 135. The adjustable contacts 151, 154 and 164 of the resistors 146, 155 and 165 are operated by the control 129. This control determines the amount of phase shift and attenuation in order to produce the polar response characteristic at a desired orientation.

From the foregoing it will become apparent that in Figure 3 the outputs of mixers B, C, D and E are each mixed differentially with the output of microphone A to produce a bi-directional pressure gradient response such as that shown in Figure 8. After passing through the phase shifters and attenuators these combined voltages are again mixed differentially to produce a directional characteristic comparable to those illustrated in Figures 9 and 10. The general form of the resultant polar response characteristic is $(a+b \cos \theta) \times \cos \theta$ where θ is the angle measured from the angle of maximum pick up.

Thus, it will be appreciated that by means of electric control and without any mechanical movement other than the adjustable resistor contacts shown in Figures 2 and 4 an action can be obtained similar to that previously produced by mechanical systems which rotated two spaced apart microphones. In addition, the present invention contemplates successive differential combinations of the outputs of the microphones to provide still higher orders of directional response. Thus, higher orders of pressure gradient microphone systems can be obtained than as was possible by the mechanical systems.

An example of a still higher order system of pressure gradient response is shown in the block diagram of Figure 5. In this arrangement, a larger number of microphones is employed which for sake of illustration are arranged along the diagonals of a square or along two lines perpendicular to each other. Four microphones F, G, H and K are arranged at the corners of a large square. Four other microphones L, M, N and O are arranged at the corners of a smaller square symmetrically arranged within the larger square. Components of the outputs of microphones F, L and N are supplied to a mixer 175, the output of which is fed to a phase shifter and attenuator 176 which in turn is connected to a mixer 177.

The outputs of microphones G, M and O are supplied to a mixer 178 which is connected to a phase shifter 179 supplying energy to a mixer 181. Outputs from the microphones H, N and L are connected to a mixer 182 which supplies energy to a phase shifter 183 which in turn is connected to a mixer 184. Outputs from the microphones K, O and M are supplied to a mixer 185 which is connected to a phase shifter 186 which in turn supplies energy to a mixer 187. The several mixers 177, 181, 184 and 187 are connected to one of the output terminals 188, the other output terminal 189 being connected to ground.

An illustration of the circuit arrangement employed in Figure 5 is shown in Figure 6. The microphone jack

F for the microphone F is connected to a transformer 191 having its secondary winding connected to the grid of a vacuum tube 192. The cathode of the vacuum tube 192 is connected to a bias resistor 193 which is bypassed by a capacitor 194.

The anodes of the vacuum tubes 192, 196 and 201 are connected together and receive anode potential through a common resistor 204. These anodes are also connected to a coupling capacitor 205 which is connected to one terminal of a resistor 206 having its other terminal connected to cathode biasing resistors 297 and 208 at a vacuum tube 209. The grid of the vacuum tube 209 is connected to an adjustable contact 211 of the resistor 206. Suitable anode potential is supplied to the vacuum tube 209 through an anode coupling resistor 212. The anode of the vacuum tube 209 is connected to a capacitor 213 which is connected to the adjustable contact 214 of a resistor 215 having one end connected directly to the cathode of the vacuum tube 209. The adjustable contact 214 of the resistor 215 is connected to a capacitor 216 which is connected to the grid of a vacuum tube 217. The grid of the vacuum tube 217 is connected to a grid resistor 218 having one end connected to ground. The cathode of the vacuum tube 217 is provided with a grid bias resistor 219 having one end connected to ground.

The several vacuum tubes 192, 196 and 201 comprise the mixer 175 of Figure 5. The vacuum tube 209 and its associated circuits comprise the phase shifter and attenuator 176. The vacuum tube 217 and its associated circuits comprise the mixer 177. The anodes of the vacuum tubes in the various mixers 177, 181, 184, and 187 are all connected together as indicated in Figure 6 and receive suitable anode potential through an anode coupling resistor 221 which is connected through a capacitor 222 to the output terminal 188. The adjustable contacts 211 and 214 of the resistors 206 and 215, respectively, are actuated by the control 190.

In view of the explanation given in respect to the preceding figures, it is believed that no lengthy detailed explanation of the operation of Figures 5 and 6 is required. It was noted that the outputs of two microphones could be combined to produce a response characteristic similar to that shown in Figure 8 dependent upon what type of microphones were employed. From the preceding circuit arrangements, it further became apparent that such combination of voltages resulting in responses similar to that shown in Figure 8 could be combined with a voltage component of another microphone to produce the unidirectional response shown in Figure 9. By proper selection of the magnitude of the voltage components from the several microphones, the proper resultant voltage will be derived from mixing components from each of the groups of microphones, as for example the microphones F, L and N. The introduction of attenuation and phase shift and the subsequent mixing of the resultant voltage components by the mixers 177, 181, 184 and 187 accordingly will produce a higher order gradient response than was heretofore possible by the circuits of Figures 1 and 3. By proper design, the control 190 will operate to produce the desired highly directional unidirectional response characteristic which can be orientated along any angle or which may be moved in a scanning fashion throughout 360°.

While for the purpose of illustrating and describing the present invention several particular embodiments have been shown and described in the drawings, it is to be understood that the invention is not to be limited thereto since such other embodiments are contemplated as may be commensurate with the spirit and scope of the invention set forth in the accompanying claims.

I claim as my invention:

1. A higher order pressure gradient microphone sys-

tem comprising a plurality of spaced pressure microphones symmetrically arranged along a plurality of intersecting axes, means for variably shifting the phase and differentially combining the outputs of said microphones to produce a highly directional polar response pattern in any desired direction.

2. A higher order pressure gradient microphone system comprising a plurality of spaced pressure microphones symmetrically arranged along a plurality of intersecting axes having equal angles therebetween, means for variably shifting the phase and differentially combining the outputs of said microphones to produce a highly directional polar response pattern, and means for controlling simultaneously all said phase shifting means to rotate said polar response pattern.

3. A higher order pressure gradient microphone system comprising a plurality of spaced pressure microphones symmetrically arranged along a plurality of intersecting axes having equal angles therebetween, means for differentially combining the outputs of a plurality of microphones along each axis, means for simultaneously variably shifting the phase of said combined outputs, and means for differentially combining said phase shifted outputs to produce a highly directional polar response pattern.

4. A higher order pressure gradient microphone system comprising a plurality of spaced pressure microphones symmetrically arranged along a plurality of intersecting axes having equal angles therebetween, means for differentially combining the outputs of a plurality of microphones along each axis, means for variably shifting the phase of said combined outputs, and means for differentially combining said phase shifted outputs to produce a highly directional polar response pattern, and means for controlling simultaneously all said phase shifting means to adjust said directional polar response pattern to selected orientation.

5. A higher order pressure gradient microphone system comprising a plurality of spaced pressure microphones arranged in a pattern having at least two dimensions, a plurality of phase shifting networks for selectively shifting the phase of the outputs of said microphones, means for differentially combining said phase shifting outputs, and means for adjusting simultaneously all of said phase shifting networks to produce a highly directional polar response pattern of selected orientation.

6. A higher order pressure gradient microphone system comprising a plurality of spaced pressure microphones arranged in a pattern having at least two dimensions, a plurality of phase shifting networks for selectively shifting the phase of the outputs of said microphones, means for differentially combining said phase shifted outputs, and means for continuously adjusting all of said phase shifting networks to produce a rotating highly directional polar response pattern.

7. A higher order pressure gradient microphone system comprising a plurality of spaced pressure microphones symmetrically arranged along a plurality of intersecting axes, one of said microphones being at said intersection, means for shifting the phase and combining the outputs of said other microphones with the output of said microphone at said intersection to produce highly directional polar response patterns of desired orientation.

8. A higher order pressure gradient microphone system comprising a plurality of spaced apart pressure microphones arranged in a pattern having at least two dimensions, and means for shifting the outputs of said microphones relative to one microphone output and differentially combining components from said microphone outputs.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

July 21, 1959

Patent No. 2,896,189

Alpha M. Wiggins

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 3, line 15, for "contacts" read -- contact --; column 4, line 4, after "capacitor" for the numeral "196" read -- 106 --; line 13, for "tube 106" read -- tube 107 --; line 14, for "capacitor 107" read -- capacitor 106 --; line 31, for "construction" read -- constructed --.

Signed and sealed this 1st day of March 1960.

(SEAL)

Attest:

KARL H. AXLINE

Attesting Officer

ROBERT C. WATSON
Commissioner of Patents

UNITED STATES PATENT OFFICE
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