June 23, 1970 R. E. JONES, SR 3,517,226

ULTRASONIC PIEZOELECTRIC TRANSDUCER WITH ACOUSTIC LENS

Filed March 25, 1968 2 Sheets-Sheet 1

Fig. 1

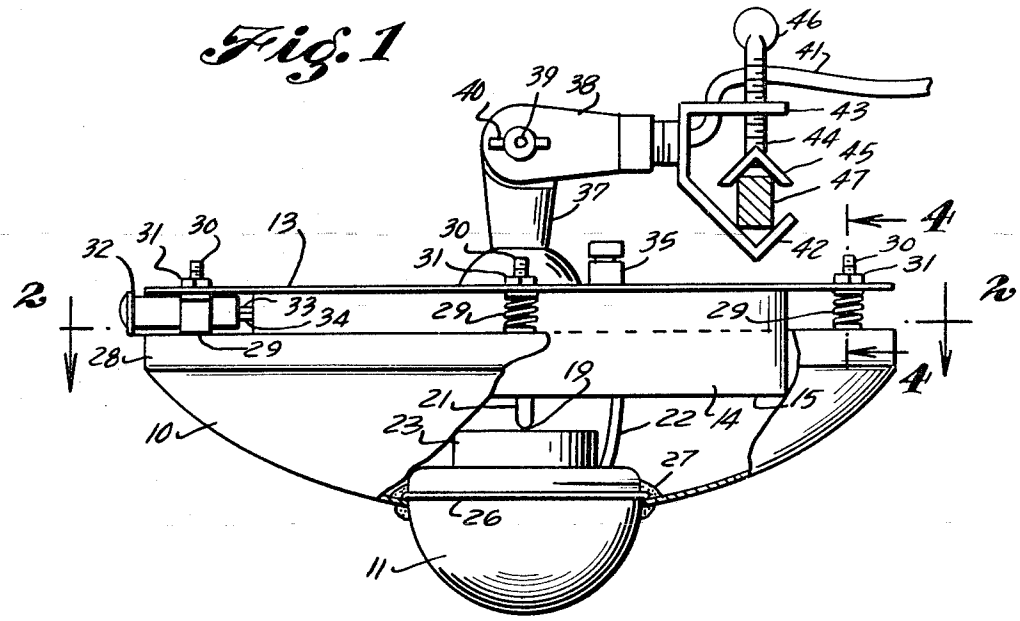


Fig. 3

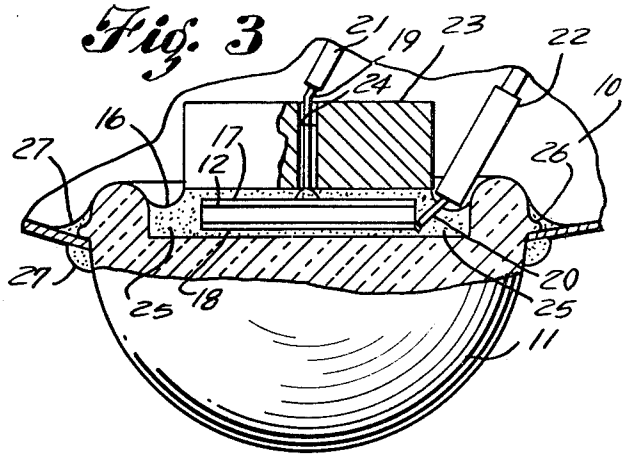
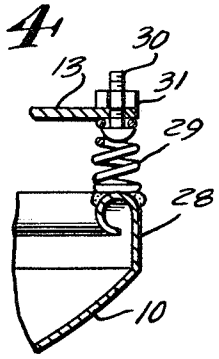


Fig. 4



INVENTOR.
Roy E. Jones, Sr.
BY
Rogers Martin
Attorney

June 23, 1970 R. E. JONES, SR 3,517,226

ULTRASONIC PIEZOELECTRIC TRANSDUCER WITH ACOUSTIC LENS

Filed March 25, 1968 2 Sheets-Sheet 2

Fig. 2

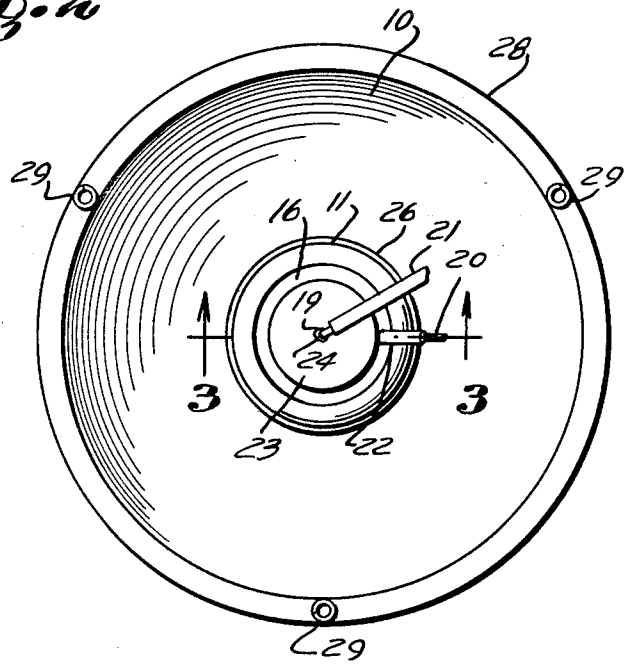
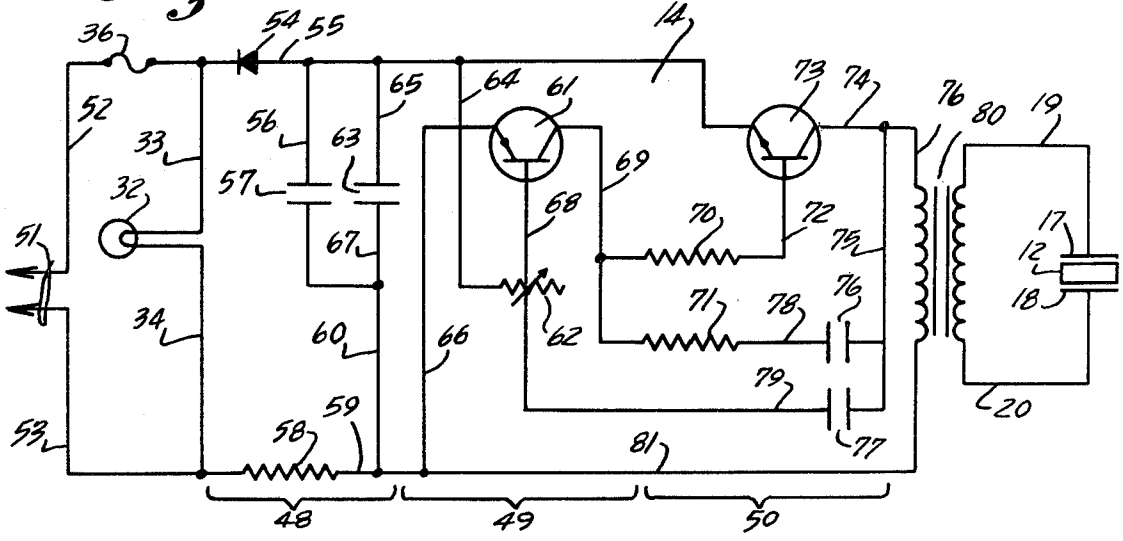


Fig. 5



INVENTOR.
Roy E. Jones, Sr.
BY
Roger L. Martin
Attorney

United States Patent Office 3,517,226 Patented June 23, 1970

3,517,226

ULTRASONIC PIEZOELECTRIC TRANSDUCER WITH ACOUSTIC LENS

Roy E. Jones, Sr., Orlando, Fla., assignor to U-Sonics, Inc., Cocoa Beach, Fla., a corporation of Florida

Filed Mar. 25, 1968, Ser. No. 715,714
Int. Cl. H04r 17/00
U.S. Cl. 310—8.5 2 Claims

ABSTRACT OF THE DISCLOSURE

This application contains a technical disclosure of an electrosonic aparatus in the form of an acoustical lens which includes a ceramic-type piezoelectric transducer mounted on a formed silicate incursion block of hemispheric shape, which is in turn mounted in the center of a semi-hemispheric radiating plate, thereby permitting radiation through the atmosphere of ultrasonic frequencies in a non-directional pattern. There is further disclosed the manner by which this lens structure, in combination with specialized electronic circuitry generating erratic and harmonic filled ultrasonic frequencies, may be utilized to repel and destroy vermin such as rats, mice and bats. Utilization of the disclosed acoustical lens system as a radiator for audio frequencies in combination with high fidelity and stereo systems is also described.

BACKGROUND OF THE INVENTION

This invention relates to improved electrosonic apparatus and particularly to such apparatus utilizing piezoelectric transducers in association with structures and circuitry for generating and radiating sonic vibrations. More particularly, this invention relates to the generation and radiation of energy in the form of ultrasonic waves through a gaseous medium in a non-directional pattern by means of an acoustical lens system.

The radiation of sonic waves, particularly waves of ten kilocycles and higher in a broad pattern is often much desired. For example, sonic waves having frequencies within this range may be used for repelling and/or exterminating rodents, insects and other undesirable vermin, but for such purposes it is essential that the sonic waves be radiated to effectively cover a wide area. Similarly, effective wide area radiation of sonic waves is especially desirable in connection with high fidelity and stereo music systems, and this is particularly difficult to accomplish with the higher frequency sonic waves such as those normally radiated with tweeter components of such systems.

While various types of apparatus are known for the generation of sonic waves in the range of ten kilocycles and higher, many of these devices are relatively low in efficiency in the transfer of such vibrational energy through a gaseous medium, such as the atmosphere, besides being inadequate for wide area radiation. Certain of these devices utilize mechanical means for the desired purposes, such as fluid or air operated resonators, and other such devices operate on magnetostrictive principles. Still others utilize various types of piezoelectric transducers arranged in various types of mounts. The prior art also shows high speed rotators creating shock waves to kill insects and other vermin.

SUMMARY OF THE INVENTION

The invention described herein is directed to the solution of problems encountered in prior art devices by the provision of electronsonic apparatus in the form of an acoustical lens whereby vibrational energy may be radiated through a gaseous medium with high efficiency over a wide area.

More specifically an object of this invention is the provision of apparatus wherein a piezoelectric transducer is associated with a mounting structure of such a nature and in such a manner as to increase the effectiveness of the transfer of sonic and supersonic waves generated thereby, to and through the atmosphere non-directionally.

Even more specifically, an object of this invention is to provide improved generation and radiation of sonic frequencies of the order of ten killocycles and higher for various purposes such as vermin repelling and destroying systems and high fidelity sound systems.

Another object of this invention is to provide a novel combination of radiating structure and electronic circuitry whereby the injurious and destructive properties of ultrasonic waves on rodents such as rats is greatly intensified.

Additionally, the provision of apparatus specifically directed to the wide angle non-directional radiation of sonic waves of audio frequencies is a further object of the invention herein described.

Other objects of this invention will be apparent to those skilled in the art from the following detailed description of this invention in certain preferred embodiments and from reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

A preferred embodiment of the invention is shown in the drawings, wherein:

FIG. 1 depicts a side view of the major structural components of this embodiment, with a portion of one component thereof cut away to more clearly show other components thereof;

FIG. 2 is a top or plan view of certain of the major components as seen along the lines **2**—**2** of FIG. 1 after separation of these components from other of the major components shown in FIG. 1;

FIG. 3 is an enlarged sectional view of a portion of the major components of FIG. 2, as seen along the lines **3**—**3** of FIG. 2;

FIG. 4 is an enlarged sectional view, as seen along lines **4**—**4** of FIG. 1, showing one of the plurality of means for mounting the major components shown in FIG. 2 to the remaining components shown in FIG. 1; and

FIG. 5 is a schematic diagram of the electronic circuit forming one of the major components of a preferred embodiment of the invention herein described, certain portions of which circuitry are depicted in FIG. 1 as enclosed in a housing.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Reference is first made to the drawings wherein is shown the major components of a preferred embodiment of the electrosonic apparatus of this invention, these components consisting of a radiating plate **10**, and in incursion block **11**, a piezoelectric transducer **12**, a support plate **13** and electronic circuitry **14** encased within housing **15**. As more clearly seen in FIG. 3, the piezoelectric transducer **12** is shown as mounted within a recessed cavity **16** of the incursion block **11**. The piezoelectric transducer **12** is shown as having a pair of electrodes **17** and **18** to which are connected electrical leads **19** and **20** respectively, these being encased in insulating sleeves **21** and **22**. The electrical leads **19** and **20** are further connected to the electronic circuit **14**, as more fully disclosed in connection with the description of the electronic circuitry of FIG. 5 hereinbelow. Mounted in close association with the piezoelectric transducer **12** and on the side thereof opposite to the mounted incursion block **11**, is a reflection suppressor shown as **23**, which

in the present embodiment consists of an aluminum disk which is provided with a circular opening centrally positioned therein for the passage therethrough of the electrical lead **19**. In a preferred embodiment, as shown more particularly in FIG. 3, the piezoelectric transducer **12** is bonded to the incursion block **11** and to the reflection suppressor **23** by means of a suitable cement **25**, the piezoelectric transducer **12** and the leads **19** and **20** being embedded therein within the recessed cavity **16**. Cement **25** also serves to bond the reflection suppressor **23** to the transducer **12**.

The piezoelectric transducer **12** of the preferred embodiment herein described is one of the type generally known as ceramic-type solid solution of lead-titanate and lead-zirconate. The thickness thereof which controls the resonant frequency of such a transducer, is chosen to give a prime resonant frequency in the ultrasonic range, i.e. a range of frequencies ten kilocycles and higher. Differing thicknesses of the piezoelectric transducer may be chosen for differing applications such as vermin destroying or repelling systems, and high fidelity music systems as will be more fully described hereinafter.

The incursion block **11** of the preferred embodiment herein described is formed of silica material in hemispherical shape and having a depression or recessed cavity **16** on the flat side thereof for mounting the piezoelectric transducer **12** therein. In FIGS. 1 and 3, the incursion block **11** is shown as having a small circumferential beading or ring **26** formed integrally of the silicate material, positioned approximately in line with the bottom of the recessed cavity **16**, the purpose of which is to serve as a retaining ridge on the incursion block for the radiating plate **10** which is secured to the incursion block **11** by cement **27**.

The radiating plate **10** of the preferred embodiment here shown is semihemispherical in shape, formed of stainless steel and having a circular opening in the center thereof for mounting the incursion block therein. The concave radiating surface of this plate is highly polished to obtain maximum transfer of mechanical energy to gaseous medium. The outer perimeter of the radiating plate **10** is formed in the shape of a circular band **28**, having a rolled edge to which band are secured a plurality of mounting means **29**, shown as coil springs in FIGS. 1 and 4, for connecting the radiating plate **10** to the support plate **13** while permitting free vibration of the radiating plate and preventing dampening of the sound emission therefrom. Free forward and reverse movement of the radiating plate is thus allowed.

In the embodiment herein described, the support plate **13** is shown as a circular disk provided with screws **30** and nuts **31** by which the springs **29** are fastened thereto. Secured to the support plate **13** is shown the housing **15** for the electronic circuitry, and to which the component parts of this circuitry, as schematically shown in FIG. 5, may be mounted. A pilot light **32** is shown in FIG. 1 as being mounted between the support plate **13** and the radiating plate **10**, projecting outward therefrom to indicate, when lighted, that the electronic circuitry **14** is activated, the pilot light being connected to the electronic circuitry by means of leads **33** and **34**. Also shown as mounted upon the support plate **13** is a fuse holder **35** containing therein the fuse **36** of the electronic circuitry **14**.

While various means may be utilized for mounting the support plate as may be desired, there is shown in FIG. 1 such means consisting of the arm **37** to which there is secured in adjustable relationship another arm **38**, adjustment of the relationship of these arms being accomplished by means of a screw **39** and thumb nut **40**. Arms **37** and **38** may be provided, if desired and as shown, with inter-connecting ducts therethrough by which a cable **41** carrying a source of power, for example 115 volts of alternating current, may be led to the electronic circuitry **14**. In FIG. 1, the arm **38** is shown as terminating in a clamping arrangement consisting of the angle arm **42** having a base arm **43** through which passes a threaded rod **44** to which is attached another angled arm **45**. by rotation of the knob **46** at the other end of the threaded rod **44**, the angled arm **45** may be brought into proximity to the angled arm **42** to secure the entire structure on some support **47** at whatever angle and in whatever position may be desired.

With reference now to FIG. 5, there is shown an electronic circuit **14** for generating ultrasonic frequencies, generally comprising a power supply **48**, an oscillator **49** and an amplifier **50**, the output of which is connected through a step-up transformer **51** and leads **19** and **20** to the electrodes **17** and **18** respectively of the piezoelectric transducer **12**. While the components of the electronic circuitry **14** may be varied to obtain the electrical energy having certain desired characteristics, as described below, and which is to be fed to the piezoelectric transducer **12**, the components shown in FIG. 5 and their arrangement, as now further described, comprise a preferred embodiment of this invention.

The electronic circuitry schematically shown by FIG. 5 comprises a source of power **51** preferably consisting of alternating current which is fed into the power supply **48** through leads **52** and **53**. A fuse **36** is shown as inserted in the lead **52** to protect the source of power **51** from overloads or shorts which might occur as a result of malfunctioning of the electronic circuitry **14**. The pilot light **32**, previously referenced, is shown as connected to the leads **52** and **53** by leads **33** and **34** respectively.

The power supply of this preferred embodiment is a half wave rectifier consisting of a silicon diode rectifier **54**, to the cathode of which lead **52** is connected and to the anode of which by means of leads **55** and **56** one side of a filter capacitor **57** is connected. Lead **53** from the source of power **51** is connected to one side of resistor **58**, the other side of which is connected by leads **59** and **60** to the other side of filter capacitor **57**. Through these components of the power supply **48**, there is obtained a current which is not pure direct current having been only partially rectified, as is desired for certain purposes of this invention, as more fully explained below.

The output of the power supply **48** is fed into the oscillator circuit **49** which consists, in the preferred embodiment shown, of the transistor **61**, the resistor **62** and the capacitor **63**. Leads **64** and **65** connect the resistor **62** and the capacitor **63** respectively to lead **55** from one side of the power supply while leads **66** and **67** connect the emitter of the transistor **61** and the other side of the capacitor **63** respectively to the opposite side of the power supply, i.e. lead **59**. The center tap of the resistor **62** is connected with the base of the transistor **61** by means of lead **68**. Capacitor **63** serves as a bias voltage capacitor, the leakage therefrom establishing at random the frequency of the oscillator within the range of from ten to eighty kilocycles. This capacitor has a low-accuracy discharge rating and will therefore discharge at varying intervals, forcing the oscillator transistor **61** to respond to the varying discharge cycles of the bias network. The oscillator circuit **49** is therefore seen as an unstable oscillator.

Connected to the collector element of the transistor **61** by lead **69** are resistors **70** and **71**. The opposite end of the resistor **70** is connected by lead **72** to the base of the amplifier transistor **73**, the emitter of which is connected to lead **55** from the power supply **48**. The collector of the transistor **73** is connected by leads **74** and **75** to one side of each of the capacitors **76** and **77**, the other sides of which are connected by leads **78** and **79** respectively to the opposite end of resistor **71** and to the center tap of resistor **62**. By this circuit arrangement, a feedback and clipping network is formed for the oscillator circuit in such a manner that resistor **62** and capacitor **77** limit the oscillator circuit output at a desired low frequency e.g. twenty kilocycles, while resistor **71** and capacitor **76** limit

the oscillator output at a desired high frequency e.g. eighty kilocycles.

Because of the only partially rectified output of the power supply **48**, the amplifier stage of the electronic circuit is also modulated by an impressed alternating current, thus resulting in a three to twelve cycle modulation of the signals received by the amplifier from the unstable oscillator circuitry.

From the amplifier **50** of the electronic circuit, the output pulses are fed to a coupling circuit with the transducer **12**. In FIG. 5 this coupling circuit is shown as a step-up transformer **80** one end of the primary winding of which is connected to lead **76** while the other end of this winding is connected by lead **81** to lead **59** of the power supply **48**. The secondary winding of the step-up transformer **80** is connected by leads **19** and **20** to the electrodes **17** and **18** of the piezoelectric transducer **12** as heretofore described. In the embodiment shown, the step-up transformer **80** is one having a step-up ratio of approximately nine to one and when used in the circuit as herein described gives approximately three hundred and fifty volts at one hundred milliamps to the piezoelectric transducer **12**.

MODES OF OPERATION

Exemplary utilization of the structure and circuitry hereinabove described for repelling and/or destroying rodents such as rats, mice and bats in enclosed areas where food and other similar destructable items may be stored, is now described in detail.

A lead-zirconate-titanate ceramic composition in the form of a disk having a diameter of approximately 1.5 inches and a thickness of approximately 0.25 inch, and having a prime resonant frequency of 23.5 kilocycles is utilized as the piezoelectric transducer **12**. This transducer, having fused silver electrodes **17** and **18** on each face thereof and electrical leads **19** and **20** connected to these electrodes, is cemented, preferably with epoxy cement **25**, within a recessed cavity **16**, approximately 0.5 inch in depth, in a formed silicate incursion block **11** which is hemispherical in shape and is approximately 3.25 inches in diameter. An aluminum disk reflection suppressor **23** having a diameter and thickness at least equal to those of the transducer is cemented to the electrode bearing face **17** of the lead-zirconate-titanate transducer opposite the electrode bearing face **18** cemented to the incursion block, again preferably using epoxy cement, the lead from this face of the transducer being brought out through a hole in the center of the aluminum disk.

The components of the electronic circuit **14** described above are chosen with electrical values such that frequencies ranging from approximately 20 kilocycles to 80 kilocycles are obtained therefrom, this output being applied to the lead-zirconate-titanate transducer **12** through the step-up transformer **80**. Because of the use of only partially rectified alternating current and of the characteristics of the bias voltage capacitor, as previously described, the output of the electronic circuit will be highly unstable and in the form of high intensity erratic pulses resulting from the modulation thereof by an impressed alternating current of the order of between 3 and 12 cycles derived from the 60 cycle alternating current source. Application of such an output by means of a coupling circuit, e.g. a step-up transformer to the transducer having a prime resonant frequency of 23.5 kilocycles results in the generation by the transducer of a sound pattern which is extremely erratic, rich in distorted harmonics and modulated by a sub-sonic cycle tone at random intervals varying from three to sixty milliseconds in duration. The erratic pulses in the sub-sonic range of frequency impresses a "pistol shot" effect upon the carrier frequencies, which, by measurement, have been found to peak at approximately 23.5 kilocycles, 32.5 kilocycles, 47.0 kilocycles and 65.0 kilocycles, these frequencies resulting from the interaction of the output of the oscillator-amplifier circuitry with the resonant frequency and harmonic frequencies of the piezoelectric transducer.

The erratic pulses and varying frequencies of the output of the transducer as thus generated has been found to have devastating effect upon vermin and rodents. While ultrasonic frequencies have heretofore been used to repel rodents, it has been found that rats and mice quickly adapt themselves to repeated and regular occurrences of signals at fixed ultrasonic frequencies and that while initially repelled, vermin of this type generally reappear and are henceforth immune to such signals. However, signals having the characteristics of those produced by the method herein described are found to be very effective in permanently repelling vermin and rodents, and in many cases causing their destruction.

The transfer of mechanical energy in the form of sonic and ultrasonic signals having the peculiar nature of those produced in the manner just described has been found to be particularly effective through the use of the specially designed incursion block which has been described above. Normally sonic signals at frequencies above 18 kilocycles are highly directional but by utilizing this novel type of incursion block, the sonic signals are dispersed in a 180° plane, eliminating nodes and standing waves in any one direction. Additionally, an incursion block having the characteristics herein described provides a minimal reverse reflection in comparison with the 180° forward emission. The purpose of the reflection suppressor **23** previously described is to redirect this reverse reflection back to the incursion block thereby intensifying the forward emission.

By utilizing a stainless steel semi-hemispherical radiating plate **10** of approximately 10.5 inches in diameter having its radiating surface highly polished, there is obtained a maximum reflection-dispersion of all of the resonant, and harmonic ultra-sonic and sub-sonic energy which have been generated by the transducer **12** and transferred to the incursion block **11**. The incursion block is mounted in a 3.25 inch circular opening in the radiating plate, epoxy cement being used to secure the incursion block to the plate, the incursion block being provided with a circumferential beading or ring **26** as shown in FIGS. 1 and 3.

In order that the radiating plate may fully transfer to the atmosphere the mechanical energy in the form of the erratic pulses of sonic frequencies transferred thereto by the incursion block, this plate is spring mounted to a support plate which may in turn be provided with clamping means as heretofore described to support the entire electrosonic apparatus in whatever manner may be desired. For the specific purpose of repelling and destroying vermin and rodents, it has been found advantageous to support the electrosonic apparatus from the ceiling in a room or enclosed area from which it is desired to eliminate the vermin and/or rodents.

Exemplary of a different utilization of the electrosonic apparatus herein described is its use as a component of high fidelity and stereo music systems in the following manner.

A piezoelectric transducer, for example a lead-zirconate-titanate composition, having a thickness such that its prime resonant frequency is in the order of 15 kilocycles may be mounted upon an incursion block similar to that described herein with the connections from the electrodes thereof connected to the output of an amplifier forming a normal component of the high fidelity or stereo music system. In this manner, audio signals in the ultra-sonic range, i.e. those having a frequency of between approximately 10 and 20 kilocycles are transferred from the transducer to the incursion block and thence to the radiating plate from which they are radiated through the atmosphere with a forward emission over a 360° angle in the same manner as has been described hereinabove. Here again an aluminium disk reflection suppressor may be

utilized as described above but the electronic circuitry as described in connection with FIG. 5 need not be utilized, this being replaced by other electronic circuitry, for example that of the high fidelity or stereo system with which the acoustical lens herein described is being utilized.

It will thus be seen that the electrosonic apparatus herein described may be utilized as an acoustical lens in various manners. Hence, while only certain preferred embodiments of this invention have been shown and described by way of illustration, many modifications will occur to those skilled in the art and it is, therefore, desired that it be understood that it is intended in the appended claims to cover all such modifications that fall within a true spirit and scope of this invention.

What is claimed as new and what is desired to secure by Letters Patent of the United States is:

1. An acoustical lens system for wide angle radiation of ultrasonic waves which comprises a lead-zirconate-titanate piezoelectric transducer having a prime resonant frequency in the ultrasonic range, an incursion block formed of silica material in hemispherical shape and having a recessed cavity in the flat side thereof for mounting said transducer therein, and a semi-hemispherical radiating plate having a circular opening in the center thereof for mounting therein said incursion block.

2. An acoustical lens system as recited in claim 1, including a reflection suppressor mounted on the side opposite that side of said piezoelectric transducer upon which said incursion block is mounted and having dimensions which are at least equal to those of said transducer.

References Cited

UNITED STATES PATENTS

2,593,031	4/1952	Howatt	179—110.1
3,058,103	10/1962	Evans	340—15
3,093,809	6/1963	Watlington	340—15
3,107,746	10/1963	Namon	181—32
3,179,381	4/1965	Jacke	310—9.1
3,296,586	1/1967	Midlock	340—15
3,308,904	3/1967	Kelly	181—32
3,305,824	2/1967	Brooks	340—15
3,360,664	12/1967	Straube	310—9.1
3,387,257	6/1968	Brech	340—15

MILTON O. HIRSHFIELD, Primary Examiner

M. O. BUDD, Assistant Examiner

U.S. Cl. X.R.

310—9.1; 340—15