United States Patent [19]

Carson

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[54] **TRANSDUCER**

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[73] Assignee: **The United States of America as represented by the Secretary of the Navy**, Washington, D.C.

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[52] **U.S. Cl.** **340/10**, 310/8.2

[51] **Int. Cl.** **H04b 13/00**

[58] **Field of Search** 340/8, 9, 10, 12, 340/13, 14; 310/8.2, 8.7

[56] **References Cited**

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Assistant Examiner—H. J. Tudor
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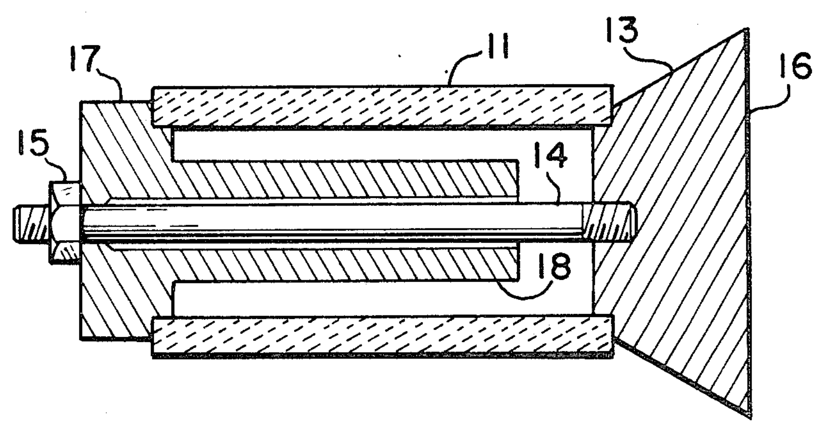
[57] **ABSTRACT**

A high energy level acoustic transducer employs a reentrant tail mass structure. Dimensions and placement of the reentrant portion of the tail piece eliminate lateral or rocking vibration modes of the transducer in the operative bandpass.

12 Claims, 6 Drawing Figures



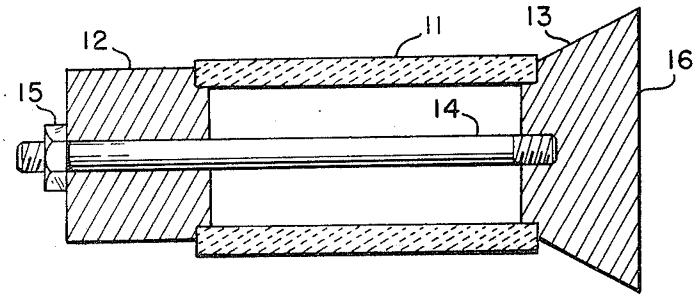


FIG. 1
(PRIOR ART)

FIG. 2

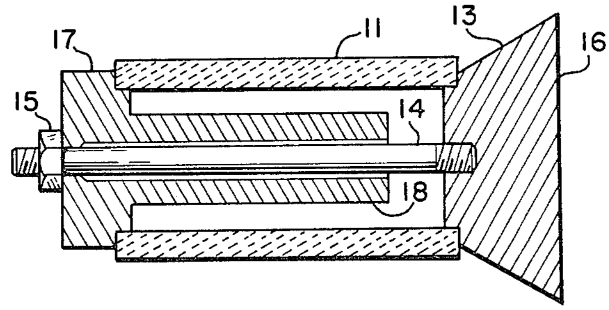
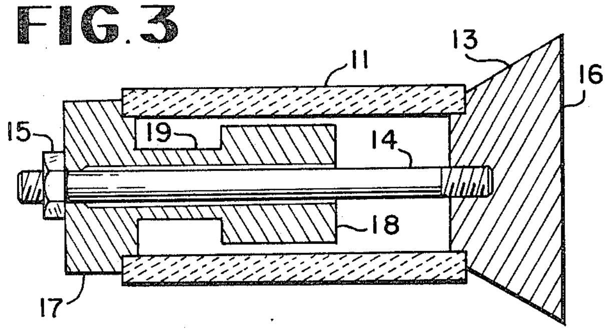


FIG. 3



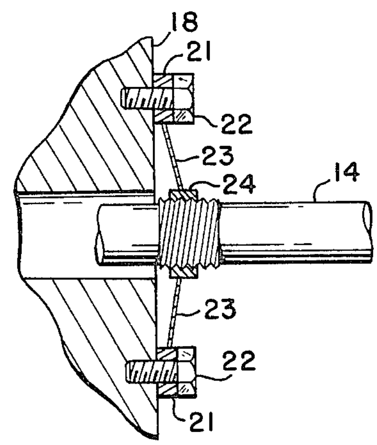


FIG. 4

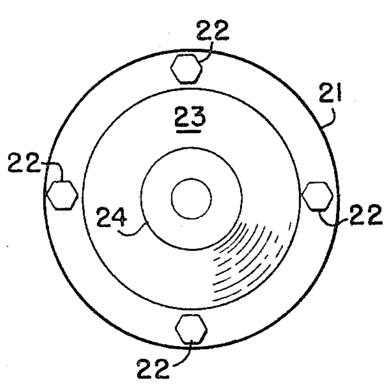


FIG. 5

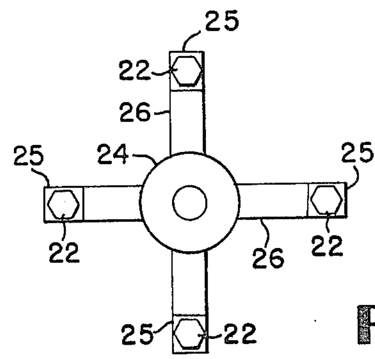


FIG. 6

TRANSDUCER

STATEMENT OF GOVERNMENT INTEREST

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

FIELD OF THE INVENTION

This invention pertains to the field of electroacoustics. More particularly, this invention pertains to the generation of compressional wave energy by electrical signals. In still greater particularity, this invention pertains to the design and utilization of high energy electroacoustic transducers. By way of further characterization, but not by way of limitation thereto, the invention pertains to the design of high energy electroacoustic transducers for use in multi-element arrays.

DESCRIPTION OF THE PRIOR ART

There are many applications in prior art where a relatively directional acoustic pattern is desired to be generated. For example, in active sonar systems and underwater communications systems it is desirable to have a highly directive pattern of acoustic energy. A well understood method of obtaining directivity or acoustic generation employs the use of a plurality of discreet electroacoustic transducers physically spaced at critical positions with respect to one another and driven with electrical signals which have a predetermined phase and amplitude relationship to the signals supplied to other transducers in the array.

One prior art transducer configuration, which has been long-recognized for its directivity and electroacoustic efficiency, employs an assembly of piezoelectric ceramic rings which are stacked, one upon another, to form a cylindrical ceramic stack. This ceramic stack, in conjunction with other components such as head and tail masses, is known as a longitudinal transducer element. This particular construction has a preferred mode of vibration in the longitudinal direction. Too, this arrangement has particularly good frequency response and efficiency characteristics that make it desirable for use in arrays.

A problem sometimes arises, however, when such individual transducer elements are incorporated in a multielement transducer array. That is, the directivity of the array varies to a marked degree from the theoretical or calculated values. One example of this departure from the predicted or calculated characteristics is particularly evident when such an array is electrically steered toward the end fire direction.

It has been observed that this departure from the predicted characteristics is due, in part, to a nonlongitudinal mode associated with a rocking resonance of the individual transducer element.

Previously, the elimination of rocking resonances has been accomplished by employing a particular electrode structure with suitable electrical drives. This arrangement, called the split foil transducer, controls but a single rocking axis. Because of its complexity, this type of transducer is expensive to fabricate and increases the likelihood of electrical failures.

The foregoing is not intended as an exhaustive analysis of the prior art pertaining to electroacoustic transducers, but merely an indication of the prior art constructions having a recognizable similarity in purpose

to this invention. The design of electroacoustic transducers remains a somewhat imperical art and a great many ostensible promising constructions have been proposed, tried, and abandoned. Most require combinations of electrode structure and electrical driving arrangements to achieve a moderate degree of success and are fragile and difficult to make, install, and operate.

SUMMARY OF THE INVENTION

The invention employs a reconfigured tail mass which is configured such as to place any rocking resonant modes of oscillation outside the desired frequency bands through which the transducer array is to be operated while leaving the longitudinal resonance undisturbed. This is accomplished by properly shaping the tail mass such that a portion thereof extends into the central enclosure of the ceramic element. In another arrangement, the tail mass is fabricated such that the portion extending into the center of the piezoelectric cavity is of a larger diameter than the supporting neck which connects it to the conventionally shaped tail piece. In other forms according to the invention, a stabilizing clamping means is connected to the tail piece and to a suitable support structure to further adjust rocking resonance in the transducer assembly.

STATEMENT OF THE OBJECTS OF INVENTION

Accordingly, it is a primary object of this invention to provide an improved longitudinal electroacoustic transducer.

A further object of this invention is to provide a transducer having the rocking resonant frequencies adjusted outside the operating band.

Another object of the present invention is to provide a longitudinal electroacoustic transducer having an improved tail mass construction.

Another object of the invention is to provide a transducer having an improved characteristic when used in an array with similar units.

Another object is to provide a low-cost, high-efficient electroacoustic transducer having improved resonant frequency characteristics.

Another object of the present invention is to provide an improved tail mass for longitudinal electroacoustic transducers which avoids rocking modes of oscillation in the operating band of the transducer.

These and other objects of the invention will become more readily apparent from the ensuing specification when taken with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a sectional view of a prior art construction arrangement;

FIG. 2 is a longitudinal sectional view of an electroacoustic transducer according to the invention;

FIG. 3 is a longitudinal sectional view of another electroacoustic transducer according to the invention;

FIG. 4 is a fragmentary sectional view of a vibration suppressing arrangement according to the invention;

FIG. 5 is an end elevation view of the vibrations suppressing arrangement shown in FIG. 4;

FIG. 6 is an end elevation view of another vibration suppressing element according to the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, the longitudinal sectional view of a typical construction according to the prior art is shown. A cylindrical piezoelectrical element 11 is retained between a tail mass 12 and a suitable dimensioned head mass 13. The assembly is helped into a unitary construction by means of a biasing rod 14, threadibly received in head mass 16 and extending through tail mass 12 where it is secured by a suitable retaining nut 15.

It will be observed that head mass 13 has a generally trapezoidal shape as seen in a longitudinal sectional view. The radiating face 16 of head mass 13 is of a larger dimension than the face coupling directly to piezoelectric element 11. This configuration is conventional in the art and is useful for an optimum transfer of the longitudinal vibrations of piezoelectric element 11 to the selected acoustic load. As will be understood, the acoustic load is most generally the ambient fluid in which the transducer is immersed.

It will, of course, be recognized the arrangement shown in FIG. 1 is conventionally mounted within a suitable housing such as to protect piezoelectric element 11 from the presence of the environment in which the device is operated. It is deemed unnecessary to show the particular details of such housings and enclosures since a wide variety of satisfactory arrangements exist in the prior art and are, in themselves, separate fields of invention.

Likewise, it will be recognized by those versed in the electroacoustic art that piezoelecttic element 11 may be comprised of a plurality of individual elements which are small, annular members and are held in a cylindrical stack by surface configurations on mating edges and by a compressional force exerted by biasing rod 14. Likewise, the interconnecting circuitry used to provide piezoelectric element 11 with a suitable electrical driving signal has been omitted for purposes of brevity and clarity of illustration. However, for purposes of completeness, it should be noted that the circuit arrangement shown in the U.S. Pat. No. 3,068,446 to S. L. Ehrlich et al issued on Dec. 11, 1962 for "Tubular Electrostatic Transducers with Spaced Electrodes and Loading Masses" may be employed, if desired.

Referring to FIG. 2, where like reference numerals indicate similar constructions, the device of the invention will be described. It will be observed that in place of tail mass 12, the invention uses a smaller external mass 17 and an integral reentrant mass 18, which extends into the cavity formed by piezoelectric element 11 concentric with, but spaced from rod 14. Since reentrant mass 18 is formed integrally with external mass 17, it presents essentially the same mass loading to piezoelectric element 11 relative to longitudinal behavior as would be afforded by tail mass 12.

As will be familiar to those versed in the mechanical engineering arts, the rocking resonance of the transducer assembly of FIG. 2 will be markedly different than that of the transducer element illustrated in FIG. 1 even though external mass 17 and reentrant mass 18 are equivalent in weight to tail mass 12. This is due, of course, to the different mass distribution along the combined length of external mass 17 and reentrant mass 18 as compared to the arrangement shown in FIG.

1. By suitably dimensioning the longitudinal length of external mass 17 and reentrant mass 18, the particular rocking resonance may be altered to place the rocking resonant frequency outside the range of electroacoustic interest.

Referring to FIG. 3, it will be observed that reentrant mass 18 need not be of uniform dimensions throughout its length. That is, if desired, the entrant mass 18 may be returned by a narrower neck position 19. Such an arrangement permits a greater latitude in control of the mechanical rocking resonance. Thus, a longitudinal length of external mass 17 the length of neck 19 and the length of reentrant mass 18, as well as their respective diameters may be chosen to produce a transducer assembly which has a minimum of rocking or lateral resonant modes in the range of electroacoustic operation of piezoelectric element 11.

As will be understood by those familar with modern mechanical engineering arts, the computation of such resonance frequencies is a routine calculation especially when performed in conjunction with a modern mathematical computer aid. In the present state of the art, mathematical synthesis of physical phenomena permits the design of reentrant masses 18 having a wide variety of cross section shapes. The particular shape used will be a compromise between the desired resonance control and fabrication costs.

As will be apparent from the inspection of the figures, the construction according to the invention using a reentrant mass is noticeably more compact than the arrangements of the prior art having equivalent tail mass weights. This compactness is of particular utility in many arrangements where a large number of elements must be used within a limited space.

As described above, a reentrant mass 18 comprises a means whereby the rocking resonance of the transducer assembly may be effectively controlled. Additional control is also possible in accordance with the invention by a clamping means which couples the reentrant means to a relatively rigid support structure. In the illustrated arrangement the support used is biasing rod 14. Such an arrangement is illustrated in FIG. 4.

Referring to FIG. 4, it may be seen that reentrant mass 18 is coupled to biasing rod 14 by a clamping means. The clamping means includes an annular ring 21 which is secured to reentrant mass 18 by suitable means, such as threaded fasteners 22. A resilient, annular diaphragm 23 is attached to annular ring 21 and is supported on biasing rod 14 by means of a collar 24 which may be, for example, threadibly attached thereto. An end elevation view of this arrangement is shown in FIG. 5.

Annular diaphragm 23 permits reentrant mass 18 to move longitudinally with respect to biasing rod 14. The longitudinal movement is, of course, occasioned by the longitudinal expansion and contraction of piezoelectric element 11 as it is driven by the electrical signals applied thereto. However, annular diaphragm 23 resists any transverse or rocking motions of reentrant mass 18 with respect to rod 14 which might tend to damage piezoelectric element 11.

Referring to FIG. 6, a light-weight arrangement for accomplishing the same result is illustrated. As will be apparent, angular ring 21 is replaced by a plurality of spaced blocks 25 and diaphragm 23 is replaced by a plurality of resilient strips 26. In the illustrated example, four strips 26 and four blocks 25 are used. Of course, a larger or smaller number may be employed if desired. If desired, strips **26** may be used with annular ring **21** and blocks **25** may be used with annular diaphragm **23.** Likewise, the method of attachment of the clamping means to reentrant mass **18** and rod **14** may be chosen among the wide variety of mechanical fasteners available without departing from the spirit or scope of the invention.

in the foregoing example, no mention has been made of the particular materials of construction, however it should be recognized that conventional materials are employed throughout and the choice between conventional materials is within the scope of one versed in the transducer arts. Thus, piezoelectric element **11** may be of barium titanate, for example, and head mass **13** may be of a suitable lightweight metal such as aluminum. Likewise conventional materials, such as steel, are used for the external mass **17** and reentrant mass **18.**

The foregoing description taken together with the appended claims constitute a disclosure such as to enable a person skilled in the electroacoustic and mechanical engineering arts and having the benefit of the teachings contained therein to make and use the invention. Further, the structure herein described meets the objects of invention, and generally constitutes a meritorious advance in the art which is unobvious to such skilled workers not having the benefit of these teachings.

What is claimed is:

1. An electroacoustic transducer comprising:

a resonant piezoelectric cylinder;

a head mass in contact with the resonant piezoelectric cylinder and configured to transfer acoustic energy therefrom to a suitable acoustic load;

an external tail mass in contact with the resonant piezoelectric cylinder;

biasing means joining the head mass and the external tail mass for holding the head mass, external tail mass, and resonant piezoelectric cylinder in a unitary assembly, and;

means effectively joined to the external tail mass and reentrantly extending within the center of the resonant piezoelectric cylinder concentric with and spaced from said biasing means for controlling lateral and rocking resonances of the unitary assembly.

2. An electroacoustic transducer according to claim **1** in which the biasing means is a resilient rod extending between the head and external tail masses.

3. An electroacoustic transducer according to claim **2** in which said reentrant controlling means comprises an integrally formed extension of said external tail mass.

4. An electroacoustic transducer according to claim **3** in which said extension is of nonuniform cross section throughout its length.

5. An electroacoustic transducer according to claim **3** in which said extension is cylindrical.

6. An electroacoustic transducer according to claim **5** in which said cylindrical extension is joined to the aforesaid external tail mass by a cylindrical neck of smaller diameter than the cylindrical extension.

7. An electroacoustic transducer according to claim **3** further including clamping means connected between said extension and the aforesaid biasing means for additional control of rocking or lateral oscillations of said extension.

8. An electroacoustic transducer according to claim **7** in which said clamping means includes:

attachment means secured to the end of said extension for providing a mounting thereon;

a collar attached to the aforesaid resilient rod; and

flexible means connected to the attaching means and to the collar for permitting axial motion of the aforesaid reentrant means while restraining the lateral or rocking motion thereof.

9. An electroacoustic transducer according to claim **8** where said attachment means includes an annular ring.

10. An electroacoustic transducer according to claim **8** wherein said attachment means includes a plurality of spaced blocks.

11. An electroacoustic transducer according to claim **8** wherein said flexible means includes an annular diaphragm.

12. An electroacoustic transducer according to claim **8** wherein said flexible means includes a plurality of radially spaced strips.

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