Dec. 1, 1964 W. C. LAUBE, JR 3,159,713

ARTIFICIAL REVERBERATION DEVICE

Filed March 10, 1961 3 Sheets-Sheet 1

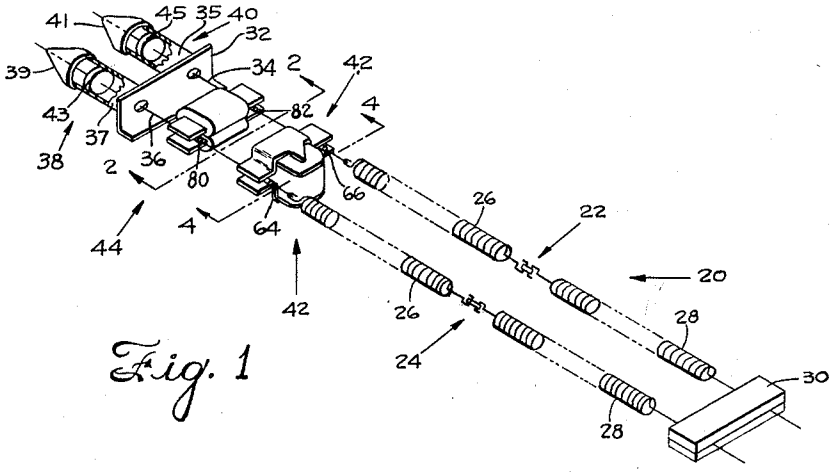


Fig. 1

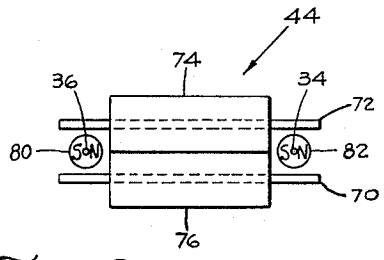


Fig. 2

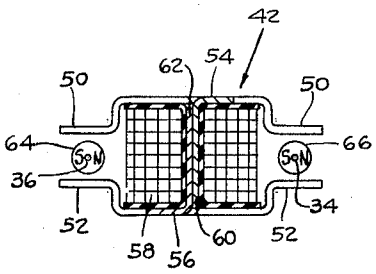


Fig. 4

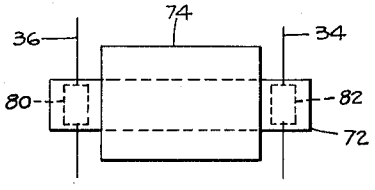


Fig. 3

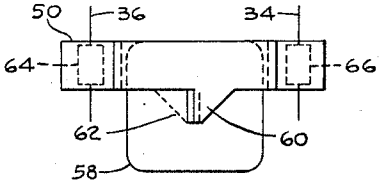


Fig. 5

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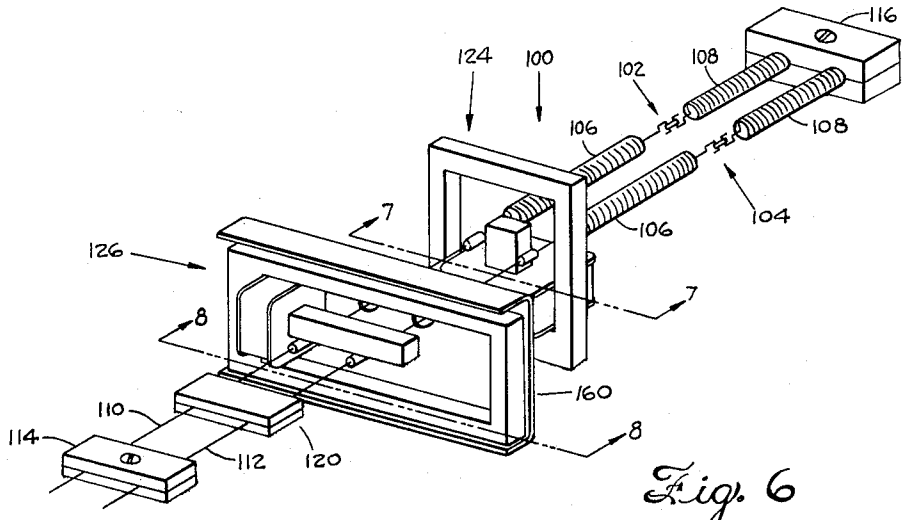


Fig. 6

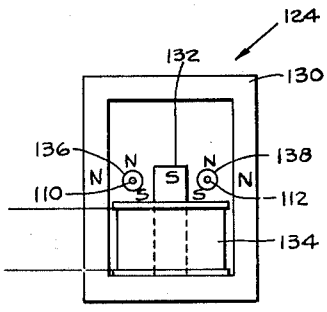


Fig. 7

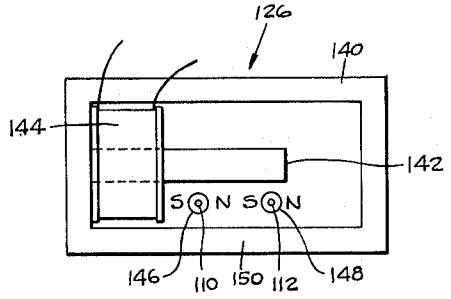


Fig. 8



Fig. 9

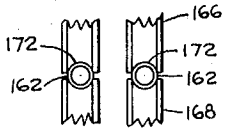


Fig. 10

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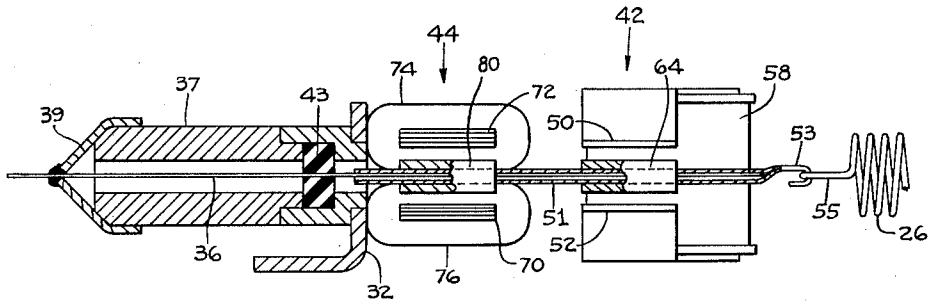


Fig. 11

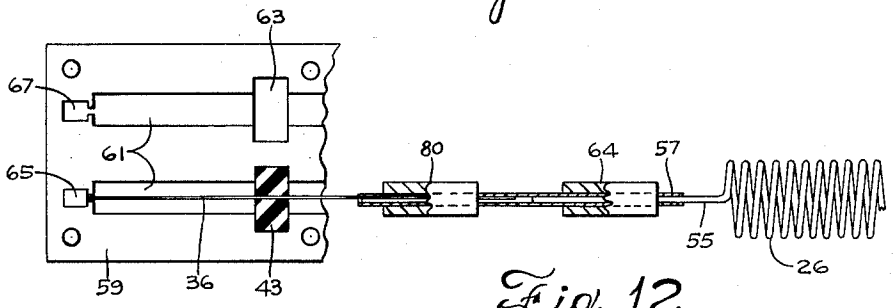


Fig. 12

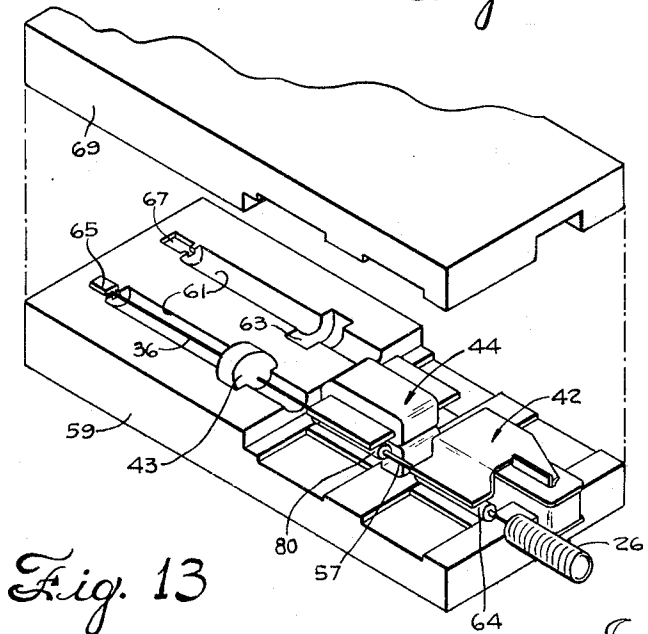


Fig. 13

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3,159,713

ARTIFICIAL REVERBERATION DEVICE

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Filed Mar. 10, 1961, Ser. No. 94,816
5 Claims. (Cl. 179—1)

This invention relates generally to improved apparatus for artificially introducing in music, reverberation effects approximating the desirable acoustic reverberation of a large auditorium, particularly for use in electrical musical instruments, phonographs, tape recorders, and the like, in which the sound signal transmitting system originates from a source lacking sufficient reverberation.

It is an object of the present invention to provide an improved reverberation device which closely simulates room acoustic reverberation effects, which device is more compact and more economical than similar prior art devices.

It is a more specific object of the present invention to provide an improved artificial reverberation device of the spring type in which the driver and the pickup are mounted closely adjacent each other at one end of a plurality of coiled wire springs of different acoustical length, arranged such that the direct signal from the driver to the pickup is eliminated and the subsequent reflected signals are sensed.

It is another object of the present invention to provide an improved reverberation device which has means for adjusting the effective length of the coiled wire springs, whereby the reverberation time delay may be adjusted to a desired value.

It is another object of the present invention to provide improved pickup and driver elements which have a magnetic circuit configuration such that little or no shielding between the driver and pickup is required even though they are located in close proximity to each other.

Other objects and the various features of the present invention will be evident upon a perusal of the following description taken in conjunction with the accompanying drawings in which:

FIG. 1 is a somewhat diagrammatic perspective view of a reverberation device made in accordance with the teachings of the present invention;

FIG. 2 is an enlarged elevational view taken substantially along the line 2—2 of FIG. 1 showing the pickup unit;

FIG. 3 is a plan view of the pickup unit;

FIG. 4 is an enlarged vertical sectional view of the driver taken substantially along the line 4—4 of FIG. 1;

FIG. 5 is a plan view of the driver;

FIG. 6 is a somewhat diagrammatic perspective view of a second embodiment of the invention;

FIGS. 7 and 8 are enlarged elevational views of the driver and pickup substantially along lines 7—7 and 8—8, respectively, of FIG. 6;

FIG. 9 is a fragmentary diagrammatic side elevational view showing a third embodiment of the present invention;

FIG. 10 is an elevational view substantially along the line 10—10 of FIG. 9;

FIG. 11 is an enlarged side elevation of a fraction of the mechanism of FIG. 1 with portions of the structure broken away to illustrate details of construction;

FIG. 12 is a top view of a structure, partially assembled, constituting a modification which may be incorporated in the device of FIG. 11; and

FIG. 13 is an exploded perspective view of the device of FIG. 12 shown partially assembled.

In known prior art mechanical artificial reverberation devices of the most nearly similar type, the driver is positioned at one end of two or more coiled wire springs, and the pickup is positioned at the opposite ends of the springs. The driver system vibrates all of the coiled wire springs together, and the signals applied to the springs by the driver are in phase. Similarly, the pickup is arranged such that it is sensitive to signals in the springs insofar as the signals have an additive phase relationship. This system may therefore be considered as of the additive signal type. So far as is known, it has been considered necessary by those experienced in this particular art to have the signals "additive" in order to produce an acceptable signal level.

However, it has been discovered that substantially the same signal level is obtained by using the "difference" signal—that is, by shifting the phase relationship of one of two pickup units or driver units 180° with respect to its counterpart—so that the picked up signal is representative of the phase difference. This is because the springs have a different acoustical lengths and the phase relationship of the signal is sufficiently disturbed by the time difference. Practically, all that appears to be changed is that the frequencies at which nulls are encountered by the "additive" signal configuration exhibit peaks in the "difference" signal configuration, whereas the frequencies which display peaks in the "additive" signal configuration are characterized by nulls in the "difference" signal configuration.

This discovery has led to the realization of a reverberation device in which the driver and pickup are positioned at the same ends of the springs in close proximity to each other. This was not believed to be possible in the prior art devices since the ordinary "in phase" direct signals from the driver would produce identically phased signals in the pickup for application to a speaker at the same time that the direct signal is applied to the same or a different speaker, thereby producing an undesirable reinforcement of the direct signals. However, in the improved "difference" signal configuration, the direct signal produced by the driver in one portion of the pickup is canceled by the oppositely phased signal in another portion of the pickup, whereby no direct output signal is produced in the pickup as a whole. Furthermore, as will appear presently, the configuration can be such as to eliminate practically all cross talk between the driver and pickup even though the signal strength in the driver is hundreds of times larger than in the pickup and even though their magnetic circuits are only a fraction of an inch apart.

In the embodiment illustrated diagrammatically in FIG. 1, the reverberation device 20 comprises a pair of coiled wire spring assemblies 22 and 24 each having left and right windings 26 and 28, wound in opposite directions for eliminating spurious signals otherwise produced by transmission in the spring compressional mode. The compressional modulation produced by torsion in the left windings 26 is canceled by the equal and opposite compressional modulation caused by torsion in the right windings 28.

The spring assemblies 22 and 24 are supported between a pair of mounting blocks or anchors 30 and 32. At the left end as seen in FIG. 1, the springs have highly compliant magnet support wire extensions 34 and 36 that pass into the open ends of fixed tubes 35 and 37 which form portions of the anchor 32. The ends of these wires are secured to conical caps 39 and 41 which fit the tube ends. A pair of dead rubber or plastic discs 43 and 45 are fitted into the tubes and are pierced by the wires 34 and 36. The discs engage the wires and absorb energy therefrom and thus act to damp the wire oscillations.

A driver 42 and a pickup 44 are suitably mounted close together on a stationary structure (not shown) between the wires 34 and 36. The driver, as best seen in FIGS. 4 and 5, comprises upper and lower pole pieces 50 and 52 formed of a strip of suitable non-permanent ferromagnetic

material. The pole piece 50 is formed upwardly at its central portion 54 and the pole piece 52 is formed downwardly at its central portion 56 to receive an electromagnetic coil 58 therebetween. The pole piece 50 includes a sideward extension with a downwardly bent lug 60, and the pole piece 52 includes an equivalent upwardly extending lug 62. The lugs 60 and 62 together form a magnetic core for the coil 58 slightly offset transversely from the center of the structure.

A pair of permanent magnets 64 and 66 are anchored to the wires 36 and 34 at positions between the pole pieces 50 and 52 on opposite sides of the driver coil 58. In the relaxed positions of the wires 36 and 34, the north and south poles of the magnets 64 and 66 assume the positions shown in FIG. 4, each equidistant from the pole pieces 50 and 52. The magnets are preferably cylindrical, and may be made of a suitable permanent magnetic material such as one of the ceramics.

The pickup 44 comprises a symmetrical magnetic circuit forming structure including a pair of flat rectangular pole pieces 70 and 72 and a pair of coils 74 and 76 wound about the pole pieces. The ends of the pole pieces define air gaps within which a pair of permanent magnets 80 and 82, similar to the magnets 64 and 66, are carried by the wires 36 and 34. This symmetrical magnetic circuit has been found to display remarkable freedom from being affected by stray fields in the vicinity thereof, especially any that are attributable to the driver which is positioned close thereto, since the magnetic systems are normal to each other. The driver also has been found to display exceptionally good characteristics with respect to minimizing stray fields.

Current in the driver coil 58 causes the pole pieces to assume opposite magnetic polarities depending upon the direction of current flow. The polarity and magnetic potential of the pole pieces vary cyclically in accordance with the tone signals applied thereto to produce torsional vibratory movement of the magnets 64 and 66. With the magnet polarities shown in FIG. 4, the magnets 64 and 66 move in unison in the same direction.

In the embodiment of FIGS. 1–5, the magnets 64, 66, 80 and 82 are about 1/16 inch in diameter and about 1/8 inch long. Because of the off-set mounting of the coil 58 with respect to the pole pieces 50 and 52, it has been possible to bring the driver 42 and the pickup 44 quite close together, to within 1/8 to 3/8 inch for instance. The wires 34 and 36 may be made as short as in the order of 1 3/8 inches. No magnetic shielding is required between the driver and the pickup because the symmetrical magnetic stray fields produced by the driver have a cancelling effect at the two ends of the symmetrical pickup.

In operation, signals applied to the coil 58 of the driver cause the pole pieces 50 and 52 to be oppositely polarized. Assuming at any instant in time that a signal of progressively increasing strength in the coil 58 causes the pole piece 50 to become a north pole and the pole piece 52 a south pole, the flux in the air gaps between the pole pieces will cause the magnets 64 and 66 to be angularly displaced in a clockwise direction an amount proportional to the intensity of the current in the coil 58. Since the magnets 80 and 82 are secured to the wires 36 and 38 which rotate with the magnets 64 and 66, the magnets 80 and 82 will also be angularly displaced in a clockwise direction. The identically moving magnets 80 and 82 therefore induce poles of the same polarity and strength at opposite ends of each pole piece 70 and 72, with the result that no current is generated in either coil 74 or 76. The pickup is therefore insensitive to direct movement of the magnets 80 and 82 by the driver.

However, the direct signal is also applied to the spring assemblies 22 and 24. Since the acoustical lengths of the two spring assemblies are different, the signals, which travel down the assemblies 22 and 24 and are reflected by the end clamp 30, are returned to the pickup with a slight time difference. The result is that the pickup responds to the signals in succession. Movement of either of the magnets 34 and 36 induces magnetic flux in opposite directions in the pole pieces 70 and 72 around which the coils 74 and 76 are wound, and the coils 74 and 76 are electrically connected so that the simultaneous voltages thus generated in each are in aiding relation. Thus it is seen that, whereas current in the driver coil 58 produces identical movement of the magnets 64, 66, it is only differential movement of the magnets 80, 82 which generates a current in the pickup coils 74, 76.

Typical time delays for the reflected signals in the respective spring assemblies 22 and 24 may be in the order of 37 milliseconds and 29 milliseconds. The damping discs 34 and 36 of known construction may be suitably fixed for a desired decay rate in successive reflected signals.

Important details of the spring supporting and magnetic structure shown particularly in FIG. 1 are illustrated in greated detail in FIG. 11. Note that the compliant support wire 36 extends into and is secured to a tube 51, the opposite end of which tube is flattened and formed to provide a small hook 53 which engages a hook 55 at the end of the spring element 26. The two hollow cylindrical magnets 80 and 64 are slid over the tube 51 and cemented in place. The tube 51 and magnets 80 and 64 form a relatively rigid structure torsionally. The magnets 80 and 64 therefore vibrate together and the rotational inertia of the mass thus formed acts to reflect the major portion of the return spring vibration, a minor portion acting to vibrate the tube 51 and magnets 80 and 64. Vibration of the magnet 80 thus induces a current in the output circuit and the major portion of this vibration is absorbed by the damping element 43.

The vibration reflected from the hook 53 returns to the opposite end of the spring system at 30 (FIG. 1), is reflected, and returns to the hook 53 where again the major portion is reflected and a minor portion passed to vibrate the magnet 80. This activity continues until the reverberative effect gradually decays.

The suspending system illustrated in FIGS. 12 and 13 is generally similar to that of FIGS. 1 and 11, but differs in detail. Instead of using the hook connections 53, 55 of FIG. 11, the end 55 of the spring simply extends into a straight tube 57 into which the support wire 36 extends from the opposite end, the assembly being made secure with a suitable adhesive. As in the previous example, the magnets 64 and 80 are cemented to the external surface of the tube 57. This arrangement may be used in the general assembly of FIG. 11 and is responsible for a slight cost saving and reduces the rotational inertia of the spring terminating system slightly. Everything else being equal, this improves the high frequency response somewhat and may be considered to be an advantage.

The structure of FIGS. 12 and 13 also shows a variation of the support wire anchorage system. Here a block 59, molded of a plastic for instance, has recesses to receive the magnetic structures 44 and 42 and a slot 61 to provide clearance for the wire 36 and a cross slot 63 into which the damping block 43 is pressed. The end of the wire 36 is secured to a short rectangular fitting 65 which drops into an opening 67 at the end of the slot 61. A separate block 69, identical to block 59, is then placed over the block 59 and the two secured together to complete the assembly. This works out well in practice and reduces the cost somewhat, particularly if production requirements are of a relatively high order.

In the embodiment illustrated diagrammatically in FIGS. 6, 7, and 8, the reverberation device 100 includes a pair of spring assemblies 102 and 104, each of which has oppositely wound left and right windings 106 and 108. Magnet support wires 110 and 112 are suitably secured to the windings 106, and the wires and windings are suitably connected between end clamps 114 and 116. A damping block 120 of suitable construction is positioned for engagement with the wires 110 and 112 to provide a suitable decay rate for successive reflected signals.

A driver 124 and a pickup 126 are provided adjacent each other between the windings 106 and the damping block 120. The driver 124 comprises a generally rectangular hollow pole piece 130 (FIG. 7) having a central core leg 132 extending upwardly into the hollow portion. A coil 134 is suitably secured at the lower end of the pole section 132. A pair of magnets 136 and 138 carried by the wires 110 and 112 are received in the hollow portion immediately above the coil 134 and on either side of the core section 132.

The magnets 136 and 138 are similar to the magnet 64 of FIG. 1; and, in the relaxed position of the wires 110 and 112, the north poles of the magnets 136 and 138 are in their uppermost vertical positions with the axis of polarization being in a vertical plane.

The pickup 126 includes a generally rectangular hollow pole piece 140 (FIG. 8) having a central horizontal core section 142 extending from one end thereof into the hollow portion. A coil 144 is received around the core section 142 and secured to the core at the end opposite the free end. A pair of cylindrical ceramic magnets 146 and 148 carried by the wires 110 and 112 or by tubes cemented to the wires (FIGS. 11, 12, and 13) are received between the core 142 and the lower side 150 of the pole piece 140.

In the relaxed position of the wires 110 and 112, the axes of polarization of the magnets 146 and 148 are in a horizontal plane and in the same direction. Thus, if the magnets 146 and 148 are rotated in the same direction, the magnetic flux field changes will be in aiding relation to produce an output voltage across the coil 144. However, if the magnets 146 and 148 are rotated similarly in opposite directions, their fields cancel to prevent the generation of a voltage across the coil 144. Differential rotation of the magnets 146 and 148 will also produce a voltage across the coil 144 as with the previouly described embodiment.

In this embodiment, a generally U-shaped magnetic shield 160 formed from a suitable non-permanent ferromagnetic sheet is positioned around the pickup 126 on the driver side. This shield helps protect the pickup against stray magnetic fields including those produced by the driver. A shield such as 160 has not been necessary in the embodiment of FIGS. 1–5, because the symmetry in the magnetic flux circuit of both the driver and pickup appears to achieve substantially full cancellation of this unwanted effect.

The direct signals applied to coil 134 of the driver cause the magnets 136 and 138 to rotate in opposite directions. As a result, the magnets 146 and 148 will also rotate in opposite directions in response to the direct signal and thereby cause their fields to cancel so that no voltage is generated across the coil 144. However, as in the first embodiment, the reflected signals are out of time phase and the differential movement of the magnets thus produced will generate a current in the coil 144.

FIGS. 9 and 10 show a modification available for either of the embodiments of FIGS. 1 and 6. In this modification, the end clamp remote from the driver and pickup is replaced by any anchorage, such as an arm 160 to which the coiled wire springs 162 may be connected. A longitudinally adjustable clamping mechanism 164 receives the springs 162 and effectively clamps them at a desired longitudinal position. The mechanism 164 shown for this purpose comprises a pair of rollers 166 and 168 connected together by a link 170. Each of the rollers 166 and 168 has a peripheral spring engaging groove 172 as is best seen in FIG. 10. The wheels are so spaced that the springs are tightly clamped in the grooves 172 to compress the springs slightly between the wheels as the wheels are rolled along the springs to a chosen position.

The time delay between the direct and the reverberative signals may be set to a desired value by adjusting the position of the mechanism 164, the delay increasing as the mechanism is moved toward the right with respect to FIG. 9. Because of the rotational inertia of the clamping mechanism 164, it acts to reflect vibration in the springs in essentially the same manner as a fixed abutment.

With this arrangement, some distortion will be introduced if the anchored spring element is changed in length very much with respect to the length of its oppositely wound counterpart attached to the driver and pickup. Within limits, and for some purposes, however, this effect may be unimportant.

In the claims, where springs are referred to as differing in length, it will be appreciated from the foregoing that this refers to their acoustical length—that is, their vibration time delay characteristics—and not necessarily their physical length, which is only one of several factors affecting the acoustical length.

While I have shown and described the preferred embodiments of my invention, it will be apparent that numerous variations and modifications thereof may be made without departing from the underlying principles of the invention. I therefore desire by the following claims to include within the scope of the invention all such variations and modifications by which substantially the results of my invention may be obtained through the use of substantially the same or equivalent means.

I claim:

1. An apparatus for providing reverberation of an electrical signal representative of sound comprising at least two coil springs having appreciably different effective vibration transmission lengths, means suspending said springs at their ends to permit vibrations in said springs to travel the lengths of said springs and be reflected from the respective ends of said springs, electromechanical driver means supported at a position adjacent one end of each spring to vibrate both of said springs when an audio frequency signal is applied to said driver means, mechanico-electrical pickup means supported adjacent said one end of each spring for translating the spring vibrations into electrical signals, each of said suspending means and the driving and pickup means comprising a torsionally rigid member secured at one end to said one end of its spring, a compliant member secured to the torsionally rigid member and extending from the opposite end thereof, means secured to and supporting said compliant member at a position spaced from said rigid member, a damping member secured to said compliant member in a position between said torsionally rigid member and said compliant member support, said driver and said pickup each including a rotatable magnetic element fixed to said torsionally rigid member to rotate therewith, said driver also including electromagnetic means for rotating one of said rotatable magnetic elements, and said pickup means including means for generating a current in response to rotation of the other of said rotatable magnetic elements.

2. The combination called for in claim 1 including means for changing the effective length of at least one of the springs, the last said means comprising an element engaging its spring near the spring end remote from the compliant support means, said spring engaging element being movable along its spring to a selected position and said spring engaging element having sufficient mass to reflect vibrations which travel along the spring to the spring engaging element.

3. An apparatus for providing reverberation of an electrical signal representative of sound comprising at least two coil springs having appreciably different effective vibration transmission lengths, means suspending said springs at their ends to permit vibrations in said springs to travel the lengths of said springs and be reflected from the respective ends of said springs, electromechanical driver means supported at a position adjacent one end of each spring to vibrate both of said springs when an audio frequency signal is applied to said driver means, mechanico-electrical pickup means supported adjacent said one end of each spring for translating the spring vibrations into electrical signals, each of said suspending

means and the driving and pickup means comprising a torsionally rigid member secured at one end to said one end of its spring, a compliant member secured to the torsionally rigid member and extending from the opposite end thereof, means secured to and supporting said compliant member at a position spaced from said rigid member, a damping member secured to said compliant member in a position between said torsionally rigid member and said compliant member support, said driver and said pickup including a pair of rotatable magnetic elements fixed to each torsionally rigid member in spaced relation to rotate therewith, said magnetic elements on one rigid member being in side-by-side relation to the comparable magnetic elements on the other rigid member, said driver also including electromagnetic means for simultaneously equally rotating one of the rotatable magnetic elements on each of said rigid members in a certain direction relative to the other, said pickup means including means for generating a current in response to rotation of the others of said rotatable magnetic elements, said pickup means being insensitive to simultaneous equal rotation of its rotatable elements in said certain relative direction.

4. An apparatus for providing reverberation of an electrical signal representative of sound comprising at least two coil springs having appreciably different effective vibration transmission lengths, means suspending said springs at their ends to permit vibrations in said springs to travel the lengths of said springs and be reflected from the respective ends of said springs, electromechanical driver means supported at a position adjacent one end of each spring to vibrate both of said springs when an audio frequency signal is applied to said driver means, mechanico-electrical pickup means supported adjacent said one end of each spring for translating the spring vibrations into electrical signals, each of said suspending means and the driving and pickup means comprising a torsionally rigid member secured at one end to said one end of its spring, a compliant member secured to the torsionally rigid member and extending from the opposite end thereof, means secured to and supporting said compliant member at a position spaced from said rigid member, a damping member secured to said compliant member in a position between said torsionally rigid member and said compliant member support, said driver and

said pickup including a pair of rotatable magnetic elements fixed to each torsionally rigid member in spaced relation to rotate therewith, said magnetic elements on one rigid member being in side-by-side relation to the comparable magnetic elements on the other rigid member, said driver also including electromagnetic coil means for simultaneously equally rotating one of the rotatable magnetic elements on each of said rigid members in a certain direction relative to the other, said pickup means including coil means for generating a current in response to rotation of the others of said rotatable magnetic elements, said pickup means being insensitive to simultaneous equal rotation of its rotatable elements in said certain relative direction, and said driver coil means being disposed at right angles to said pickup coil means.

5. An apparatus for providing reverberation of an electrical signal comprising at least two coil springs having appreciably different effective signal transmission lengths, means suspending said springs at their ends to permit vibrations comprising signals in said springs to travel the lengths of said springs and be reflected from the respective ends of said springs, said suspending means including compliant support means and damping means connected to one end of each spring for controlling the rate of vibration decay, electromechanical driver means supported at a position adjacent said one end of each spring for controlling both of said springs to vibrate both of said springs simultaneously with a certain relative vibrational relationship when an audio frequency signal is applied to said driver means, and mechanico-electric pickup means supported at a position adjacent said one end of each spring for translating vibrations transmitted over said springs into electrical signals, said pickup means being substantially insensitive to simultaneous vibrational components in said springs which have said certain relative relationship.

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