Dec. 14, 1965 B. WEINGARTNER 3,223,782

DIRECTIONAL MICROPHONE WITH DISTANCE CONTROL

Filed June 12, 1962

Fig. 1

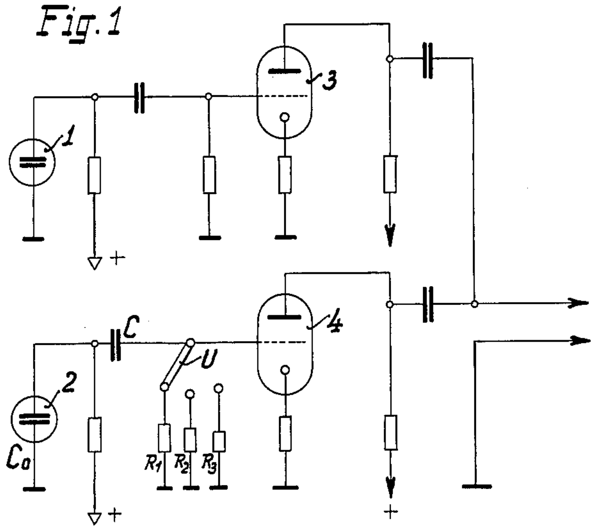


Fig. 2

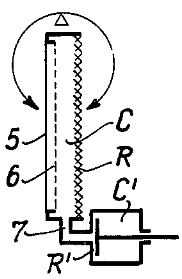


Fig. 3

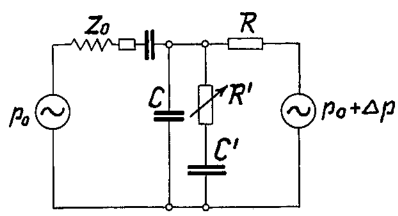


Fig. 6

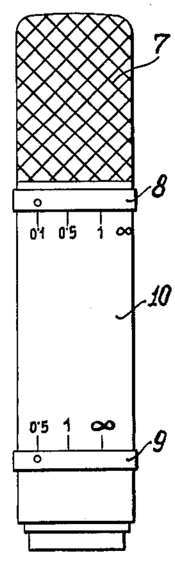


Fig. 4

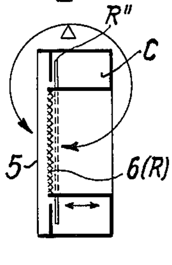
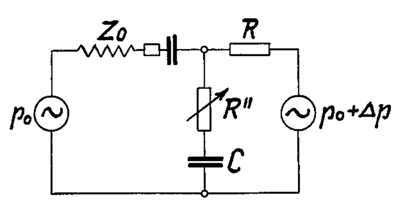


Fig. 5



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DIRECTIONAL MICROPHONE WITH DISTANCE CONTROL

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13 Claims. (Cl. 179—1)

It is known that a unidirectional pattern of a microphone is obtained if sound is caused to impinge on both faces of the moving element of the transducer, i.e., the diaphragm, one face of the diaphragm (front face) being directly exposed to the sound whereas the other face (rear face) communicates with the sound field by a phase-shifting acoustic system. With this arrangement, the phase of the actuating sound pressure is shifted by an amount which just corresponds to the time required by the sound to travel from the center of the front face to the center of the rear face of the diaphragm. It will be apparent that the action on the diaphragm of the sound waves reaching the microphone from the rear will thus be compensated so that the diaphragm remains stationary (rear attenuation).

The same effect can be achieved by electrically combining a pressure transducer having a spherical (omnidirectional) pattern with a pressure gradient transducer having a bidirectional pattern.

Such a microphone will have an optimum effect in the field of substantially plane sound waves, i.e., at a relatively large distance from the sound source. As the sound source, which in most cases is considered a point, is approached, the sound field thereof can no longer be considered to consist of substantially plane sound waves (plane sound field) but of spherical sound waves (spherical sound field).

In the spherical sound field, however, the value of the pressure gradient increases strongly with a decrease in frequency in the case of an approach toward the sound source, whereas, in a plane sound field, the pressure difference between two points lying in the direction of propagation of the sound waves increases approximately linearly up to that frequency at which half the wavelength equals the distance between the two points.

For this reason it will be understood that a microphone arranged for receiving plane sound waves and for actuation by the pressure gradient will have a preferential response to the low frequencies, compared to medium and high frequencies, in a spherical sound field (sound from nearby source).

Theoretical and practical investigations have shown another result, which resides in a very strong deterioration of the rear attenuation (suppression) of these frequencies, i.e., a deterioration of the unidirectional pattern. This involves an increase in the sound energy received, which in transducers having a pressure gradient cardioid pattern is known to be by about ¼ smaller than in a non-directional transducer.

To reduce the disadvantages described hereinbefore, it has already been suggested to compensate the boosting of the low frequencies from a nearby source by the interposition of appropriately dimensioned and, if desired, adjustable acoustic or electrical attenuating elements, the adjustment being restricted to the frequency response of the output voltage of the transducer system, which may consist of a plurality of individual systems. It is apparent that this may result in an improvement of the frequency response but can in no case result in an improvement of the rear attenuation because the same will not be influenced by the modification of the frequency

response of the combined output voltage of all transducer systems of the sound transmitter.

As distinguished therefrom, it is an object of the invention to teach how the action of pressure and of the pressure gradient can be approximately equalized at any frequency and for any distance from the sound source so as to enable not only a selective adjustment in dependence on distance of the 0° frequency response but, independently of or coupled with this adjustment, an optimum suppression of sound from the rear for any distance from the sound source.

In a sound transmitter having a preferably unidirectional pattern, which may be adjustable, and comprising one or more transducers operating on the electrostatic principle, this object is achieved in that at least one of the incorporated transducer systems has variable, frequency-dependent electrical and/or acoustic attenuating means associated with it, which are adjustable by adjusting elements associated with distance-graduated scales, marks, symbols or the like, for ensuring an optimum effect at different distances from the sound source.

According to another feature of the invention, a sound transmitter which comprises a pressure transducer and a pressure gradient transducer has the frequency-dependent, adjustable, electrical and/or acoustic attenuating means associated with the pressure gradient transducer so that the increase of the gradient at the low frequencies in the spherical sound field (sound from nearby source) can be compensated. This will enable an adjustment of both the rear attenuation and the output level in dependence on the distance from the sound source.

In a sound transmitter which comprises only one transducer system having a unidirectional pattern and provided with a phase-shifting acoustic resistance-capacitance element, a further feature of the invention resides in providing an acoustic frictional resistance which is connected in parallel to the acoustic capacitance or arranged in a series connection with this capacitance. This will enable an adjustment of the rear attenuation in dependence on the distance from the sound source.

In addition to this feature, an adjustable, frequency dependent electrical attenuating element, preferably a resistance-capacitance element, may be inserted in the electrical circuit of this transducer system. This will enable an adjustment of the output level in dependence on the distance from the sound source.

The invention will now be explained more fully with reference to the accompanying drawing. FIG. 1 is an electrical circuit diagram in which a pressure transducer and a pressure gradient transducer are combined and which provides only for an electrical control. FIG. 2 is a transverse sectional view showing diagrammatically a pressure gradient transducer which comprises acoustic attenuating means arranged according to the invention. FIG. 3 shows the corresponding equivalent-circuit diagram. FIG. 4 illustrates another embodiment of the invention, FIG. 5 the corresponding equivalent-circuit diagram and FIG. 6 an external view of a sound transmitter according to the invention.

As has already been stated in the introductory part of the specification, the object of the invention may be accomplished by purely electrical methods, or by purely acoustical means, or by a combination of both.

FIG. 1 shows an electrical circuit diagram of a sound transmitter which comprises two individual systems, one transducer of which is a pressure transducer 1 having an omnidirectional pattern. Feeding an amplifier stage 3, the transducer 1 is perfectly decoupled from the pressure gradient transducer 2. The latter feeds the amplifier 4, the output of which is connected to that of amplifier 3. According to the invention, a frequency-dependent electrical attenuating element is disposed between the output of the pressure gradient transmitter **2** and the input of the amplifier **4**. As shown in FIG. 1, this element may consist of a resistance-capacitance element, which can be switched over. This attenuating element consists of the source impedance of the transducer **2** having the capacitance C_0 and the three resistors R_1, R_2 and R_3, one of which can be connected by means of the changeover switch U to the capacitor C. The resistors R_1, R_2, R_3 enable an adjustment of the rear attenuation and of the output level in dependence on the distance from the sound source. In conjunction with a thermionic amplifier, the resistors may serve at the same time as a grid leak for the amplifier tube.

From the known arrangements in which a pressure transducer having a spherical pattern and a pressure gradient transducer having a bidirectional pattern are accommodated in a common housing and have outputs connected to the input of a common amplifier, so that a unilateral, preferably cardioid directional pattern results, the circuit according to the invention differs in that a separate amplifier is provided for each transducer and the frequency-dependent electrical attenuating element is not inserted in the common amplifier output but in the circuit of the pressure gradient transducer, preferably between the microphone output and the amplifier input. Whereas the known arrangement effects only a correction of the frequency response, the invention achieves that the transducers combined in the sound transmitter have the same sensitivity and the same rear attenuation for any frequency and any distance from the sound source.

Thus, the invention distinguishes from another previous proposal to arrange frequency-dependent electrical means in the circuit of an individual system of such a combination of transducers. These elements had only the function of correcting the frequency response in the plane sound field and at those high frequencies at which half the wavelength is equal to the sound detour (defined as the sound path from the center of the front face to the center of the rear face of the diaphragm) so that the gradient microphone has a very great, undesired phase/frequency response.

It is obvious that the resistors of the resistance-capacitance element, which can be switched in stages must be dimensioned so that the boosting of the low frequencies caused by the pressure gradient is compensated within certain limits for any distance from the sound source. As a result, the sensitivity of each of the two individual transducers will always be the same and the adjusted unidirectional pattern will also be maintained independently of the distance from the sound source.

With the arrangement according to the invention shown in FIG. 1, the sound transmitter can be selectively given an omnidirectional or a bidirectional pattern by using one or the other transducer of the system alone. The changeover may be effected by a simple switch because only electrical circuits must be switched. In the position "bidirectional pattern," the use of the arrangement according to the invention will provide for a uniform frequency response under all sound conditions.

Another illustrative embodiment of the invention, in which a frequency-dependent acoustic attenuating element is used, is shown in FIG. 2. This shows a directional microphone having a unidirectional pattern, which is achieved by a phase-shifting acoustic element. In such a microphone it is difficult to achieve a selective attenuation of the bidirectional component. Theoretical considerations relating to a phase-shifting element consisting of a resistance-capacitance element, as are used in most cases in condenser microphones, have shown, however, that the deterioration of the rear attenuation and the increase of the sound energy received from a nearby sound source can be opposed with very simple means. For this purpose the invention teaches the connection of an acoustic frictional resistance in parallel to the capacitance (restoring force) of the phase-shifting element which is responsible for the undirectional pattern; this resistance may be replaced, if desired, by an equivalent series resistance.

The value of the parallel acoustic frictional resistance should be approximately r/Δ times the frictional resistance of the resistance-capacitance element, where r is the distance of the microphone from the sound source and Δ the sound detour from the center of the front face to the center of the rear face of the diaphragm. To enable an adjustment to various distances from the sound source, the frictional resistance must be variable. It causes, above all, the maintenance of the rear attenuation at low frequencies in dependence on the distance from the sound source whereas the increase in sensitivity in the case of 0° sound incidence may be compensated, if desired, by a selective attenuating element included in the circuit. The rear attenuation and the output level may be separately controlled, or simultaneously by a single adjusting element.

In the directional condenser microphone shown in a diagrammatical sectional view in FIG. 2, the diaphragm **5** vibrates relative to the highly perforated counterelectrode **6**. The phase-shifting resistance-capacitance element responsible for the unidirectional pattern is formed by the capacitance C, constituted by a cavity, and the acoustic frictional resistance R. The duct **7** and the narrow, adjustable gap R′ provide a communication to the chamber C′, the acoustic impedance of which is much smaller than that of the frictional resistance R′ formed by the narrow gap so that the action of this resistance greatly predominates and results in the desired effect if the dimensions called for by the invention are selected.

In the equivalent-circuit diagram of FIG. 3, Z_o is the acoustic impedance of the diaphragm **5**, p_o and $p_o+\Delta p$ are the actuating forces at two different points of the sound field. The other references denote similar elements as in the circuit diagram of FIG. 2.

It has already been mentioned that the additional regulatable or adjustable acoustic frictional resistance may alternatively be connected in series with the capacitance of the phase-shifting element responsible for the unidirectional pattern. FIG. 4 is a diagrammatic transverse sectional view showing such an arrangement and FIG. 5 is the corresponding equivalent-circuit diagram.

5 and **6** denote again the diaphragm and the counterelectrode. In this case the counterelectrode **6** consists of a frictional resistance, which together with the annular space C constitutes the phase-shifting element. According to the invention, the low-volume chamber behind the diaphragm **5** is connected to the capacitance C by an acoustic frictional resistance R″, which corresponds to the parallel resistance R′ in FIG. 2. The frictional resistance R″ is also formed by a narrow, adjustable slot or gap.

The frictional resistance shown in FIGS. 3 and 4 or FIGS. 5 and 6 enables only an adjustment of the rear attenuation in dependence on the distance from the sound source. For an adjustment of the output level, an electrical resistor may be connected in parallel to the microphone capsule having a cardioid directional pattern in a circuit which is analogous to that of the capsule having a bidirectional pattern shown in FIG. 1. The time constant of the resistance capacitance element consisting of said capsule and said parallel resistor should correspond to the period of the lowest frequency to be transmitted.

FIG. 6 shows finally how the proposal according to the invention can be practically employed. The sound transmitter in the form of a cylindrical, rod-shaped body has a sound-permeable part **7** and a housing part **10**. This housing part may be provided with, e.g., annular setting elements **8**, **9**, which are associated with distance-graduated scales so that the rear attenuation and the output level may be adjusted to provide optimum transmission characteristics at each distance from the sound source. As has been mentioned hereinbefore, the adjusting elements may be arranged to be coupled or may be operated by a common member. Either of rings **8**, **9** will be sufficient if it is arranged to effect the adjustment of the rear attenuation as well as of the output level.

Finally, it may be pointed out that such a transducer having a phase-shifting element may be symmetrical and comprise two diaphragms so as to enable an adjustment of different directional patterns.

In the embodiment shown in FIG. 1, the components may have the following values:

The pressure transducer **1** may have a capsule capacitance of 100 picofarads, and the two resistors shown between the transistor **1** and the tube **3** may have a resistance of 250 megohms each. The coupling capacitor between these two resistors may have a capacitance of 1000 picofarads.

The pressure gradient transducer **2** may have a capsule capacitance C_0 of 100 picofarads. The coupling capacitor C between the transducer **2** and the tube **4** may have a capsule capacitance of 1000 picofarads.

When $C \gg C_0$, the grid leak resistance R_1 (resistor R_1, R_2 or R_3) should comply as closely as possible to the equation.

$$R_1 = \frac{2r}{C_0 c}$$

wherein

C_0=capsule capacitance of transducer **2** in farads
R_1=resistance of resistor R_1, R_2 or R_3 in ohms
r=distance of sound source from microphone in meters
c=velocity of sound in meters per second.

For a distance of 15 cm. from the sound source to the microphone and a capsule capacitance C_0=100 picofarads, a grid leak resistor R_1 having a value of 10 megohms may be used.

In the embodiment shown in FIG. 2, the value of the acoustic frictional resistance R′ should comply with the following equation:

$$R' = R\frac{r}{\Delta}$$

wherein the symbols have the meaning defined hereinbefore.

The capacitance C′ should comply with the following relation:

$$C' \gg \frac{1}{R'\omega_t}$$

wherein

$1/C'$=restoring force of the cavity C′ in N/m.
R'=frictional resistance of the gap R′ leading into the cavity C′ in kg./sec.
R=frictional resistance of the element R at the rear sound inlet to the transducer in kg./sec.
ω_t=lower limiting frequency (−3 decibel limit) of the transducer
Δ=sound detour (as defined hereinbefore) around the transducer, in meters.

Using the first ("dual") mechanical-electrical analogy

$$(1\text{ kg.} \triangleq 10^3\text{H},\ 1\text{ N} \triangleq 10^{3/2}\text{V},\ 1\text{ m./sec.} \triangleq 10^{-3/2}\text{A},$$
$$1\text{ m./N.} \triangleq 10^{-3}\text{F},\ 1\text{ kg./sec.} \triangleq 10^3\text{ ohms},\ 1\text{ m.} \triangleq 10^{-3/2}\text{ As})$$

the following values are obtained in a practical embodiment: R=51 ohms, r=15 centimeters, Δ=2.2 centimeters

$$\frac{\omega_t}{2\pi} = 30 \text{ cycles per second}$$

R'=347.7 ohms, C'>15 microfarads.

What is claimed is:

1. A sound transmitter having a unidirectional pattern comprising, in combination, at least one electrostatic transducer having a unidirectional pattern and a frequency response characteristic normally varying with the distance from a 0° frequency sound source; and selectively adjustable, frequency dependent attenuating means operatively coupled to said transducer and adjustable to effect optimum attenuation of the rear frequency response of the latter independently of the distance of said transducer from a sound source to compensate said distance-variable frequency response of said transducer to maintain the unidirectional frequency response of said sound transmitter substantially constant over a range of such distances.

2. A sound transmitter as set forth in claim **1**, which comprises means for adjusting the unidirectional pattern of the transmitter.

3. A sound transmitter as set forth in claim **1**, which comprises at least two electrostatic transducers.

4. A sound transmitter as set forth in claim **1**, in which said attenuating means comprise electric attenuating means electrically coupled to said transducer.

5. A sound transmitter as set forth in claim **1**, in which said attenuating means comprise acoustic attenuating means acoustically coupled to said transducer.

6. A sound transmitter as set forth in claim **1**, in which said attenuating means comprise electric attenuating means electrically coupled to said transducer and acoustic attenuating means acoustically coupled to said transducer.

7. A sound transmitter as set forth in claim **1**, which comprises adjusting elements operatively connected to said attenuating means for adjusting the same, and a distance scales associated with said adjusting elements.

8. A sound transmitter as set forth in claim **1**, in which said one transducer is a pressure gradient transducer and said attenuating means are adjustable to compensate for an increase of the low-frequency response of the pressure gradient acting on the transducer to sound from a nearby source, said transmitter further comprising a pressure transducer electrically connected to said pressure gradient transducer.

9. A sound transmitter as set forth in claim **1**, in which said one transducer comprises an acoustic capacitance and in which said attenuating means comprise an adjustable acoustic frictional resistance connected to said capacitance to form a phase-shifting acoustic system therewith.

10. A sound transmitter as set forth in claim **9**, in which said frictional resistance is connected in series with said capacitance.

11. A sound transmitter as set forth in claim **9**, in which said frictional resistance is connected in parallel to said capacitance.

12. A sound transmitter as set forth in claim **9**, in which said attenuating means comprise electric attenuating means electrically coupled to said transducer.

13. A sound transmitter having a unidirectional pattern and comprising at least one electrostatic transducer and frequency-dependent attenuating means coupled to said transducer and adjustable to improve the characteristics of the transmitter for the reception of sound from at least two different distances, said one transducer comprising an acoustic capacitance, and said attenuating means comprising an adjustable acoustic frictional resistance connected to said capacitance to form a phase-shifting acoustic system therewith; said attenuating means further comprising an electric attenuating means electrically coupled to said transducer; said electric attenuating means comprising a resistance-capacitance element.

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