LOUD SPEAKER

Filed Aug. 17, 1928 2 Sheets-Sheet 1

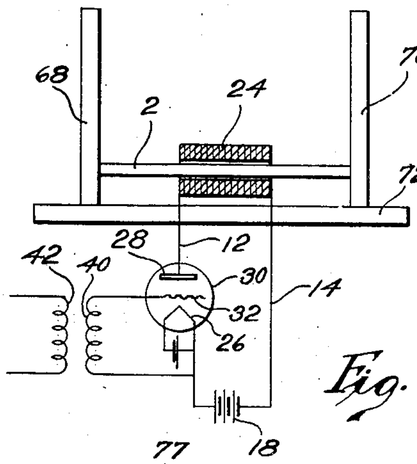

Fig. 1

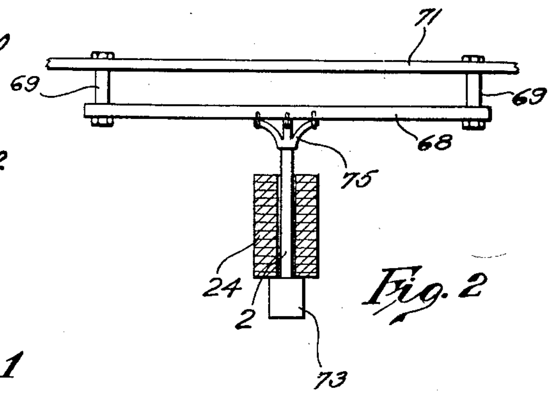

Fig. 2

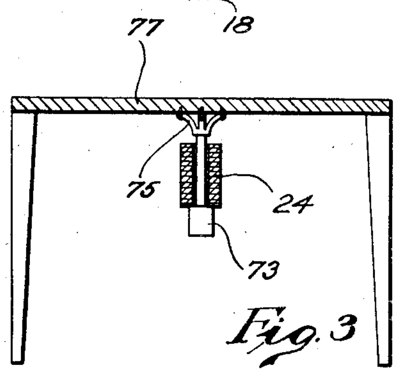

Fig. 3

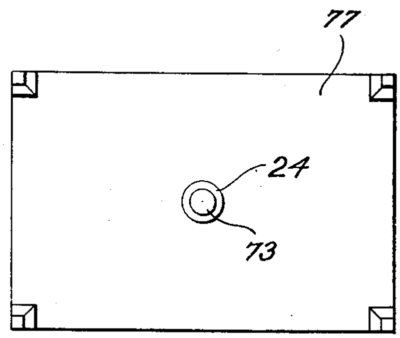

Fig. 4

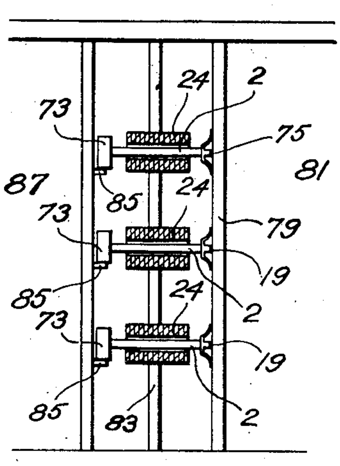

Fig. 5

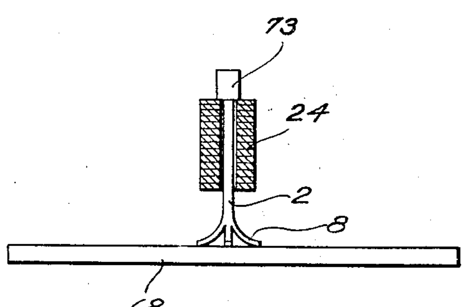

Fig. 6

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LOUD SPEAKER

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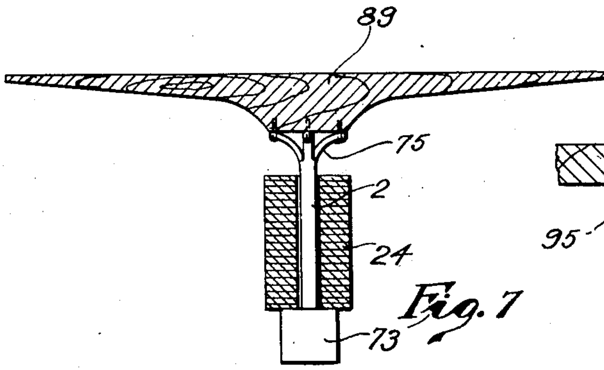

Fig. 7

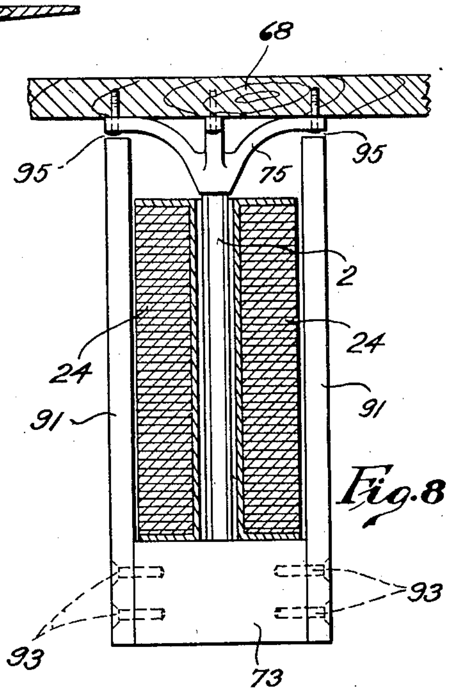

Fig. 8

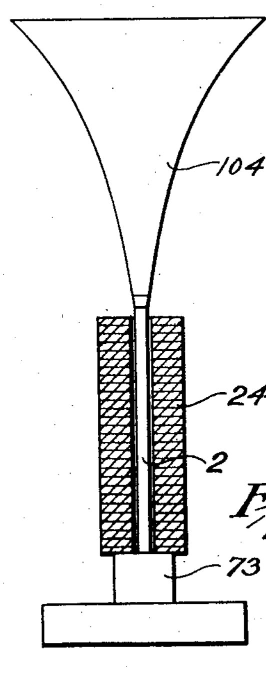

Fig. 9.

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LOUD SPEAKER

Application filed August 17, 1928. Serial No. 300,248.

The present invention relates to loud speakers and its chief object is to provide a loud speaker operable by magnetostrictive action. Other objects will be explained hereinafter, and will be particularly pointed out in the appended claims.

The term "loud speaker" is used herein to denote a device for delivering sound with sufficiently faithful quality and sufficient intensity to be heard throughout a room. The device of the present invention yields acoustic energy of essentially the same magnitude as the other types of loud speakers now on the market and the quality is essentially as good. It will, therefore, be understood that the term "loud speaker", as used herein, is not properly applicable to an ordinary telephone receiver that is designed to be held to the ear. A telephone receiver, if driven with enough power to raise the intensity to loud-speaker proportions, is defective in quality. It has heretofore been proposed to operate telephone receivers and other acoustic devices magnetostrictically. But none of the prior-art proposals, so far as known, have been even remotely serviceable as loud speakers. The reasons for this will be discussed more at length hereinafter.

A magnetostrictive vibrator comprises a magnetostrictive core disposed in an electromagnetic field, such as may be established by passing an electric current through a field coil or winding. The core may be in the form of a rod or tube, or any other desired form. Any material having suitable properties may be used for the core, but the material should obviously be characterized by comparatively large magnetostrictive effects and comparatively low vibrational decrement.

When stimulated magnetically by the field, the core becomes very slightly mechanically deformed or distorted by magnetostriction. The resulting increment of deformation may be a lengthening or a shortening, or some other distortion, depending on the material and on the polarity of the increment of the magnetic field. This action of the magnetic field upon the core will, for brevity, be hereinafter termed "stimulation". Conversely, when the vibrator is mechanically deformed or distorted, it will react magnetically upon the magnetic field by magnetostriction, with an increment of magnetization depending upon the nature of the preexisting magnetic field and the mechanical deformation, and this will produce its effect upon the electric current or voltage in the coil. This reaction will, for brevity, be hereinafter referred to as the "response". The mechanical deformation is produced by exciting reversible internal stresses in the core, and the core readily recovers upon the withdrawal of the deforming forces.

If the current or voltage is alternating, the electromagnetic field created thereby will also be alternating. The core will, therefore, increase and decrease in length, let us say, many times a second, every variation in the current producing its stimulative effect on the core, and every deformation of the core producing its reaction response upon the current. The core will, in consequence, vibrate mechanically by magnetostriction. Ordinarily, these vibrations will be quite small. When the alternating frequency is varied so as to assume a value close to, or substantially the same as, the natural frequency of mechanical vibration of the core, however, the amplitude of vibration of the core, though still small, becomes relatively quite large. The core will then react inductively on the load to render its consumption of power critical as to frequency for frequencies near the free frequency of the core. There will usually be more than one specific frequency of magnetization at which the core will thus resonate; for, in addition to one or more natural fundamental frequencies of mechanical vibration, it has also frequencies of vibration determined by the operation of the core in halves, thirds, fourths, fifths, etc.

The invention will be explained in greater detail in connection with the accompanying drawings, in which Fig. 1 is a diagrammatic view of circuits and apparatus arranged and constructed in accordance with one embodiment of the present invention; Fig. 2 is a similar view of a modification; Fig. 3 is a similar view, showing the loud speaker illustrated in Fig. 2 attached to the under side of a table;

Fig. 4 is an under-side plan of the same; and Figs. 5 to 9, inclusive, are views of further modifications.

Referring first to Fig. 1, a magnetostrictive core 2, preferably in the form of a rod or tube, is shown attached at its ends to sound-radiating wings or faces 68 and 70 which are attached at their lower ends to a base 72. The wings and the base may be parts of a sounding box, properly shaped, proportioned and mounted for quality. The core 2 is preferably connected to the wings 68 and 70 near their points of attachment to their connecting base 72, in order that the free ends of the wings may have a larger amplitude. The magnetostrictive core is axially positioned within a solenoid coil 24, with clearance to permit free vibrations. The coil 24 may be connected in the output circuit of a vacuum tube 30, as illustrated, or in any other desired way. The plate 28 of the vacuum tube is shown connected to the coil by conductor 12, and the filament 26 by conductor 14, in series with a local battery 18. The grid 32 and the filament 26 are shown in circuit with the secondary coil 40 of a transformer, the primary coil of which is indicated at 42. The tube 30 constitutes a source of alternating electromotive force for the solenoid 24, to enable the latter to drive the magnetostrictive core 2. The battery 18 may serve also to apply a steady magnetizing or polarizing field to the core 2, over which the alternating field produced by the generator 30 is superposed. The alternating field is preferably smaller than the steady field, in order that the combined field may not at any time fall to zero. Polarization may be effected in other ways also, as described in a copending application, Serial No. 158,452, filed January 3, 1927, of which the present application is a continuation in part, and which matured, on March 11, 1930, into Patent No. 1,750,124.

The vibrations of the core 2 will be transmitted to the radiating wings 68 and 70, and the latter will produce sound vibrations in the air. The system thus constitutes a loud speaker, as above defined.

According to the modification of Fig. 2, one of the radiating faces, shown at 68, and which may, for example, be constituted of a wooden board or a metal sheet, is attached, as by bolts 69, to any desired support, such as the ceiling 71. The other radiating face is replaced by a heavy mass 73 that is integrally joined to the lower end of the core 2. The other end of the core 2 is attached to the radiating face 68 by a crow foot or spider 75. The spider 75 serves to extend the attachment of the core to a larger area of the radiator 68, which permits a better path for transmission of sound vibrations.

The heavy mass 73 holds the end of the core to which it is attached stationary, producing a node of motion, while a loop of motion is produced at the other or free end of the core, causing the radiating face 68 to vibrate. The sound waves propagated through the core 2 are thus reflected back at the weighted end of the core, and the length of the rod is thus equal to a quarter-wave length. For the unweighted rod, on the other hand, the reflections within the rod take place with a loop of motion at both ends, making the length of the rod equal to a half-wave length.

The operation will be better understood by the following example: Nickel is a magnetostrictive material that shortens with an increase of magnetization. The shortening or static magnetization is very minute. If, however, it is polarized by an applied steady field, upon which is superposed an alternating current resonant with its natural frequency of mechanical vibration, its amplitude of length variation may become 100 times as great as with static on non-resonant magnetization. The resonant frequency of a nickel tube 8 inches long, ½ inch in external diameter and 0.005 inch thick is about 12,000 per second. If, now, the core has a heavy mass 73 attached to one end, with the other end free, the system will then be resonant to a frequency of 6,000 per second, instead of 12,000 as before. The system is still very sharply resonant but, of course, at the 6,000-cycle frequency, and not the 12,000. If the core is excited by alternating currents of all frequencies, the 6,000-cycle component only will have any significant intensity, and speech frequencies applied to the system would appear as an irregular succession of ringing sounds of high frequency and would be unintelligible.

In all prior-art proposals for producing sound magnetostrictively, there have always been involved certain difficulties which the present invention overcomes. These difficulties arise in large part from the considerations above discussed of resonance. Not only is resonance at the fundamentals involved, but, as before stated, the system may resonate also to multiples of the fundamentals. In order to make good speech reproduction possible, all such resonant frequencies in the audible range must be suppressed. This may be partially effected by attaching a radiator of sound to one or both ends of the core. Such radiators of sound increase the damping of the system and dull the resonance, provided the sound radiators have the proper design and the proper constants.

So far as known, in all prior-art proposals for producing sound magnetostrictively, the design has been such that the radiators attached to the core have had so little effect as to leave the system highly resonant. Telephone diaphragms, paper cones and thin balsa wood sheets of the telephone art, attached to a magnetostrictive driving core, yield merely a monotone reproducer and introduce such great distortion that they cannot serve as loud speakers. Thus, a thin, light-weight diaphragm on the free end of the weighted rod described in the present application adds no weight comparable with the weight of a small length of the rod, and it adds no force comparable with the force necessary to stretch the rod to an amount required for audible sound amplitude.

It does not, therefore, react on the rod's vibration, and it does not take from the rod any significant amount of energy. In the example above given, the resonance is still sharp and the resonant frequency is still 6,000.

According to the present invention, however, a diaphragm is effectively driven by a relatively rigid driving mechanism.

The spider 75 may be attached direct to the underside of a table top 77, as shown in Figs. 3 and 4, or to other members which, like the table top 77, may be adapted to serve as the radiating face. One such member is shown in Fig. 5 as the wall 79 of a room 81, the vibrations of the core causing the sound vibrations produced by the wall 79 to radiate into the room 81. To enhance the effect, the wall 79 is shown provided with, not one, but a number, of magnetostrictive vibrators, supports 83 and 85, in an adjacent room 87, acting to sustain the masses 73 and the windings 24.

The magnetostrictively-operated member may, however, be separate from the board, or the like, so as to provide a portable loud-speaker unit that may be carried about from place to place, as shown in Fig. 6. The crow foot or the like 8 may be placed upon a table top, piano top, or any other suitable support that is adapted to act as a sound radiator 68.

Instead of being plane, as in the other figures so far discussed, the sound-radiating face may be in the form of a specially designed, curved diaphragm 89, as shown in Fig. 7, supported upon the end of the core 2 opposite to the weight 73. Here, again the device may be used as a portable loud-speaker unit, or the diaphragm 89 may be attached to the ceiling, a table top, a room wall, or in other ways obvious to persons skilled in the art.

The radiator of Fig. 7 is thicker near the driving point and the thickness is inversely proportional to the distance from the center. This type of diaphragm has especial merit in that the acoustical impedance of the diaphragm may be made equal to that of the driving core at all frequencies. Near the center, this diaphragm, if made of wood, may be of the order of 4 or 5 inches thick.

The positioning of the diaphragm 68 in Fig. 2 near an extended area, such as the ceiling 71, has the merit of damping out and baffling the wave from the upper side of the diaphragm 68, which might otherwise destructively interfere with the wave from the lower side. For the same purpose, the arrangement of Fig. 1 may have enclosing faces about the open sides between the diaphragms 68 and 70, and in Fig. 3 the lower part of the table may be boxed in. The arrangement of Fig. 5 also obviates the back wave by causing it to be developed in a different room from that of the face of the radiator.

According to the modification of Fig. 8, permanent magnets or ferro-magnetic bars 91 are attached at one end as by means of bolts 93, to the weighted mass 73 and extend upwardly from their attaching points throughout substantially the length of the core 2. The crow foot or spider 75 may then preferably be made of iron, and small air gaps 95 may be provided between the ends of the spider and the ends of the bars 91 to permit free vibration of the radiating face 68.

In the modifications described herein, the loud speaker is actuated by the longitudinal magnetostrictive vibrations of the core.

In the modification of Fig. 9, the radiating member 104 is horn-shaped. The small end of the horn is attached to the free end of the core 2, thus permitting the horn to be driven bodily. The horn may extend beyond the core 2, as illustrated, or, if desired, the position of the horn may be reversed, so as to cause it to enclose partially its driving core 2 and the solenoid coil 24.

According to my experiments, the following materials and dimensions result in a satisfactory loud speaker. The magnetostrictive driving element may be a soft-nickel tube 4 to 30 inches long, about ½ inch in diameter, and 0.005 to 0.025 inches thick, the driving coil 24 may have about 15,000 turns of wire to match the impedance of amplifying tubes, the spider 75 may be of metal, with an area, where attached to the core, about equal to the cross section of the core and having three or more legs tapering toward the sound radiator and spread out so that their ends, where attached to the radiator, lie along the circumference of a circle 3 to 5 inches in diameter. The weight attached to the non-radiating end of the core may be about ten pounds. The radiator may be a plane wooden board, about 1 to 2 inches thick, preferably more than one inch thick, and may have an area of 8 to 100 or more square feet, but other shapes of radiating members may be used, as before described, characterized by graduated stiffness, density or speed. Where the radiator is curved or in the form of a cone, the thickness should correspond to the increase of stiffness of the curved or conical surface.

The invention is not, of course, limited to the modifications illustrated herein, and may be further modified and changed by persons skilled in the art without departing from its spirit and scope, as defined in the appended claims.

What is claimed is:

1. A loud speaker comprising a magnetostrictive core, a sound-radiating member to which the magnetostrictive core is secured, and means for suppressing the resonant frequencies of the core.

2. A loud speaker comprising a magnetostrictive core, a sound-radiating member to which the magnetostrictive vibrations of the core is transmitted, and means comprising a graduated coupling element between the core and the member for suppressing the resonant frequencies of the core.

3. A loud speaker comprising a magnetostrictive core weighted at one end and secured at its other end to a sound radiating member through the intermediation of a transition mechanical impedance designed to suppress acoustic reflections.

4. A loud speaker comprising a magnetostrictive core weighted at one end and secured at its other end to a diaphragm.

5. A loud speaker comprising a plurality of magnetostrictive cores each weighted at one end and secured at their other ends to a sound-radiating member.

6. A loud speaker comprising a magnetostrictive core weighted at one end and provided at its other end with a spider, and means for securing the spider to a sound-radiating member, the spider serving as a graduated mechanical impedance between the core and the diaphragm for suppressing resonance.

7. A loud speaker comprising a magnetostrictive core secured at one end to a sound-radiating member, and a magnet secured at one end to one end of the core and extending throughout substantially the length of the core.

8. A loud speaker comprising a magnetostrictive core attached to a sound-radiating member, means for suppressing the resonant frequencies of the core, and means for baffling out the sound waves from one side of the member.

9. A loud speaker comprising a magnetostrictive core weighted at one end and provided at its other end with a spider, means for securing the spider to a sound-radiating member and magnets each secured at one end to the weighted end of the core and extending throughout substantially the length of the core, there being an air gap between the free end of each magnet and the sound-radiating member.

10. A loud speaker comprising a magnetostrictive driving element and a sound-radiating member coupled together through a resonance-suppressive junction.

11. A sound reproducer comprising a magnetostrictive driving member and a sound-transmitting, resonance-suppressing coupler, said driving member being attached to said coupler, and said coupler being adapted to contact with a sound radiator.

12. A sound reproducer comprising a magnetostrictive driving member and a sound-transmitting coupler, said driving member being attached to said coupler, and said coupler being adapted to contact with a sound radiator and designed to suppress resonant frequencies of the constituent parts of the system.

13. A loud speaker comprising a magnetostrictive core, means for magnetically polarizing the core, and a sound-radiating member to which the magnetostrictive core is secured, the core and the sound-radiating member being so designed as to suppress the resonant frequencies of the core.

14. A loud speaker comprising a magnetostrictive core, a sound-radiating member to which the magnetostrictive core is secured, the core and the sound-radiating member being so designed as to suppress the resonant frequencies of the core, and a permanent magnet for magnetizing the core.

15. A loud speaker comprising a magnetostrictive core, a sound-radiating member to which the magnetostrictive core is secured, the core and the sound-radiating member being so designed as to suppress the resonant frequencies of the core, and a space-current device having an input circuit and an output circuit, the core being connected in the output circuit.

16. A loud speaker comprising a rigid magnetostrictive core weighted at one end and secured at its other end to a sound-radiating diaphragm through a resonance-suppressing coupler.

17. A loud speaker comprising a magnetostrictive core secured at one end to a sound-radiating member, and a magnet secured at one end to one end of the core and extending throughout substantially the length of the core, there being an air gap between the free end of the magnet and the sound-radiating member.

18. A loud speaker comprising a magnetostrictive core attached at one end to a sound-radiating member, the member being thicker at the point of attachment to the core than at other places.

In testimony whereof, I have hereunto subscribed my name.

GEORGE W. PIERCE.