

Nov. 1, 1960

K. SCHOEPS ET AL
ELECTROACOUSTIC TRANSDUCER

2,958,739

Filed July 31, 1957

2 Sheets-Sheet 1

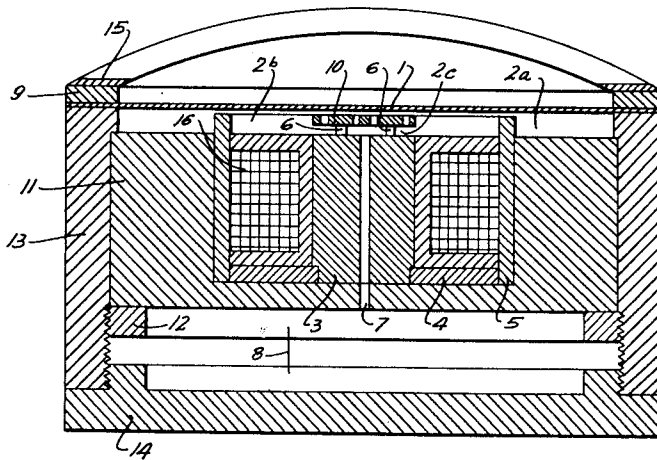


FIG. 1

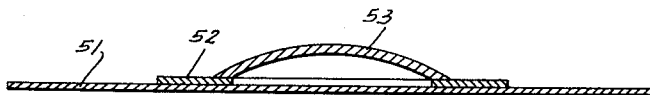


FIG. 3

INVENTORS
Karl Schoeps AND
Willy Müstters
BY
Michael S. Striker
ATTORNEY

Nov. 1, 1960

K. SCHOEPS ET AL

2,958,739

ELECTROACOUSTIC TRANSDUCER

Filed July 31, 1957

2 Sheets-Sheet 2

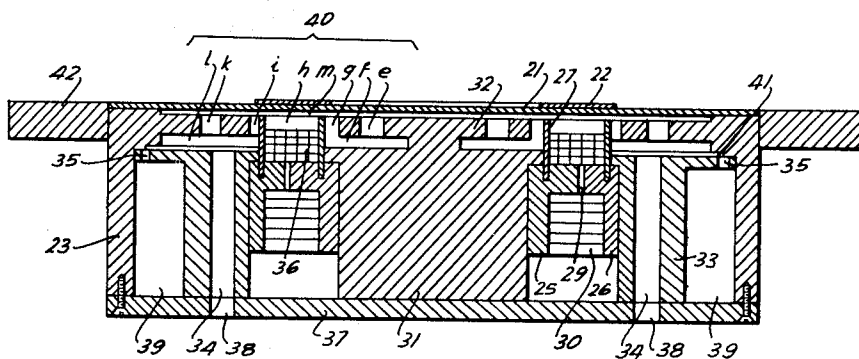


FIG. 2

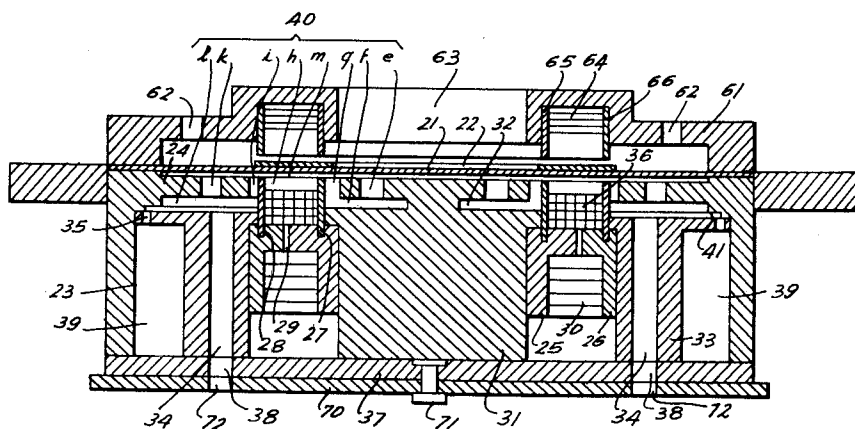


FIG. 4

INVENTORS
Karl Schoeps and
Willy Wieders
BY
Michael A. Striker
ATTORNEY

1

2,958,739

ELECTROACOUSTIC TRANSDUCER

Karl Schoeps and Willy Küsters, Karlsruhe-Durlach, Germany, assignors to Schalltechnik Dr.-Ing. K. Schoeps, Karlsruhe-Durlach, Germany

Filed July 31, 1957, Ser. No. 675,321

Claims priority, application Germany Aug. 13, 1954

13 Claims. (Cl. 179-114)

The present invention relates to an electroacoustic transducer. More particularly, the present invention relates to an electromagnetic microphone capable of providing a high quality response throughout a very wide frequency range.

The present application is a continuation-in-part application of my co-pending patent application Serial No. 527,348 filed on August 9, 1955, now abandoned.

In the electroacoustic transducer art, there are several different physical principles used to produce electrical impulses from sound waves or vice versa. These principles include the electrodynamic, the electromagnetic and capacitive principles which can be used for producing pressure and velocity operated microphones.

The condenser microphone produces a good quality response because it operates without transient oscillations in its oscillatory system. However, the condenser microphone has a high impedance characteristic which usually requires an amplifier to be connected directly to the condenser oscillatory system. Accordingly, the condenser microphone must be built relatively larger and relatively sturdier than any of the microphones operating on other principles.

The microphones operating with electrodynamic and electromagnetic principles have low impedance characteristics but these conventional microphones have the disadvantage that transient oscillation phenomena are developed in the oscillatory system of the microphone to distort the reproduction of sound waves impinging on the membrane of the microphone.

The mode of operation of an oscillatory system of an electroacoustic transducer is determined primarily by its three parameters. These parameters include the rigidity or elasticity of the oscillatory system; the mass of the system; and the friction of the system. The mode of operation of the oscillatory system changes in accordance with established physical principles depending on which of these parameters predominates. In order to simplify the terminology used hereinafter in the application, the terms "frictional retardation" and "frictional retarding means" will be used to indicate the mode of, and the means for, operation of the oscillatory system when it is primarily determined by the friction of the oscillatory system. The terms "elastic retardation" and "elastic retarding means" will indicate the mode of, and the means for, operation when the elasticity of the oscillatory system is predominant and the terms "mass retardation" and "mass retarding means" will indicate conditions and means wherein the influence of the mass predominates. The terms "non-elastic retardation" and "non-elastic retarding means" will encompass generically both frictional and mass retardation and means.

The present invention permits the construction of a microphone or electroacoustic transducer operating on electromagnetic principles which is capable of high quality reproduction throughout a very wide frequency range. This is accomplished by constructing the oscillatory system so that it is predominantly elastically retarded

2

throughout the upper portion of the frequency range while in the remaining or lower portion of the frequency range either the mass or the friction retardation predominates.

In addition, it is known that the iron losses in the magnetic circuit of the electroacoustic transducer increase with frequency. This usually causes a decrease in transmission in the higher frequency range. In the electroacoustic transducer constructed in accordance with the principles of the present invention, the oscillatory system which is predominantly elastically retarded in this portion of the frequency range is constructed to produce a desired response by compensating for the iron losses.

Accordingly, it is an object of the present invention to provide an electroacoustic transducer operating on electromagnetic principles and overcoming the disadvantages described hereinabove.

A second object of the present invention is to provide a new and improved electroacoustic transducer which operates throughout a wide frequency range without developing a distorted response.

Another object of the present invention is to provide a new and improved method for operating an electroacoustic transducer utilizing electromagnetic principles.

A further object of the present invention is to provide a new and improved method and apparatus for constructing and operating a wide frequency range electroacoustic transducer wherein the oscillatory system of the transducer is retarded in the upper portion of the frequency range predominantly elastically while it is retarded throughout the remainder of the frequency range by predominantly frictional or mass retardation means.

Yet another object of the present invention is to provide a new and improved unidirectional electroacoustic transducer which is responsive only to sound waves coming from a predetermined direction.

Still a further object of the present invention is to provide a new and improved unidirectional electromagnetic microphone having an oscillatory system which is predominantly elastically retarded in the upper portion of its operable frequency range and is mass retarded throughout the remaining lower portion of its operable frequency range.

With the above objects in view, the present invention mainly consists of an electroacoustic transducer for use throughout a wide frequency range and including an open-ended housing, means mounted in the housing for producing a magnetic field having magnetic lines of flux with a preselected distribution extending through the open end of the housing. Membrane means containing ferromagnetic material is arranged on the open end of the housing to substantially seal the open end from the surrounding atmosphere. The membrane means is adapted to be vibrated in the magnetic field by sound waves transmitted through the surrounding atmosphere and impinging thereon to vary the distribution of the magnetic lines of flux. In addition, frictional retardation and mass retardation means are arranged in the housing spaced from the membrane. At least one of the retardation means is arranged to predominantly retard the membrane when it vibrates in the wide frequency range below a predefined frequency. Elastic retarding means are also arranged in the housing for predominantly retarding the membrane when it vibrates throughout the remainder of the wide frequency range. Finally, means are provided which are responsive to the changes of the distribution of the magnetic lines of flux to produce electrical impulses proportional to such distribution changes.

The present invention also includes an apparatus for carrying out a method for converting sound waves occurring in a wide frequency range into electrical impulses. This method includes the steps of establishing a magnetic

3

field having magnetic lines of flux with a preselected distribution. A ferromagnetic material is vibrated in the lines of flux in response to the sound waves to be converted thereby changing the distribution of the magnetic lines of flux. The vibrating ferromagnetic material is predominantly elastically retarded when it vibrates in the wide frequency range above a predefined frequency. In the remainder of the wide frequency range, the vibrating ferromagnetic material is retarded in a manner other than by elastic retardation. Finally, the method includes the step of converting the changes of the magnetic flux distribution of the magnetic field into electrical impulses which are proportional to such changes.

In another embodiment of the present invention, a unidirectional electroacoustic transducer is produced by introducing a time delay network in the path of the sound waves. The sound waves coming from the area in front of the microphone impinge directly on the front side of the membrane and also pass by means of the time delay network to the rear or inner side of the membrane. The phase shift due to the time delay produces a pressure gradient across the membrane which increases the effect of the sound waves coming from the area in front of the microphone. On the other hand, sound waves coming from a direction to the rear of the microphone, pass through the time delay network to the rear or inner face of the membrane. These waves also pass around the microphone to the front face of the membrane but the time delay is such that the sound waves from the rear of the microphone produce no pressure gradient across the membrane.

In the electroacoustic transducer, the oscillatory system can include a membrane made of ferromagnetic material, it can also include a membrane made of non-ferromagnetic material if a second member made of ferromagnetic material is arranged on the membrane.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings, in which:

Fig. 1 is a longitudinal, sectional view of a first embodiment incorporating the principles of the present invention;

Fig. 2 is a longitudinal, cross-sectional view of a unidirectional embodiment of the present invention;

Fig. 3 is a transverse, sectional view of membrane means used in the transducer; and

Fig. 4 is a longitudinal, cross-sectional view of another embodiment of the present invention.

Referring now to the drawings, and more particularly to Fig. 1, it can be seen that the electromagnetic microphone constructed in accordance with the principles of the present invention is arranged within an open-ended cylindrical housing made up of a cylindrical wall member 13 and a closure member 14 which threadedly engages the cylindrical member 13.

Arranged across the open end of the open-ended housing is a membrane 1 made of ferromagnetic material and substantially sealing the open end of the housing from the surrounding atmosphere. It should be appreciated that all of the elements shown in Fig. 1 are symmetrical about a central axis so that the membrane 1 is disc-shaped and has an annular peripheral portion.

The peripheral portion of the membrane 1 is maintained in its position against the end of the cylindrical member 13 by means of an annular holding ring 9 arranged on the outer face of the membrane 1. In order to avoid the influences of any stray magnetic fields, a perforated cap 15 is arranged on the holding ring 9 facing the outer or front face of the membrane 1.

In the interior of the housing, opposite the rear face of

4

the membrane 1 is arranged the means for producing a magnetic field. This includes the central core 3 being formed with a central air passage 7 therethrough, an annular disc 4 and a cylindrical element 5. Arranged between the central core 3 and the membrane 1 is a perforated disc 10 which is supported on the core 3 by pin means 6.

The arrangement of the perforated disc 10 and the support means 6 are dimensioned to produce a frictional damping for the oscillatory system, which frictional damping becomes effective only in the upper portion of the frequency transmission range of the transducer.

It can be seen that adjacent the inner face of membrane 1 is an air cushion 2 made up of air spaces 2a, 2b and 2c. These air spaces communicate with each other.

To hold the magnetic field producing means in its axial position within the housing, a non-ferromagnetic member 11 is provided. The member 11 in turn is urged against an inner shoulder of the cylindrical element 13 by means of a holding ring 12 that threadedly engages the inner face of the cylindrical member 13.

Surrounding the central core 3 is a coil 16 in which the electromotive force is produced for providing the conversion between the sound waves and the electrical impulses. Any of the elements 3, 4 or 5 of the magnetic field producing means may be made of a permanent magnetic material. It is also possible to provide a separate excitation coil to establish the magnetic field.

Finally, it can be seen in Fig. 1 that an air space 8 which is arranged for compensating purposes is provided between the non-ferromagnetic member 11 and the housing member 14. The air passage 7 communicates with the air space 8.

In operation, when the electroacoustic transducer shown in Fig. 1 is used for converting sound waves into electrical impulses, the sound waves coming from any direction impinge on the outer face of the membrane 1. This causes the membrane 1 to vibrate in the magnetic field set up by the magnetic field producing members 3, 4 and 5. The membrane is made of a ferromagnetic material and accordingly changes the predetermined distribution of the magnetic lines of flux of the magnetic field due to the vibration thereof.

The vibration of the membrane depends on the frequency of the sound waves impinging thereon. As the number of lines of flux flowing through the central core 3 varies due to the change of the magnetic circuit, electrical impulses are produced in the coil winding 16, which impulses are proportional to the original sound waves impinging on the membrane 1.

In the lower frequency portion of the wide frequency range in which the microphone is used, the vibrating membrane 1 is retarded in the following manner:

Air vibrations are set up in the air cushion 2, which vibrations pass through the air passage 7 into the second air space 8. Since the air passage 7 has a very small diameter, the amplitudes of the air vibrations passing therethrough are decreased by the frictional resistance of the passage 7. Therefore, at the lower frequency portion of the frequency range, the oscillating system of the microphone is predominantly frictionally retarded corresponding to a membrane deflection inversely proportional to the frequency.

In the lower frequency portion of the frequency range, above mentioned, the losses introduced by the iron in the magnetic circuit are negligible. In a conventional electromagnetic microphone the voltage frequency response of the microphone will increase linearly with ω which is 2π times the frequency of the impinging sound waves. With the arrangement shown in Fig. 1 for the above-mentioned lower portion of the frequency range the frictional retardation of the oscillating system compensates for the linear rise of the voltage frequency curve so that a constant frequency independent voltage (E.M.F.) results.

5

Above a predefined frequency, the effect of the iron in the magnetic circuit of the microphone will become important. The diameter of the air passage 7 is therefore designed to block air vibrations occurring above the predefined frequency so that these air vibrations will not pass through the passage 7. The air passage 7 thereby becomes an effective blocking member so that the retardation of the oscillating system is provided by the air cushion 2. This operates as a conventional air cushion and provides predominantly elastic retardation. This elastic retardation will remain predominant throughout the entire upper frequency portion of the wide frequency range which includes that portion above the predefined frequency.

It is clear that as the frequency of the air vibrations produced by the membrane 1 increases, the greater will become the effectiveness of the air passage 7 as a blocking member.

In the upper frequency portion wherein the iron in the magnetic circuit is effective, the effect on the voltage-frequency response curve of the microphone is the tendency to decrease the voltage-frequency response in accordance with ω^2 . Since in this range, the air passage 7 no longer provides the frictional retardation, but acts as a blocking member, the normal tendency of the electromagnetic microphone to produce a voltage increasing linearly with ω is no longer compensated. It is therefore seen that this normal voltage-increasing tendency of the electromagnetic microphone partially compensates for the voltage-decreasing effect of the iron in the magnetic circuit. The remainder of this effect of the iron is compensated for by properly dimensioning the components of the oscillating system so that the mechanical resonance thereof with a proper decrement occurs in the proper portion of the frequency transmission range of the microphone.

The result of the compensating factors of the embodiment shown in Fig. 1 is a high quality electromagnetic microphone capable of operating throughout a very wide range while still maintaining constant, frequency independent voltage response throughout the entire frequency range. This high quality electromagnetic microphone has the advantageous low impedance characteristic of electromagnetic microphones as compared to the disadvantageous high impedance characteristic of condenser microphones. This result is obtained by providing predominantly frictional retardation of the oscillatory system in the lower portion of the frequency range and providing predominantly elastic retardation in the remaining upper frequency portion of the frequency range. The area of transition between the two modes of retardation is determined by the dimension of the air passage 7 and can be chosen to correspond to the frequency at which the effect of the iron in the magnetic circuit starts to be no longer negligible.

As already mentioned, it is not necessary to use permanent magnets in the magnetic field producing means since separate energizing windings may be provided for setting up the predetermined magnetic flux distribution. In addition, the membrane 1 need not be made entirely of ferromagnetic material since the magnetic circuit can be completed by ferromagnetic foils arranged on the membrane. These foils can be disc-shaped, annularly shaped, strip shaped, or of any other suitable shape which can be mounted on either the outer or inner face of the membrane 1 or on both sides thereof.

In the non-directional type of microphone described and illustrated in Fig. 1 different friction-retardation producing arrangements may be provided. For example, a plurality of passageways may be provided between the air cushion 2 and the air space 8. Instead of the frictional retardation produced by the air passageways, it is possible to use a porous material which can also effect such frictional retardation. In addition, any desired combination of different types of frictional retardation means

6

can be employed. The frictional retardation producing members may be made adjustable, if desired, to permit variation of the frequency response of the microphone with a simple adjustment.

Referring now to Fig. 2, a unidirectional microphone is illustrated which is designed to be capable of responding only to sound waves coming from a predetermined direction while sound waves coming from any other direction will not produce any pressure gradient across the membrane 1.

In Fig. 2, the cylindrical housing is made up of a cylindrical element 23 which is provided with an inner annular flange 24 having a plurality of perforations therethrough. In addition, a disc-shaped member 37 is mounted on the lower end of the cylindrical element 23 to complete the housing for the electroacoustic transducer.

A membrane 21 is attached by the outer peripheral edge thereof to the cylindrical element 23 by a suitable adhesive. The membrane of Fig. 2 is made of a non-ferromagnetic material and accordingly has arranged on the outer face thereof an annular member 22 made of ferromagnetic material. The annular member 22 is arranged concentrically with the membrane 21.

Arranged opposite the inner face of the membrane 21 is the stationary portion of the magnetic field producing means. This includes the annular permanent magnet 30 which is magnetized to have radial lines of magnetic flux. The magnetic circuit further includes cylindrical ferromagnetic elements 25 and 26 and cylindrical pole shoes 27 and 28.

The electromotive force of the transducer is produced in the coil 36 which is arranged between the cylindrical pole shoes 27 and 28. Between the permanent magnet 30 and the coil 36 is arranged an annular air gap 29 to reduce the resistance in the magnetic alternating circuit.

Coaxially arranged within the cylindrical housing of the transducer is a member 31 made of non-magnetic material. The member 31 is formed with a perforated disc-shaped portion 32 in the area adjacent the inner face of the membrane 21. Also within the housing but external to the magnetic circuit is arranged a cylindrical member 33 made of non-magnetic material and provided with a plurality of channels 34 and 35 therethrough. It can be seen that the channels 35 are formed in the upper flange portion of the non-magnetic member 33.

The channels 34 communicate with openings 38 in the housing member 37 so that the channels 34 actually communicate with the surrounding atmosphere.

Adjacent the inner face of the membrane 21 is an air cushion 40 which is made up of a plurality of partial air volumes as follows: The air volume *e* in the perforations of the disc 32; the annular air volume *f* beneath the disc portion 32; the annular air volume *g* between the inner pole shoe 27 and the disc portion 32; the annular air volume *h* between the pole shoes 27 and 28; the annular air volume *i* between the outer pole shoe 28 and the inner flange 24; the air volume *k* in each perforation of the inner flange 24; the annular air volume *l*; and the layer of air *m* existing between the membrane 21 and the parts arranged opposite the inner face of the membrane 21.

The arrangement of Fig. 2 also provides a path for sound waves directly to the inner face of the membrane 21. This path leads through the holes 38 and the channels 34 into the air cushion 40. An annular recess 41 formed in the member 23 cooperates with the holes 35 to constitute narrow passages communicating with the compensating air volume 39 formed between the element 33 and the elements 23 and 37. The narrow passages between 41 and 35 are part of the time delay means mentioned further below.

In operation, in the lower portion of the frequency range of the unidirectional microphone of Fig. 2, the mass retardation mentioned above is supported by the air in the channels 34 and the holes 38. Therefore, in this

lower portion of the frequency range, the tendency of the voltage-frequency response curve to rise with frequency is compensated to provide a constant frequency independent voltage (E.M.F.)

The channels 34 and holes 38 also provide a path for the sound waves to reach the inner face of the membrane 21. Accordingly, while sound waves arriving in substantially axial direction at the outer face of the membrane 21 will impinge directly on the membrane to deflect the same, these waves will also travel around the microphone and pass through the channels 34 and holes 38 so as to reach the inner face of the membrane after a time delay influenced by the effect of the channels 34 and holes 38 forming part of the delay means so that the pressure difference produced across the membrane by these sound waves increase due to the phase difference introduced by the time delay.

The above is true as long as the wavelength of the sound waves is large compared to the dimensions of the microphone.

If, however, the sound waves arrive in substantially axial direction at the rear side of the microphone, they will, for reaching the inner face of the membrane pass through the channels 34 and the holes 38 and reach the inner face of the membrane 21 after a time delay caused by the delay means mentioned above. These waves will also travel around the microphone and arrive then at the outer face of the membrane, in which case no pressure difference will be produced across the membrane if the channels 34, the holes 38, the slot 41 and the volume 39 are properly dimensioned to introduce the proper amount of time delay substantially equal to the time needed for the sound waves to travel around the microphone which is thus rendered unidirectional.

At the predefined frequency, the air cushion 40 will become effective to elastically retard the oscillatory system of the transducer so that the effect of losses in the iron in the magnetic circuit will again be compensated throughout the entire frequency range.

In the embodiment of Fig. 2, additional friction means may be provided other than that provided by the narrow passages 41/35. For example, a plurality of channels may be provided, porous material or a combination of these different means. Again, in this embodiment, the friction element may be designed to be adjustable to permit a simple adjustment of the frequency response of the sound receiver.

The annular disc 42 arranged as shown in Fig. 2 is particularly effective for a unidirectional microphone since it influences the phase shift between the directly arriving sound waves and the sound waves passing from the front of the microphone around the latter to the rear and vice versa. As explained hereinabove, the time delay means insure the proper phase relationships for these sound waves with either additive or compensating effect, as the case may be.

Instead of the annular disc 42 a wire gauze ring consisting of one or more layers of wire gauze may be employed.

The arrangement of Fig. 2 can be slightly modified to permit an operator to have a unidirectional or non-directional microphone. For example, an additional plate might be provided and mounted adjacent to the member 37. This additional plate will have holes therethrough corresponding to the holes 38, but would be rotatable so that the holes 38 could either be exposed to the atmosphere or closed. If the holes are closed, a non-directional microphone is produced. If the holes are opened to the atmosphere, a uni-directional microphone is produced. Such a plate 70 will be illustrated in Fig. 4.

When the holes are closed the element 41 cooperating with the compensating volume 39 will operate as the frictional retardation means in the lower portion of the transmission range while the channels 36 and holes 38 are rendered ineffective. It is apparent that a remotely actu-

ated device may also be used for changing the directional characteristics of the microphone.

If desired, two unidirectional electromagnetic microphones embodying the principles of the present invention can be arranged so that each of the microphones is directed toward a different sector of the surrounding area or space. Means could be provided for selectively operating the microphones in phase or in opposing phase to provide a very flexible microphone arrangement which can provide a coverage pattern in the nature of a figure-eight, a circular pattern, or a cardioid pattern which can be produced for either sector covered by each microphone. With such two microphones, different directional patterns may be provided which are intermediate the above listed patterns.

As mentioned hereinabove, the membrane can be made of a ferro-magnetic material or some ferromagnetic member may be arranged thereon. In either event, it may be desirable to have a stiffening element. One such arrangement is shown in Fig. 3 wherein a cap 53 is mounted on a ferromagnetic annular member 52. The member 52 in turn is arranged on the non-magnetic membrane 51. The dome-shaped cap is adapted to increase the rigidity of this arrangement.

It may be desirable for transducers having the arrangement shown in Figs. 1 and 2 to provide an auxiliary magnetic system which is substantially symmetrical to the magnetic circuit in the interior of the housing. In this way it is possible to relieve the membrane of the magnetic forces which are produced by the magnetic excitation and operation at only one side of the membrane. At the same time the amount of steady magnetic flux in the ferromagnetic material of the membrane will be compensated.

One such arrangement is shown in Fig. 4. In this figure, each of the elements identified by the same numerals as in Fig. 2 have the same function. However, in Fig. 4 it can be seen that an auxiliary magnetic arrangement is provided adjacent to the outer face of the membrane 21.

The auxiliary circuit includes a support element 61 having channels 62 therethrough and a large diameter central passageway 63 for passage of the sound waves therethrough. A second radially magnetized permanent magnet 64 is mounted between two cylindrical pole shoes 65 and 66.

It can be seen that the auxiliary magnetic system is mounted on the microphone concentric to the central axis of the housing of the microphone. The pole shoes of the microphone and of the auxiliary system are aligned with each other.

For more simple adjustment, the auxiliary magnetic circuit may be provided with means for adjusting the position thereof with respect to the microphone proper. This will provide more flexibility in the resulting transducer.

It is also possible in all of the embodiments shown in Figs. 1, 2 and 4 to provide a magnetic shunt in the magnetic circuit of the transducer and to make this shunt adjustable. In this way, it is possible to influence the continuous magnetic electromotive force in the alternating magnetic circuit.

If desired, the frequency curve in the lower portion of the frequency transmission range may be varied by various conventional arrangements such as a Helmholtz resonator.

In Fig. 4, a plate 70 is shown having openings 72 cooperating with the openings 38 in the plate 37 and being rotatably mounted at the center thereof by means of a screw 71. As explained hereinabove, the plate 70 may be rotated to cover the openings 38 to change the microphone from a unidirectional to an omnidirectional microphone.

It will be understood that each of the elements described above, or two or more together, may also find a

useful application in other types of electroacoustic transducers differing from the types described above.

While the invention has been illustrated and described as embodied in an electromagnetic microphone having a desired frequency response throughout a very wide frequency range, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be secured by Letters Patent is:

1. An electroacoustic transducer for use throughout a wide frequency range, comprising, in combination, an open-ended housing; means arranged in said housing for producing a magnetic field having magnetic lines of flux with a preselected distribution extending through the open end of said housing; membrane means containing ferromagnetic material and arranged on said open end of said housing to substantially seal said open end from the surrounding atmosphere, said membrane means being adapted to be vibrated in said magnetic field by sound waves transmitted through said surrounding atmosphere and impinging thereon to vary the distribution of said magnetic lines of flux; a plurality of retarding means arranged within the air space in said housing opposite said membrane means and including elastic and non-elastic retarding means, at least one of said non-elastic retarding means being arranged for, and capable of, predominately retarding said membrane when it vibrates in the lower portion of said wide frequency range below a predefined frequency, but ineffective above said predefined frequency, said elastic retarding means being arranged for, and capable of, predominately retarding said membrane when it vibrates throughout the remainder of the wide frequency range; and means responsive to the changes of distribution of said magnetic lines of flux for producing electrical impulses as a function thereof.

2. An omnidirectional electroacoustic transducer for use throughout a wide frequency range, comprising, in combination, an open-ended housing; means mounted in said housing for producing a magnetic field having magnetic lines of flux with a preselected distribution extending through the open end of said housing; membrane means containing ferromagnetic material and arranged on said open end of said housing to substantially seal said open end from the surrounding atmosphere, said membrane means being adapted to be vibrated in said magnetic field by sound waves transmitted through said surrounding atmosphere and impinging thereon to vary the distribution of said magnetic lines of flux; frictional retarding means arranged within the air space in said housing, said frictional retarding means being arranged for, and capable of, predominately frictionally retarding said membrane when it vibrates in the lower portion of said wide frequency range below a predefined frequency but being ineffective above said predefined frequency; elastic retarding means arranged within the air space in said housing for, and being capable of, predominately retarding said membrane when it vibrates throughout the remainder of the wide frequency range; and means responsive to the changes of distribution of said magnetic lines of flux for producing electrical impulses as a function thereof.

3. A directional electroacoustic transducer for use throughout a wide frequency range, comprising, in combination, an open-ended housing; means mounted in said

housing for producing a magnetic field having magnetic lines of flux with a preselected distribution extending through the open end of said housing; membrane means containing ferromagnetic material and arranged on said open end of said housing to substantially seal said open end from the surrounding atmosphere, said membrane means being adapted to be vibrated in said magnetic field by sound waves transmitted through said surrounding atmosphere and impinging thereon to vary the distribution of said magnetic lines of flux; mass retarding means arranged within the air space in said housing, said mass retarding means being arranged for, and capable of, predominately retarding said membrane when it vibrates in the lower portion of the wide frequency range below a predefined frequency; elastic retarding means arranged within the air space in said housing for, and being capable of, predominately retarding said membrane when it vibrates throughout the remainder of the wide frequency range; and means responsive to the changes of distribution of said magnetic lines of flux for producing electrical impulses as a function thereof.

4. An omnidirectional electroacoustic transducer for use throughout a wide frequency range, comprising, in combination, an open-ended housing; means mounted in said housing for producing a magnetic field having magnetic lines of flux with a preselected distribution extending through the open end of said housing; membrane means containing ferromagnetic material and arranged on said open end of said housing to substantially seal said open end from the surrounding atmosphere, said membrane means being adapted to be vibrated in said magnetic field by sound waves transmitted through said surrounding atmosphere and impinging thereon to vary the distribution of said magnetic lines of flux; frictional retarding means arranged in said housing spaced from said membrane, said frictional retarding means being arranged for, and capable of predominately retarding said membrane when it vibrates in the lower portion of the wide frequency range below a predefined frequency range, said frictional retarding means including air duct means dimensioned to prevent passage of air therethrough vibrating at a frequency above said predefined frequency; elastic retarding means arranged within the air space in said housing for predominately retarding said membrane when it vibrates throughout the remainder of the wide frequency range and being ineffective below said predefined frequency; and means responsive to the changes of distribution of said magnetic lines of flux for producing electrical impulses as a function thereof, the intensity of said impulses remaining substantially constant through said lower portion of the wide frequency range due to effect of said frictional retarding means.

5. A substantially unidirectional electroacoustic transducer for use throughout a wide frequency range and responding only to sound waves coming from a predetermined frontal direction, comprising, in combination, a housing having an open and an opposite closed end; means mounted in said housing for producing a magnetic field having magnetic lines of flux with a preselected distribution extending through the open end of said housing; membrane means containing ferromagnetic material and arranged on said open end of said housing to substantially seal said open end from the surrounding atmosphere, said membrane means being adapted to be vibrated in said magnetic field by sound waves transmitted through said surrounding atmosphere and impinging thereon to vary the distribution of said magnetic lines of flux; retardation means arranged in said housing and including air passage means leading through said closed end of said housing to the inner side of said membrane means, said retardation means being arranged for, and capable of, predominately mass retarding said membrane when it vibrates in the lower portion of the wide frequency range below a predefined frequency; elastic retarding means arranged in said housing

for, and capable of, predominately retarding said membrane when it vibrates throughout the remainder of the wide frequency range; and means responsive to the changes of distribution of said magnetic lines of flux for producing electrical impulses as a function thereof.

6. An electroacoustic transducer for use throughout a wide frequency range, comprising, in combination, an open-ended housing; means mounted in said housing for producing a magnetic field having magnetic lines of flux with a preselected distribution extending through the open end of said housing; a ferromagnetic membrane arranged on said open end of said housing to substantially seal said open end from the surrounding atmosphere, said membrane means being adapted to be vibrated in said magnetic field by sound waves transmitted through said surrounding atmosphere and impinging thereon to vary the distribution of said magnetic lines of flux; a plurality of retarding means arranged within the air space in said housing opposite said membrane means and including elastic and non-elastic retarding means, at least one of said non-elastic retarding means being arranged for, and capable of, predominately retarding said membrane when it vibrates in the lower portion of the wide frequency range below a predefined frequency, said elastic retarding means being arranged in said housing for, and being capable of, predominately retarding said membrane when it vibrates throughout the remainder of the wide frequency range; and means responsive to the changes of distribution of said magnetic lines of flux for producing electrical impulses as a function thereof.

7. A substantially unidirectional electroacoustic transducer for use throughout a wide frequency range and responding only to sound waves coming from a predetermined frontal direction, comprising, in combination, a housing having an open end and an opposite closed end; means mounted in said housing for producing a magnetic field having magnetic lines of flux with a preselected distribution extending through the open end of said housing; membrane means containing ferromagnetic material and arranged on said open end of said housing to substantially seal said open end from the surrounding atmosphere, said membrane means being adapted to be vibrated in said magnetic field by sound waves transmitted through said surrounding atmosphere and impinging thereon to vary the distribution of said magnetic lines of flux; retardation means arranged in said housing and including air passage means leading through said closed end of said housing to the inner side of said membrane means for delaying the transmission of sound waves therethrough, said retardation means being arranged for, and capable of, predominately mass retarding said membrane when it vibrates in the lower portion of the wide frequency range below a predefined frequency; elastic retarding means arranged in said housing for, and capable of, predominately retarding said membrane when it vibrates throughout the remainder of the wide frequency range; and means responsive to the changes of distribution of said magnetic lines of flux for producing electrical impulses as a function thereof.

8. Apparatus as claimed in claim 7 wherein said air passage means are capable of introducing a time delay for sound waves transmitted therethrough so that sound waves coming from a direction other than said predetermined frontal direction will be prevented from establishing a pressure gradient across said membrane means.

9. An electroacoustic transducer for use throughout a wide frequency range, comprising, in combination, an open-ended housing; means mounted in said housing for producing a magnetic field having magnetic lines of flux with a preselected distribution extending through the open end of said housing; membrane means containing ferromagnetic material and arranged on said open end of said housing to substantially seal said open end from the surrounding atmosphere, said membrane means including a membrane of non-magnetic material and an annular fer-

romagnetic member arranged on said membrane in said magnetic field and being adapted to be vibrated in said magnetic field by sound waves transmitted through said surrounding atmosphere and impinging thereon to vary the distribution of said magnetic lines of flux; a plurality of retarding means arranged within the air space in said housing opposite said membrane means and including elastic and non-elastic retarding means, at least one of said non-elastic retarding means being arranged for, and capable of, predominately retarding said membrane when it vibrates in the lower portion of the wide frequency range below a predefined frequency, said elastic retarding means being arranged in said housing for, and capable of, predominately retarding said membrane when it vibrates throughout the remainder of the wide frequency range; and means responsive to the changes of distribution of said magnetic lines of flux for producing electrical impulses as a function thereof.

10. Apparatus as claimed in claim 1 wherein said ferromagnetic material contained by said membrane means includes permanent magnetic material.

11. An electroacoustic transducer for use throughout a wide frequency range, comprising, in combination, an open-ended housing; means mounted in said housing for producing a magnetic field having magnetic lines of flux with a preselected distribution extending through the open end of said housing; membrane means containing ferromagnetic material and arranged on said open end of said housing to substantially seal said open end from the surrounding atmosphere, said membrane means being adapted to be vibrated in said magnetic field by sound waves transmitted through said surrounding atmosphere and impinging thereon to vary the distribution of said magnetic lines of flux; a plurality of retarding means arranged within the air space in said housing opposite said membrane means and including elastic and non-elastic retarding means, at least one of said non-elastic retarding means being arranged for, and capable of, predominately retarding said membrane when it vibrates in the lower portion of the wide frequency range below a predefined frequency, said elastic retarding means being arranged in said housing for, and capable of, predominately retarding said membrane when it vibrates throughout the remainder of the wide frequency range; means responsive to the changes of distribution of said magnetic lines of flux for producing electrical impulses as a function thereof; and an auxiliary magnetic circuit arrangement mounted on said housing on the opposite side of said membrane from said magnetic field producing means.

12. An electroacoustic transducer for use throughout a wide frequency range, comprising, in combination, an open-ended housing; permanent magnet means mounted in said housing for producing a magnetic field having magnetic lines of flux with a preselected distribution extending through the open end of said housing; membrane means containing ferromagnetic material arranged on said open end of said housing to substantially seal said open end from the surrounding atmosphere, said membrane means being adapted to be vibrated in said magnetic field by sound waves transmitted through said surrounding atmosphere and impinging thereon to vary the distribution of said magnetic lines of flux; a plurality of retarding means arranged within the air space in said housing opposite said membrane means and including elastic and non-elastic retarding means, at least one of said non-elastic retarding means being arranged for, and capable of, predominately retarding said membrane when it vibrates in the lower portion of the wide frequency range below a predefined frequency, said elastic retarding means being arranged in said housing for, and being capable of, predominately retarding said membrane when it vibrates throughout the remainder of the wide frequency range; and means responsive to the changes

13

of distribution of said magnetic lines of flux for producing electrical impulses as a function thereof.

13. An electroacoustic transducer for use as a unidirectional or omnidirectional transducer throughout a wide frequency range, comprising, in combination, a housing having an open end and a closed end, the latter having air passages therethrough; means arranged in said housing for producing a magnetic field having magnetic lines of flux with a preselected distribution extending through the open end of said housing; membrane means containing ferromagnetic material and arranged on said open end of said housing to substantially seal said open end from the surrounding atmosphere, said membrane means being adapted to be vibrated in said magnetic field by sound waves transmitted through said surrounding atmosphere and impinging thereon to vary the distribution of said magnetic lines of flux; a plurality of retarding means arranged within the air space in said housing opposite said membrane means and including elastic and non-elastic retarding means, at least one of said non-elastic retarding means being arranged for, and capable of, predominately retarding said membrane when it vibrates in the lower portion of the wide frequency range below a predefined frequency, said elastic retarding means being arranged within the air space in said

14

housing for, and capable of, predominately retarding said membrane when it vibrates throughout the remainder of the wide frequency range; means responsive to the changes of distribution of said magnetic lines of flux for producing electrical impulses as a function thereof; and means movably mounted on said closed end of said housing and moveable between a first position wherein said air passages are closed thereby and said membrane is predominately frictionally retarded below said predefined frequency and a second position wherein said air passages are open to the atmosphere and said membrane is predominately mass retarded below said predefined frequency.

References Cited in the file of this patent

UNITED STATES PATENTS

1,137,235	Schneider	Apr. 27, 1915
2,520,640	Kreisel	Aug. 29, 1950
2,587,684	Bauer	Mar. 4, 1952
2,791,641	Pye	May 7, 1957
2,794,862	Topholm	June 4, 1957

FOREIGN PATENTS

738,029	Great Britain	Oct. 5, 1955
---------	---------------	--------------