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Fidi

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[54] **ARTIFICIAL REVERBERATION DEVICE USING A DELAY ELEMENT WITH A LOCALLY INCONSTANT PROPAGATION PROPERTY**

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[52] **U.S. Cl.** .... **179/1 J,** 84/DIG. 26

[51] **Int. Cl.** **H03h 9/30**

[58] **Field of Search** .... 179/1 J; 84/DIG. 26; 330/30 R; 333/30 R

[56] **References Cited**

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[57] **ABSTRACT**

The device includes two identical electromechanical transducer systems, constituted by reciprocal transducers, and which are symmetrical with each other. A delay element mechanically interconnects the transducer systems, and has a locally inconstant propagation property. The transducer systems are incorporated in a differential circuit arrangement having a signal input and a signal output, with the reciprocal transducers being directly or indirectly electrically connected to the signal input in identical manners and in series or parallel with each other. The signal output of the differential circuit arrangement provides an output signal corresponding to the difference between the respective electromotive forces arising in the transducers due to their mechanical interconnection by the delay element.

10 Claims, 5 Drawing Figures

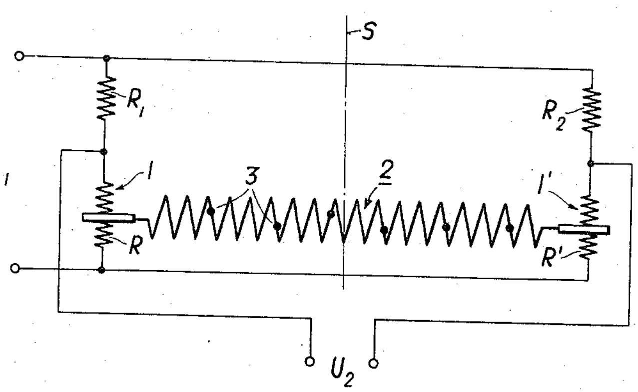


FIG. 1

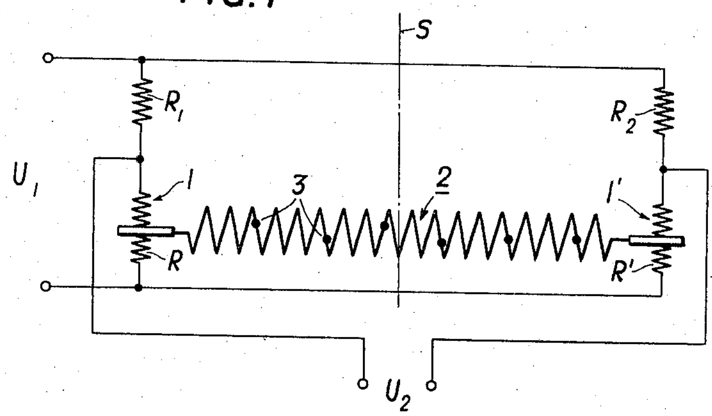


FIG. 2

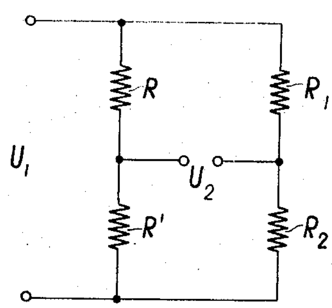


FIG. 3

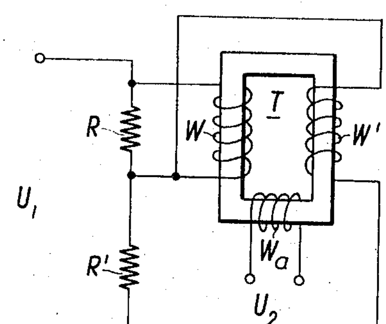


FIG. 4

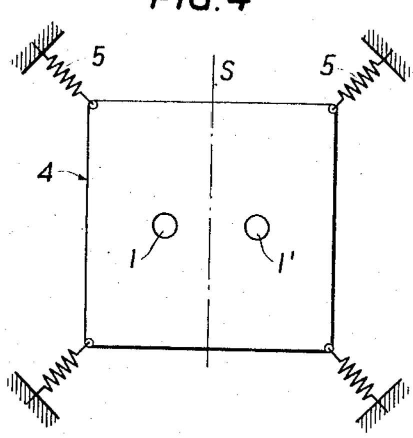
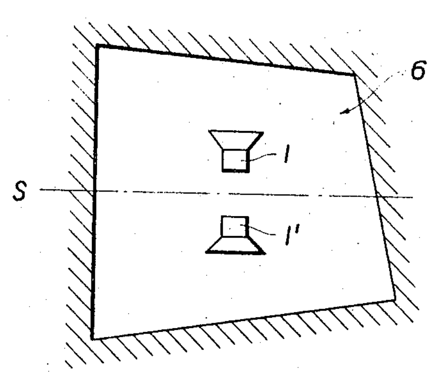


FIG. 5



ARTIFICIAL REVERBERATION DEVICE USING A DELAY ELEMENT WITH A LOCALLY INCONSTANT PROPAGATION PROPERTY

FIELD AND BACKGROUND OF THE INVENTION

This invention relates to an artificial reverberation device having two identical electromechanical transducer systems which are mechanically interconnected by way of a delay element having a locally inconstant propagation property and which are symmetrical.

Echo is, of course, a very important factor in room acoustics and, as such, is an important parameter in the acoustical quality of rooms. Basically, it can be defined by the temporal, physical and frequency distribution or decay of the sound energy present in a room after cessation of the original sound. The temporal, physical and frequency structure of the exho in a sound-reproduction room can be modified basically by varying the mode of excitation, the geometry and the arrangement of sound-absorbing materials.

An aperiodic decay of the sound energy, uniform for all frequency groups, is the usual requirement for echo, with lower frequencies requiring a longer echo time than high frequencies, more particularly in large premises.

The fine structure of an echo consists, of course, of a large number of sound reflections on the walls bounding the space continuum and can be quantized in statistical room acoustic terms. The acoustics engineer is familiar with a number of criteria determining echo quality and hence good room acoustics. One of the main criteria is the avoidance of discrete echoes in the decay phenomenon, such echoes occurring after the ear's integration time, i.e., from about 30 to 50 msec after cessation of the original sound, and being perceptible as discrete sound signals. Periodic structures during the "life" of the decay phenomenon (flutter echoes, roughness of the sound) are also unpleasant. Linked theoretically with these time prognoses is the requirement, so far as the frequency range of transmission is concerned, that the number of natural resonances be distributed over the spectrum very close together but without any periodic structure, and that all natural resonances have approximately the same quality (relative band-width).

Meeting these criteria is the main problem, more particularly in the devising of artificial reverberation devices. An artificial reverberation device comprises two main parts, a delay part and a feedback part. The delay part provides a basic delay of the signal to be reverberated, and the feedback part multiplies this basic delay.

The two parts can be combined in a single element, as is done in the case of mechanical uni-dimensional or multi-dimensional delay elements (wave guides), for example a torsionally excited helical spring, where a signal is injected at an input location by an appropriate electro-mechanical transducer, travels through the delay element (the spring) as a mechanical oscillation and is reflected at the other end, the cycle repeating until the energy has been consumed by the internal friction of the system and by reflection losses. The mechanical energy can be tapped anywhere in the transmission system and converted into electrical energy. As already stated, a system of this kind can be embodied in one or two or more dimensions. Their small size makes uni-dimensional delay systems very advantageous, with particular advantages attaching to the use of torsionally-excited helical springs, because of the delay which they can provide per unit of size. The basic delay time must be relatively long, approximately 200–500 msec, to insure that an echo system of this kind has the necessary number of natural resonances. The echo structure arising from the arrangement is initially of course periodic.

To obviate this disadvantage of a periodic echo structure, it has already been suggested that the propagation constants of the delay element, such as a helical spring, be varied randomly throughout the element to provide a statistical dispersion of the signal transit time along the spring. The macroscopic and microscopic methods already used have led, in fact, to a very considerable improvement in the fidelity of artificial reverberation devices. Another suggestion has been so to excite an artificial reverberation device, comprising a single or multi-dimensional delay element which itself provides a number of reflections, that, with respect to any energy plane of symmetry of the system, the signal be injected at least twice and be sampled by two separate sampling systems, the sampled signals being so combined that coherent portions cancel out and the output signal comprises portions having no regular amplitude or phase relationship to one another. This feature helps further to improve the quality of reverberation and to suppress all the periodic features, more particularly discrete echoes.

SUMMARY OF THE INVENTION

Proceeding from the above-mentioned prior art, the invention teaches how, for a small further expenditure, very natural true-tone reverberation can be provided.

According to the present invention, there is provided an artificial reverberation device including two identical electromechanical transducer systems which are mechanically interconnected by way of a delay element having a locally inconstant propagation property and which systems are symmetrical with each other. In the device, the transducer systems are reciprocal transducers which are directly or indirectly electrically connected to a signal input in the same sense, in series or parallel with one another, and are so incorporated in a differential circuit arrangement that an output of the arrangement delivers an output signal corresponding to the difference between the electromotive forces arising in the transducers.

As delay elements, there can be employed uni-dimensional structures, such as inhomogeneous torsionally-excited elements, two-dimensional structures, such as thin plates excited to bending oscillations, or even three-dimensional structures, such as natural spaces or sound tanks. The invention is more effective with the simpler kinds of delay elements, the spring systems being the best.

In theory, all types of reciprocal transducers can be used as the electromechanical transducers, and the term "reciprocal transducer" denotes a transducer which may operate as an oscillation transmitter or as an oscillation receiver. Very advantageously, such transducers are moving-coil systems, disposed in permanent magnet fields, or are rotary-magnet systems, disposed in open magnetic circuits with a stationary field coil.

In one embodiment of the invention, the two transducer systems each have one winding connection taken to a common input terminal of a bridge circuit.

In another embodiment, windings of the two transducer systems are connected consecutively in one arm of a bridge circuit and have their free ends connected to respective input terminals.

In both these embodiments, the other components of the bridge are ohmic resistances.

In a third embodiment, the windings of the two transducer systems are connected to the input in a series circuit arrangement, each transducer winding extending to a respective input winding of a common differential transformer having a common output winding.

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

Another object of the invention is to provide such an artificial reverberation device capable of producing very natural true-tone reverberation.

A further object of the invention is to provide such an artificial reverberation device which is simple in construction, economical to manufacture, and has numerous practical advantages.

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 drawings.

BRIEF DESCRIPTION OF THE DRAWING

In the Drawing:

FIG. 1 is a schematic electro-mechanical diagram illustrating the basic arrangement of a device embodying the invention;

FIG. 2 is a schematic wiring diagram of another form of bridge circuit which may be used in the invention device;

FIG. 3 is a schematic wiring diagram of the invention device using a differential transformer;

FIG. 4 is a somewhat schematic view illustrating the invention as used with a two-dimensional delay element; and

FIG. 5 is a view similar to FIG. 4 and illustrating the invention as used with a three-dimensional delay element.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The embodiment of the reverberation device shown in FIG. 1 uses a bridge circuit arrangement. A signal to be reverberated, in the form of an input voltage U_1 is applied across one diagonal of the bridge, and an output voltage U_2 appears across the other diagonal of the bridge. The bridge has a completely symmetrical arrangement, with each arm of the bridge comprising a respective ohmic resistance R_1, R_2 and, in series with the respective ohmic resistance, a respective transducer system **1, 1'** having a respective impedance R, R'. The impedances R, R' are equal to each other, and the resistances R_1 and R_2 also are equal to each other. Transducer systems **1, 1'** are mechanically interconnected by means of a uni-dimensional wave guide **2**, such as a torsionally oscillated helical spring. For the effect according to the invention to be operative, the wave guide **2** must have no constant propagation properties with respect to the torsional oscillations impressed on it. If it were to have such constancy, voltage U_2 would always be nil, since the bridge circuit arrangement is a completely balanced one. A differential voltage U_2 can arise only if the wave guide **2** has randomly distributed irregularities which upset the symmetry, represented in FIG. **1** by the symmetry line S.

The injected energy oscillates in the wave guide **2,** with statistically distributed multiple reflections at the places **3,** and because of the reciprocity of the transducer systems **1, 1'** produces at the places where such systems are connected to the wave guide **2,** an EMF signal whose difference can be sampled in one diagonal of the bridge as the output voltage U_2. If required, the bridge resistances can be complex resistances so that the bridge circuit arrangements can be balanced accurately.

The arrangement provided by the invention makes it possible to eliminate all signal components which would appear cophasally and with the same amplitude in the two transducer systems and cause disturbing echoes or periodicities. The output signal is substantially statistical and has only a low degree of correlation, in the manner necessary for echo decaying naturally.

In the form of bridge circuit shown in FIG. **2,** the transducer systems are connected in series in one arm of a bridge, as indicated by the impedances R and R', with the other arm of the bridge comprising only ohmic resistances R_1 and R_2 connected in series with each other. The bridge is balanced so that $R_1 R' = R_2 R$, with impedances R and R' having the same impedances as the transducer systems. When the voltage U_1 is applied to one bridge diagonal, then, in the same manner as described for FIG. **1,** there appears, on the other diagonal, an output voltage which takes the form of the difference between the respective electromotive forces induced in the two transducer systems.

FIG. **3** illustrates a circuit arrangement embodying the invention and utilizing a differential transformer T. The respective impedances R, R' of the two identical transducer systems **1** and **1'** are connected in series across the input voltage U_1. Transformer T has three windings W, W' and W_a. Winding W is connected in parallel with transducer impedance R, and winding W' is connected in parallel with impedance R', these being the respective impedances of the two transducer systems. The direction of winding of the two windings W and W' is such that cophasal and equal amplitude voltages cancel out in transformer T, with only the difference voltages being transmitted to the output winding W_a to provide the output signal voltage U_2.

FIG. **4** illustrates one possible mechanical arrangement of the reciprocal transducer systems, in association with a two dimensional delay element, such as a thin plate **4** which is energized to make bending oscillations and which is suspended at its corners by means of springs **5.** The important feature of this arrangement is that the two transducer systems **1** and **1'** are disposed completely symmetrically of an imaginary symmetry line S subdividing delay element **4** into two equivalent halves insofar as energy storage and echo amplitudes are concerned.

A second embodiment of the invention also can be used in association with a three-dimensional delay element, such as shown in FIG. **5.** In the arrangement of FIG. **5,** the reciprocal transducer systems **1** and **1'** are disposed in an acoustic space, for example a hall **6.** In this case also symmetry of the two transducer systems must be maintained, this time in relation to an imaginary plane of symmetry SB.

In the devices of FIGS. 4 and 5, the electrical arrangement of the transducers may have any one of the four forms illustrated in FIGS. 1, 2 and 3.

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. An artificial reverberation device comprising, in combination, two identical electromechanical transducer systems which are symmetrical with each other; a delay element mechanically interconnecting said identical transducer systems and having a locally inconstant propagation property; and a differential circuit arrangement incorporating said identical transducer systems and having a signal input and a signal output; said transducer systems being electrically connected in identical manners to said signal input, whereby said signal output provides an output signal corresponding to the difference between the electromotive forces arising in said transducer systems due to their mechanical interconnection by said delay element.

2. An artificial reverberation device, as claimed in claim 1, wherein said transducer systems are reciprocal transducers.

3. An artificial reverberation device, as claimed in claim 2, in which said transducers are directly connected to said signal input.

4. An artificial reverberation device, as claimed in claim 2, in which said transducers are indirectly connected to said signal input.

5. An artificial reverberation device, as claimed in claim 2, in which said transducers are connected in series with each other to said signal input.

6. An artificial reverberation device, as claimed in claim 2, in which said transducers are connected in parallel with each other to said signal input.

7. An artificial reverberation device, as claimed in claim 1, wherein said differential circuit arrangement comprises a bridge circuit having a pair of input terminals constituting said signal input and a pair of output terminals constituting said signal output; each transducer system including a winding, with one terminal of each winding being connected to the same common input terminal of said bridge circuit.

8. An artificial reverberation device, as claimed in claim 1, in which said differential circuit arrangement comprises a bridge circuit having a pair of input terminals constituting said signal input and a pair of output terminals constituting said signal output; each of said transducers including a winding and said windings being connected in series in one arm of said bridge circuit; the free terminals of said windings being connected to respective input terminals of said bridge circuit.

9. An artificial reverberation device, as claimed in claim 1, wherein said differential circuit arrangement comprises a bridge circuit having a pair of input terminals constituting said signal input and a pair of output terminals constituting said signal output; each transducer system including a winding, and said windings being connected to the signal input of said bridge circuit; the other components of said bridge circuit constituting ohmic resistances.

10. An artificial reverberation device, as claimed in claim 5, in which each transducer system includes a transducer winding; said differential circuit arrangement comprising a differential transformer having two input windings and a common output winding; each transducer winding being connected to a respective input winding of said differential transformer.

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