May 2, 1961 H. E. MEINEMA ET AL 2,982,819

ARTIFICIAL REVERBERATION APPARATUS

Filed Oct. 13, 1958 2 Sheets-Sheet 1

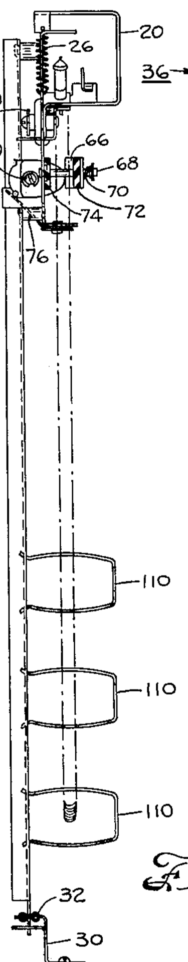

Fig. 2

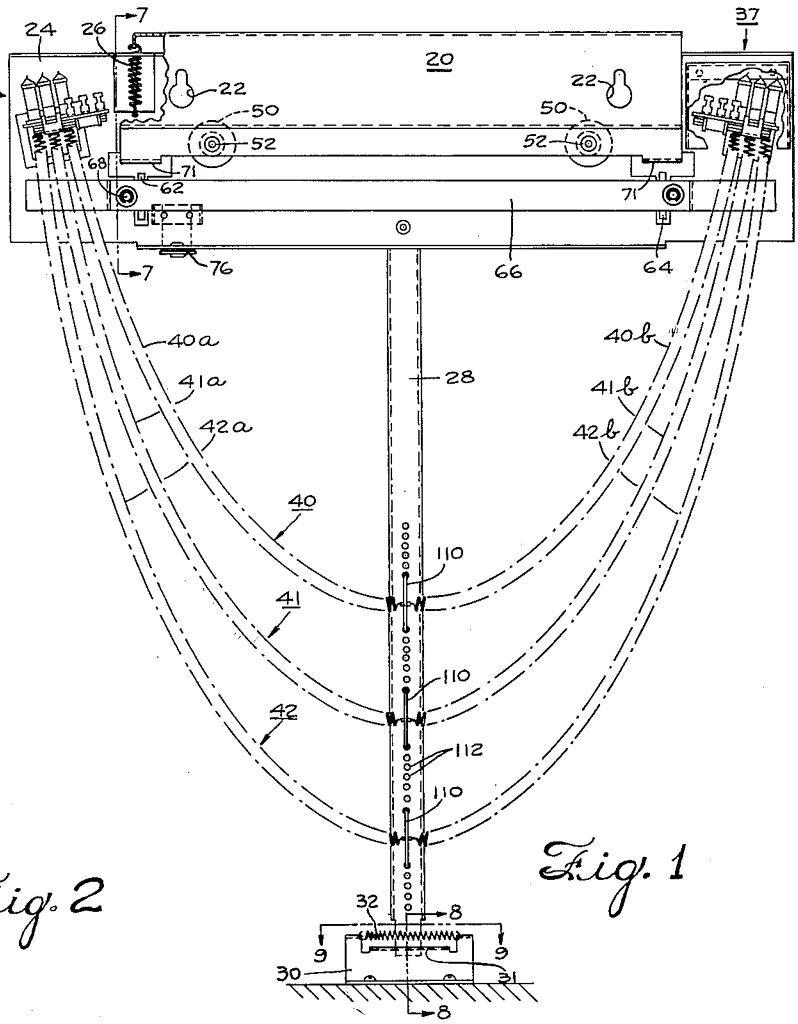

Fig. 1

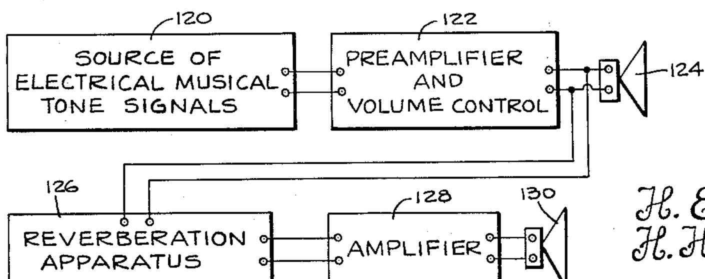

Fig. 10

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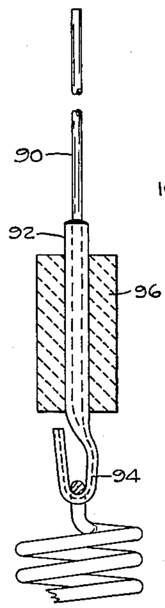

Fig. 5

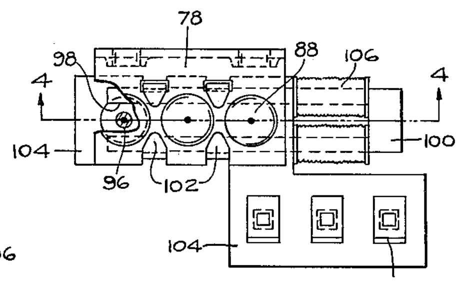

Fig. 3

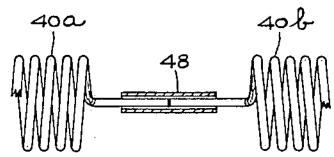

Fig. 6

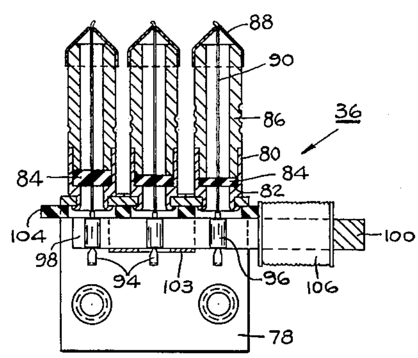

Fig. 4

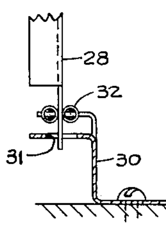

Fig. 8

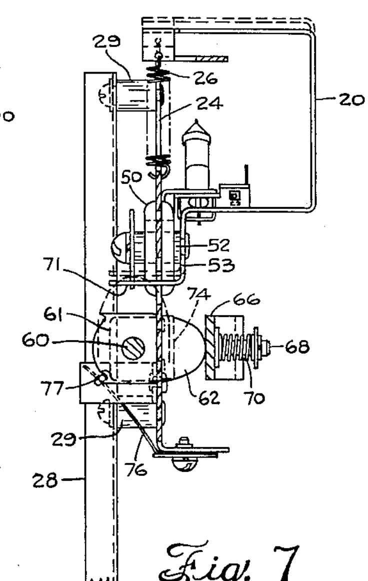

Fig. 7

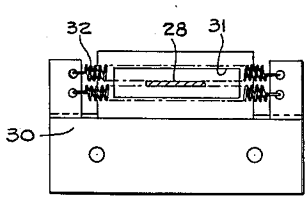

Fig. 9

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ARTIFICIAL REVERBERATION APPARATUS

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16 Claims. (Cl. 179—1)

The invention relates generally to apparatus for mechanically and electrically introducing reverberation effects in music, approximating desirable acoustic reverberation, particularly for use in electrical musical instruments, phonographs, tape recorders, and, in general, in a sound signal transmitting system in which the signal source lacks reverberation.

It is an object of the invention to provide an improved reverberation apparatus which closely simulates acoustic reverberation effects, in which disadvantageous cancellation and reinforcement of direct and reflected signals is minimized.

A further object is to provide an improved compact reverberation apparatus in which the electric sound signal is mechanically transmitted through a plurality of coiled wire springs of different lengths, and employing similar driver and pickup means at the ends of the springs.

A further object is to provide improved electromagnetic drivers and pickups.

A further object is to provide a reverberation apparatus having improved locking means for the mechanism to prevent damaging of the apparatus by mechanical shock.

A further object is to provide a helical coiled wire as a transmitter of sound vibrations, in which the sound is transmitted as a torsional vibration and in which compensation is made for the concomitant compressional modulation by the sound signal transmitted. A further object is to provide an improved means for partially damping the sound vibrations at the ends of the springs.

Other objects will appear from the following description, reference being had to the accompanying drawings in which:

Fig. 1 is an elevational view of the reverberation apparatus, shown approximately half-size;

Fig. 2 is a side elevational view thereof;

Fig. 3 is an enlarged plan view of one of the electromagnetic driver (or pickup) assemblies;

Fig. 4 is a vertical sectional view taken on the line 4—4 of Figure 3;

Fig. 5 is a greatly enlarged view (approximately ten times) of the armature magnet support assembly of an individual pickup or driver;

Fig. 6 is a fragmentary sectional view of the central portion of one of the springs showing the manner in which the two portions of the spring are joined;

Fig. 7 is an enlarged fragmentary sectional view taken on line 7—7 of Fig. 1;

Fig. 8 is an enlarged fragmentary sectional view taken on line 8—8 of Fig. 1;

Fig. 9 is an enlarged fragmentary sectional view taken on line 9—9 of Fig. 1, and;

Fig. 10 is a block diagram illustrating a typical system in which the reverberation apparatus may be used.

The art of delaying sound transmission by imparting torsional or compressional vibrations at one end of a coiled spring and picking up the vibrations by a mechanico-electric transducer at the other end of the spring is well known. (See patent to R. L. Wegel No.

1,852,795.) It is also known that such sound delay spring may be used as a reverberation apparatus by causing the sound to be repeatedly reflected at the ends of the spring, and by providing means to damp the vibrations of the spring to cause gradual decay in the amplitude of vibration, and thus simulate the effect of reverberation. (See patent to Laurens Hammond No. 2,230,836.)

Because of the finite effective length of the spring it is highly probable, that, in transmitting sound vibrations of a certain frequency or frequencies, the reflective sound wave will return to the electromechanical input driver in phase opposite to that of the signal which is electrically supplied to the driver and will thus partially cancel the input signal or, depending upon the relative phases of the reflected and driving signals, there may be an impairment of the ultimate sound signal picked up by the electromechanical transducer ranging from nearly total cancellation to total reinforcements. Thus, the frequency response curve of the apparatus as a whole will not be smooth but instead have deep valleys where the reflected and direct signals are out of phase and peaks at such frequencies at which the direct and reflected signals at the pickup are more or less in phase. This non-uniformity in frequency response is particularly noticeable and very undesirable at the lower frequencies.

In acoustic reverberation, as heard when music is played, especially in a large room, the sound from the source is reflected by the walls, ceiling, and floor of the room and by objects in the room so that the music reaches the listener's ear through a large, practically infinite, number of paths. These multiple reflections continue until the sound energy is gradually absorbed by objects of poor sound reflection characteristics and by the surfaces of the objects which reflect the sound, causing a gradual reduction in sound volume or intensity to a level below the lower threshold of hearing.

Thus, an ideal electromechanical reverberation apparatus should likewise include a substantially infinite number of points at which sound waves may be reflected and thus provide a large number of paths by which the direct end reflected sound waves are transmitted to the ear. In view of the impracticality of providing a very large number of points of reflection of the sound energy, and a corresponding large number of paths for transmission of the sound, and means absorbing the sound energy, a reasonable number of such paths and points of reflection and absorption of the sound has been selected.

In said Hammond patent the sound is transmitted to the pickup through only one path (spring) although there are quite a few points at which the sound vibration may be reflected, and in this patent there are shown three means for damping or absorbing the sound energy. It has been found that transmitting the sound energy from the driver to the pickup through two springs greatly improves the overall frequency response of the apparatus, but by providing three coil springs forming paths of sound transmission between the driver and pickup, the frequency response curve of the apparatus as a whole is startlingly improved as compared with the apparatus using two springs. Use of more than three springs does not notably improve the results obtainable.

As shown in the drawings, the reverberation apparatus of this invention comprises a mounting channel **20** (Figs. 1 and 7) having keyhole slots **22** therein for facilitating its attachment to a musical instrument case or cabinet. A driver, pickup and spring supporting frame **24** is suspended from the channel **20** by a pair of tension coil springs **26**. These springs form antishock mounts so as to minimize the transmission of externally induced mechanical vibration to the frame **24**. The support frame has a central downwardly extending channel member **28** secured thereto by studs **29** (Fig. 7). The lower end portion of the channel (Figs. 1, 8 and 9) has its flanges cut away and extends through a rectangular hole **31** in a suitable bracket **30**, the lower extremity of the channel **28** floating between two tension coil springs **32** suitably anchored to the bracket **30**. The latter may be secured to any stationary part of the instrument cabinet, or the like, with which the apparatus is used. The springs **32** maintain the channel end part centered in the hole **31** and also serve to damp the transmission of vibration from the cabinet through the channel **28** to the vibration sensitive portions of the apparatus.

A driver assembly, designated generally by the reference character **36** (Figs. 1 and 4), and a pickup assembly **37** are suitably mounted on the frame **24** and serve as end supports for three helical coil spring assemblies **40**, **41**, and **42** which naturally assume the catenary shape. As shown in Fig. 6, each of the springs is, in effect, two springs such as **40*a*** and **40*b*** which have their lower ends, bent to extend axially of the coil, and secured to each other by a coupling sleeve **48**, as by soldering or brazing.

The two portions **40*a*** and **40*b*** of the spring as a whole are wound in opposite directions to compensate for the vibrations transmitted in the compressional mode. As will be more clearly described hereinafter, the sound vibrations are transmitted through the springs in the torsional mode, but as a result of such torsional undulations of the springs the sound also tends to be transmitted in the compressional mode. Thus, as one section of the spring, due to the slight "winding up" thereof resulting from the torsional vibration, the other section of the spring will be "unwinding." Because the sections of the springs are of equal lengths for each spring there is a net cancellation of compressional vibration of the spring and it does not have any effect either at the driver or at the pickup. Vibrations transmitted in the torsional mode travel along a coil spring at a velocity differing from that at which compressional vibrations travel and if the compressional vibrations were not "cancelled out" distortion would result.

The frame **24** is provided with a pair of rubber-like grommets **50** (Figs. 1 and 7) through the enlarged hole of which project a pair of studs **52** respectively, which are secured to a downwardly extending flange **53** of the channel **20**.

Means are provided to clamp the frame and the springs to prevent damage in shipment. This means comprises a shaft **60** (Figs. 2 and 7) suitably journaled in bearing brackets **61** secured to the frame **24**, has plate cams **62** and **64** rigidly secured thereto near its ends, which, in the position shown in Figs. 2 and 7, engage a metal strip **66** mounted for lateral movement on a pair of studs **68** secured to frame **24**, and is held in contact with the cams by compressed coil springs **70**. The end portions of the strip **66** are offset to the right (Fig. 2) and have cemented thereto strips of rubber **72**, which are of sufficient length to overlie the upper ends of the springs **40**, **41**, and **42**. Corresponding strips of rubber **74** are cemented to the frame **24** to the left (Fig. 2) of the strip **66**. The rotation of the cams **62** and **64** is limited to 90° by detent spring means **76** carrying a suitably guided pins **77** engageable with 90° spaced limit stop lugs on the cams.

The shaft **60** is provided with a kerf at one end so as to be rotatably adjusted by a screwdriver. When it is rotated counterclockwise 90° from the position shown in Fig. 2, the springs **70** cause the ends of the springs **40**, **41**, and **42** to be clamped between the felt pads. Engagement of the lobes of the cams with flanges **71** on the channel **20** causes the frame to be moved downwardly and tilts it slightly so that the lower end of the channel **28** is pressed against the edge of the hole **31** in the bracket **30**. This occurs as downward movement

of the frame is limited by engagement of the grommets **50** with studs **52**.

The driving assembly **36** (Figs. 1, 3, and 4) is substantially the same as the pickup assembly **37** in its mechanical construction and only the driver assembly will be described in detail. This assembly comprises an angle bracket **78** suitably secured to the frame **24**. The generally horizontal part is provided with three perforations for the reception of the three collars **80** which are swaged to the bracket. Each of these collars is provided with an internal shoulder **82** against which a damping disk **84** is pressed by a second sleeve **86**, the latter having a hollow conical metallic cap **88** pressed thereon. This cap has an aperture to receive the end of an armature supporting wire **90**, which is soldered to the cap **88**.

As best shown in Fig. 5 the wire **90**, which is preferably made of a copper-beryllium alloy, extends through a length of tubing **92**. The lower end portion of the tubing **92** is flattened and formed into a hook **94**. The wire preferably extends through at least a portion of the hook portion **94** and is soldered to the tube **92**. The hollow cylindrical magnet **92** is polarized in a direction parallel to the pole faces **98** of a generally U-shaped laminated core structure **100** which has two relatively long parallel legs and is suitably secured to the bracket **78** by bending over tabs **102** of an apertured channel-shaped clamping member **103**. A suitably perforated insulating sheet **104** is clamped between the core and the horizontal portion of the bracket **78**, and has soldering lugs **79** riveted thereto. A pair of coils **106**, one over each leg of the core structure are wound so as to be effective in the same direction to produce additive electrical results. Two coils, rather than one, are provided in order to reduce pickup of stray magnetic fields.

As above mentioned, the permanent magnets **96** are magnetized diametrically, in a plane parallel to the inner pole faces **98** of the core **100**. The magnetization is perpendicular to the direction in which the hook portion **94** is bent. The magnet may be of any suitable material of high retentivity, preferably a ceramic material of the ferrite group. The rotary moment of inertia of the magnet **96** is matched to the compliance of its support wire **90** and also matched to one turn of the spring which is attached to the hook portion **90**.

The damping washers **84**, are made of a so-called "dead" rubber or the like, that is, a rubber-like composition which has internal friction operating to slow down its return to normal shape after it has been distorted. These washers are pierced by the magnet supporting wires **90** and have differing thicknesses so as to apply successively greater damping as the length of the spring, with which it is associated, increased. The reason for this is that a longer time is taken for transmission of the signal through the longer coil spring wires than through the shorter ones and, since it is desirable that the signals transmitted and reflected through the three springs should decay at about the same rate, the extent of damping must be greater as the length of the spring increases. The ends of the three composite springs have their last half turn bent at right angles in the usual manner, and these ends are hooked into the portions **94** and thus, as previously indicated, are suspended in catenary shape. The brackets **78** are mounted at an angle to the horizontal to accommodate the manner of spring suspension.

The central portions of the composite springs **40**, **41**, and **42**, extend through U-shaped wire spring clips **110** the ends of which are pressed into suitable perforations **112** formed in the vertical channel **28** to prevent the springs from swinging too far if the support for the apparatus is tilted.

As previously noted, the pairs of spring portions which are joined as shown in Fig. 6 are wound in opposite directions and that the ends of these springs which project into the connecting sleeve **48** are coaxial with the axis of the springs so that this joint is capable of torsional transmission of the sound vibrations. Since the compressional modulation of the spring is balanced by the fact that the two sections of the spring are wound in opposite directions the torsional vibration input supplied by the magnets 96 of the drivers are transmitted solely as torsional impulses to the magnets 96 of the pickup assembly.

The fact that the musical tone signal is transmitted from driver to pickup through three unique paths make it highly probable that the output frequency response curve will be very smooth and this probability is enhanced by the fact that the springs are of different lengths which are not integral multiples of some whole number. Generally speaking, it is desirable that the attenuation provided by the damping disks 84 be approximately −8 decibels per reflection for the spring 42, −6 decibels for the spring 41, and −4 decibels for the spring 40. The springs preferably have the same propagation velocity and the same impedance and are mechanically identical except for their length and number of turns.

It will be noted that the driver has constant current drive which yields a constant velocity drive in a mechanical spring system and in the pickup. The constant velocity at which the pickup magnets are oscillated results in the production of a constant voltage in the reactive output, with respect to frequency. This is a further important factor which results in a smooth frequency response curve in the output.

The coils of the driver assembly are, of course, matched in impedance with the source of signal input while those in the pickup are impedance matched with the input impedance of the amplifier or other device to which the signal is to be supplied.

Because of the use of three spring transmission paths the decay time may be extended to as long as two seconds with pleasing results, but to the average listener a decay or reverberation time of about one and one-half seconds is preferable. The three path transmission system insures that the apparatus, as a whole, will not be resonant at any frequency.

The apparatus of the invention has many useful applications. One typical type of circuitry in which this apparatus may be used is shown in Fig. 10 and comprises a source of electrical musical tone signals 120 which has its output coupled to a preamplifier and volume control 122, the output of the latter being supplied to a speaker 124. Also connected to the output of the preamplifier 122 is the reverberation apparatus 126 disclosed in detail in this application. The output of the reverberation apparatus is coupled to an amplifier 128 which feeds a speaker 130. Suitable switching means will usually be provided so that the signals may or may not be transmitted through the reverberation apparatus 126 and such switching means may also be utilized to couple the amplifier 128 to a suitable stage in the preamplifier 122 or to the output of the source 120 so that the intensity of the sound output will be approximately the same whether or not the reverberation apparatus is in use.

The source of electrical musical tone signals 122 may comprise an electric or electronic organ, a microphone, a phonograph, a tape recorder, or, in fact, any source of sound may have the reverberation effect added to it by the apparatus of this invention.

While we have shown and described particular embodiments of our invention, it will be apparent to those skilled in the art that numerous modifications and variations may be made in the form and construction thereof, without departing from the more fundamental principles of the invention. We therefore desire, by the following claims, to include within the scope of our invention all such similar and modified forms of the apparatus disclosed, by which substantially the results of the invention may be obtained by substantially the same or equivalent means.

We claim:

1. An apparatus for providing reverberation of an electrical signal comprising electro-mechanical driver means, said driver means having an electrical circuit with input electrical terminals therefor and mechanical connections for a plurality of coil springs, said electrical circuit operating to vibrate said mechanical connections when an audio frequency signal is applied to said input terminals, mechanico-electric pickup means, said pickup means having mechanical connections for a plurality of coil springs and an electrical circuit having output electrical terminals, said pickup means operating to generate an electrical signal and apply the last said signal to said output electrical terminals when its mechanical connections are vibrated, and a plurality of coil springs individually connected to the mechanical connections of said driver means and to the mechanical connections of said pickup means, said springs having appreciably different effective lengths with respect to their rate of vibration transmission.

2. An apparatus for providing reverberation of an electrical signal comprising electro-mechanical driver means, said driver means having an electrical circuit with input electrical terminals therefor and mechanical connections for a plurality of coil springs, said electrical circuit operating to vibrate said mechanical connections torsionally when an audio frequency signal is applied to said input terminals, mechanico-electric pickup means, said pickup means having mechanical connections for a plurality of coil springs and an electrical circuit having output electrical terminals, said pickup means operating to generate an electrical signal and apply the last said signal to said output electrical terminals when its mechanical connections are vibrated torsionally, and a plurality of coil springs individually connected to the mechanical connections of said driver means and to the mechanical connections of said pickup means, said springs having appreciably different effective lengths with respect to their rate of vibration transmission.

3. An apparatus for providing reverberation of an electrical signal comprising electro-mechanical driver means, said driver means having an electrical circuit with input electrical terminals therefor and mechanical connections for a plurality of coil springs, said electrical circuit operating to vibrate said mechanical connections when an audio frequency signal is applied to said input terminals, mechanico-electric pickup means, said pickup means having mechanical connections for a plurality of coil springs and an electrical circuit having output electrical terminals, said pickup means operating to generate an electrical signal and apply the last said signal to said output electrical terminals when its mechanical connections are vibrated, and a plurality of coil springs individually connected to the mechanical connections of said driver means and to the mechanical connections of said pickup means, said springs having appreciably different effective lengths with respect to their rate of vibration transmission, and each of said springs being comprised of a pair of oppositely wound spring elements joined in end-to-end axial alignment.

4. An apparatus for providing reverberation of an electrical signal comprising electro-mechanical driver means, said driver means having an electrical circuit with input electrical terminals therefor and mechanical connections for a plurality of coil springs, said electrical circuit operating to vibrate said mechanical connections torsionally when an audio frequency signal is applied to said input terminals, mechanico-electric pickup means, said pickup means having mechanical connections for a plurality of coil springs and an electrical circuit having output electrical terminals, said pickup means operating to generate an electrical signal and apply the last said signal to said output electrical terminals when its mechanical connections are vibrated torsionally, and a plurality of coil springs individually connected to the mechanical connections of said driver means and to the mechanical connections of said pickup means, said springs

having appreciably different effective lengths with respect to their rate of vibration transmission, and each of said springs being comprised of a pair of oppositely wound spring elements joined in end-to-end axial alignment.

5. An apparatus for providing reverberation of an electrical signal comprising at least two coil springs having appreciably different effective lengths with respect to their rate of vibration transmission, means supporting said springs at their ends to permit vibrations in said springs to travel the lengths of said springs and be reflected at both ends of said springs, damping means connected to at least one end of each spring for controlling the rate of decay of spring vibration, electro-mechanical means having input electrical terminals and connected to both said springs outwardly of an end of each spring to vibrate both of said springs when an audio frequency signal is applied to said terminals, and mechanico-electric pickup means having output electrical terminal and having connections outwardly of an end of each spring for producing reverberative signals at said output terminals in response to vibrations in said springs.

6. An apparatus for providing reverberation of an electrical signal comprising at least two coil springs having appreciably different effective lengths with respect to their rate of vibration transmission, means supporting said springs at their ends to permit vibrations in said springs to travel the lengths of said springs and be reflected at both ends of said springs, damping means connected to at least one end of each spring for controlling the rate of decay of spring vibration, electro-mechanical means having input electrical terminals and connected to both said springs outwardly of an end of each spring to vibrate both of said springs torsionally when an audio frequency signal is applied to said terminals, and mechanico-electric pickup means having output electrical terminals and having connections outwardly of an end of each spring for producing reverberative signals at said output terminals in response to torsional vibrations in said springs.

7. An apparatus for providing reverberation of an electrical signal comprising at least two coil springs having appreciably different effective lengths with respect to their rate of vibration transmission, each of said springs being comprised of a pair of oppositely wound spring elements joined in end-to-end axial alignment, means supporting said springs at their ends to permit vibrations in said springs to travel the lengths of said springs and be reflected at both ends of said springs, damping means connected to at least one end of each spring for controlling the rate of decay of spring vibration, electro-mechanical means having input electrical terminals and connected to both said springs outwardly of an end of each spring to vibrate both of said springs when an audio frequency signal is applied to said terminals, and mechanico-electric pickup means having output electrical terminals and having connections outwardly of an end of each spring for producing reverberative signals at said output terminals in response to vibrations in said springs.

8. An apparatus for providing reverberation of an electrical signal comprising at least two coil springs having appreciably different effective lengths with respect to their rate of vibration transmission, each of said springs being comprised of a pair of oppositely wound spring elements joined in end-to-end axial alignment, means supporting said springs at their ends to permit vibrations in said springs to travel the lengths of said springs and be reflected at both ends of said springs, damping means connected to at least one end of each spring for controlling the rate of decay of spring vibration, electro-mechanical means having input electrical terminals and connected to both said springs outwardly of an end of each spring to vibrate both of said springs torsionally when an audio frequency signal is applied to said terminals, and mechanico-electric pickup means having output electrical terminals and having connections outwardly of an end of each spring for producing reverberative signals at said output terminals in response to torsional vibrations in said springs.

9. Apparatus for providing reverberation of an electrical signal comprising driver and driven units, a plurality of coil springs mechanically interconnecting said units, said coil springs having appreciably different lengths with respect to the time for transmission of vibrations from one end to the other, said driver and driven units each comprising means including an electric coil and a magnetic structure providing a magnetic circuit including a gap, a plurality of magnetically polarized armatures, one connected to each of said springs, positioned in said gap, a compliant wire member connected to each of said armatures and extending away from its spring, means secured to and supporting the end of each of said wire members, and damping means connected to each of said wire members adjacent its armature for damping torsional vibration of said wire.

10. Apparatus for providing reverberation of an electrical signal comprising driver and driven units, a plurality of coil springs mechanically interconnecting said units, each of said springs being comprised of a pair of oppositely wound spring elements joined in end-to-end axial alignment, said coil springs having appreciably different lengths with respect to the time for transmission of vibrations from one end to the other, said driver and driven units each comprising means including an electric coil and a magnetic structure providing a magnetic circuit including a gap, a plurality of magnetically polarized armatures, one connected to each of said springs, positioned in said gap, a compliant wire member connected to each of said armatures and extending away from its spring, means secured to and supporting the end of each of said wire members, and damping means connected to each of said wire members adjacent its armature for damping torsional vibration of said wire.

11. Apparatus for providing reverberation of an electrical signal comprising driver and pickup units, a plurality of coil springs mechanically interconnecting said units, said coil springs having appreciably different lengths with respect to the time for transmission of vibrations from one end to the other, each of said springs comprising a pair of oppositely wound spring elements joined in end-to-end axial alignment, said driver and pickup units each comprising means including an electric coil and a magnetic structure having pole faces providing a magnetic gap, a plurality of armatures positioned in each of said gaps, each of said armatures being magnetically polarized transversely relative to its gap and connected one to each end of each of said springs, a compliant wire member connected at one end to each of said armatures and extending away from its spring, means secured to and supporting the opposite end of each of said wire members, damping means connected to each of said wire members adjacent its armature for damping torsional vibration of its wire member, and each of said springs extending away from both of its armatures in a direction to apply tension to both of its wire members and center both of its armatures in said gaps.

12. The combination set forth in claim 1 in which the springs are loosely suspended between the driver means and the pickup means so as to define catenary curves.

13. The combination set forth in claim 5 in which the springs are loosely suspended between the electro-mechanical means and the mechanico-electric means so as to define catenary curves.

14. The combination set forth in claim 9 in which the springs are loosely suspended between their wire members so as to define catenary curves.

15. The combination set forth in claim 11 in which the

springs are loosely suspended between their wire members so as to define catenary curves.

16. An apparatus for providing reverberation of an electrical signal comprising electro-mechanical driver means, said driver means having an electrical circuit with input electrical terminals therefor and a movable element, said electrical circuit operating to vibrate said movable element when an audio frequency signal is applied to said input terminals, mechanico-electric pickup means, said pickup means having a movable element and an electrical circuit having output electrical terminals, said pickup means operating to generate an electrical signal and apply the last said signal to said output electrical terminals when its movable element is vibrated, a vibration transmitting coil spring mechanically connected to the movable element of said driver means and to the movable element of said pickup means, and said spring being comprised of oppositely wound spring elements joined in end-to-end axial alignment.

References Cited in the file of this patent

UNITED STATES PATENTS

354,672	Barling	Dec. 21, 1886
1,469,788	Hellenthal	Oct. 9, 1923
2,104,811	Pfister	Jan. 11, 1938
2,230,836	Hammond	Feb. 4, 1941
2,437,445	Stack	Mar. 9, 1948
2,853,145	Martin	Sept. 23, 1958