

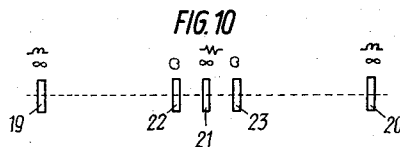
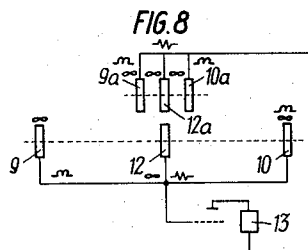
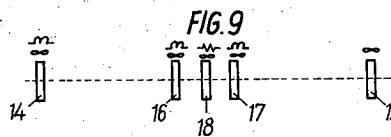
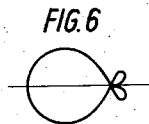
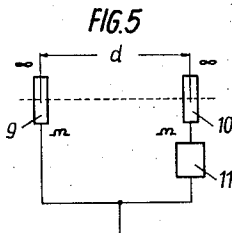
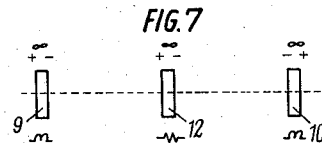
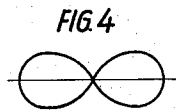
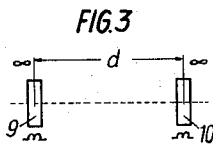
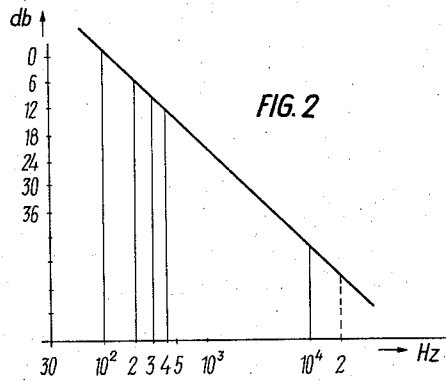
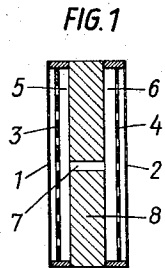
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R. GÖRIKE

3,146,308

CAPACITOR MICROPHONES

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INVENTOR:
RUDOLF GÖRIKE
BY *Karl F. Pörn*
AGENT.

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CAPACITOR MICROPHONES

Rudolf Görike, 15 Gregor Mendelstrasse,
Vienna 18, Austria

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Directional microphones can be divided into two groups. The first group comprises all those directional microphones which make use of sound-wave interference, while the second group comprises all those directional microphones in which the directional sensitivity is derived from the difference of acoustic pressure between two points of the sound field.

The last-mentioned type of microphones, also known as gradient microphones, can be used in order to obtain higher-order directional characteristic curves, with a sharper response than those of a lower order.

The subject matter of the invention is a capacitor microphone and its application as a gradient microphone of second order whose directional characteristic corresponds to the pressure gradient between two points of the sound field. It is a capacitor microphone with a figure-eight-shaped directional characteristic, with two diaphragms lying in parallel planes and made of electrically conductive material or of an insulator with a conductive layer on one side, connected in bucking relationship and placed at a small distance from electrodes with a multiplicity of apertures, respective air chambers being situated each behind one of the electrodes and being interconnected by one or more channels; characterized according to the invention in that the apertures of the electrodes are so numerous and the channel or channels are so dimensioned as to length and cross-section that within the transmission range the mass control of the diaphragms predominates. Thus a frequency response which increases with decreasing frequency occurs in the plane sound field.

Further features of the invention relate to the arrangement of a plurality of capacitor microphones according to the invention in order to obtain specific directional characteristics and a horizontal frequency response of the system.

In known capacitor microphones with two diaphragms and with passages connecting the two air chambers between the diaphragms and the electrode, for instance according to the Austrian Patent No. 180,313, the passages are designed to provide an acoustical frictional resistance. The oscillatory system of such a microphone is therefore damped predominantly by friction and the frequency response is horizontal.

The frequency response of the microphone according to this invention, on the other hand, is not linear (when measured in the plane sound field) but decreases with increasing frequency.

The advantage of such a microphone according to the invention is its simple construction and the possibility of obtaining, by arranging a plurality of such microphones with suitable spacing, a directional characteristic of second order and obtaining a horizontal frequency response.

The invention will now be further explained with reference to the accompanying drawing: FIG. 1 is a cross-sectional view of the capacitor microphone according to the invention. FIG. 2 shows the frequency response of such a microphone. FIG. 3 shows the arrangement of two microphones according to the invention required for realizing the directional characteristic shown in FIG. 4, the same applying to FIGS. 5 and 6. FIG. 7 illustrates a combination of two mass controlled microphones according to the invention with a predominantly friction-

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ally damped microphone known per se. FIG. 8 illustrates an arrangement with a low-pass filter, FIG. 9 one with four microphones according to the invention and one frictionally damped microphone known per se, and FIG. 10, finally, an arrangement in which microphones having different directional characteristics are combined with one another.

FIG. 1 schematically shows an embodiment in section. Two diaphragms 1, 2 made of electrically conductive material, or of an insulator with a conductive layer on one side, are placed at a small distance of the electrodes 3, 4. The electrodes contain numerous apertures in order to provide a sufficiently small frictional resistance. Behind the electrodes 3, 4 are situated the air chambers 5, 6 which are interconnected by a channel 7, situated for instance in a solid body 8. A capacitor microphone of such design has, on account of its predominant mass control in the plane sound field when both diaphragms connected to an electrical source and are in bucking relationship a figure-eight-shaped directional characteristic and a frequency response which increases with decreasing frequency.

In FIG. 2 there is shown the frequency response of a microphone according to the invention. In place of a single channel 7 a plurality of channels may be provided, but in that case the ratio between mass and frictional resistance must be sufficiently great. It may be desirable to have a plurality of apertures in order slightly to change the frequency response curve. In case two of the described microphones, arranged at a distance d , are used as illustrated in FIG. 3 and are connected in a bucking relationship, a system of second order is obtained with a horizontal frequency response and a figure-eight-shaped directional characteristic with the analytical function $e=e_0 \cdot \cos^2 \phi$, as illustrated in FIG. 4. The amplitude increases linearly with an increase in the distance up to the value

$$d=\frac{\lambda}{2}$$

If the phase of the output voltage of a microphone is shifted by means of a phase-shifting member 11, as illustrated in FIG. 5, so as to obtain for each frequency the transit-time difference for d , then the directional characteristic as illustrated in FIG. 6 with the analytical function $e=e_0 \cdot (\cos \phi + \cos^2 \phi)$ is obtained. The same directional characteristic is also realized by placing between the microphones 9 and 10 a third microphone 12 whose diaphragms are, however, predominantly frictionally damped and also connected in bucking relationship. This arrangement is illustrated in FIG. 7.

Advantageously, the microphones are connected to the source of biasing voltage with mutual insulation for D.-C. voltage, as illustrated in FIG. 7, while being interconnected for alternating current. The advantage of a microphone with a figure-eight-shaped directional characteristic according to the invention is its limited space requirement. It has already been proposed to arrange in alignment two capacitor microphones with a kidney-shaped directional characteristic and to connect them in bucking relationship. The analytical function in this case is: $e=e_0 \cdot (1 + \cos \phi) \cdot \cos \phi$. The numeral 1 indicates that there is present a component with spherical directional characteristic which is produced by a predominantly frictionally damped oscillatory microphone. The cavity necessary for this purpose, closed off from the outer sound field and coupled with the diaphragm by means of an acoustical frictional resistance, must be of relatively large dimensions. In contrast to this, the arrangement with the microphones according to the invention as illustrated in FIG. 1 saves space, as the larger cavities are omitted in these microphones. The analytical func-

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tion is: $e=e_0(\cos \phi + \cos^2 \phi)$. In this expression the numeral 1 no longer occurs. It will be noted that there is involved here the vector addition of a microphone 12 with $\cos \phi$ and a double microphone 9, 10 with $\cos^2 \phi$. With increasing separation of the individual microphones the sensitivity of the microphone increases, yet the frequency curve descends beyond

$$d=\frac{\lambda}{2}$$

then rising again upon traversing the minimum at λ , and so on. In order to obtain the advantage of high sensitivity, an arrangement as illustrated in FIG. 8, using six microphones consisting of two groups of three mutually coaxial microphones each, may be used. The microphones 9, 10, 12, arranged with greater separation (20-30 cm.), serve for the conversion in the lower frequency range. The closely spaced microphones 9a, 10a, 12a (3-5 cm.) are destined for the conversion in the higher frequency range. By means of a suitable mechanical tension of the diaphragms as well as by a suitable dimensioning of the apertures 7 the individual microphones may be tuned to their fundamental resonance which determines the inertia damping. As shown for instance in FIG. 8, a low-pass filter 13 may be inserted into the circuit of the more widely spaced individual microphones. Another arrangement is illustrated in FIG. 9. The more widely separated individual microphones 14, 15 supply a figure-eight-shaped directional characteristic with $\cos^2 \phi$ up to

$$d=\frac{\lambda}{2}$$

The microphones 16, 17 serve for the conversion of the higher frequencies with $\cos^2 \phi$. A single common microphone 18 with predominantly frictional damping and a directional characteristic of $\cos \phi$, coaxial with microphones 14, 15, 16 and 17, is designed for the whole frequency range. The interconnection of the individual microphones may be accomplished by electric switches. By inclusion and disconnection of the microphone 18 it is possible to shift from the unsymmetrical directional characteristic ($\cos \phi + \cos^2 \phi$) to the symmetrical directional characteristic ($\cos^2 \phi$).

A further example for the application of the microphone according to the invention is illustrated in FIG. 10. Two microphones 19, 20, predominantly mass controlled and with a figure-eight-shaped directional characteristic, and one microphone 21, frictionally damped and also provided with a figure-eight-shaped directional characteristic, are used in the lower frequency range up to

$$d=\frac{\lambda}{2}$$

Further there are present two microphones 22, 23 with a kidney-shaped directional characteristic arranged in bucking electrical relationship. These microphones have each two diaphragms as is known per se, yet only one of these is electrically active at any given time. These microphones operate with regard to their directional characteristic according to the analytical function

$$e=e_0(1+\cos \phi) \cdot \cos \phi$$

The microphones 19, 20, 21, 22, 23 are all centered on a common axis. Thus there is present a spherical directional characteristic, as expressed by the numeral 1, which requires a space closed off from the outer sound field. Since, however, the damped natural oscillation has a resonance frequency of 3000-4000 c.p.s., the space may be relatively small, i.e. designed in a compact manner. All individual microphones can again, advantageously, be interconnected via electrical filters. The individual directional characteristics are symbolically represented above the corresponding microphones in FIG. 10.

Whereas the system represented in FIG. 10 comprises

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microphones having different directional characteristics, the systems shown in FIGS. 3, 5, 7, 8 and 9 consist all of condenser microphones having a figure-eight-shaped directional characteristic. Microphones of this general class are known in the art as pressure-gradient condenser microphones. The previously known pressure-gradient condenser microphones are mainly frictionally damped. Such frictionally damped pressure-gradient condenser microphones are disclosed in, for example, U.S. Patent No. 2,179,361 and are used as microphones 12, 12a, 18 and 21 in the systems shown in FIGS. 7, 8, 9 and 10, where they are labeled with the symbol for a resistor, which is the electrical equivalent of acoustical frictional resistance. The novel pressure-gradient condenser microphone shown in FIG. 1 and described above is distinguished from this known type of microphone by being mainly mass controlled. Such microphones are used in the systems shown in FIGS. 3, 5, 7, 8, 9 and 10 as microphones 9, 10, 9a, 10a, 14, 15, 16, 17, 19 and 20 and are labeled with the symbol for an inductor, which is the electrical equivalent of an acoustic mass. The horizontal "figure eight" with which the microphones 9, 9a, 10, 10a, 12, 12a, 14, 15, 16, 17, 18, 19, 20 and 21 are also labeled indicates the directional characteristics of the microphones. Microphones 22 and 23 are condenser microphones having a generally cardioid directional characteristic, as disclosed, for example, in FIG. 4 of U.S. Patent No. 2,179,361.

What is claimed is:

1. A directional microphone for transmitting a predetermined range of audible sound frequencies, comprising a pair of parallel vibratory membranes, a pair of electrode plates each closely spaced from a respective one of said membranes and positioned between them, each of said membranes being provided with at least one conductive surface forming a condenser with the adjacent electrode plate, and a support carrying said membranes and said electrode plates, and defining two air chambers, each of which adjoins one of said electrode plates on the side opposite the adjacent membrane, said support being provided with at least one channel and said electrode plates being each provided with a multiplicity of perforations for the passage of air between said membranes, the spacing of said perforations being so small that the frictional resistance exerted on the air between each membrane and the electrode plate associated therewith is negligible, the cross-sectional area and length of said channel being selected so that the natural frequency of said membranes as modified by the mass of air in said channel lies near the lower end of said predetermined range of frequencies.

2. A directional microphone for transmitting a predetermined range of audible sound frequencies, comprising a pair of parallel vibratory membranes, a pair of electrode plates each closely spaced from a respective one of said membranes and positioned between them, each of said membranes being provided with at least one conductive surface forming a condenser with the adjacent electrode plate, a support carrying said membranes and said electrode plates and defining two air chambers, each of which adjoins one of said electrode plates on the side opposite the adjacent membrane, said support being provided with at least one channel and said electrode plates being each provided with a multiplicity of perforations for the passage of air between said membranes, the spacing of said perforations being so small that the frictional resistance exerted on the air between each membrane and the electrode plate associated therewith is negligible, the cross-sectional area and length of said channel being selected so that the natural frequency of said membranes as modified by the mass of air in said channel lies near the lower end of said predetermined range of frequencies, means including said condensers for converting the vibrations of said membranes into electrical oscillations, and circuit means for combining the oscillations respectively due to said membranes in bucking relationship.

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3. A directional microphone for transmitting a pre-terminated range of audible sound frequencies, comprising an annular housing, a pair of vibratory membranes spanning opposite sides of said housing, a pair of electrode plates in said housing respectively positioned adjacent said membranes, each of said membranes being provided with at least one conductive surface forming a condenser with the adjacent electrode plate and a central disk in said housing dividing the interior thereof into two air chambers adjoining said electrodes, said disk being provided with at least one channel and said electrode plates being each provided with a multiplicity of perforations for the passage of air between said membranes, the spacing of said perforations being so small that the frictional resistance exerted on the air between each membrane and the electrode plate associated therewith is negligible, the cross-sectional area and length of said channel being selected so that the natural frequency of said membranes as modified by the mass of air in said channel lies near the lower end of said predetermined range of frequencies.

4. A directional acoustic system for transmitting a predetermined range of audible sound frequencies, comprising a pair of microphones spaced apart along a common axis; each of said microphones including a pair of parallel vibratory membranes transverse to said axis, a pair of electrode plates each closely spaced from a respective one of said membranes and positioned between them, each of said membranes being provided with at least one conductive surface forming a condenser with the adjacent electrode plate, and a support carrying said membranes and said electrode plates and defining two air chambers, each of which adjoins one of said electrode plates on the side opposite the adjacent membrane, said support being provided with at least one channel and said electrode plates being each provided with a multiplicity of perforations for the passage of air between said membranes, the spacing of said perforations being so small that the frictional resistance exerted on the air between each membrane and the electrode plate associated therewith is negligible, the cross-sectional area and length of said channel being selected so that the natural frequency of said membranes as modified by the mass of air in said channel lies near the lower end of said predetermined range of frequencies; means including said condensers for converting the vibrations of said membranes into electrical oscillations; first circuit means for combining in bucking relationship the oscillations due to the pair of membranes of each microphone; and second circuit means for combining in bucking relationship the oscillations from both said microphones and for applying the resulting alternating current output to a load.

5. A system according to claim 4 wherein the spacing of said microphones is so selected at a fraction of the shortest acoustic wavelength to be received as to provide a generally flat frequency-response curve of said output through said range.

6. A system according to claim 4, further comprising delay means in the output of one of said microphones for compensating the transit time of sound waves between said microphones in one axial direction of propagation whereby a substantially uniaxial reception characteristic of the second order is established for said system.

7. A system according to claim 4, further comprising a frictionally damped pressure-gradient-responsive third microphone with a cosine characteristic centered on said axis positioned between said pair of microphones, said

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third microphone having a substantially constant frequency response within said range; and third circuit means for electrically combining the output of said third microphone with that of said pair of microphones.

8. A system according to claim 7, further comprising two unidirectional microphones with a cardioid pattern of reception positioned on opposite sides of said third microphone and between said pair of microphones with a substantially smaller axial separation than the latter, said unidirectional microphones being dimensioned to respond predominantly to frequencies near the upper end of said predetermined range of frequencies.

9. A system according to claim 4, further comprising a second pair of mutually coaxially positioned microphones having substantially the same construction as the first-mentioned pair but a considerably lower natural frequency, said first and second circuit means being duplicated for said pairs, the spacing of said second pair exceeding that of said first-mentioned pair whereby said second pair preferentially responds to frequencies lying in a range below that of said first-mentioned pair.

10. A system according to claim 9 wherein at least one of said circuit means includes electrical filter means for at least partially suppressing in the output of one of said pairs the frequencies of the preferential range of the other of said pairs.

11. A system according to claim 10 wherein said filter means comprises a low-pass filter forming part of the second circuit means of said second pair.

12. A system according to claim 9 wherein said pairs are disposed along the same axis, further comprising a frictionally damped pressure-gradient-responsive fifth microphone with a cosine characteristic centered on said axis disposed between said pairs, and third circuit means for electrically combining the output of said fifth microphone with that of each of said pairs.

13. A system according to claim 9 wherein said pairs are disposed along parallel axes offset from each other, further comprising two additional microphones each centrally positioned on the axis of a respective pair and forming a three-microphone array therewith, and third circuit means for electrically combining the output of each of said additional microphones with that of the pair of microphones of the respective array, said additional microphones being frictionally damped and having a figure-eight-shaped directional characteristic.

14. A system according to claim 13, further comprising a low-pass filter in the output of the array including said second pair, said filter discriminating against frequencies preferentially received by the other array.

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