

[54] **ELECTROSTATIC TRANSDUCER**

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[58] Field of Search 179/111 R, 111 E, 106,
179/179, 1 R

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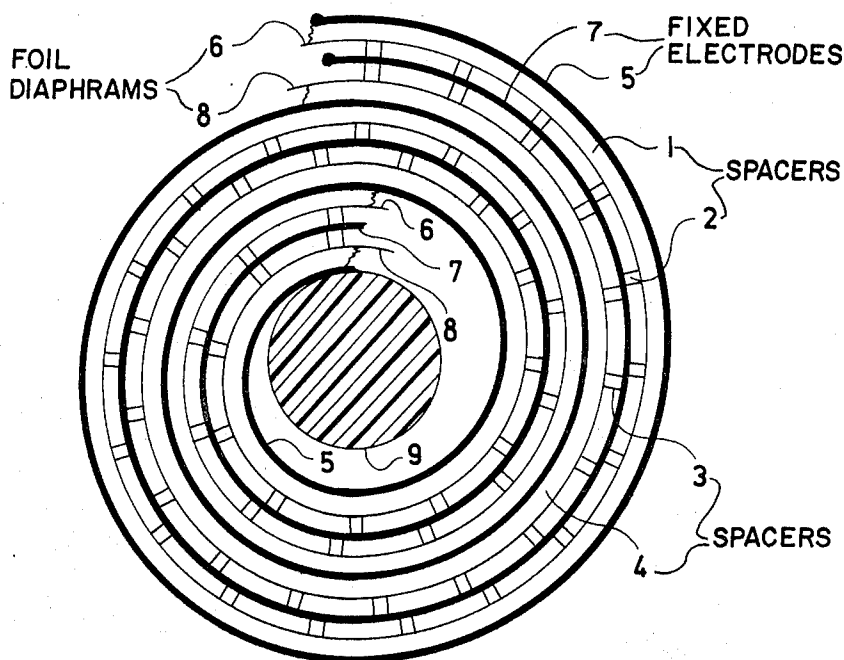
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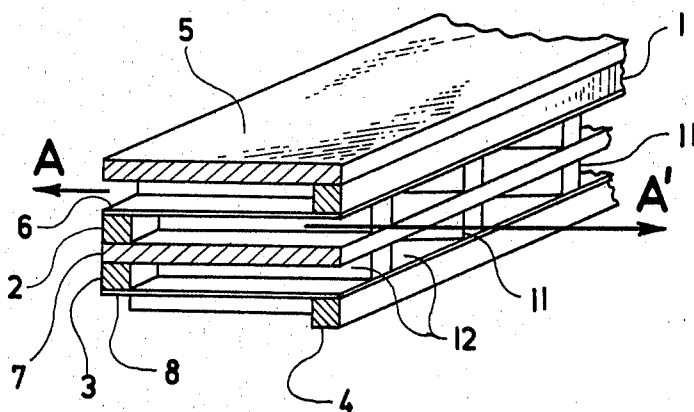
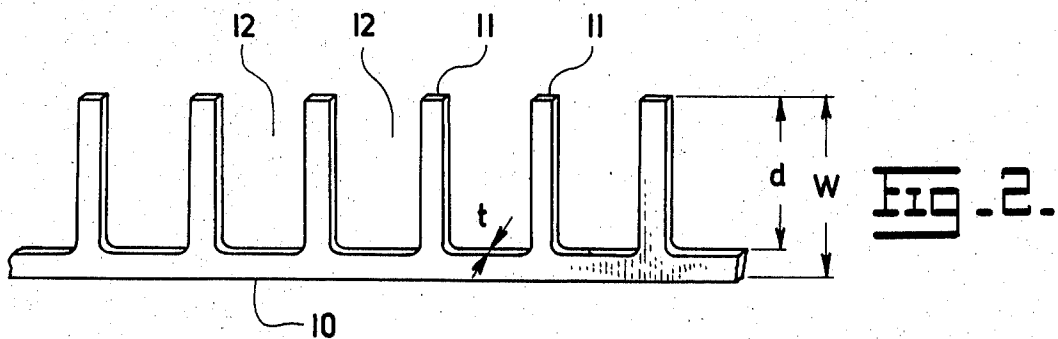
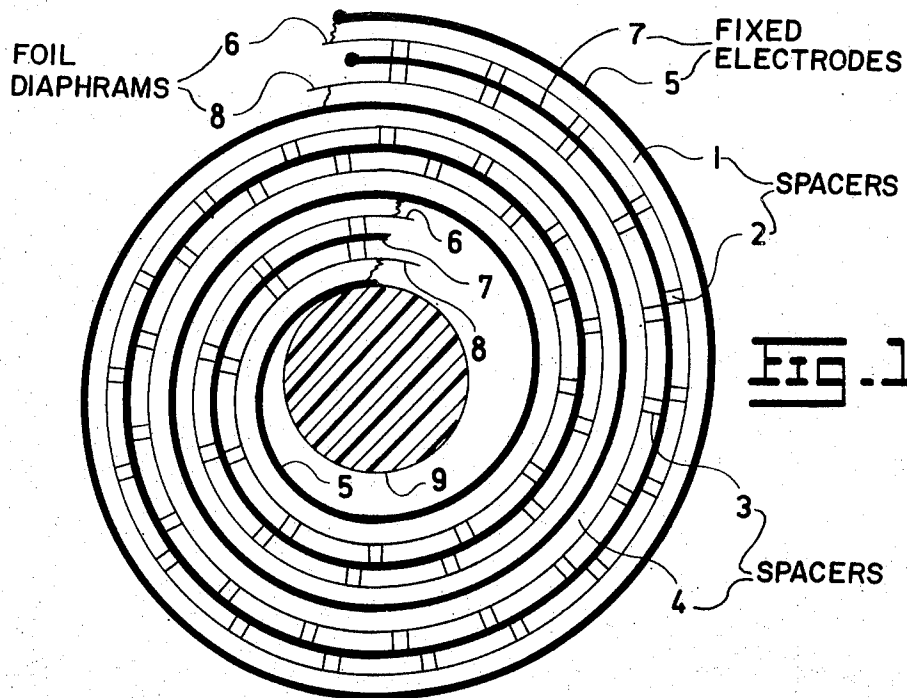
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[57] **ABSTRACT**

An electrostatic transducer of the condenser type used as a loudspeaker and/or microphone comprising an assembly of at least one fixed electrode, a diaphragm and a spacer arranged therebetween. The assembly is spirally wound about a central core into a substantially cylindrical shape. The acoustic input/output thereof being situated at at least one of the frontal ends of the cylinder.

10 Claims, 6 Drawing Figures





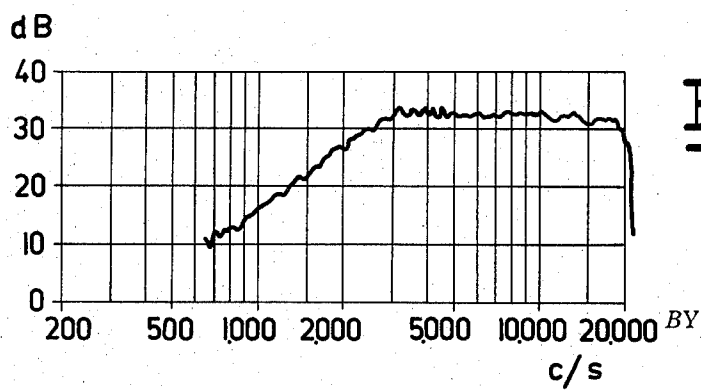
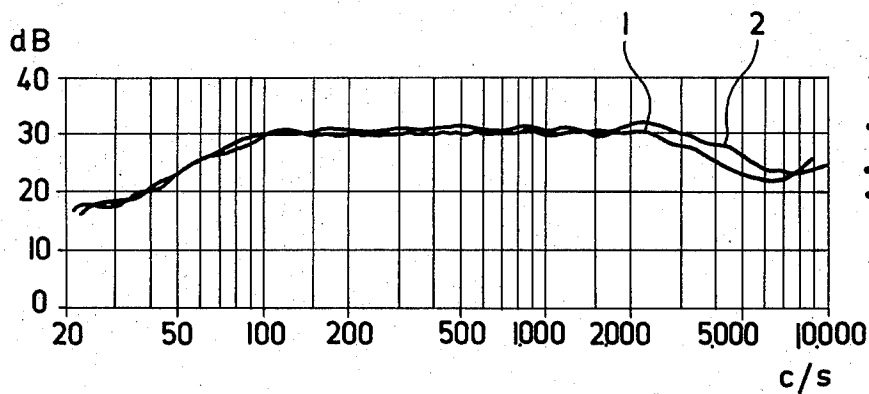
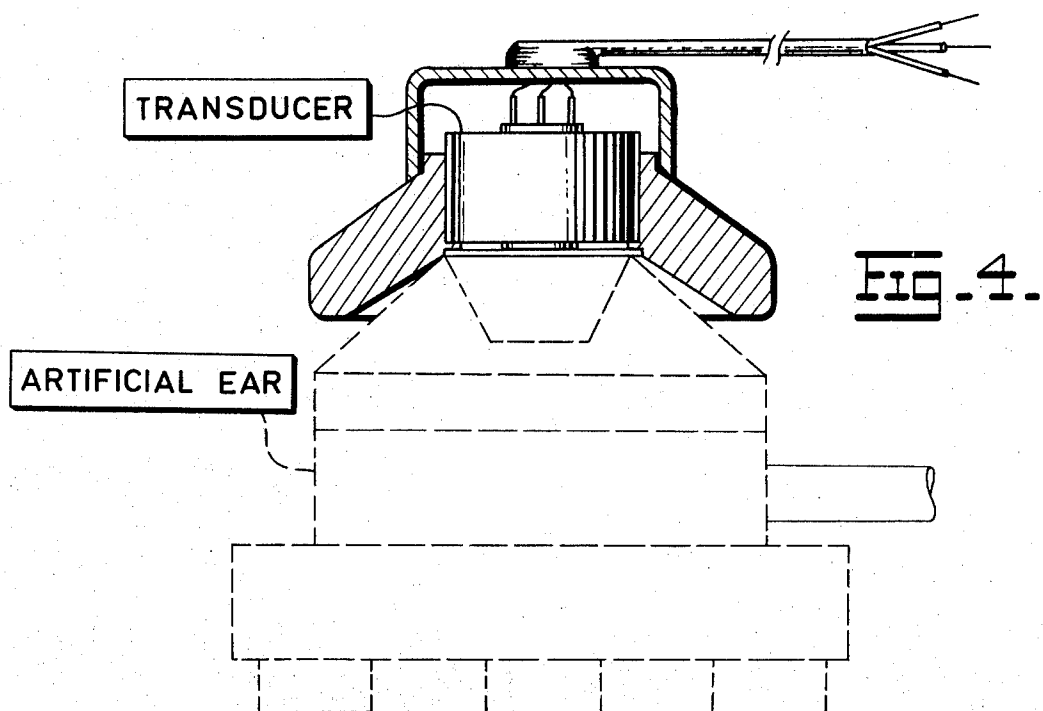
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ELECTROSTATIC TRANSDUCER

This is a continuation of Ser. No. 156,316, filed June 24, 1971.

BACKGROUND OF INVENTION

The present invention relates to the construction of electrostatic acoustic transducers and particularly to electrostatic loudspeakers, microphones and the like.

Electrostatic or condenser transducers have been known for some time but have only recently attained a more general use. Such devices employ a vibrating foil diaphragm spaced from a single fixed electrode or sandwiched between a pair of electrodes. A static electrical charge is set between the fixed electrodes and/or between the fixed electrodes and the diaphragm in much the same manner as is employed in producing a fixed charge condenser. When used as a loudspeaker, a variable voltage is imposed upon the polarising voltage, resulting in a variation in charge between the diaphragm and the fixed electrodes and consequently a movement in the diaphragm. When used as a microphone, the vibrations of the diaphragm produced by incident sound waves produces change in the electrical capacity of the electrodes. As a result, a variable electrical signal is produced across the diaphragm and fixed electrodes which may then be used to power suitable receiving equipment.

The functional properties of such transducers, that is, the emitted received power, the sensitivity of the receiver, the full frequency range, and other factors depends upon the effective area of the diaphragm. Since the diaphragm is the receiver or radiator of all of the acoustic waves, the diaphragm regardless if planar or concave must be situated in the front of the transducer, to insure proper radiation or reception of the waves. Consequently, the size of the diaphragm is determinative of the entire size and volumetric dimension of the transducer. It has been found necessary to employ larger and larger diaphragms to obtain more effective efficient and sensitive reception and/or radiation of sound waves, both from the acoustical and electrical standpoints. Thus, more recent versions of electrostatic transducers have increased in volume as well as frontal area so that sizes and dimensions have been reached which no longer render them practical.

It is the object of the present invention to provide an electrostatic acoustic transducer overcoming the problems of the prior art.

It is another object of the present invention to provide an electrostatic acoustic transducer which is more efficient and more sensitive as a sound radiation and receiving device.

It is a further object of the present invention to provide an electrostatic transducer which is smaller in size and yet more efficient than those known in the prior art.

It is the specific object of the present invention to provide a spirally wound electrostatic transducer wherein the effective area of the diaphragm is much larger in respect to the total volumetric space encompassed by the device, and where radiation and reception of acoustic signals is obtained from the frontal ends thereof.

These objects, and other objects, have numerous advantages which will be apparent from the following disclosure.

SUMMARY OF INVENTION

According to the present invention, an electrostatic transducer suitable for use as either a loudspeaker or a microphone is provided comprising an assembly of at least one fixed electrode, a diaphragm and a spacer arranged there between. The assembly is spirally wound about a central insulator core into a substantially cylindrical shape. The acoustic input/output thereof are situated at at least one of the frontal ends of the cylinder.

Preferably, according to the present invention, the transducer assembly comprises a pair of electrodes and a diaphragm located between them. Spacers are arranged between the diaphragm and each of the fixed electrodes and between successive convolutions of the spiral. The fixed electrodes, diaphragms and spacers comprise elongated narrow strips wound about the core in the direction of their longitudinal axis to thus form an axially limited cylinder. The spacers are formed with a plurality of cut out portions, the cut out portions forming gaps between the diaphragm and the fixed electrodes. Preferably, the spacers are arranged alternatively with respect to the diaphragm so that after the winding of the assembly into its spiral cylindrical form, gaps are provided at opposite ends of the assembly.

It is an aspect of the present invention that the frontal ends of the cylindrical assembly can be shaped and formed to provide both planar and/or curved acoustic radiating surfaces and either/or both may be provided with acoustic wave guide. The transducer thus produced can function as either a loudspeaker or as a microphone dependent upon the desired hook-up of the electrical and impedance functions of the device.

Full details of the present invention are set forth in the foregoing description and in the accompanying drawings of one embodiment of the present invention.

BRIEF DESCRIPTION OF DRAWINGS

In the accompanying drawings:

FIG. 1 is a sectional view of a cylindrical transducer formed in accordance with the present invention, the view is seen cut transversely to the axis of the cylindrical form;

FIG. 2 is an enlarged view of the spacer element employed in the present device, and

FIG. 3 is an enlarged development of the laminate arrangement forming the structure shown in FIG. 1,

FIG. 4 is a view of a transducer embodying the present invention arranged with an artificial ear piece;

FIG. 5 is a graph showing the frequency response of the device of FIG. 4;

FIG. 6 is a graph illustrating the frequency response of the device used as a tweeter.

DESCRIPTION OF INVENTION

The following description and drawings are directed to a showing of so much of an electrostatic acoustical transducer as is necessary for an understanding of the present invention. The description is directed largely to the structure of the transducer and not to its function or connection in an appropriate loudspeaker radiating or receiving system. The impression of electrostatic charges and variable signals upon the device and the location of the device in an appropriate radiating and receiving system are essentially conventional in nature and therefore their disclosure and full description need

not be made in the present description. Polarisation of the air gap can likewise be carried out by means of electret. Reference, however, may be made to such publications as the following for complete descriptions and details of these references, which references are embodied on the inclosed list forming a part of the description.

Turning now to the drawings, the transducer comprises a laminate structural assembly rolled into a spiral form in the shape of a cylinder. The laminate assembly comprises alternating layers of spacer 1, 2, 3 and 4; fixed electrodes 5 and 7; and diaphragm foils 6 and 8. All are wound about a core 9 made of insulated or insulator material.

As seen in FIG. 2, the spacers 1, 2, 3 and 4 each comprise a strip of insulator material such as foamed or solid rubber, plastic, paper, or similarly suitable material. Each spacer formed by a strip comprises a continuous straight back 10 along which are spaced at predetermined intervals transverse parallel ribs 11 defining open spaces or cut out portions 12 between them. Each strip has a depth d which is determined and preselected according to the electro-acoustical characteristics desired for particular use of the transducer. Preferably, the spacer 1, 2, 3 and 4 are of each uniform dimension throughout their length and have a uniform width w and a wall thickness t , sufficient to provide the required physical strength to support and hold the electrodes and diaphragms in secure rigid position when flexed and rolled into the spiral form seen in FIG. 1.

Each of the fixed electrodes 5 and 7 is of the same width of the spacers 1, 2, 3 and 4 and are made of electrically conductive material suitable for use in electrostatic transducers such as a thin elongated foil of flexible and mechanically soft metallic material. The fixed electrodes 5 and 7 are designed to be fixed and non-vibratory and therefore should have a thickness which provides such characteristics. The diaphragms 6 and 8 are also formed of thin metallic foils and/or metal coated plastic or other synthetic foil capable of easily vibrating according to the characteristics desired. The diaphragms 6 and 8 also have a width w corresponding to that of the spacers and electrodes and a thickness which would insure desired vibration under proper excitation.

The transducer is assembled by stacking the components as seen in FIG. 3 and then rolling the same about the core 9 into the form seen in FIG. 1. The uppermost layer of the stack is the fixed electrode 5, followed by the spacer 1, the diaphragm 6, the spacer 2, the fixed electrode 7, the spacer 3, the diaphragm 8, and finally, the spacer 4. The adjacent upper spacers 1 and 2 and the adjacent lower spacers 3 and 4 are superimposed from both sides of the diaphragm so that their ribs 11 face and provide cut out portions 12 on either side of its associated diaphragm 6 or 8. These spacers 1 and 4, or 2 and 3 resp., provide input/output openings outwardly in the same direction. The paired spacers 1 and 2 and 3 and 4 have their ribs facing in opposite directions as indicated by the arrows A and A' . Thus, the opposed spacing of the input/outputs provide free chambers on opposite sides of each diaphragm facing in the direction of each of the frontal faces of the spirally wound cylindrical form. The acoustic inputs/outputs thus formed are directed outwardly of either side of the cylindrical assembly and form directional input/outputs following the arrows A , A' . Since, in the final

form of the transducers, the sides represented by the arrows A and A' constitute the axial frontal ends of the cylinder, sound will be projected or received at both ends of the cylindrical transducer simultaneously.

It will be observed that the critical feature of the size of the transducer is determined by the width w of the strips forming the fixed electrodes, diaphragm, and spacers. This width determines the axial length of the cylinder since, as has been shown before, the stack of layers of the assembly are wound about their longitudinal length. After winding or rolling the stack seen in FIG. 1, the upper fixed electrode 5 turns in its spiral convolution from being the outermost layer to being the innermost layer and, in fact, becomes contiguous to the lower most spacer 4, thus after the spiral is wound, the lowermost diaphragm 8 is sandwiched between fixed electrodes 5 and 7 just as the upper diaphragm 6 is. Both diaphragms are thus subject to simultaneous excitation by signals impressed on both fixed electrodes 5 and 7 and thus a bilateral or push-pull transducer may be produced. On the other hand, the assembly may be so arranged that the fixed electrodes may be excited so that a standard pressure transducer can be produced. The reception of acoustic sound waves on the diaphragm may be converted into an electrical signal in usual manner.

The spiral configuration of the device leads to the advantage of enabling the enlargement of the effective area of the diaphragm while maintaining the overall volume of the device small. The effective area of the device, as has been noted, extends along the frontal ends of the spirally wound cylinder, constituted by the longitudinal edges of the strips of the fixed electrodes, diaphragms and spaces forming the assembly which are spirally convoluted about themselves. The radius of the spiral is obviously very small compared to the length of the strips employed. Thus, extremely elongated strips, providing extensive effective diaphragm surfaces, may be wound into narrow spiral coils of relatively small radius or diameter. The use of thin fixed electrode and diaphragm material and of spacers designed for maximum electrostatic function with minimum of width further enables the production of small diameter transducers. The axial length of the cylindrical assembly is, as will be obvious, not a critical factor in the electrostatic acoustic operation of the device provided that sufficient area is permitted for the diaphragm to vibrate freely.

It has been found preferable to maintain a range of the ratio between the frontal area of the transducer, i.e., the base of the cylinder and the active area of the diaphragm between 1:5 to 1:25. In this range, highly efficient and effective transducers can be obtained which provide full range of frequency and sound wave production and reception. As seen in the drawings, the frontal ends of the cylinder can be made planar. These frontal ends may also be convexly or concavely formed so as to vary the acoustic input or output function thereof.

The transducer may be loaded with any arbitrary acoustic impedance to produce a radiating output or a radiation reception input. The device, as noted above, may operate as a push-pull electrostatic device or as a pressure device wherein sound waves are directly emitted or received on the diaphragm itself. The transducer may also be loaded with an input or output impedance of an exponential or similar wave guide type so as to

5

provide an indirect radiating horn-type loudspeaker or even ear-piece. The transformation of the transducer into a horn-type loudspeaker may be obtained by connecting either of the frontal ends to an exponential wave guide or horn having an input cross-section. On the other hand, the input impedance of the ear may be used to allow the transducer to operate as an earphone at which the transformation of the velocity can be reached in a similar manner as given above.

As one of the examples of the use of the spiral transducer according to the invention an earphone is shown in the FIG. 4. Said earphone is illustrated in connection with an artificial ear operating according to IEC specification, said artificial ear being shown in dotted lines. The frequency response of this earphone is shown in FIG. 5. The curve 1 represents the response of the earphone measured by the artificial ear having a cavity of 2.5 cm³, the curve 2 represents the frequency response of the same cavity increased by 2 cm³, i.e., to the total value of 4.5 cm³.

The very same type of transducer can also be used as a tweeter. The FIG. 6 illustrates the frequency response measured in the axis of the transducer, the latter being placed in a plane baffle.

It will be thus seen that the present invention provides a very simple device by which the defects of the prior art are overcome. The present device is capable of being made in rather small sizes producing, to contrary, an effective sensitive and full-frequency radiation and reception. It will be obvious that the present invention may be embodied in many forms and it is, therefore, intended that the present description be taken as illustrative only and not as a limitation.

What is claimed:

1. An electrostatic transducer capable of receiving and transmitting, comprising an assembly of a pair of elongate fixed electrodes, alternating with a pair of conforming diaphragms and two pairs of similarly elongate dielectric strip spacers, said assembly being convoluted into a tight spirally wound cylinder having the electrodes, and diaphragms alternating successively from the center to the outer periphery thereof, each separated by a spacer strip in contiguous contact therewith, said spacer strips being constructed in the configuration of a unitary comb-like structure to provide in

6

said tight spirally wound cylinder a plurality of separated ports being open to free space on one plane which would lie on a base, herein termed frontal end, of said cylinder and closed on another plane which would lie on the opposite base, herein also termed frontal end, of said cylinder for each spacer strip, said ports providing a free space between successive radial convolutions of said electrodes and diaphragms, the acoustic input/outputs of said transducer being said ports.

2. The transducer according to claim 1 including an acoustic wave guide axially located at at least one end of said cylindrical assembly, said wave guide having an input cross-section substantially equal to the area of the frontal end of said transducer.

3. The transducer according to claim 1 wherein a variable charge is impressed upon the fixed electrodes about said assembly operating as a push-pull transducer.

4. The transducer according to claim 1 wherein a variable charge is impressed between at least one diaphragm and at least one of said fixed electrodes, said assembly operating as a pressure transducer.

5. The transducer according to claim 1 wherein an amplifier is attached to said fixed electrodes, said assembly operating as a microphone receiver.

6. The transducer according to claim 1, including a central core formed of insulator material, said convoluted assembly being secured about said core.

7. The transducer according to claim 6 wherein said fixed electrodes, diaphragms, and spacers comprise elongated narrow strips wound about said core in the direction of the longitudinal axis of the strips.

8. The transducer according to claim 1 wherein said spacers comprise elongated strips of insulator material, said spacers being alternatively arranged with respect to said one plane so that input/output ports are provided on both frontal ends of said assembly.

9. The transducer according to claim 8 wherein at least one of the frontal ends of said cylindrical assembly are planar.

10. The transducer according to claim 8 wherein at least one of the frontal ends of said cylindrical assembly is curved.

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