United States Patent [19]

Barleen et al.

[11] **3,890,513**

[45] **June 17, 1975**

[54] **ACOUSTIC TRANSDUCER**

[75] Inventors: **David G. Barleen**, Lafayette; **Rex B. Peters**, Concord, both of Calif.

[73] Assignee: **Systron-Donner Corporation**, Concord, Calif.

[22] Filed: **Feb. 14, 1974**

[21] Appl. No.: **442,387**

[52] **U.S. Cl.** ..... **310/9.1**; 179/110 A; 310/8.2; 310/8.1; 310/8.5

[51] **Int. Cl.** **H04r 17/00**

[58] **Field of Search** ..... 310/8.2, 8.5, 8.6, 9.1, 310/9.4; 179/110 A, 181 R, 181 W, 115 R, 138 R; 181/31 R, 32 R; 340/261, 384, 388, 391

[56] **References Cited**

UNITED STATES PATENTS

3,578,995	5/1971	Massa	310/8.2 X
3,736,632	6/1973	Barrow	310/8.2 X
3,737,690	6/1973	Antonio	310/8.2
3,761,956	9/1973	Takahashi et al.	310/9.1 X

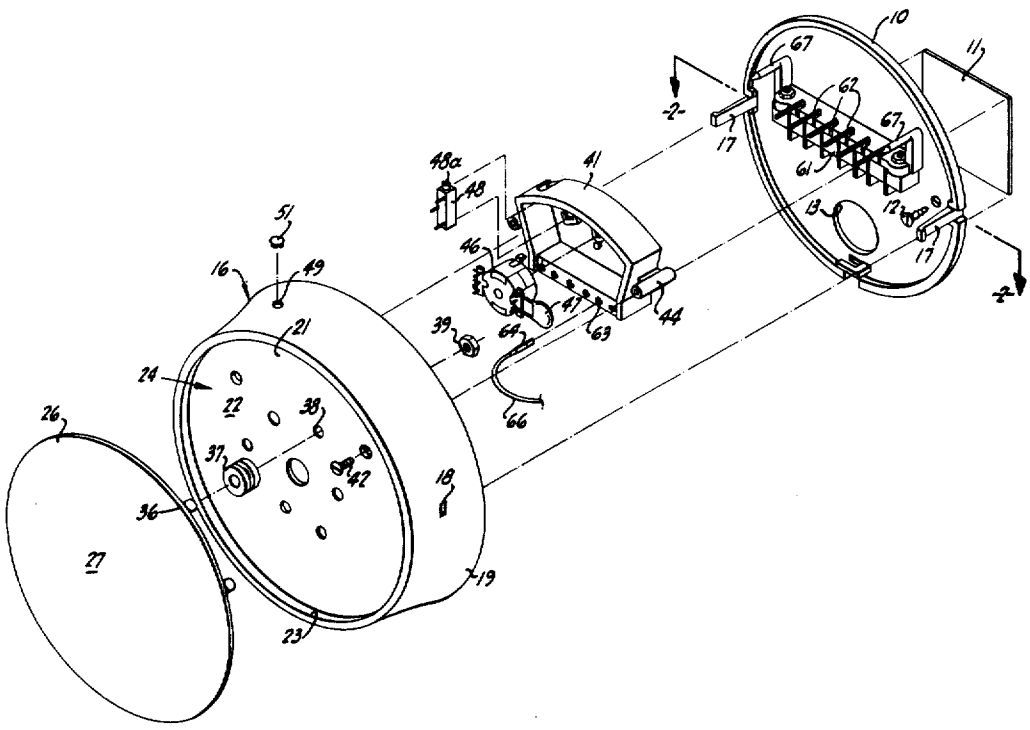
Primary Examiner—Mark O. Budd

Attorney, Agent, or Firm—Flehr, Hohbach, Test, Albritton & Herbert

[57] **ABSTRACT**

Transducer for ultrasonic intrusion alarm systems utilizing a flat circular plate as a diaphram operating in a bending mode. The plate is mounted at nodal points to prevent interference with the desired mode of vibration, and a reflective surface is provided behind the plate to reinforce its vibrations. The transducer has a housing removably mounted on a base which can be permanently affixed to a suitable mounting surface.

12 Claims, 6 Drawing Figures



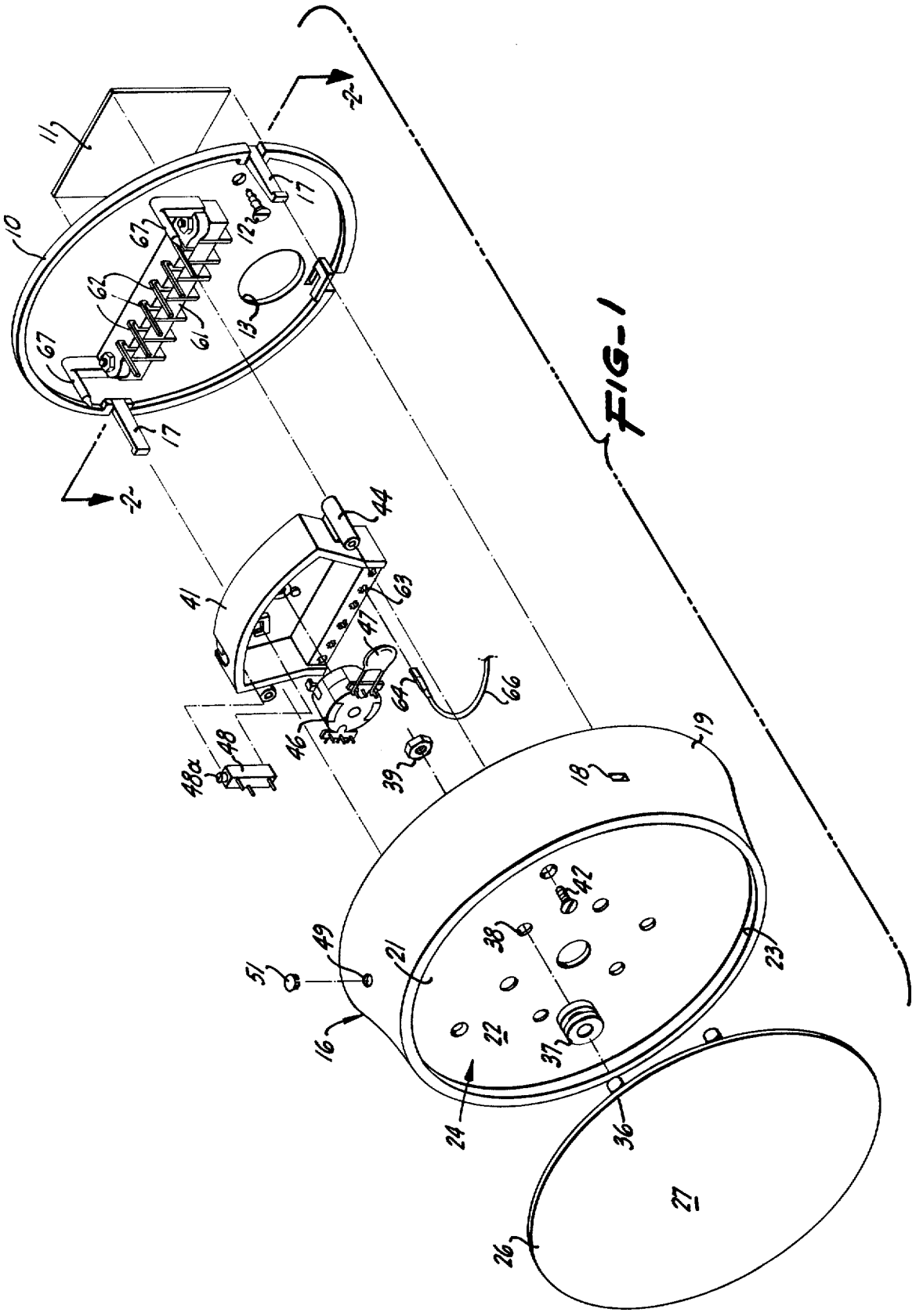

11
10
67
62
61
12
13
17
2
41
44
63
47
64
66
46
48
48a
39
18
19
42
38
49
51
21
23
22
37
16
24
36
27
26

FIG. 1

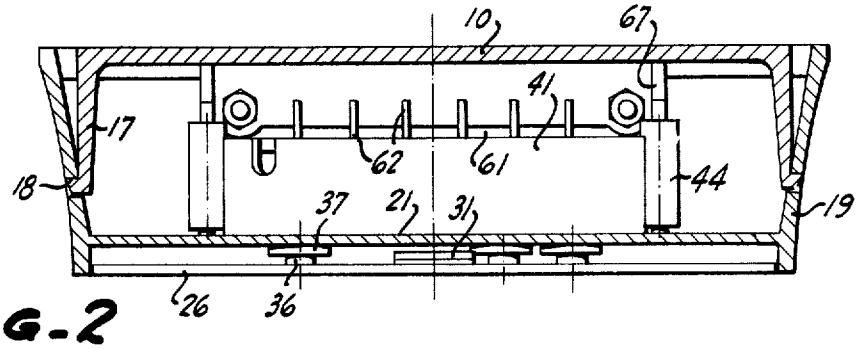


FIG-2

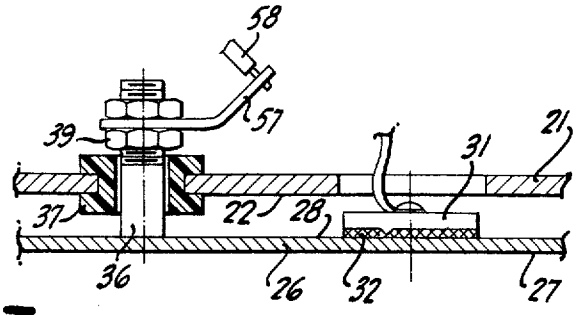


FIG-3

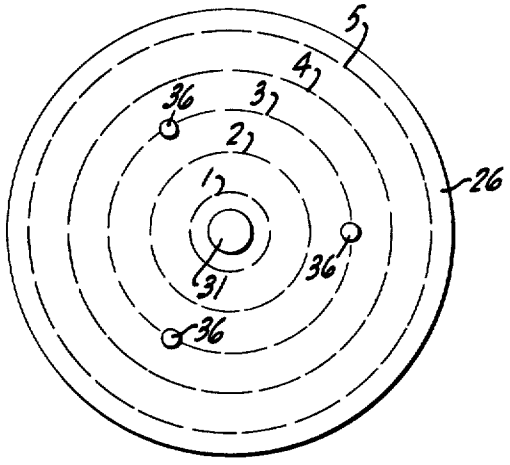


FIG-4

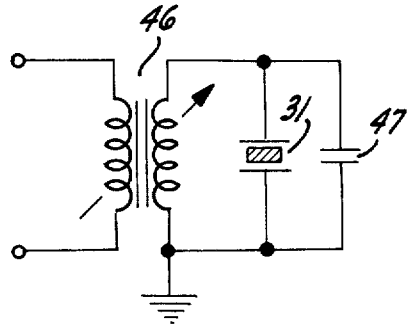


FIG-5

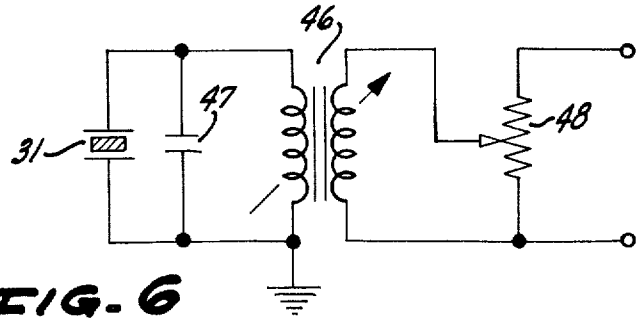


FIG-6

ACOUSTIC TRANSDUCER

BACKGROUND OF THE INVENTION

This invention pertains generally to electroacoustic transducers and more particularly to a transducer for use in an ultrasonic intrusion alarm system.

In ultrasonic intrusion alarm systems, ultrasonic energy of a predetermined frequency, for example 19.2 KHz is transmitted by one or more transducers into a room or other area to be protected. The energy is reflected by the walls, floor, ceiling and other objects in the protected area and received by one or more receiving transducers, If an intruder enters the protected area, the energy reflected by his moving body undergoes a Doppler frequency shift, and this shift is detected by suitable equipment connected to the receiving transducer.

The transducers used in ultrasonic alarm systems are commonly mounted on the ceiling of the room or other area to be protected. One type of transducer which has been used in such systems in the past is described in U.S. Pat. No. 3,287,693, issued Nov. 22, 1966 to Samuel M. Bagno and assigned to the assignee herein. Although generally efficient and effective, the Bagno transducer has a bell shaped diaphram which makes it conspicuous and subject to damage by vandals. These transducers radiate strongly from their edges, producing an intense acoustic field parallel to the ceiling or other mounting surface. This edge radiation is of little or no use in detecting intruders, and it can interfere with the operation of the system by passing directly to a receiving transducer and producing a strong signal which suppresses the desired signals. In addition, the edge radiation can cause undesirable coupling between adjacent alarm systems.

Other transducers heretofore provided have a strong axial component of radiation which is generally reflected directly back to the transducer in a rectangular room and is of little or no use in detecting intruders.

SUMMARY AND OBJECTS OF THE INVENTION

The transducer of the invention utilizes a flat circular plate operated in a bending mode for radiating or receiving ultrasonic energy. When the transducer is utilized as a transmitter, the energy radiated is concentrated in a conical region lying midway between the axis and the mounting plane of the transducer where it has been found to provide the most effective coverage of the protected area. The plate is mounted by studs affixed to its nodal points, and a reflector mounted behind the plate tends to reinforce the vibrations of the plate. The transducer has a streamlined housing which makes it relatively inconspicuous, and the housing mounted on a base from which it can be readily removed to permit access to components within the housing.

It is in general an object of the invention to provide a new and improved transducer for use in ultrasonic intrusion alarm systems.

Another object of the invention is to provide a transducer of the foregoing character which utilizes a flat circular plate as a diaphram operating in a bending mode.

Another object of the invention is to provide a transducer of the above character having a housing removably mounted on a base adapted for mounting on a planar surface.

Another object of the invention is to provide a transducer of the above character in which most of the energy radiated is concentrated in a conical region between the axis and mounting plane of the transducer.

Additional objects and features of the invention will be apparent from the following description in which the preferred embodiment is set forth in detail in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an exploded perspective view of one embodiment of a transducer according to the invention.

FIG. **2** is a cross-sectional view of the assembled transducer, taken along line **2—2** in FIG. **1.**

FIG. **3** is an enlarged sectional view of a portion of the transducer of FIG. **1.**

FIG. **4** is a rear elevational view of the circular plate utilized as a diaphram in the transducer of FIG. **1.**

FIG. **5** is a circuit diagram of the transducer of FIG. **1** connected for use as a transmitter.

FIG. **6** is a circuit diagram of the transducer of FIG. **1** connected for use as a receiver.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The transducer includes a generally circular base **10** which is adapted to be mounted on a planar surface such as the ceiling of a room. The base can be secured to the mounting surface by suitable means such as a two-sided adhesive member **11** or mounting screws **12.** An opening **13** is provided in the base to accomodate wires for making electrical connections to the transducer.

A housing **16** is removably mounted on base **10** and releasably secured thereto by resilient latch hooks **17.** The latch hooks are attached to the base, and they engage openings **18** formed in the side wall **19** of the housing.

Housing **16** includes a front wall **21** having a generally planar outer surface **22** which is highly reflective to the energy to be radiated or received by the transducer. An annular lip **23** extends from the outer surface of the front wall and cooperates with this surface to define a cavity **24** in which a circular plate **26** is mounted. In the embodiment illustrated, front wall **21** and plate **26** are of smaller diameter than base **10,** and side wall **19** is tapered in the manner shown. The outer surface **27** of plate **26** is generally flush with the outer margin of anular lip **23,** and the distance between the base and the plate is substantially less than the diameter of the plate whereby the transducer has a relatively flat, streamlined appearance.

Plate **26** has a diameter greater than several wavelengths of the energy to be radiated or received. In the preferred embodiment, the plate is fabricated of aluminum, and for an operating frequency of 19.2 KHz, it has a thickness of 0.040 inch and a diameter of 4.56 inches. The bending wavelength of the 19.2 KHz energy in this material is approximately 0.865 inch, and the diameter of the plate is 4.56/.865 or 5.27 wavelengths.

A piezoelectric ceramic resonator **31** is bonded to the back side **28** of plate **26** by a conductive adhesive **32.** The resonator is a thin flat disk which is polarized through its thickness, i.e. perpendicular to the surface of the plate. When the transducer is used as a transmitter, the resonator is driven in the d_{31} or radial expandor

mode to produce a circular bimorph at the center of the plate. The alternately reversing curvature induced by the resonator at the center of the plate sets up a standing wave condition in the plate. The plate vibrates with standing wave undulations having circular nodes disposed concentrically of the resonator and spaced apart by a distance corresponding to one-half of the bending wavelength of the energy radiated or received. A plate operating at a frequency of 19.2 KHz and having the dimensions given above has 5 nodes, designated 1–5 in FIG. 4. The size of the resonator is not critical, but its thickness is preferably of the same order as that of the plate and its diameter is preferably slightly less than one-half wavelength of the bending waves in the plate at the frequency of operation.

Plate **26** is mounted on the front wall **21** of housing **16** by means of studs **36** which are welded to the plate. In the preferred embodiment, three such studs are provided, and they are spaced equally along the path of the third node from the center of the plate. Rubber grommets **37** are mounted in openings **38** in the front wall, and the studs extend through the grommets. Inside the housing, nuts **39** are mounted on the studs to retain them in the grommets. In the preferred embodiment, the plate is spaced approximately one-half wavelength from the front wall of the housing so that the space between the plate and wall serves as a resonant chamber which tends to reinforce the vibrations of the plate at the frequency operation. The same reinforcement can be provided by making the spacing any other integral multiple of one-half wavelength.

A component mounting fixture **41** is mounted within housing **16** and secured to wall **21** by flat-headed screws **42.** The screws are mounted in countersunk recesses **43** on the front side of the wall, and they engage ears **44** on the sides of the fixture.

Coupling to resonator **31** is accomplished by components mounted inside fixture **41.** These components include a transformer **46,** a capacitor **47,** and a potentiometer **48.** The potentiometer has an adjusting shaft **48a** which is accessable through an opening **49** in side wall **19** of the housing. A removable plug **51** provides means for closing this opening.

When the transducer is used as a transmitter, potentiometer **48** is not used, and the remaining components are interconnected in the manner illustrated in FIG. **5.** The signal to be radiated is applied to the primary winding of transformer **46,** resonator **31** and capacitor **47** are connected in parallel across the secondary winding, and one side of this winding is grounded. The capacitor and resonator are chosen to have temperature coefficience of opposite polarities to provide temperature compensation and stability. The electrical connections to resonator **31** are made by a first lead **56** connected directly to one side of the resonator and a second lead **57** connected to a ground lug **58** mounted on one of the studs **36** affixed to plate **26.**

When the transducer is used as a receiver, the components are interconnected in the manner shown in FIG. **6.** As illustrated, resonator **31** and capacitor **47** are connected in parallel with the primary winding of transformer **46,** and potentiometer **48** is connected across the primary to provide means for adjusting the sensitivity of the system.

Means is provided to permit housing **16** and the components carried thereby to be removed from base **10** without disturbing the external connections to the transducer whereby the housing and components can be removed even though the base is installed on a mounting surface and wired permanently in place. For this purpose, a terminal block **61** is mounted on base **10,** and external connections are made to this block. The block includes connector pins **62** which extend into openings **63** in fixture **41** where they mate with connector sockets **64.** Permanent connections between the connector sockets and the components are made in a conventional manner such as by leads **66.** Alignment pins **67** carried by base **10** engage guide openings in fixture ears **44** to assure proper alignment and mating of the connector pins and sockets when the housing is on the base.

Operation and use of the transducer can be described briefly. The transducer is installed by mounting base **10** on a suitable surface, such as a ceiling, with the connecting leads passing through opening **13.** The leads are connected to terminal block **61,** and the housing is mounted on the base where it is secured by latch hooks **17.** Thereafter, the housing can be removed by depressing the latch hooks through openings **18** and withdrawing the housing from the base.

When the transducer is operated as a transmitter, resonator **31** is energized at the desired operating frequency, e.g. 19.2 KHz, producing a circular bimorph at the center of the plate. The alternately reversing curvature induced by resonator **31** causes plate **26** to vibrate with standing wave undulations having circular nodes, as illustrated in FIG. **4.** The nodes are disposed concentrically of the resonator and spaced apart by a distance of one wavelength of the bending waves in the plate at the frequency of operation. The space between plate **26** and housing wall **21** serves as a resonant cavity which tends to reinforce the vibrations of the plate at the frequency of operation.

The radiation pattern produced by the plate is determined by the interference and reinforcement of the acoustic waves originating from the different parts of the plate. All of the patterns are circular and in form of conical rays of sound pressure. The pattern has a low value along the transducer axis because the peaks and valleys of the bending waves tend to cancel in that direction. Likewise, very little energy is radiated in the plane of the mounting surface because of the combined effects of cancellation and relatively poor coupling parallel to the plate. The majority of the acoustic output from the transducer is directed in a conical region between the axis and the mounting plane. The angle of the cone is determined by the relative wavelengths of the energy radiated in the plate and in air, and this relationship is dependent on the thickness of the plate. In the preferred embodiment, the plate thickness is such that the wavelength in the plate is on the order of 1.4 times the wavelength in air, and the conical region is about midway between the axis and the mounting plane.

When the transducer is used as a receiver, received energy causes the plate to vibrate, producing an output signal from resonator **31.** At the frequency for which the transducer is designed, e.g. 19.2 KHz, the energy reflected by wall **21** enhances the vibrations, and the output from the resonator is maximized. The sensitivity of the transducer can be adjusted by means of potentiometer **48.** As in the case of the transmitter, the sensitivity of the transducer as a receiver is greatest in a con-

ical region between the axis and the mounting plane of the transducer.

The transducer has a number of important features and advantages. It is relatively inconspicuous in that it protrudes a relatively short distance from the surface on which it is mounted, and it can be mounted in a recessed area to make it even more inconspicuous. The radiation pattern of the transducer makes it ideal for use in an ultrasonic intrusion alarm system. The transducer is readily installed and removed, and the mounting studs do not interfere with the desired vibration of the plate since they are attached at nodal points where the motion is essentially zero. Moreover, because of the flat plate, the transducer is economical to manufacture.

It is apparent from the foregoing that a new and improved transducer has been provided. While only the presently preferred embodiment has been disclosed, as will be apparent to those familiar with the art, certain changes and modifications can be made without departing from the scope of the invention as defined by the following claims.

We claim:

1. In an acoustic transducer for radiating or receiving energy of predetermined frequency: a base, a housing having a wall with a generally planar outer surface removably mounted on the base, mating electrical connectors carried by the base and housing for making electrical connections to components mounted in the housing, a substantially flat circular plate mounted outside the housing and spaced from the outer surface of the wall by a distance on the order of an integral number of half wavelengths of the energy to be radiated or received, a piezoelectric ceramic resonator affixed centrally to one side of the plate, and mounting means extending between the plate and the wall, said mounting means engaging the plate at a plurality of points spaced from the center of the plate by a distance corresponding to an integral multiple of one-half wavelength of energy of the predetermined frequency in the plate.

2. The transducer of claim **1** further including an anular lip extending from the outer surface of the wall and cooperating with said surface to define a cavity in which the plate is mounted.

3. The transducer of claim **1** the housing is removably mounted on the base and mating electrical connectors are carried by the base and housing for making electrical connections to components mounted in the housing.

4. The transducer of claim **1** further including latch members for releasably securing the housing to the base.

5. The transducer of claim **4** wherein the latch members comprise latch hooks carried by the base for releasably engaging openings in a wall of the housing.

6. The transducer of claim **1** wherein the base comprises a generally planar circular member disposed on the side of the housing opposite the plate and adapted to be mounted on a generally planar surface such as the ceiling of a room, the plate being spaced from the base member by a distance substantially less than the diameter of the plate.

7. The transducer of claim **6** wherein the diameter of the base member is greater than the diameter of the plate and the housing includes a tapered side wall extending between the base member and the wall with the planar surface.

8. In an acoustic transducer for radiating or receiving energy of predetermined frequency: a generally flat circular plate having a diameter greater than several wavelengths of the energy to be radiated or received, a piezoelectric ceramic resonator having a flat face affixed centrally to one side of the plate, the plate being vibrated with standing wave undulations having circular nodes disposed concentrically of the resonator and spaced apart by a distance corresponding to one-half wavelength of the energy radiated or received, a plurality of mounting studs attached to the plate along one of the nodes, resilient grommets mounted on the reflective member, said grommets having openings through which the studs extend, and means engaging the studs on the side of the grommets opposite the plate for retaining the studs in the grommets.

9. The transducer of claim **8** further including a generally planar reflective member on one side of the plate and spaced therefrom by a distance corresponding to an integral number of half wavelengths of the energy radiated or received.

10. The transducer of claim **8** wherein the studs are attached to the plate at the third node from the center of the plate.

11. In an acoustic transducer for radiating or receiving energy of predetermined frequency: a base, a housing having a wall with a generally planar outer surface mounted on the base, a substantially flat circular plate mounted outside the housing and spaced from the outer surface of the wall by a distance on the order of an integral number of half wavelengths of the energy to be radiated or received, a piezoelectric ceramic resonator affixed centrally to one side of the plate, a plurality of studs affixed to the plate at points spaced from the center of the plate by a distance corresponding to an integral multiple of one-half wavelengths of energy of the predetermined frequency in the plate, resilient grommets mounted in openings of the housing wall, said grommets having openings through which the studs extend, and means engaging the studs inside the housing for retaining the studs in the grommets.

12. In an acoustic transducer for radiating or receiving energy of predetermined frequency: a base, a housing having a wall with a generally planar outer surface mounted on the base, a substantially flat circular plate mounted outside the housing and spaced from the outer surface of the wall by a distance on the order of an integral number of half wavelengths of the energy to be radiated or received, said plate operating in a bending mode wherein the wavelength of bending waves in the plate at the predetermined frequency is greater than the wavelength of radiation in the air corresponding to the bending waves, a piezoelectric ceramic resonator affixed centrally to one side of the plate, and mounting means extending between the plate and the housing at a plurality of points spaced from the center of the plate by a distance corresponding to an integral multiple of one-half wavelength of the bending waves at the predetermined frequency.

* * * * *