May 31, 1966 P. C. DESMARES 3,253,674

CERAMIC MICROPHONE

Filed Sept. 11, 1961

FIG. 1

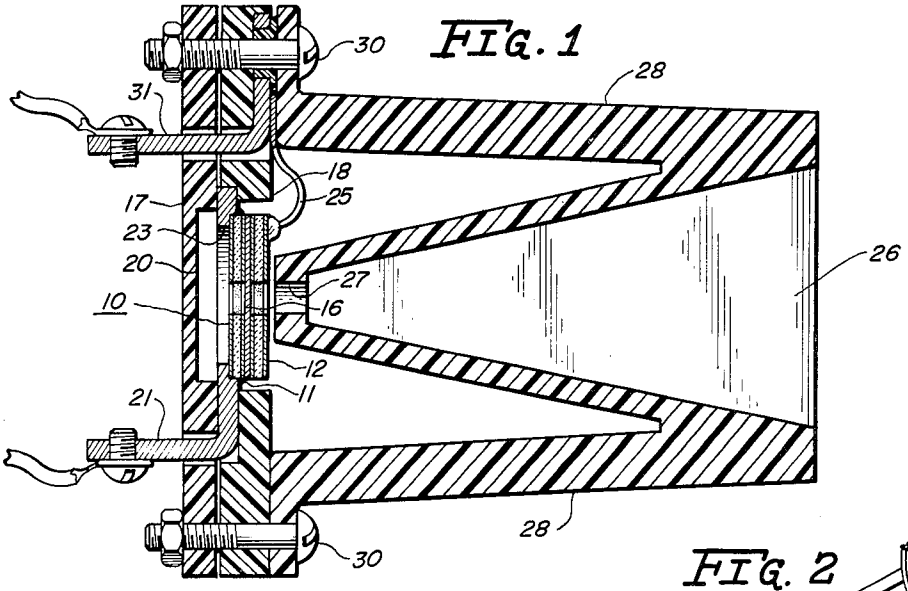


FIG. 2

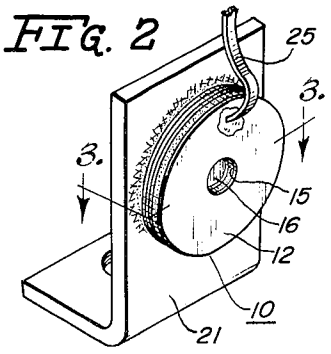


FIG. 5

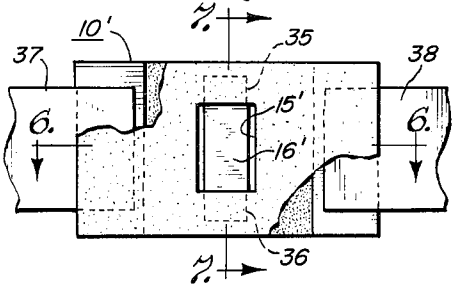


FIG. 6

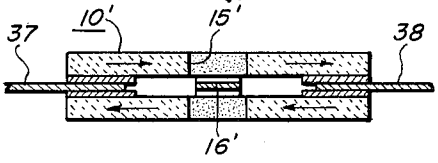


FIG. 3

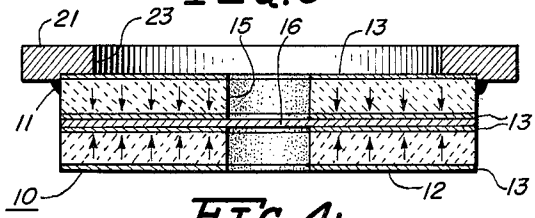


FIG. 4

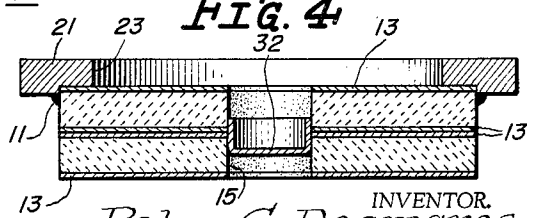
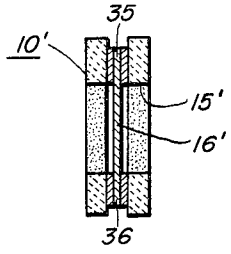


FIG. 7



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3,253,674

CERAMIC MICROPHONE

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1 Claim. (Cl. 181—.5)

This invention relates to electromechanical transducers in general and is particularly concerned with the construction of an improved transducer arrangement for effecting energy transfer to or from a wave-propagating medium which exhibits a materially different impedance at a given signal frequency than the mechanical impedance of the transducer itself.

Transducers of the type under consideration are frequently employed for the purpose of transferring acoustic signal energy from air or other wave-propagating mediums to a wave signal receiver. Because of the reciprocal properties of wave signal reception and transmission, the teachings hereof may be advantageously applied to transmitting as well as to receiving systems. The invention is especially suited for use in remote control systems wherein a controlled or satellite station executes any of several control functions depending upon the frequency of the command signal transmitted by the controlling station. Therefore, for convenience of illustration, the ensuing detailed description will be directed to a microphone and transmitter for that application.

For example, a very successful remote control system featuring the use of a multiplicity of command signals, distinguishable from one another by the frequency of the transmitted energy, is the subject of the United States Letters Patent 2,817,025, issued on December 17, 1957 in the name of Robert Adler and assigned to the same assignee as the present invention. As there described, the controlled device is a television receiver in which the functions of on-off switching, channel selection and sound muting are accomplished by remote control. It is necessary that the controlled receiver be as insensitive to false actuation as practicable or, expressed in other words, it must be relatively free from actuation in response to interference from spurious signals that may be encountered in the vicinity of the controlled receiver. To that end, the controlled station has a narrow acceptance band and is thus able to reject, on the basis of frequency discrimination, interfering signals which do not fall within its acceptance band. By way of illustration, the command signals may be included in the frequency range from 38 to 42 kilocycles and the controlled device only responds to this small band of frequencies.

Some microphones used in remote control receivers have been of an electrostatic type. It is desirable to use a piezoelectric type microphone because of its potentially greater sensitivity. However, a piezeoelectric microphone has the disadvantage of poor impedance match to the wave-propagating medium, especially if this medium is air; in addition, such a microphone usually has a rather sharp acoustical response peak. A piezoelectric microphone of improved construction which provides good impedance matching and a relatively flat response, thereby remedying certain of the above defects, is described and claimed in a copending application of Robert Adler, Serial No. 735,548, filed May 15, 1958, now Patent No. 3,058,539, entitled Ceramic Microphone with Impedance-Matching Bridge, and assigned to the present assignee.

The Adler microphone comprises a piezoelectric or similar bender which is coupled to a matching device in order to obtain a better match between the transducer and the medium into which it transduces. In a specific embodiment as applied to a typical bender, the matching device comprises a U-shaped resonant bridge having its free ends bent toward and secured to one of the flat surfaces of the bender along the flexural lines thereof. In addition to its improved impedance matching, the bridge also provides a flat response peak which is ordinarily characteristic of such a device. While the Adler microphone has performed admirably, simplification of construction and increased transformation efficiency are desirable aims.

Accordingly, it is an object of the present invention to provide an improved electromechanical transducer.

It is another object of this invention to provide an improved electromechanical transducer which exhibits increased band width.

It is yet another object of this invention to provide an improved electromechanical transducer which is compact.

It is a further object if this invention to provide a piezoelectric microphone which has improved shock resistance.

An arrangement of the above type for effecting transfer of acoustical energy with respect to a medium having a predetermined acoustical impedance at a given signal frequency comprises an internally apertured electromechanical transducer having a vibratory frequency of mechanical resonance approximately equal to the desired signal frequency and a mechanical impedance at the signal frequency which is high relative to the impedance of the medium. A mechanical impedance transformation device comprises a mechanically resonant diaphragm which is disposed in the plane of the transducer, exposed to the medium through the aperture, has an impedance at the signal frequency intermediate that of the transducer and the medium, and has a frequency of flexural resonance corresponding to the resonant frequency of the transducer. The diaphragm and transducer constitute a mechanical impedance transformer which is the analogue of an electrical impedance transformer for converting between parallel and series resonant impedance relationships.

The features of the present invention which are believed to be novel are set forth with particularity in the appended claim. The organization and manner of operation of the invention, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawings, in the several figures of which like reference numerals identify like elements, and in which:

FIGURE 1 is a view, in vertical section, of a microphone assembly embodying the present invention;

FIGURE 2 is an enlarged perspective view of a portion of FIGURE 1 showing in detail how the microphone is mounted in the microphone assembly;

FIGURE 3 is an enlarged sectional view taken along line 3—3 of FIGURE 2;

FIGURE 4 shows a modification of the microphone structure shown in FIGURE 3, utilizing a different impedance matching device;

FIGURE 5 is an elevation view, partially cut away, showing still another modification of an impedance matching device;

FIGURE 6 is a sectional view taken along line 6—6 of FIGURE 5; and

FIGURE 7 is a sectional view taken along line 7—7 of FIGURE 5.

Referring now more particularly to the drawings, in FIGURE 1 there is depicted a microphone for effecting transfer of ultrasonic energy with respect to air, which has a predetermined acoustical impedance at a given signal frequency. Air, like any wave signal propagating medium, has a characteristic or acoustical impedance at sonic frequencies which may be described as the ratio of force to velocity of volume flow in a distributed

medium. The difficulty encountered in achieving a piezoelectric ceramic microphone of high sensitivity is in effecting a good impedance match between the piezoelectric element and the air, because of the fact that the mechanical impedance of the ceramic element is very much higher than the impedance of air at the signal frequency. Air is a light medium, is easy to move and experiences a large displacement in response to a relatively small moving force, whereas a piezoelectric transducer is very hard to move and is a heavy device compared with air. It yields but little and experiences only a small displacement in response to the application of a relatively large moving force.

A salient feature incorporated into the invention is an improved structure which, in effect, bridges such dissimilar impedances to attain an efficient coupling therebetween. This is accomplished through the agency of an auxiliary mechanical device which is itself heavier than air and yet lighter than the piezoelectric element. The matching structure is further characterized by a frequency of mechanical resonance matching that of the piezoelectric element and it is connected to that element to define therewith a mechanical structure which is the full equivalent of an electrical impedance transformation network converting between series and parallel impedance in a resonant circuit. A structure which accomplishes the above matching is, as mentioned above, described and claimed in the Adler copending application. The present application provides an improved matching structure which has several advantages as will be described below.

The microphone structure of the embodiment of the invention under consideration comprises a flexural-mode piezoelectric element or bender **10**. A piezoelectric bender is a device which illustratively has two piezoelectric plates or wafers having such relative polarization and electrical connection through an electrode structure that electrical signals developed in response to bending are additively related. As detailed in FIGURE 3, the bender is made up of two plates **11** and **12**, of a material having a high electro-mechanical coupling factor, in order to provide a high efficiency of energy transfer between the electrical and mechanical actions. The class of materials known as titanates is particularly suited for use in such wafers. These compositions, such as barium titanate and strontium titanate, are frequently employed as transducers.

Piezoelectric plates **11**, **12** are circular in shape and have silvered surfaces **13** completely covering both sides. The silvered surfaces serve two purposes: first, they act as electrodes through which a uni-directional potential is applied to the plate for the purpose of establishing a permanent polarization in a given direction in the thickness mode as indicated by the arrows in FIGURE 3; secondly, the silvered surfaces constitute contact points for the output leads of the microphone. As here embodied, the piezoelectric plates individually are polarized in opposed directions.

As best shown in FIGURE 2, the bender consisting of piezoelectric plates **11** and **12** has a hole **15** through its center. The mechanical impedance transformation device of the invention comprises a mechanically resonant diaphragm disposed in the plane of the transducer and exposed to the air through hole **15**. More specifically, a thin circular piece of metallic foil **16** is sandwiched between piezoelectric plates **11** and **12** to couple the bender **10** to air. Preferably, an adhesive is placed on both sides of the diaphragm to permanently unite plates **11** and **12**, forming bender **10**. As shown in FIGURE 3, the cemented edges of the diaphragm extend to the outer diameter of bender **10**. This is done to simplify construction; actually the diaphragm need be affixed only to a small portion of the bender. Since diaphragm **16** is disposed in the plane of bender **10**, no part of it protrudes above the outside surfaces of the bender, thereby making a more compact and durable structure.

A "diaphragm" as used in this context may be defined as a thin flexible sheet that can be moved by sound waves, as in a microphone, or can produce sound waves when moved, as in a loudspeaker. The diaphragm has an acoustical impedance at a predetermined signal frequency intermediate that of the transducer and the air. The frequency of flexural resonance of diaphragm **16** corresponds to the resonance frequency of the transducer and is inversely proportional to the size of aperture **15**. In the specific case of the circular aperture, the frequency of flexural resonance varies as the inverse square of the diameter of hole **15**. Of course, this assumes that the thickness of the diaphragm is constant since the resonant frequency is also proportional to the dimension.

Bender **10**, with its impedance matching diaphragm **16**, is housed within a mounting structure, as shown in FIGURE 1, comprising a base **17** and a cap **18** both formed of an insulating material such as polystyrene. Base **17** has a centrally located recess **20**. Cap **18** has a central aperture which in conjunction with recess **20** of base **17** defines a cavity for receiving the bender-diaphragm assembly. Bender **10** itself is mounted on an electrode **21**, as shown in FIGURE 2, which has a circular aperture **23** adapted to receive the bender and make electrical contact with plate **11**. The electrode and its mounted bender are retained on base **17** by cap **18**. Another output lead **25** of the bender is cemented to the opposite plate **12**, preferably at a nodal circle to present a minimum resistance to vibration.

Diaphragm **16** and bender **10** are coupled to air through a tapered horn **26**. The dimensions of the mouth of the horn are selected in accordance with the requirements of the signalling system in which the microphone is to be employed. In the case of a microphone for use with remotely controlled television receivers, a horn design found to have acceptable directivity is one having a mount dimension one wave-length in the horizontal direction and two wave-lengths in the vertical direction.

The throat of the horn communicates with diaphragm **16** through an acoustical impedance matching section **27** which is a tubular space having a length of ¼ wave-length at the signal frequency. A flange plate **28** mechanically secured to the mouth of the horn is fastened to base **17** and cap **18** by means of fasteners **30**. Fasteners **30** also serve the function of retaining cap **18** against base **17**, thus holding electrode **21** in place and in addition retaining an electrode **31**, as shown in FIGURE 1, against cap assembly **18** to which lead **25** is attached. In the operation of the described microphone, an ultrasonic radiated signal reaching horn **26** is channeled through the quarter-wave impedance matching section **27** to impinge upon diaphragm **16**. The received sonic signal constitutes a small force applied to the resonant diaphragm to set it into flexural mode vibration. The small force applied to the center of the diaphragm produces a displacement of large amplitude and results in a much larger force appearing around the edge of the diaphragm. This large force developed at the edge is applied to the bender and results in its displacement or bending. This displacement is of much smaller amplitude than that experienced by the diaphragm in view of the high mechanical impedance of the bender, but, nonetheless, establishes flexural mode vibration therein of an amplitude considerably larger than that which would have resulted had the bender been directly exposed to the acoustic pressure. The mechanical bending action, through piezoelectrical conversion, results in an electrical signal appearing on electrodes **21** and **31**.

The described mechanical impedance transformation, from a condition of large amplitude displacement and low driving force acting upon diaphragm **16** to a condition of low amplitude displacement and high driving force

acting upon the bender, is analogous to an electrical impedance transformer for converting between parallel and series resonant impedance relationship. This basic concept is more completely explained in the abovementioned copending application of Robert Adler.

A modified microphone is shown in FIGURE 4, where, instead of sandwiching diaphragm **16** between plates **11** and **12**, a cup-shaped diaphragm **32** has its sides cemented to the sides of hole **15**. This embodiment is advantageous in that there is greater flexibility in the placement of the diaphragm within hole **15**. The operation of the device is in all respects similar to that of the embodiment of FIGURES 1–3.

Still another embodiment is shown in FIGURES 5–7 where a rectangular bender **10'** is utilized with a rectangular hole **15'** having a rectangular diaphragm **16'** which is clamped at two ends **35** and **36** as shown in dashed outline in FIGURE 5 and in FIGURE 7. Bender **10'** is suspended in the microphone housing by means of two thin flexible sheets **37** and **38** which extend from the edges of the bender and are clamped between the respective plates.

As detailed in FIGURE 6, the individual piezoelectric plates are polarized longitudinally in contrast to the thickness polarization shown in FIGURE 3; the operation is similar to that of the embodiment of FIGURES 1–3. However, here the frequency of flexural resonance is inversely proportional to the square of the length of one side of the rectangular hole. A further modification of the embodiment of FIGURES 5–7 may be made by clamping diaphragm **16'** at only one end thus allowing the diaphragm to vibrate in a free-clamped mode.

Since there are no protrusions above the surface of the bender, as in the Adler microphone, the microphone of the present invention is more compact. Also, the sandwiching of the impedance matching diaphragm between the plates of the bender, or as in FIGURE 4 the cementing of the sides of the diaphragm to the bender, results in a more shock-resistant, structurally stronger microphone.

The band width of a microphone of this type is related to the mass of the impedance matching diaphragm. The type of construction disclosed provides greater variety in choice of band width since the impedance matching structure can be made with less mass.

While particular embodiments of the invention has been shown and described, it is apparent that modifications and alterations may be made, and it is intended in the appended claim to cover all such modifications and alternations as may fall within the true spirit and scope of the invention.

I claim:

An arrangement for effecting transfer of acoustical energy with respect to a medium having a predetermined acoustical impedance at a given signal frequency comprising: a flexural element comprising two piezoelectric plates including means defining at least one hole therein and having a vibratory frequency of mechancial resonance approximately equal to said signal frequency and a mechanical impedance at said signal frequency which is high relative to the impedance of said medium; a mechanical impedance-transformation device sandwiched between said piezoelectric plates for coupling said flexural element to said medium and comprising a mechanically resonant vibrator element exposed to said medium through said hole in said flexural element and having an impedance at said signal frequency intermediate that of said flexural element and said medium and a frequency of flexural resonance corresponding to that of said flexural element, said flexural element and said vibrator element constituting a mechanical impedance transformer which is the analogue of an electrical impedance transformer for converting between parallel and series resonant impedance relationships.

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