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Fidi

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[45] March 6, 1973

[54] DEVICE FOR CREATING ARTIFICIAL REVERBERATION

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[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.** **333/30**, 333/71, 179/1.26, 84/1.24

[51] **Int. Cl.** **H03h 7/30**

[58] **Field of Search** ....333/30, 71, 30 M; 84/1.24, 84/1.26; 179/1, 1.6

[56] **References Cited**

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Attorney—John J. McGlew et al.

[57] **ABSTRACT**

In a device for the creation of artificial reverberation using single or multi-dimensional wave guides with $2n$ input systems and $2m$ pick-up systems, of equal sensitivity, where n and m are any positive integers, the input and pick-up systems are located on an axis of symmetry of the wave guide in symmetrical relation to the other axis of symmetry thereof. The input and pick-up systems may all be located on the same axis of symmetry or they may be located on different axes of symmetry. The signal to be reverberated either is supplied to all the input systems in-phase, with the pick-up systems being connected in pairs in phase operation, or the signal to be reverberated is supplied to the input systems in pairs in phase opposition and all the pick-up systems are connected in-phase. The reverberated signals are supplied, from the pick-up systems, to at least one pick-up amplifier. The wave guide may be a helical spring, constituting a single-dimensional wave guide, or may be a thin plate, constituting a multi-dimensional wave guide.

13 Claims, 6 Drawing Figures

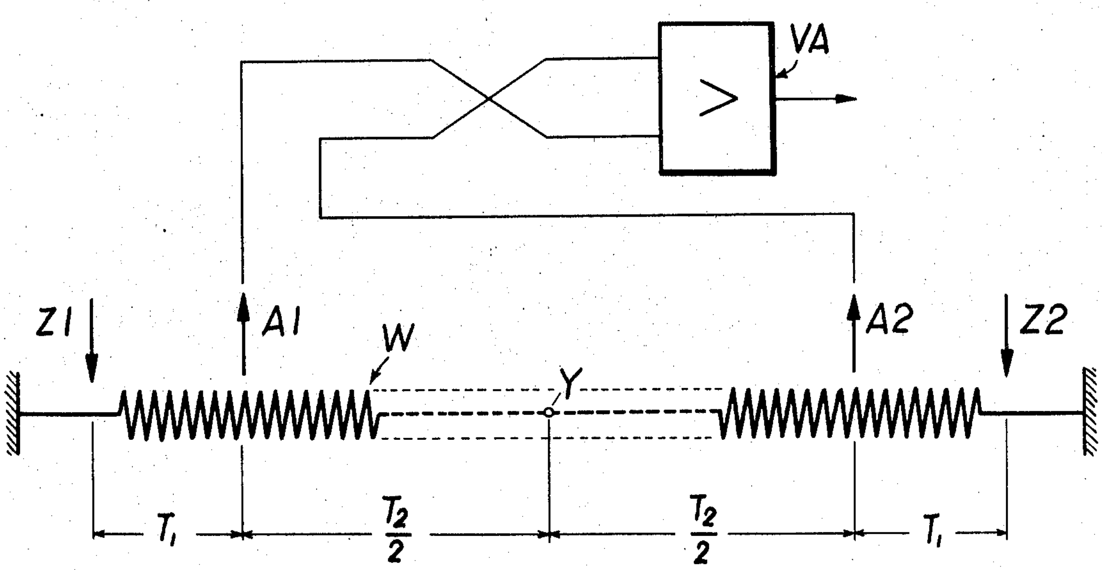

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FIG. 1

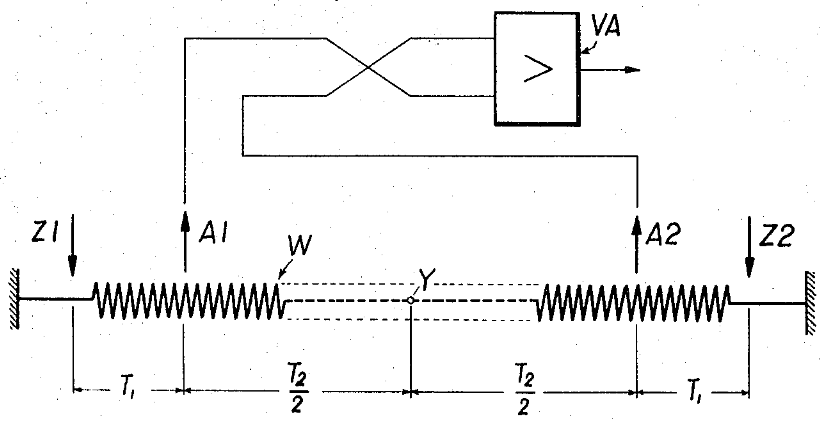

FIG. 2

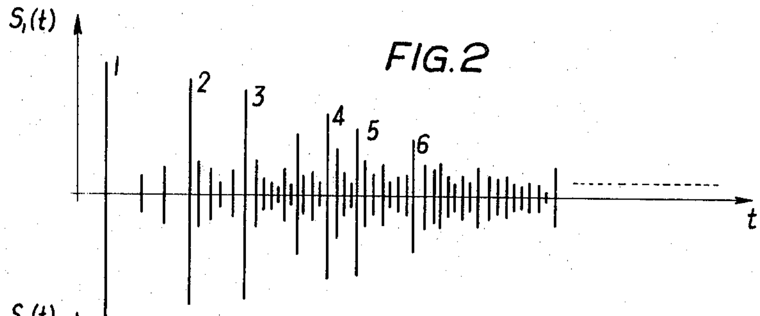

FIG. 3

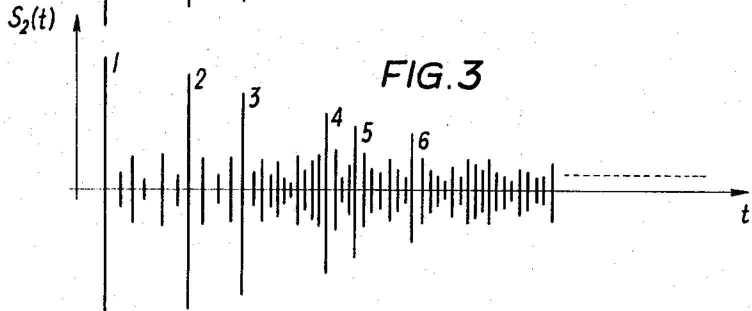

FIG. 4

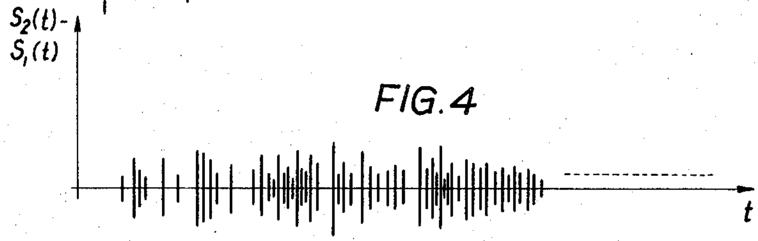

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FIG. 5

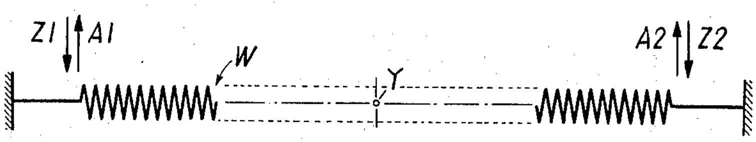
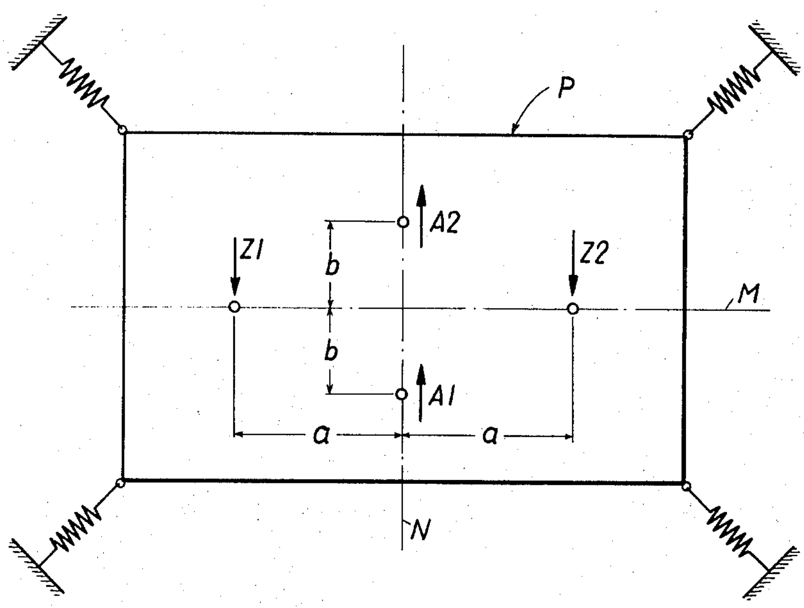


FIG. 6



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DEVICE FOR CREATING ARTIFICIAL REVERBERATION

BACKGROUND OF THE INVENTION

Irrespective of the kind of wave guide used, artificially produced reverberation is always evaluated in comparison with the natural room acoustics. Some important criteria derived therefrom must be taken into consideration in the creation of artificial reverberation, for example when using helical springs. In particular, it should be made certain that the transit time of the impressed signals is statistically different over the entire frequency range entering into consideration. That is, signals of different frequency content should traverse the wave guide, between the input, or driver and pick-up systems, in different times and which are not in any regular proportion. If this is sufficiently the case, one may speak of a "disintegration" of the signal. The degree of disintegration increases with increasing time, that is the time elapsing since impression of the signal on the wave guide. The disintegration is obtained, in a known manner, in that the gauge of the spring and also its restoring forces are statistically varied by a special physical treatment of the spring.

Despite these measures, it still is not possible to reduce the difference between natural and artificial reverberation to the extent that such difference can no longer be noticed, since, in particular with one-dimensional wave guides, it is not possible to vary the mass or spring elements so greatly that the disintegration alone is sufficient. The cause of this is that, with naturally occurring reverberations, the diffuse signal components, in particular from 50 msec on, are greatly predominant after the stimulation of the wave guide.

If the reverberation is produced artificially, for example, by means of a helical spring stimulated to torsional vibrations and having a transit time of about 100 msec and a statistical mass and elasticity distribution, it is found that, if a single pulse is impressed at one end, this pulse is received by the pick-up system, at the other end, relatively unaltered. If one were to travel with the pick-up system along the spring toward the impressing, driver, or input system, the first pick-up pulse of the impressed or input signal would appear more and more clearly and unaltered at the output of the pick-up system, whereas all further pulses of the impressed signal appear more and more disintegrated according to their distance in time from the stimulation of the helical spring.

Consequently, if artificially produced reverberation is to be made largely like natural reverberation, provision must be made that essentially only diffuse signal components occur. This means that those pulse components which have traversed the guide without major disintegration, in particular the first pulse arriving at the pick-up system, must be eliminated from the frequency mixture forming the artificial reverberation.

SUMMARY OF THE INVENTION

This invention relates to devices for creating artificial reverberation using wave guides and, more particularly, to an improved device of this nature in which the artificial reverberation produced closely approaches natural reverberation corresponding to the natural room acoustics.

The invention relates to a device for the creation of artificial reverberation by means of a one-dimensional or multi-dimensional wave guide and $2n$ driver and $2m$ pick-up systems of equal sensitivity, where n and m are any positive integers. By a one-dimensional wave guide is understood one whose length exceeds all other dimensions by a considerable multiple, for example a long helical spring. By a multi-dimensional wave guide is understood a plate whose length and width may be a multiple of the plate thickness, in which case one may speak approximately of a two-dimensional structure.

In accordance with the invention, the driver and pick-up systems are located on one of the axes of symmetry of the wave guide, and are arranged symmetrically with respect to the other axis of symmetry of the wave guide, the driver and pick-up systems either all lying on the same axis of symmetry or on different axes of symmetry. The signal to be reverberated is supplied in-phase to all driver systems and the pick-up systems are connected together in pairs in phase opposition. Conversely, the signal to be reverberated can be supplied to the driver systems in pairs in phase opposition, and the pick-up systems may be connected in pairs in-phase. The reverberated signals are supplied to one or more pick-up amplifiers.

If the invention is applied to a device with a one-dimensional wave guide, in particular to a device comprising a helical spring stimulated to torsional vibrations, it may be advantageous, for installation reasons, to design the wave guide as an endless loop. In such a case, all of the converter or transducer systems would be arranged symmetrically with respect to any desired freely selectable point.

However, in principle, the invention is applicable also to multi-dimensional wave guides, for example to a thin plate stimulated to bending vibrations. While the diffuse signal components are, in this case, greater from the start than in one-dimesional wave guides, they still are not great enough, in comparison to the natural room acoustics, so that also here the idea of the invention increases the ratio of the diffuse components to the strictly correlated components, and thus increases the liveness. Advantageously, the arrangement then could be such that two input or driver systems and two pick-up systems lie on one of the axes of symmetry and are arranged symmetrically with respect to the other axis of symmetry, the input and pick-up systems being located either all on the same axis or on different axes.

In accordance with the invention, in order to achieve compensation of the first, little-deformed pulses reaching the pick-up systems over the entire frequency range, it is important to arrange the transducer systems very exactly. In the case of a one-dimensional wave guide in the form of a helical spring, for example, a precision of one-half a spring turn is necessary. A simplification can be attained according to the invention in that one input system and one pick-up system are combined to form one mechanical unit in which, however, each system is electrically and magnetically independent of the other. In this manner, due to the reciprocity, an ideal compensation is insured with the use of two systems, if such a combined system is provided at each end of a wave guide of one-dimensional type tensioned substantially in a straight line.

An object of the invention is to provide an improved device with a creation of artificial reverberation.

Another object of the invention is to provide such a device using either single or multi-dimensional wave guides with 2*n* driver systems and 2*m* pick-up systems of equal intensity, where *n* and *m* are any positive integers.

A further object of the invention is to provide such a device in which the artificial reverberation very closely approaches natural reverberation.

For an understanding of the principles of the invention, reference is made to the following description of typical embodiments thereof as illustrated in the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWInG

In the drawing:

FIG. 1 is a schematic illustration of the principle of the invention;

FIGS. 2, 3 and 4 are pulse sequences explaining the effect of the application of the principles of the invention to a device for creating artificial reverberation;

FIG. 5 schematically illustrates a preferred embodiment of the invention utilizing a helical spring; and

FIG. 6 illustrates a similar embodiment utilizing a thin plate as the wave guide.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

To illustrate the underlying principles of the invention, there is assumed, in FIG. 1, a one-dimensional wave guide *W* in the form of a tensioned helical spring stimulated to torsional vibrations. In accordance with the invention, there are arranged, on opposite sides of the point of symmetry *Y*, which lies on the longitudinal axis of helical spring *W*, input or driver systems Z1 and Z2, which are at the ends of spring *W*, and respective pick-up systems A1 and A2 for each of the input systems. The input systems are indicated by arrows directed toward helical spring *W*, and the pick-up systems by arrows pointing away from helical spring *W*. The two input systems Z1 and Z2 are disposed, with equal polarity, at the output of an input amplifier (not shown), while the pick-up systems A1 and A2 are connected, with opposite polarity, to the pick-up amplifier VA, this being symbolized by the crossing of the input lines to the amplifier.

If now a pulse is applied to the input systems Z1 and Z2, these systems transmit to helical spring *W* simultaneously and in-phase, so that a pulse traverses helical spring *W* from left to right, and an identical or similar pulse traverses helical spring *W* from right to left. The pulse originating from system Z1 arrives at pick-up system A1 after the time T1, and the pulse originating from system Z2 arrives at pick-up system A2 after the same time T1. Thus, there occur, at the terminals of the two pick-up systems, similar electrical pulses which, however, since the windings of the pick-up systems A1 and A2 are connected electrically in opposition, do not become operative at the input of amplifier VA, as they cancel each other out. This cancellation will be practically complete, since the signals which pass from the system Z1, A1 to the system Z2, A2 are equal to the signals passing from the system Z2, A2 to the system Z1, A1. There remain all those signals which are reflected back to the input point. This interplay repeats for all further reflections.

In FIGS. 2, 3 and 4, this process is explained in greater detail, FIGS. 2 and 3 showing those pulse sequences which, after stimulation of the wave guide by a single pulse, occur in the form of electrical oscillations at the outputs of the two pick-up systems A1, A2. FIG. 2 represents the output voltage of pick-up system A1, as a function of time, and FIG. 3 represents the output of the pick-up system A2, as a function of time. The first echo is indicated at 1, the second at 2, etc. It is evident that these echos occur with great strength as to amplitude, and have few diffuse components therebetween. As time progresses, the pure echos become smaller and smaller (4, 5, 6, etc.) while, between the echos, the diffuse components continue to increase in number, a process which occurs also in natural reverberation. In the production of artificial reverberation, on the contrary, the little-deformed first pulses 1, 2, 3, etc., which hardly exist in natural reverberation, are disturbing.

This is where the principles of the invention take effect. By the completely symmetrical arrangement of the transducer systems and the corresponding electrical circuit arrangement, the invention arrangement compensates the first echos, the result of which is visible in FIG. 4 in the form of a pulse diagram of the voltage at the input of the pick-up amplifier VA. The first echos 1, 2, 3, etc., cancel each other out by the electrical opposition connection of the pick-up systems, leaving only those residual voltage components which are completely irregular, that is unsymmetrical. After conversion to sound vibration, they result in a tone pattern which is typical of natural reverberation.

An obvious prerequisite for attaining the desired effect is not only the completely symmetrical arrangement of the electro-mechanical transducer systems but also their identity with respect to their transducer or converter function, which is easy to carry into effect.

As mentioned, a simplification as to the arrangement of the systems can be obtained by combining each input system with a pick-up system to form a mechanical unit, but with the combined input and pick-up systems being mutually independent electrically and magnetically. Such an arrangement is illustrated schematically in FIG. 5, in which the systems Z1, A1 and Z2, A2 are combined to form mechanical units, with each unit being arranged at a respective end of the one-dimensional wave guide *W*.

FIG. 6 illustrates the application of the invention to a reverberation device including a so-called reverberation plate *P* which is caused to undergo bending vibrations. In this example of construction, the drive or input systems Z1, Z2 lie on opposite sides of the axis of symmetry *N* at equal distances *a* on the axis of symmetry *M*. In a like manner, pick-up systems A1, A2 are arranged on the axis of symmetry *N* at equal distances *b* from the axis of symmetry *M*. If a pulse is imparted to plate *P* through the drive or input system Z1, Z2, plate *P* goes into bending vibrations, which propagate like waves on a water surface after a stone has been thrown into the water. At least the first pulses arriving at pick-up systems A1, A2, and which would contribute substantially to falsifying the tone pattern of the artificially produced reverberation, arrive at the pick-up systems essentially undeformed, cancelling each other out.

In summary, it may be said that the greatest liveness is attained when the corresponding picked up signals are connected together strictly in phase opposition on the assumption of equal conversion or transducing functions of the transducers. By varying the degree of compensation, different effects can be obtained. Thus, for example, the compensation can be made completely disconnectable, the impression being created, without the compensation, that the sound event is in the foreground and the reverberation arrises from the depth of the room and is clearly perceptible as separate.

With increasing compensation, the sound event moves more and more into the depth of the room until, in the end, the optimally attainable reverberation exists. It is thus possible, in a simulated manner, to let the sound event apparently travel in the room at will, by variation of the degree of compensation, for example, in that the voltage is tapped by the pick-up systems by means of an adjustable voltage divider included in at least one pick-up system.

While specific embodiments of the invention have been shown and described in detail to illustrate the application of the principles of the invention, it will be understood that the invention may be embodied otherwise without departing from such principles.

What is claimed is:

1. In a device for the creation of artificial reverberation, using single or multi-dimensional wave guides wherein the velocity of propagation of the waves varies, over the frequency range of interest, by means of statistically distributed variations of the local mass and spring elements, the device having $2n$ driver systems and $2m$ pick-up systems, of equal sensitivity, where n and m are any positive integers, so that the number of pairs of driver systems is equal to the number of pairs of pick-up systems, the improvement comprising, in combination, said driver and pick-up systems being located in one axis of symmetry of the wave guide, having mutually perpendicular axes of symmetry, and arranged symmetrically relative to the other axis of symmetry of the wave guide; the input signal to be reverberated being supplied to all said driver systems and the output signal being derived from all of said pick-up systems one of said driver system and said pickup system having its pairs in-phase and the other having its pairs in phase opposition.

2. In a device for the creation of artificial reverberation, the improvement claimed in claim **1**, in which all of said driver and pick-up systems are located on the same axis of symmetry.

3. In a device for the creation of artificial reverberation, the improvement claimed in claim **1**, in which said driver systems and said pick-up systems are arranged on respective different axes of symmetry.

4. In a device for the creation of artificial reverberation, the improvement claimed in claim **1**, in which the signal to be reverberated is supplied to all said driver systems in-phase; said pick-up systems being connected together, in pairs, in phase opposition.

5. In a device for the creation of artificial reverberation, the improvement claimed in claim **1**, in which the signal to be reverberated is supplied to said driver systems in pairs in phase opposition; all said pick-up systems being connected in-phase.

6. In a device for the creation of artificial reverberation, the improvement claimed in claim **1**, in which the wave guide is a helical spring constituting a one-dimensional wave guide.

7. In a device for the creation of artificial reverberation, the improvement claimed in claim **1**, in which each driver system is combined with a respective pick-up system to form a mechanical unit in which the two combined systems are uncoupled electrically as well as magnetically.

8. In a device for the creation of artificial reverberation, the improvement claimed in claim **1**, in which the wave guide is a helical spring constituting a one-dimensional wave guide.

9. In a device for the creation of artificial reverberation, the improvement claimed in claim **8**, in which $2n$ driver systems and $2m$ pick-up systems are arranged in pairs symmetrically relative to the midpoint of said helical spring.

10. In a device for the creation of artificial reverberation, the improvement claimed in claim **8**, comprising $2n$ units, each unit comprises one driver system and one pick-up system, arranged symmetrically with respect to the midpoint of said spring.

11. In a device for the creation of artificial reverberation, the improvement claimed in claim **10**, in which said units are arranged at respective opposite ends of said helical spring, one at each end.

12. In a device for the creation of artificial reverberation, the improvement claimed in claim **1**, in which said wave guide is a multi-dimensional wave guide constituted by a thin plate; and separate driver and pick-up systems associated with said thin plate and arranged on both axes of symmetry and in each case symmetrically with respect to the other axis of symmetry.

13. In a device for the creation of artificial reverberation, the improvement claimed in claim **1**, in which said wave guide is a multi-dimensional wave guide constituted by a thin plate; and units, each comprising a driver system and a pick-up system, associated with said thin plate and arranged on both axes of symmetry, in each case symmetrically with respect to the other axis of symmetry.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,719,908 Dated March 6, 1973

Inventor(s) WERNER FIDI

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

On the cover sheet [73], the assignee should read as follows: -- AKG Akustische u. Kino-Gerate, Wien, Austria -- .

Signed and sealed this 13th day of August 1974.

(SEAL)
Attest:

McCOY M. GIBSON, JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

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