May 18, 1954 H. GROSSKOPF 2,678,967

CAPACITY MICROPHONE WITH VARIABLE DIRECTIONAL CHARACTERISTIC

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Fig. 1

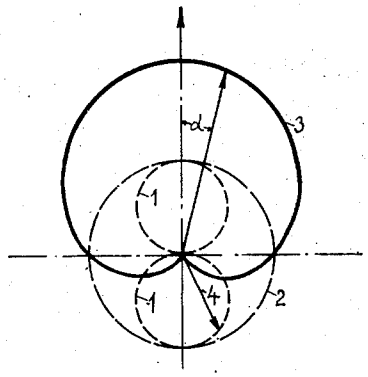


Fig. 2

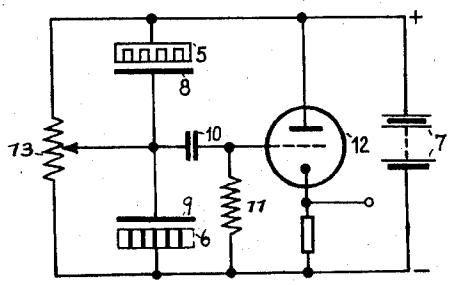
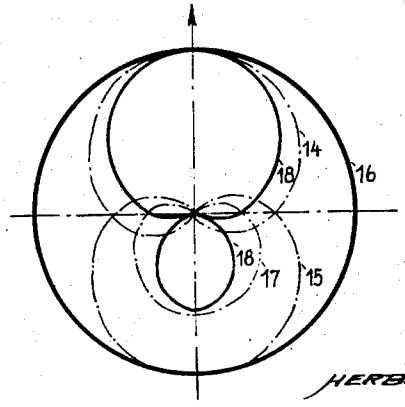


Fig. 3



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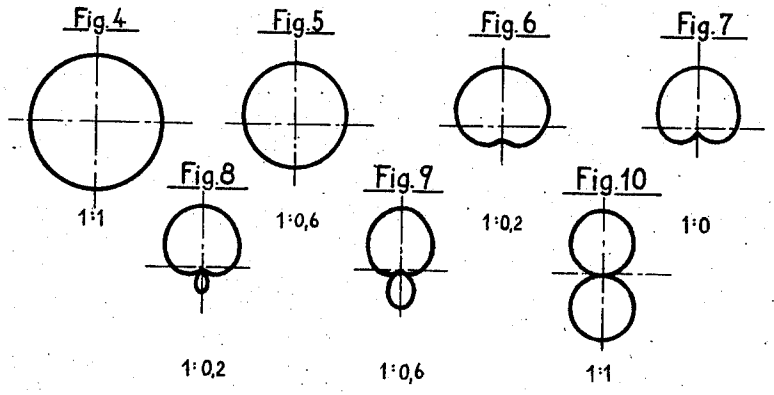


Fig.11

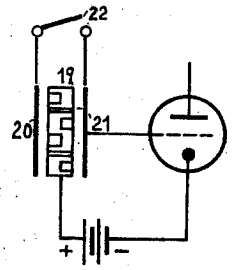


Fig.12

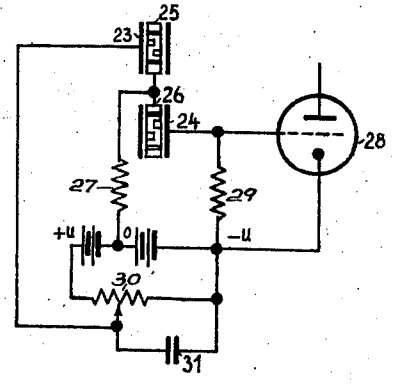
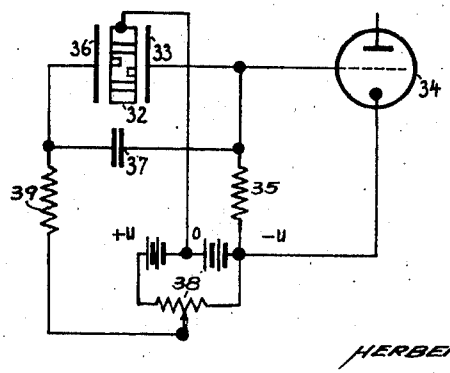


Fig.13



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CAPACITY MICROPHONE WITH VARIABLE DIRECTIONAL CHARACTERISTIC

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8 Claims. (Cl. 179—1)

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This invention relates to a capacity microphone in which a plurality of single microphones are connected together to form a combination having a variable directional characteristic.

Among the efficient microphones the capacity microphone is especially suitable owing to its small dimensions for the production of directional characteristics having a favourable sound input in one or two directions. Such characteristics are known in practice as "kidney" (cardioid) or "eight" characteristics. The directional reception of sound with such microphones is often very advantageous. Thus, for instance, with a directional microphone one is able to reduce the effect of excessive echo on the input side or to substantially increase the distance between the source of sound and the microphone in ordinary rooms owing to the smaller input of sound without the sound pattern being wiped out. In practice one tries to ascertain in individual cases which one of the three characteristics should be selected. It is therefore a pressing requirement in the technique of sound to be able readily to exchange microphones of different characteristics.

Since a capacity microphone has always to be connected with an amplifier, it is nowadays usual to connect the capacity systems (capsules) with the amplifier by means of a plugging-in device so that they can be exchanged. For these reasons it is understandable that endeavours were made to construct microphones, the characteristic of which could be altered simply by operating a switch. As regards capacity receivers only one microphone of this kind has hitherto been used. With such a microphone it is possible to switch over from a circular to a cardioid characteristic, however, with the switching over the sensitiveness is also altered. This is undesirable since if one wishes to observe directly the action of the change of direction of a microphone, it is required that the sound coming from the main direction, thus for instance directly from the sounding body in spite of the change of the directional characteristic, shall be taken up by the microphone unchanged, and actually only the sound coming from the other directions shall be taken up in changed intensity. Moreover, the change in sensitiveness causes in most cases a subsequent regulation in the amplification.

By the present invention it is possible to produce a microphone which not only combines in one system the three microphones used in practice with circular cardioid and "eight" characteristics, but in addition thereto, it enables, with

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the same sensitiveness in the main direction, to effect a gradual transition from the circular to the cardioid and to the "eight" characteristic.

The invention consists in this that the individual microphones are connected together with respect to alternating voltage but are separated from one another with respect to continuous current voltage, so that the voltage biases of the individual microphones are independent of one another, and consequently the directional characteristic of the combination varies gradually or in steps from one directional characteristic to several others. In order to avoid a change in sensitiveness of the combination in the main direction, the voltage bias of the individual microphones is suitably varied in each case. The invention also relates to further details, inter alia to: the use of a microphone known per se with a perforated plate and two electrically conducting diaphragms mounted in an insulated manner, as a combination of two cardioid microphones; further, various kinds of alternating voltage connections of the individual microphones of the combination; also various means for effecting the variations of the directional characteristic as well as the control of the directional characteristic from a distance. Since these variations are effected by the regulation of a continuous current voltage, the directional characteristic can be controlled from a distance.

The invention is illustrated by way of example in the accompanying drawings.

Figure 1 shows the production of a cardioid characteristic from a circular and an "eight" characteristic.

Figure 2 shows a fundamental diagram of connections for a microphone with variable directional characteristic consisting of an "eight" and a cardioid microphone.

Figure 3 shows the production of a characteristic of a combination of microphones consisting of two cardioid microphones arranged in opposite directions.

Figures 4 to 10 show characteristics produced by different conditions and polar dispositions of the voltage biases.

Figure 11 is a fundamental diagram of the known microphone consisting of one electrode and two diaphragms and capable of being switched over.

Figure 12 is a fundamental diagram of a microphone with variable directional characteristic using two cardioid microphones arranged in opposite directions.

Figure 13 is a fundamental diagram of a mi-

crophone with variable directional characteristic using the microphone of Figure 11.

As regards Figures 1 and 3 they show the generally used representation of a directional characteristic in a system of polar co-ordinates. The co-ordinates provided with an arrow represent the main direction. The vector under the angle α from the zero point to the curve represents the sensitiveness of the microphone for a sound incidence from the direction α (Figure 1).

As is well known, the sensitiveness of a condenser microphone is directly proportional to the applied direct current voltage. The greater the applied continuous current voltage the greater is the load applied to the microphone. If, for instance, the capacity is increased by approaching the diaphragm towards the counter-electrode the continuous current voltage on the microphone drops, and if the diaphragm moves away from it, the voltage increases. When the diaphragm fluctuates around the position of rest, the voltage fluctuations around the value corresponding to the position of rest will be the greater, the greater the continuous current voltage itself. Further, it can easily be seen, that the fluctuations in the continuous current voltage, which do not represent anything else but the alternating current voltage that is applied, are turned through a phase angle of 180°, if the sign of the continuous current voltage is changed. One is thus able to change the amplitude of the applied alternating current voltage by the value of the amplitude of the continuous current voltage that is applied, and by changing the polarity of the continuous current voltage, to change the phase of the applied alternating current voltage through an angle of 180°.

The characteristic feature of the present invention is that a change in the directional characteristic has not been released by a switching operation, but that the amplitude of the applied alternating current voltage of a condenser microphone is continuously varied by variation of its voltage bias, and the phase of the alternating current voltage is varied by the change in polarity of the voltage bias, whereby a change in the directional characteristic is obtained in a combination of individual microphones.

It is known to obtain a plurality of directional characteristics by connecting together two or more microphones of different directional characteristics, so long as the whole of the system is small compared with the wave-length of the highest frequency to be transmitted. In all these cases of a capacity microphone, the regulation of the voltage bias provides a simple means for continuously varying the directional action, by the thereby effected change in sensitiveness and in phase, if, according to the invention, the microphones are separated with respect to the continuous current voltage but are connected together with respect to the alternating current voltage. Fundamentally, this may be effected in various ways; for instance by means of a battery (according to Figure 2), a condenser (according to Figure 13) or by the internal capacity resistance of the microphones (according to Figure 12).

If, for instance, a microphone with an "eight" characteristic is placed directly in the proximity of a microphone with a circular characteristic, one is thereby enabled to obtain characteristics between the circular, cardioid and "eight" formations, if the sensitiveness of the two microphones is adjusted by their voltage bias. If the voltage bias of the microphones is so adjusted that both have the same sensitiveness in the main direction, one obtains by their being connected together the combined characteristic of a cardioid. This is represented in Figure 1, which shows how by the addition of the "eight" characteristic **1** and circular characteristic **2** of two microphones of the same sensitiveness in the main direction, a cardioid characteristic **3** with double sensitiveness in the main direction is obtained. Since an "eight" microphone responds to pressure differences between the front and rear of the microphone, the movement of the diaphragm reverses its phase, if the microphone is excited from the rear. Therefore, the vectors for the rear half of the "eight," for instance the vector **4**, are to be represented as negative. If the voltage bias of the one microphone is altered from the adjusted value to zero, the cardioid **3** of Figure 1 passes gradually into the characteristic of the microphone, the voltage bias of which has not been altered.

If it is desired to avoid the variations (more particularly increases) of the sensitiveness in the main direction, which variations arise when the directional characteristic varies, this can be attained according to the invention by this, that the voltage bias of the one microphone is increased exactly to the same extent as that of the other one is decreased. This can be obtained for instance according to Figure 2 by means of a single potentiometer. In Figure 2 the electrode **5** of a microphone with a circular characteristic (pressure receiver) is connected to the positive pole of a battery **7**, and the electrode **6** of a microphone with an "eight" characteristic (pressure gradient receiver) with the negative pole thereof, which battery effects at the same time the connection of the two electrodes with respect to the alternating current voltage. The diaphragms **8** and **9** of the two microphones are connected, over a condenser **10**, with the leak resistance **11** and the grid of a tube **12**, only with respect to the alternating current voltage, so that their continuous current voltage potential can be varied by means of a potentiometer **13** from the minus to the plus battery voltage, the voltage bias of the one microphone being increased exactly to the same extent as that of the other one is decreased. The separation on the continuous voltage side and the connection on the alternating current side is effected in this case by the source of voltage.

The same number of characteristics are obtained also by using two microphones with cardioid characteristic the maximum sensitiveness of which lies in opposite direction. If these two microphones are connected, in the manner previously described, only with respect to the alternating current voltage so that the two microphones obtain different voltage biases, it is possible, by changing the amplitude of the voltage bias of only one of the microphones, to effect a difference in the directional action of the reception of the sound from all sides with respect to the preferred one or two sides, while maintaining the same sensitiveness in the main direction. Figure 3 illustrates this action with respect to two cardioids in opposite directions. To a decrease of the voltage bias there corresponds a reduction in the corresponding cardioid. The combined characteristic results for the same sign of polarity from the addition and for different signs of polarity from the subtraction of the two characteristics. The cardioids **14** and **15** shown in Figure 3 represent the characteristics of two

oppositely directed cardioid microphones with the same voltage bias, the combined characteristic of which results in the circle 16. The ratio of the dimensions of the cardioids 14 and 17 is 1:0.6 corresponding to the same ratio of the voltage biases. 18 is the difference of the two cardioids, corresponding to unlike polarities of the two voltage biases. One can easily recognise the development of the "eight" characteristic, which is obtained for the same voltage biases of unlike polarities.

Figures 4 to 7 show the characteristics which are obtained (according to Figure 3) for like polarity and different ratios of the voltage biases.

Figures 8 to 10 show the characteristics which are obtained (according to Figure 3) with unlike polarities for different ratios of the voltage biases. Figures 4 to 10 clearly shows the transitions from the circular form through the cardioid form to the "eight" form.

The types with circular, "eight" and cardioid characteristic exclusively used in practice are the simplest forms of a directional characteristic. In order to obtain a directional action independent of frequency, it is necessary in each case that the receiver shall be small with respect to the wave lengths of the highest frequency to be transmitted. A circular characteristic (receiving sound from all sides) is obtained if use is made of a microphone responding only to pressure, and an "eight" characteristic (reception of sound from both sides) is obtained by means of a microphone which responds to the pressure difference between two closely adjacent points in the field of the sound or to the speed. In order to obtain a cardioid characteristic (reception of sound from one side) the microphone has to respond to pressure as well as to pressure difference or to the speed.

For instance, a microphone such as shown in Figure 11 is known. A counter-electrode 19 partly perforated and partly provided with sack-like recesses carries on each side, insulated therefrom, an electrically conducting diaphragm 20 and 21, respectively. If only one diaphragm 21 is electrically effective, a cardioid microphone is produced, and if the two diaphragms are connected together one obtains a microphone with a circular characteristic. The production of the characteristic can be explained, for instance, as follows: The pressure of the sound waves, which is independent of distance, moves both diaphragms thereby compressing the enclosed volume of air; the pressure difference between the front and rear of the microphone (pressure gradient), which is a maximum in the direction of the sound waves, moves the two diaphragms by merely displacing the air volume parallel to each other, whereby the one diaphragm moves away from the electrode and the other one towards it. The two movements are superposed so that the capacity change of one diaphragm is produced by the pressure as well as by the pressure gradient. The microphone obtains a cardioid characteristic. If the two diaphragms are connected together, the capacity changes of the two diaphragms are added together; the capacity changes of the two diaphragms produced by the pressure gradient are thus in opposite phase and they cancel each other. Thus the remaining capacity change is due to pressure only. The microphone has a circular characteristic.

The above-mentioned microphone with switched over characteristic is so arranged, that the diaphragms can be connected together or

be separated by a switch 22. If such a microphone is connected up as a cardioid microphone, the connected up diaphragm 21 effects the greatest movement, if it faces the source of sound. Therefore, corresponding to the cardioid characteristic, it must remain at rest if it faces away from the source of sound. Assuming that the diaphragm 21 faces the source of sound and that the other diaphragm 20, which then is at rest, is connected up, then only the capacity is doubled but not the capacity change. The sensitiveness must then drop to half the value.

Two cardioid microphones, for instance, of the kind shown in Figure 11, may be connected together. The principle of connections for this arrangement is shown in Figure 12. The two connected diaphragms 23 and 24 face away from each other, so that their characteristics are in opposition. The two electrodes 25 and 26 are connected jointly, over a resistance 27, to zero potential. The diaphragm 24 is connected to the grid of the tube 28 and lies over the leak resistance 29 on the potential minus U. The potential of the diaphragm 23 can be changed by means of the potentiometer 30 from minus U to plus U. A condenser 31 connects the diaphragm 23 with respect to alternating current voltage to minus U. The separation with respect to the continuous voltage and the connection with respect to the alternating voltage is effected in this case by the internal resistance of the microphones.

If we bear in mind, however, that when the one diaphragm of a microphone according to Figure 11 effects with the counter-electrode a cardioid characteristic, and owing to the symmetrical assembly the other diaphragm must effect with the counter-electrode a similar characteristic, but in opposite direction, we can easily see that even such a microphone alone represents an ideal combination of two cardioid microphones, by means of which one can produce a continuous variation in the directional characteristic. The fundamental diagram of connections of Figure 13 shows how the voltage bias of the one diaphragm can be changed independently of the other. In this case the electrode 32 with the sack-like holes and full holes lies on the zero-potential. The diaphragm 33 is connected with the grid of the tube 34, which receives the potential minus U over a resistance 35. The potential of the diaphragm 36, which is connected with respect to the alternating current voltage with the diaphragm 33 over the condenser 37, can be changed by means of the potentiometer 38 from minus U to plus U. The resistance 39 prevents a short circuit of the grid on the alternating voltage side taking place over the comparatively low resistance potentiometer. The permanent connection of the two diaphragms with respect to the alternating current by means of the condenser avoids a change in the sensitiveness which would otherwise be produced by the switching over (according to Figure 11).

The potentiometers shown in Figures 2, 12 and 13 may also be replaced by a stepped switch, and since by this means only continuous current voltages are varied they can be mounted at any desired point separated from the actual microphone, whereby a control of the directional characteristic can be effected from a distance.

This is especially an advantage when a microphone is mounted at points which are not readily accessible and the directional characteristics have to be changed. Since the sound action of

a space can be influenced by the directional characteristic on the reception side, and this should take place according to the invention not only between two limits, but also with gradual transition between them, the control from a distance further enables one to observe the acoustic action of the varying characteristics and adjust it on the optimum value directly at the point of control, for instance in the case of radio, in the control room, as regards its acoustic action. Since such a microphone combines all the characteristics nowadays used in practice, one can dispense in the construction of the microphone with a separation of the capsules and amplifiers, since the capsules have no longer to be exchanged and one can assemble the two in one enclosure, whereby the dimension of the microphone, which nowadays is still substantial, can be greatly reduced. As regards storing, the obtention of only one microphone instead of the three different ones hitherto used, means a substantial economy.

I claim:

1. A microphone having variable direction characteristics comprising a plurality of microphone condensers, a source of direct current, separate circuits connecting said source to an electrode of each condenser, a common alternating current output circuit from the other electrode of such condensers, and means to vary individually and inversely the voltage bias in said direct current circuits while maintaining constant the voltage in the output circuit.

2. In a microphone as claimed in claim 1, one of said condensers comprising a pressure operated transducer and the other a pressure-difference operated transducer.

3. A microphone as claimed in claim 1, in which said microphone condensers have cardioid characteristics, the maximum sensitivities of which extend in opposite directions.

4. A microphone as claimed in claim 3 in which said two condensers include a common electrode formed of a perforated metallic plate and electrically conducting insulated membranes symmetrically positioned on opposite sides of said plate.

5. A microphone according to claim 1, in which the output circuit includes a condenser.

6. A microphone according to claim 1, in which the output circuit includes the direct current source.

7. A microphone according to claim 1, in which said voltage bias varying means is a potentiometer.

8. A microphone according to claim 1, in which said voltage bias varying means operates step by step.

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