April 10, 1956 H. B. MILLER 2,741,754

DISK TRANSDUCER

Filed Dec. 27, 1950

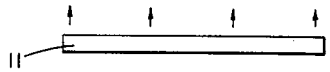


FIG. 1A



FIG 1B

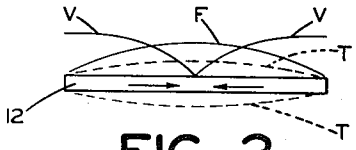


FIG. 2

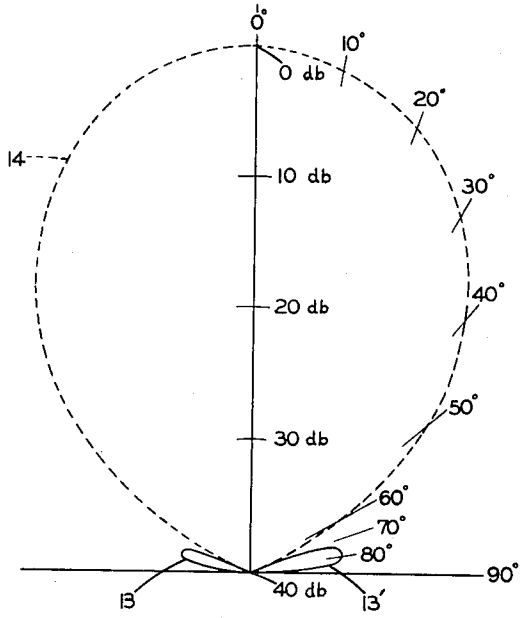


FIG. 3

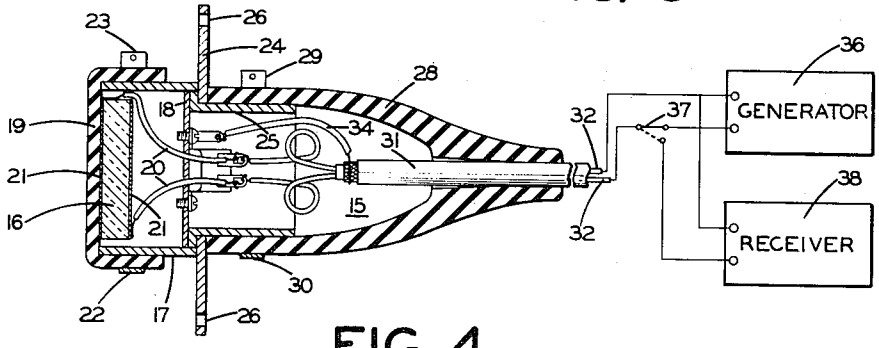


FIG. 4

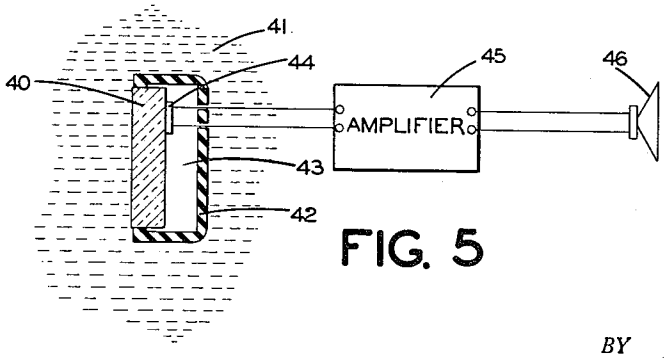


FIG. 5

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2,741,754

DISK TRANSDUCER

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11 Claims. (Cl. 340—10)

The present invention relates to transducers for operation in liquid mediums, and specifically relates to a transducer of a simplified type which has a single-lobed well-defined directional pattern with respect to sound waves in a liquid medium.

It is frequently desirable to send out a pattern of sound waves in a liquid medium, such as water, with a directional pattern which is essentially a single lobe; that is, one in which all other lobes which may be present are of a relatively small amplitude. As used in this specification, the term "sound" is intended to include any of the audible frequencies as well as any of the frequencies above the audible range or in the supersonic range. Also, in many cases, it is desired to pick up a sound wave in a liquid medium with a microphone which has a directional characteristic similar to that described above. Various arrangements have been proposed for the general types of operation here under consideration. In general, many of these arrangements will operate in either direction; that is, they can be caused to produce a pattern of sound waves in a liquid medium, or they can be used to receive sound waves in a liquid medium with a directional characteristic of the type here under consideration. Specifically, most underwater piezoelectric transducers can be used either to send or receive sound waves in water.

Prior art transducers of the type here under consideration have taken many forms. For example, a single-crystal expander element has been utilized to provide a radiation from a face of the crystal, but a very poor directional characteristic is associated with such an element. Accordingly, therefore, such elements have been used in various arrays and mosaics in order to provide more desirable directional characteristics. Some of these devices have used hundreds of crystal elements and, inasmuch as each such element must be constructed to operate at a predetermined frequency and arranged in a predetermined position with relation to the other elements involved, such devices become very difficult to construct and very expensive. Many of the devices using mosaics are intended to provide a structure which has a "piston action"; that is, one in which all elements move forward and backward simultaneously in the water, but it is very difficult to control the phase of an element with respect to other elements of the mosaic, thus adding to the difficulties involved in a transducer of the mosaic type.

Attempts have also been made to obtain the "piston action" by means of a diaphragm which is driven by a single crystal or a mosaic of crystals. This, in general, is very difficult to do for the reason that flexural modes of motion are always encountered and such motions generally have the effect of providing a directional pattern of a very undesirable type.

Applicant has discovered that it is possible to operate a disk of solid material in a liquid medium in a particular manner such that the difficulties mentioned above are eliminated, thus providing a very simple and useful transducer for use in a liquid medium.

It is an object of the invention, therefore, to provide an improved transducer for operation in a liquid medium.

It is a further object of the invention to provide an improved transducer for operation in a liquid medium and one which has essentially a single-lobed well-defined directional pattern with respect to sound waves in the liquid medium.

It is still another object of the invention to provide an improved transducer for producing sound waves in a liquid medium having a directional pattern which is essentially a single lobe.

It is still a further object of the invention to provide an improved transducer for receiving sound waves in water and which has a directional characteristic which is essentially a single lobe.

In accordance with the invention, a transducer for transducing between sound energy of a predetermined frequency in a liquid medium and energy of another type in the transducer, and having essentially a single-lobed well-defined directional pattern with respect to the sound energy in the liquid medium, comprises a device for transducing between energies of the above-mentioned two different types which includes a disk of material having at the above-mentioned predetermined frequency a mechanical resonance across a diameter thereof which is coupled relatively strongly mechanically to motions in the thickness direction of the disk due to the Poisson ratio of the material of the disk and having other mechanical resonances all of which are relatively remotely removed from the above-mentioned predetermined frequency. This transducer also includes a means for operating the disk in the liquid medium so that the edge or rim and one end face of the disk are acoustically shielded from the liquid medium and so that at least a portion of the other face of the disk is acoustically coupled to the liquid medium. Means are also provided for exciting the disk to resonance across a diameter thereof with energy of one of the types mentioned above and for deriving therefrom energy of the other of the types mentioned above.

For a better understanding of the present invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawing and its scope will be pointed out in the appended claims.

Reference is made to the drawing for a more complete description of several embodiments of the present invention.

In the drawing, Fig. 1A illustrates the desired action of a piston-type transducer; Fig. 1B illustrates a defect which is almost always present in piston-type devices of the prior art; Fig. 2 illustrates the operating principles of a disk operated in accordance with the teachings of the present invention; Fig. 3 shows a directional characteristic which can be obtained with a particular form of the invention illustrated schematically in Fig. 2; Fig. 4 is a cross-section through a complete transducer device which is effective to produce the directional characteristic of Fig. 3; while Fig. 5 illustrates another embodiment of a transducer device in accordance with the invention and operated in a liquid.

It has been stated above that transducer devices for operation in a liquid and which have a piston-type action have been widely used in prior-art devices. The desired action of such a transducer is represented by the illustration of Fig. 1A wherein the numeral 11 represents the transducer which may, for example, be comprised of piezoelectric material and which is so operated that the application of alternating voltages thereto causes expansions and contractions of the element in the direction of the arrows shown and in the opposite directions. The arrows are intended to indicate that, at the instant under consideration, the upper face of this plate is moving in

direction indicated by the arrows. It will be understood that, if the element **11** is a piezoelectric expander, the lower face is at the same instant tending to move in the opposite direction. However, such a device is generally operated in the liquid medium so that the lower face is mounted to a base of relatively large mass or so that a sound-impervious material is present on the lower face, thus causing radiation into the liquid only from the upper face of the material. When operating properly, such a moving surface has a very desirable radiation characteristic, but, as stated above, it is very difficult in practice to provide a surface, all points of which move forward and back in the same plane at all times. If this is done by a single piezoelectric expander element having a relatively small radiating surface presented to the liquid, the directional pattern produced is not very sharp. On the other hand, if it is attempted effectively to provide such an action by a plurality of crystal faces operating simultaneously together, it is very difficult to control the phase of all of the crystal faces so that all move forward and back simultaneously in the same plane. This is the principle upon which most of the mosaic crystal devices operate however and, if satisfactory results are obtained, it is in general necessary to give a great deal of attention to the constructional details of the device and such devices frequently comprise a number of crystals well into the hundreds.

It has also been proposed to drive a diaphragm forward and back in such manner that all parts of its face move simultaneously in the same direction. This again is a very difficult action to procure. The type of action which is generally present with diaphragm-type piston transducers of the prior art is illustrated generally in an exaggerated manner in Fig. 1B. Such diaphragms, whether they be comprised of a single piece of material or effectively made up of a number of separate elements as in the crystal mosaics, generally break up into flexural modes of operation so that all parts of the piston face do not move forward and back in exact phase. In Fig. 1B this is illustrated by the fact that the radiating face involved is not a straight line but has a decided curvature. If such flexural modes are present in the operation of the device under consideration, the directional pattern associated with the device becomes very deleteriously affected. Generally speaking, such a directional pattern does not have a single well-defined lobe but may have one lobe which is larger than the others but with which there is associated a number of minor lobes, which have sufficient size with reference to the main lobe as the cause the over-all operation of the device to become quite unsatisfactory.

In Fig. 2 there is illustrated by the numeral **12** a diametral segment of a disk transducer of the present invention. The disk is so operated that it has a mechanical resonance across a diameter thereof. Accordingly, therefore, in the portion **12** of the disk which is being considered in connection with Fig. 2, it effectively becomes an expander bar which alternately expands and contracts in the direction of the arrows shown in Fig. 2. In considering the operation of such an expander bar, it will be seen that its operation is symmetrical about the midpoint in the length thereof and that, during one cycle of its oscillations, the bar expands in both directions from this midpoint and that, during the other half cycle of its operation, the bar contracts from each end toward this midpoint. If this bar-shaped portion **12** of the disk is considered at the instant when both ends thereof tend to move toward the midpoint of the bar, it will be seen that the force at each end of the bar is at that time a minimum while the force at the midpoint of the bar is at the same time a maximum. Actually the variation in force along the bar is as illustrated by the curve F in Fig. 2. At the same instant, it will be seen that the velocity of the vibration of material along the bar is a maximum at each extreme end thereof and zero in the center of the bar. Actually this variation of velocity along the bar is symmetrical from each end and is represented generally by the curve V of Fig. 2. The strain in the material along a bar of the type illustrated is, in all hard solids, coupled to a transverse strain and it is the motion resulting from this transverse strain which is utilized in the operation of the present invention. The ratio of transverse-to-longitudinal strain estimated per unit length produced by the longitudinal stress is known as "Poisson's ratio." Its value lies between 0.25 and 0.33 for most hard solids. The transverse motions of the material which result from the longitudinal stresses, represented by the curve F of Fig. 2, are as represented by curves T, T of Fig. 2. It will thus be seen that the upper face of the bar **12** is distorted upwardly an increasing amount from each end towards the center of the bar and that the lower face is conversely distorted in a downward direction an amount which increases from each end of the bar toward its center point.

Curve T may be considered to correspond to the current curve of a center-fed dipole radio antenna. A disk of material, of which the bar-shaped section **12** is considered to be a small slice across a diameter thereof, can be considered to have the same type of action across each of its diameters and can be said to be a "dipole of rotation." The operating characteristic of a disk of the type under consideration, and comprised of a material which is primarily barium titanate and which is electrically excited by means of electrodes on each face of the disk to which a voltage of required frequency is applied so that the disk has a mechanical resonance across a diameter thereof, is illustrated in Fig. 3. It will be seen that this operating characteristic comprises a single major lobe, represented by the dotted line **14**, and two very small minor lobes, represented by the full line loops **13** and **13'**. The barium titanate disk from which the operating characteristic of Fig. 3 was derived had a diameter of 2⅛" and a thickness of ½". This disk had a total beam width of 72° at the minus 10 decibel points; that is, the point compared to maximum response which occurs at 0°. An extension of the 10 db reference circle of Fig. 3 to its intersection with the dotted curve **14** shows an intersection at about 36° giving, for both sides of the figure, a total beam width of 72°.

It is thought that the reason that the bar **12** of Fig. 2, or the complete disk of which the bar is a section, does not break up into flexural modes is because the transverse motions, represented by the curves, T, T, are rigidly controlled, in phase and amplitude, by the action or motions of the bar or disk along the length or diameter thereof, as represented by the curves F and V. This effectively causes all vertical movements of the material to be rigidly controlled in accordance with the movements along the diameter. In any event, it has been found that a disk of the type here under consideration provides a single-lobed well-defined directional pattern.

Reference is now made to Fig. 4 for a description of a specific embodiment of the present invention. In Fig. 4 the numeral **15** designates generally a cross-section through a disk-type transducer of the present invention. The disk itself is shown in section and is represented by the numeral **16**. An acoustically impervious enclosure is provided for the edge and one face of the disk. This is done by providing a liquid-impervious enclosure, which includes a portion **17** of a housing for the transducer and a partition **18**, around the surfaces involved. Since air provides a very poor matching impedance for sound as compared to liquid, in this design, the edge and the righthand face of the disk **16** are effectively acoustically insulated. An acoustically transparent window is bonded to the other face of the disk to permit operation of the disk in a liquid medium so that this last-named surface of the disk is acoustically coupled to the liquid medium. This is represented in Fig. 4 by a rubber cap **19** which is bonded to the disk **16**. The disk **16** is comprised primarily of barium

titanate which has been prepolarized to provide a substantially linear transducing action in a manner well understood by those skilled in the art. A transducer of this material and the manner in which it can be polarized are disclosed in United States Letters Patent 2,486,560 granted on November 1, 1949 on an application filed September 20, 1946 by Robert B. Gray. Voltages are applied between the two faces of the disk by means of leads **20**, **20** and electrodes **21**, **21**, on the faces of disk **16**. The rubber cap **19** is clamped on the portion of the housing represented by the numeral **17** by means of a clamp, portions of which are shown at **22** and **23**. The remaining portions of the housing are completed by metallic members **24** and **25**, the portion **24** including holes **26**, **26** to permit mounting the transducer shown and the portion **25** serving, with a second rubber cap member **28**, to enclose the lead structure of the transducer. The cap **28** is fastened to the cylindrical member **25** by means of a clamp, portions of which are represented at **29** and **30**. Leads are brought in through the rear cap **28** through a terminal arrangement, represented generally by the reference numeral **31**. It will be understood that the external terminals **32**, **32** are connected to leads **20**, **20** which, in turn, are connected to electrodes **21**, **21**. A shielded cable is used to bring the leads **32**, **32** through the rubber cap **28** and this shield is grounded inside the device by a connection **34** to the metallic portions of the conductive housing.

The device of Fig. 4 may be used either as a radiator or as a receiver of radiation. In order to illustrate its use as a radiator, a generator **36** is provided which may be coupled to terminals **32**, **32** through a switch **37** when the switch blade is in the position illustrated in the drawing. In order to illustrate its operation as a receiver, there may be coupled thereto an amplifying and reproducing device, represented generally by the numeral **38**, when the switch **37** is moved to its dotted position.

In considering the operation of the device of Fig. 4, it will be first assumed that the switch **37** is in the position shown. Under these conditions, the generator **36** supplies to the disk **16** oscillations of the frequency at which the disk **16** has a mechanical resonance across the diameter thereof. These oscillations are applied through terminals **32**, **32** and leads **20**, **20** to the electrodes **21**, **21** on the faces of the disk. The disk **16** is effective, upon the application thereto of oscillations from generator **36**, to provide motions across all diameters. This provides an action in the disk similar to that described in connection with Fig. 2 above and causes the faces of the disk to have motions, due to the Poisson ratio of the material, as represented by curves T, T of Fig. 2. The left-hand face (of Fig. 4) of the disk will become acoustically coupled to the liquid in which the transducer is submerged. The right-hand face of the disk, on the other hand, is not coupled to such liquid, and sound signals are therefore radiated into the liquid medium only from the left-hand face of disk **16** and with a radiation pattern such as that illustrated in Fig. 3.

Conversely, when the device is to be operated as a receiver, the switch **37** is closed to its dotted position. Any radiation in the liquid medium in which the transducer **15** is submerged, and which is of a frequency corresponding to the mechanical resonance across a diameter of the disk, causes oscillations of the disk in a manner which is effectively the converse of that described in connection with Fig. 2 above. These oscillations cause voltages to be generated across the two faces of the disk which are in turn applied to receiver **38** and amplified and reproduced. The receiving directional characteristic of the device is also as represented by the curves of Fig. 3.

While the invention has been described in Fig. 4 in connection with an embodiment using a barium titanate transducer which has a strong electromechanical action, the principles of the invention can be applied to disks of other material, whether or not the material of the disk is in itself effective to transduce between the two types of energies involved. Thus a disk transducer of the invention may be comprised of magnetostrictive material. Such a disk can be driven magnetically, for operation as a transmitter, or can be driven mechanically by sound energy in the liquid medium, which energy is thereafter converted by the magneto-strictive properties of the disk into magnetic energy which can, in turn, be received and reproduced in a manner generally well understood by those skilled in the art.

Actually the width of the directional characteristic of the transducer of the invention depends upon the diameter of the disk and upon the wavelength of the sound energy in the liquid medium in which the disk is operated. The velocity of propagation of a compression wave through a diameter of a disk of barium titanate material is a substantially fixed value. The frequency at which such a disk operates is inversely proportional to its diameter. The wavelength in the medium is inversely proportional to the frequency involved. Therefore the wavelength in the medium is directly proportional to the diameter of the disk, when the disk is being operated as described above. Therefore the ratio of the diameter of the disk to the wavelength in the medium, for any given medium and any given disk material, is a constant. It therefore becomes somewhat difficult to vary the directional properties of the transducer of the present invention where the liquid medium in which the transducer is to operate is fixed. This liquid medium generally is water. However, disks of other materials may have a somewhat larger diameter corresponding to a mechanical resonance across a diameter at a particular frequency, due to the fact that their velocity of propagation for compression waves is higher than that for barium titanate. For example, the diameter of a steel or glass disk which has a mechanical resonance across a diameter at a given frequency is appreciably greater than that of a barium titanate disk. This being the case and under the considerations given above, it will be seen that, for a given frequency, a glass disk has a considerably sharper directional characteristic than that of a barium titanate disk. On the other hand, glass in itself does not provide the transducer action which is available in the titanate disk. However, other means can be used to drive such a glass disk into a resonance across a diameter which then, by Poisson coupling, excites a normal motion, and the glass disk then becomes a good radiator in accordance with the teachings of the present invention and can be effective to provide sound waves in a liquid medium with a directional characteristic which is considerably sharper than that represented in Fig. 3 A glass disk may be driven, for example, by affixing thereto a disk of a material which is electromechanically active, such as a disk of barium titanate material, or by affixing thereto a disk of material which is magnetostrictive. Similarly, the glass disk can be used as a receiver where some means is associated with the disk for picking up the motions of the disk with which we are here concerned and translating them into an energy which can be reproduced and utilized. One such arrangement is shown in Fig. 5 where a disk **40** is illustrated as operating in a liquid medium **41**, such as water. The disk **40** also is acoustically shielded on its edge and the right-hand face thereof by means of a rubber cap **42** which surrounds the edge and one face of the disk in such a manner that an air space **43** is provided which effectively produces the required acoustic insulation. Affixed to one face of the disk **40** is a transducer **44** which is responsive to the movements of the disk **40** as it is actuated by the reception of sound waves in the liquid medium to provide energy which can be amplified and reproduced. The transducer **44**, for example, may be a piezoelectric element of quartz or Rochelle salt or may comprise a barium titanate transducer, all of which are effective upon the receipt of mechanical vibrations to provide an electrical voltage which

an be amplified and reproduced, as by an amplifier 45 nd a loudspeaker 46.

The velocity of propagation of a compressional wave 1 glass can be as high as 6000 meters per second com- ared to about 4200 meters per second for material of the arium titanate type. A corresponding figure for steel about 5000 meters per second and that for brass is about 500 meters per second.

While there have been described what are at present onsidered to be the preferred embodiments of the in- ention, it will be obvious to those skilled in the art that arious changes and modifications may be made therein vithout departing from the invention, and it is, therefore, imed in the appended claims to cover all such changes nd modifications as fall within the true spirit and scope f the invention.

What is claimed is:

1. A transducer for producing essentially only a single- obed well-defined directional pattern of sound waves in vater, comprising: a disk of permanently polarized barium itanate material having a mechanical resonance across ll diameters thereof at one predetermined frequency, lependent upon the velocity of propagation of compres- ional waves in any radial direction in said material, and aving, other mechanical resonances, all of which are elatively remotely removed from said predetermined requency; means for acoustically shielding the edge and ne face of said disk and for permitting radiation of sound waves from at least a portion of the other face of said lisk; and means for electrically exciting said resonance across said diameters at a frequency selected to be ex- clusively within a narrow range of frequencies adjacent to said predetermined resonance frequency.

2. A transducer for producing essentially only a single-lobed well-defined directional pattern of sound waves in water, comprising: a disk of permanently polarized material including at least a major portion of barium titanate and having a mechanical resonance across all diameters thereof at one predetermined frequency, dependent upon the velocity of propagation of compressional waves in any radial direction in said material, and having, other mechanical resonances, all of which are relatively remotely removed from said predetermined frequency; and acoustically transparent and liquid impervious window bonded to one face of said disk and an acoustically impervious and liquid impervious enclosure for the other face and the edge of said disk for permitting radiation of sound waves only from said one face of said disk; and means for electrically exciting said resonance across said diameters at a frequency selected to be exclusively within a narrow range of frequencies adjacent to said predetermined resonance frequency.

3. A transducer for transducing between sound energy in a liquid medium and energy of another type in said transducer, comprising: a device for transducing between energies of said two different types, including a disk of a material having at one predetermined frequency, dependent upon the velocity of propagation of compressional waves in any radial direction in said material, a mechanical resonance across all diameters of said disk which is coupled relatively strongly mechanically to motions in the thickness direction of said disk due to the Poisson ratio of said material and having other mechanical resonances, all of which are relatively remotely removed from said predetermined frequency; means for operating said disk in said liquid medium so that the edge and one face of said disk are acoustically shielded from said medium and so that acoustical coupling is effected between said medium and at least a portion of the other face of said disk, said coupling causing said motions in said thickness direction of said disk to be associated with an essentially single-lobed well-defined directional pattern of said device with respect to sound energy at said predetermined frequency in said medium; and means for exciting said transducing device with energy of one of said types at a frequency selected to be approximately said predetermined frequency to excite said resonance across said diameters of said disk and for deriving from said device energy of the other of said types.

4. A transducer for transducing between sound energy in a liquid medium and energy of another type in said transducer, comprising: a device for transducing between energies of said two different types, including a disk of a material having at one predetermined frequency, dependent upon the velocity of propagation of compressional waves in any radial direction in said material, a mechanical resonance across all diameters of said disk which is coupled relatively strongly mechanically to motions in the thickness direction of said disk due to the Poisson ratio of said material and having other mechanical resonances, all of which are relatively remotely removed from said predetermined frequency; means for operating said disk in said liquid medium so that the edge and one face of said disk are acoustically shielded from said medium and so that acoustical coupling is effected between said medium and at least a portion of the other face of said disk, said coupling causing said motions in said thickness direction of said disk to be associated with an essentially single-lobed well-defined directional pattern of said device with respect to sound energy at said predetermined frequency in said medium; and means for driving said transducing device with energy of one of said types at a driving frequency to excite said resonance across said diameters of said disk and for deriving from said device energy of the other of said types at a corresponding output frequency, at least one of said driving and output frequencies being selected to exclude frequencies not approximately equal to said predetermined resonance frequency.

5. A transducer for transducing to sound energy in a liquid medium from energy of another type in said transducer, comprising: a device for transducing from energy of said other type to sound energy, including a disk of a material having at one predetermined frequency, dependent upon the velocity of propagation of compressional waves in any radial direction in said material, a mechanical resonance across all diameters of said disk which is coupled relatively strongly mechanically to motions in the thickness direction of said disk due to the Poisson ratio of said material and having other mechanical resonances, all of which are relatively remotely removed from said predetermined frequency; means for operating said disk in said liquid medium so that the edge and one face of said disk are acoustically shielded from said medium and so that acoustical coupling is effected between said medium and at least a portion of the other face of said disk, said coupling causing said motions in said thickness direction of said disk to be associated with an essentially single-lobed well-defined directional pattern of said device with respect to sound energy at said predetermined frequency in said medium; and means for exciting said transducing device with energy of said other type at an input frequency selected to be within a narrow range of frequencies adjacent to said predetermined resonance frequency to excite said resonance across said diameters of said disk and for deriving from said device sound energy with said directional pattern.

6. A transducer for transducing from sound energy in a liquid medium to energy of another type in said transducer, comprising: a device for transducing from sound energy to energy of said other type, including a disk of a material having at one predetermined frequency, dependent upon the velocity of propagation of compressional waves in any radial direction in said material, a mechanical resonance across all diameters of said disk which is coupled relatively strongly mechanically to motions in the thickness direction of said disk due to the Poisson ratio of said material and having other mechanical resonances, all of which are relatively remotely removed from said predetermined frequency; means for operating said disk in said liquid medium so that the edge and one face

of said disk are acoustically shielded from said medium and so that acoustical coupling is effected between said medium and at least a portion of the other face of said disk, said coupling causing said motions in said thickness direction of said disk to be associated with an essentially single-lobed well-defined directional pattern of said device with respect to sound energy at said predetermined frequency in said medium; and means for exciting said disk to said resonance across said diameters thereof with sound energy in said liquid medium at a frequency selected to be approximately said predetermined frequency and for deriving from said device energy of the other of said types.

7. A transducer for transducing between the types of energy consisting of sound energy in a liquid medium and electrical energy, comprising: a device for transducing between electrical energy and sound energy, including a disk of a material having at one predetermined frequency, dependent upon the velocity of propagation of compressional waves in any radial direction in said material, a mechanical resonance across all diameters of said disk which is coupled relatively strongly mechanically to motions in the thickness direction of said disk due to the Poisson ratio of said material and having other mechanical resonances, all of which are relatively remotely removed from said predetermined frequency; means for operating said disk in said liquid medium so that the edge and one face of said disk are acoustically shielded from said medium and so that acoustical coupling is effected between said medium and at least a portion of the other face of said disk, said coupling causing said motions in said thickness direction of said disk to be associated with an essentially single-lobed well-defined directional pattern of said device with respect to sound energy at said predetermined frequency in said medium; and means for exciting said transducing device with energy of one of said types at a frequency selected to be approximately said predetermined frequency to excite said resonance across said diameters of said disk and for deriving from said device energy of the other of said types.

8. A transducer for transducing between the types of energy consisting of sound energy in a liquid medium and magnetic energy, comprising: a device for transducing between sound energy and magnetic energy, including a disk of a material having at one predetermined frequency, dependent upon the velocity of propagation of compressional waves in any radial direction in said material, a mechanical resonance across all diameters of said disk which is coupled relatively strongly mechanically to motions in the thickness direction of said disk due to the Poisson ratio of said material and having other mechanical resonances, all of which are relatively remotely removed from said predetermined frequency; means for operating said disk in said liquid medium so that the edge and one face of said disk are acoustically shielded from said medium and so that acoustical coupling is effected between said medium and at least a portion of the other face of said disk, said coupling causing said motions in said thickness direction of said disk to be associated with an essentially single-lobed well-defined directional pattern of said device with respect to sound energy at said predetermined frequency in said medium; and means for exciting said transducing device with energy of one of said types at a frequency selected to be approximately said predetermined frequency to excite said resonance across said diameters of said disk and for deriving from said device energy of the other of said types.

9. A transducer for transducing between sound energy in a liquid medium and energy of another type in said transducer, comprising: a device for transducing between energies of said two different types, including a disk of a material having at one predetermined frequency, dependent upon the velocity of propagation of compressional waves in any radial direction in said material, a mechanical resonance across all diameters of said disk which is coupled relatively strongly mechanically to motions in the thickness direction of said disk due to the Poisson ratio of said material and having other mechanical resonances, all of which are relatively remotely removed from said predetermined frequency; an acoustically impervious enclosure for the edge and one face of said disk and an acoustically transparent window bonded to the other face of said disk to permit operation of said disk in said liquid medium so that said edge and said one face are acoustically shielded from said medium and so that acoustical coupling is effected between said medium and said other face of said disk, said coupling causing said motions in said thickness direction of said disk to be associated with an essentially single-lobed well-defined directional pattern of said device with respect to sound energy at said predetermined frequency in said medium; and means for exciting said transducing device with energy of one of said types at a frequency selected to be approximately said predetermined frequency to excite said resonance across said diameters of said disk and for deriving from said device energy of the other of said types.

10. A transducer for transducing between sound energy in a liquid medium and energy of another type in said transducer, comprising: a device for transducing between energies of said two different types, including a disk of a material having at one predetermined frequency, dependent upon the velocity of propagation of compressional waves in any radial direction in said material, a mechanical resonance across all diameters of said disk, said resonance being coupled relatively strongly mechanically to motions in the thickness direction of said disk due to the Poisson ratio of said material, and having other mechanical resonances, all of which are relatively remotely removed from said predetermined frequency; means for operating said disk in said liquid medium so that the edge and one face of said disk are acoustically shielded from said medium and so that acoustical coupling is effected between said medium and substantially all portions of the other face of said disk, said coupling causing said motions in said thickness direction of said disk to be associated with an essentially single-lobed well-defined directional pattern of said device in all planes normal to said other face of said disk with respect to sound energy at said predetermined frequency in said medium; and means for exciting said transducing device with energy of one of said types at a frequency selected to be approximately said predetermined frequency to excite said resonance across said diameters of said disk and for deriving from said device energy of the other of said types.

11. The process for transducing between sound energy in a liquid medium and energy of another type in a transducer device having essentially a single-lobed well-defined directional pattern with respect to said sound energy, comprising: providing in said transducer device a disk of material having at one predetermined frequency, dependent upon the velocity of propagation of compressional waves in any radial direction in said material, a mechanical resonance across all diameters of said disk which is coupled relatively strongly mechanically to motions in the thickness direction of said disk due to the Poisson ratio of said material, all other substantial mechanical resonances of said disk, including any resonance across said thickness thereof, being relatively remotely removed in frequency from said predetermined frequency; disposing said device with said disk in said liquid medium so that the edge and one face of said disk are shielded acoustically from said liquid medium while at least a portion of the other face of said disk is coupled acoustically to said liquid medium; exciting said disk to said resonance across said diameters with energy of one of said types at a frequency selected to be within a narrow range of frequencies adjacent to said predetermined frequency; and deriving from said device including said disk energy of the other of said types transduced in said device at

aid last-mentioned frequency and utilizing said derived nergy.

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