

[54] **ULTRASONIC WAVE DELAY DEVICE
HAVING A TRAP ZONE FOR
UNDESIRE SIGNAL COMPONENTS**

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[22] Filed: Dec. 4, 1970

[21] Appl. No.: 95,018

[30] **Foreign Application Priority Data**

Dec. 6, 1969 Japan.....44/98087

[52] U.S. Cl.333/30 R, 333/72

[51] Int. Cl.H03h 7/30, H03h 9/30

[58] Field of Search333/30, 71, 72; 310/8, 8.1,
310/9.6, 9.7, 9.8

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[57] **ABSTRACT**

An ultrasonic wave delay device for delaying an ultrasonic wave signal a predetermined time by propagating the ultrasonic wave signal through a solid propagation medium, in which principal signal component reflection surfaces constituting a path of propagation for principal components of the signal are arranged in the solid component propagation zone in the solid propagation medium and cause unnecessary components of the signal to escape from the principal signal component propagation zone. Reflection surfaces exclusively for the unnecessary signal components may be provided adjacent the principal signal component propagation zone in the solid propagation medium, whereby the unnecessary signal components can be subjected to multiple reflection between the unnecessary signal component reflection surfaces and outer walls of the solid propagation medium to ensure that the unnecessary signal components become extinct.

3 Claims, 6 Drawing Figures

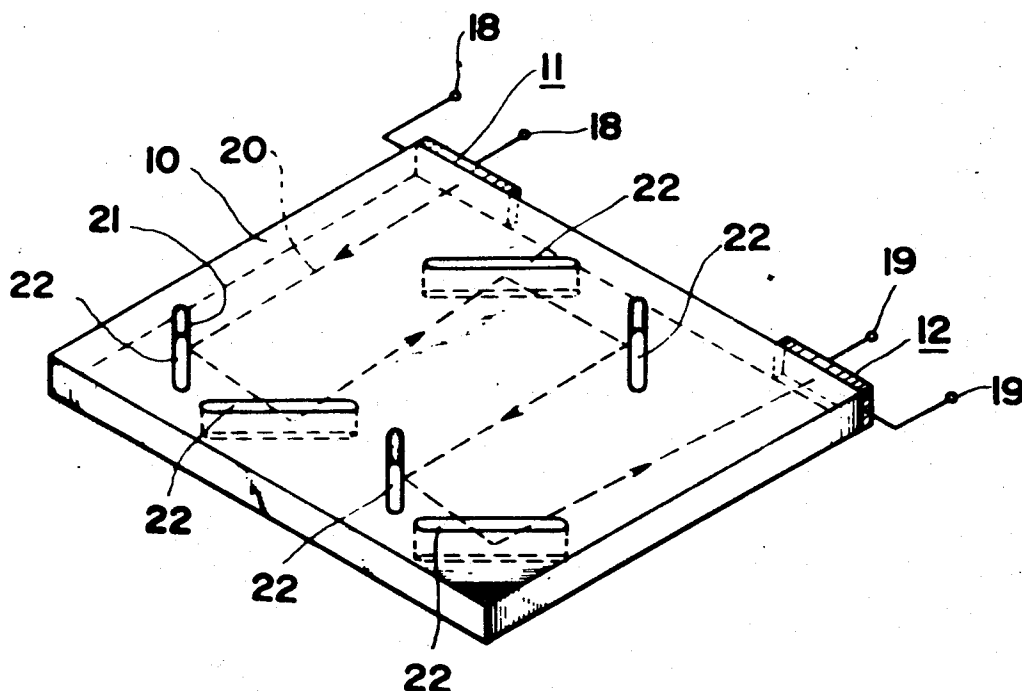


FIG. 3

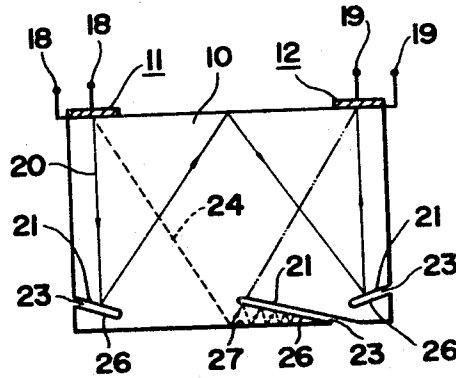


FIG. 1

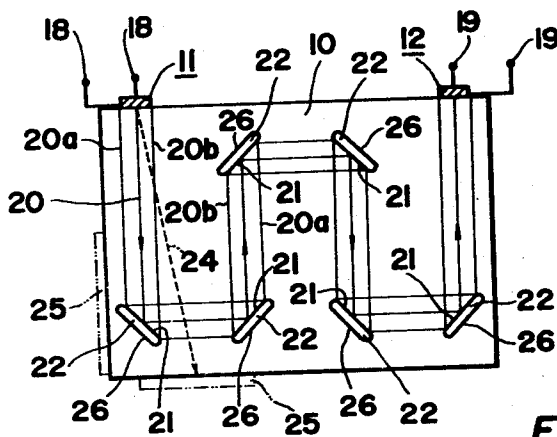


FIG. 4

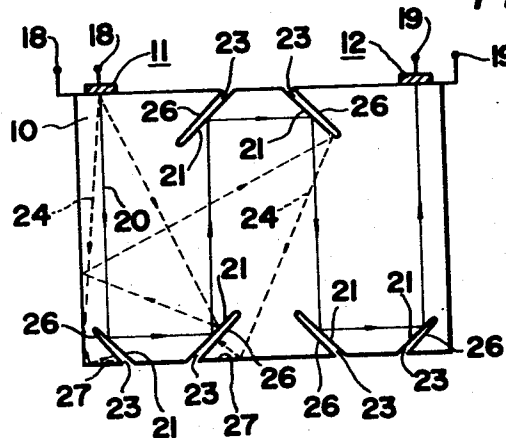
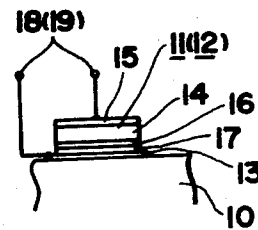


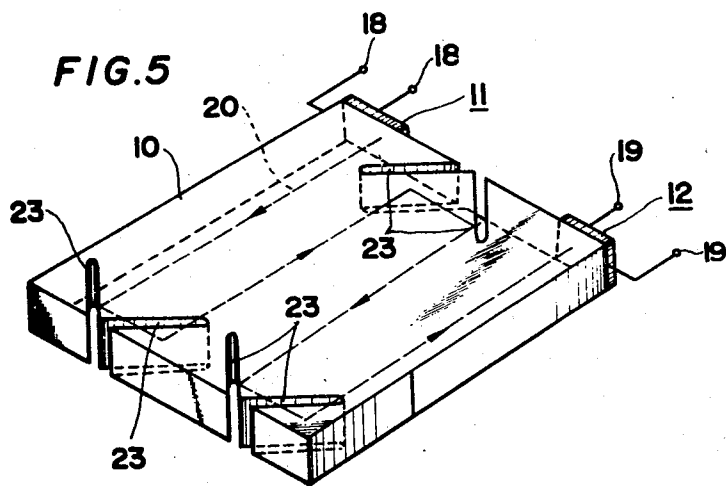
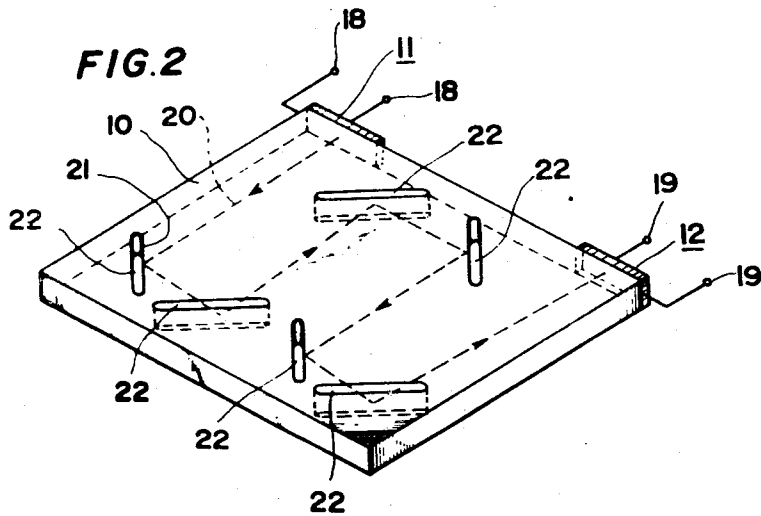
FIG. 6



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ULTRASONIC WAVE DELAY DEVICE HAVING A TRAP ZONE FOR UNDESIRE SIGNAL COMPONENTS

This invention relates to ultrasonic wave delay devices, and more particularly it is concerned with an ultrasonic wave delay device which permits effective removal by a simple structure of the unnecessary components from an ultrasonic wave signal propagated through a solid propagation medium.

It has been the usual practice in the electric communication equipment industry to cause an electric signal to be delayed a predetermined time by propagating the signal through a solid propagation medium after converting the electric signal into an acoustic signal by means of an electro-acoustic transducer and reconverting the signal back into an electric signal by means of an acousto-electric transducer element when it emerges from the solid propagation medium.

Generally, it is essential that any circuit element built into an electric circuit be compact in size. This is also true of an ultrasonic wave delay device intended for use in attaining the aforementioned object. Therefore, it has hitherto been customary to produce a compact ultrasonic wave delay device wherein a number of reflection surfaces are provided in a medium for propagating an ultrasonic wave signal so as to define an ultrasonic wave propagation path therein in accordance with a so-called multiple reflection process.

When the multiple reflection process is employed for producing a compact ultrasonic wave delay device, the electro-acoustic transducer element provided in an input end of the device and the acousto-electric transducer element provided in an output end thereof must be compact in size. Reduction in size of the electro-acoustic transducer element results in a reduction in the area of its oscillation surface, and the radiation characteristics of the oscillation surface of a small electro-acoustic transducer element have a directivity such that a supersonic wave signal is not only directed to a predetermined path of propagation for the ultrasonic wave signal (principal ultrasonic wave signal component propagation path) but also transmitted in other directions as well. Thus, an ultrasonic wave signal produced by the compact electro-acoustic transducer element moves in other directions than the direction in which it is intended to move through the principal ultrasonic wave signal component propagation path, so that some components of the ultrasonic wave signal (which are unnecessary components of the signal) are transmitted through other paths in the propagation medium than the principal ultrasonic wave signal component path to the acousto-electric transducer element at the output end of the propagation medium.

The unnecessary signal components differ from the principal signal components in the time in which they are delayed in being transmitted through the propagation medium. Thus, it is essential in ultrasonic wave delay devices of the type described that the unnecessary signal components should be eliminated. Many proposals have hitherto been made for solving this problem.

Known devices for obviating the problem of how to eliminate the unnecessary signal components from an acoustic signal have all been unsatisfactory in attaining the end for which they are intended. No satisfactory ultrasonic wave delay device has ever been developed which is simple in construction and yet effective in removing the unnecessary signal components from an ultrasonic wave.

This invention is intended to provide a novel ultrasonic wave delay device which obviates the aforementioned disadvantages of devices of the prior art.

Accordingly, a principal object of the present invention is to provide an ultrasonic wave delay device which is compact in size, simple in construction, and yet effective to remove unnecessary components from an ultrasonic wave signal.

Another object of the invention is to provide an ultrasonic wave delay device in which a solid propagation medium is used for transmitting an ultrasonic wave signal therethrough, and which lends itself to fabrication with ease by means of an ultrasonic processing operation or by using a press.

A further object of the invention is to provide an ultrasonic wave delay device in which reflection surfaces for principal components of an ultrasonic wave signal are provided in the interior of an ultrasonic wave signal propagation medium for forming a path of propagation for the principal components of the signal in the propagation medium.

Still another object of the invention is to provide an ultrasonic wave delay device effective to remove unnecessary components from an ultrasonic wave signal by employing a multiple reflection process in the fabrication of an ultrasonic wave propagation medium, in which there are provided reflection surfaces for principal components of the signal and reflection surfaces for the unnecessary components thereof in the interior of the propagation medium, such two types of surfaces being arranged in a specific manner for effectively eliminating the unnecessary signal components.

A still further object of the invention is to provide an ultrasonic wave delay device in which reflective surfaces for principal components of an ultrasonic wave signal are provided in the interior of an ultrasonic wave propagation medium so as to thereby define a principal signal component propagation zone therein, and in which unnecessary components of the signal are effectively removed in portions of the propagation medium other than the principal signal component propagation zone.

Yet a further object of the invention is to provide an ultrasonic wave delay device in which at least one of a plurality of reflection surfaces for principal components of an ultrasonic wave signal provided in the path of propagation for the principal components of the signal is constructed such that its configuration and area are substantially equal to the cross-sectional configuration and area of the principal components of the signal incident thereon, whereby unnecessary components of the signal can be removed with increased effectiveness.

Additional objects as well as features and advantages of this invention will become evident from the description set forth hereinafter when considered in conjunction with the accompanying drawings, in which:

FIG. 1 is a view in explanation of the ultrasonic wave delay device incorporating one embodiment of this invention;

FIG. 2 is a perspective view of a modification of the embodiment illustrated in FIG. 1;

FIG. 3 is a view in explanation of the ultrasonic wave delay device comprising a second embodiment of this invention;

FIG. 4 is a view in explanation of the ultrasonic device comprising a third embodiment of this invention;

FIG. 5 is a perspective view of a modification of the third embodiment of the invention; and

FIG. 6 is a view in explanation of one example of means for attaching a transducer element to a propagation medium in the device according to this invention.

In FIGS. 1 to 5, an electro-acoustic transducer element 11 is attached to one portion of an outer wall of a rectangular propagation medium 10 for an ultrasonic wave which is made, for example, of iron, aluminum, glass, ceramics or the like, and an acousto-electric transducer element 12 is attached to the other portion of the outer wall of the propagation medium 10.

FIG. 6 shows one example of means for adhering such transducer elements to the propagation medium. As shown, silver or other metal 13 is deposited by vaporization in vacuum on a surface of such propagation medium 10 in a case that the propagation medium 10 is made of glass. Soldered at 17 to the metal layer 13 is the transducer element which consists of a transducer 14 sandwiched by electrodes 15 and 16 made of silver or the like and attached to opposite surfaces of the transducer 14, said transducer element being made of lead titanate-zirconate ceramics or crystal and the like.

Input terminals 18 for an input electric signal are connected to the electrodes 15 and 16 of the electro-acoustic transducer element 11, and output terminals 19 for an output electric signal, which has been delayed a predetermined time, are con-

nected to the electrodes 15 and 16 of the acousto-electric transducer element 12.

In FIGS. 1 and 2 which illustrate a first embodiment of this invention, a plurality of reflection surfaces 21, 21, . . . are provided in the solid propagation medium 10 between the electro-acoustic transducer element 11 and acousto-electric transducer element 12 so as to form a path of propagation 20 for principal components of an ultrasonic wave signal therein. Such reflection surfaces are provided by forming a plurality of openings 22, 22, . . . in the interior of the solid medium 10 by ultrasonic processing, pressing, or milling.

FIG. 2 shows a modification of the first embodiment of the invention. FIG. 3 shows a second embodiment and FIGS. 4 and 5 show a third embodiment thereof. In these figures, the plurality of reflection surfaces 21, 21, . . . for forming the path of propagation 20 for the principal components of the ultrasonic wave signal in the solid medium 10 are provided by forming a plurality of grooves 23, 23, . . . in the solid medium by cutting inwardly from outer walls of the solid medium 10 by the same means of processing as used in the first embodiment.

The reflection surfaces 21 have a surface grain size ranging from 10 to 100 μ which may vary depending on the frequency band of a particular ultrasonic wave used. In FIGS. 1 to 5, an input electric signal supplied to the input terminal 18 is converted into an ultrasonic wave signal by the electro-acoustic transducer element 11 and radiated into the solid medium 10.

As aforementioned, principal components of the ultrasonic wave signal radiated into the solid medium 10 are subjected to multiple reflection between the reflection surfaces 21, 21, . . . for the principal components of the signal provided in the interior of the solid medium 10, so that they pass through the predetermined path of travel 20 for the principal components of the signal and reach the acousto-electric transducer element 12, where the ultrasonic wave signal is converted into an electric signal again to provide an output electric signal which has been delayed a predetermined time.

On the other hand, unnecessary components of the signal radiated from the electro-acoustic transducer element 11 into the solid medium 10 are transmitted through a path of propagation 24 for unnecessary components of the signal shown in broken lines in the figures, and ultimately reach portions of the solid medium which are outside a zone (principal signal component propagation zone) defined by the reflection surfaces 21, 21, . . . for the principal components of the signal, so that acoustic energy is converted into thermal energy in such portions of the solid medium 10. Thus, the unnecessary components of the signal are effectively eliminated.

In FIG. 1, there are illustrated sound absorbing members 25 in phantom lines. Such sound absorbing members 25 are illustrated to show that the unnecessary components of the signal deflected from the path of propagation 20 for the principal signal components and not incident on one of the reflecting surfaces 21 for the principal signal components can be absorbed by the sound absorbing members 25 when they reach a portion between the principal signal component propagation zone and an outer wall of the solid medium after they have passed through such zone.

The modification of the first embodiment shown in FIG. 2, the second and third embodiments shown in FIGS. 3 and 4, and the modification of the third embodiment shown in FIG. 5 are shown as not being provided with the sound absorbing members 25. It should be understood, however, that suitable sound absorbing members may be provided in outer walls of the solid medium 10 in these embodiments as well, and that the principal signal components are not damped even if the sound absorbing members are attached to the outer walls of the solid medium along substantially the entire circumferential extent thereof, because the reflection surfaces for the principal signal components in the instant ultrasonic wave delay device are scattered independently of one another in the interior of the solid medium 10 or provided by cutting into its interior from its outer walls.

Any material which is compatible with mechanical impedance of the solid medium and which has good adhering and shaping properties, such as an epoxy resin containing powdered metal, for example, may be used for making such sound absorbing members.

Referring to FIG. 1 again, lines 20a and 20b represent boundaries of the path of propagation 20 for the principal signal components. Stated differently, they indicate a range of the principal components of the ultrasonic wave signal radiated from the electro-acoustic transducer element 11 into the solid medium 10. Such range corresponds to the width of a beam of the principal signal components and is from 5 to 10 mm in this embodiment, although its values may vary depending on the size of transducer elements used. The lines 20a and 20b may be considered to represent sides of a cylindrical body having its axis at 20 whose transverse sectional configuration (transverse sectional configuration of the beam of principal signal components) may vary depending on the shape and configuration of an oscillation surface of the electro-acoustic transducer element.

It will be seen that the present invention resides in the provision of one or a plurality of reflection surfaces 21, 21, . . . for the principal signal components in the interior of the solid medium 10 so as to thereby provide a principal signal component propagation zone in the interior of the solid medium 10. It is one of the features of this invention that if, in providing such principal signal component propagation zone in the solid medium, the configuration and area of at least one of the reflection surfaces 21, 21, . . . forming the path of propagation 20 for the principal signal components between the electro-acoustic transducer element 11 and acousto-electric transducer element 12 are made substantially equal to the cross-sectional configuration and area of the beam of principal signal components incident thereon, it is possible to achieve better results in removing the unnecessary signal components.

When this feature is incorporated in the ultrasonic wave delay device, the configuration and area of the reflection surface 21 which is disposed in face to face relation with the electro-acoustic transducer element 11 are preferably made to be substantially equal to the cross-sectional configuration and area of the beam of principal signal components incident thereon. However, it should be understood that this invention is not limited to this particular arrangement, and that the configuration and area of any one or more reflection surfaces 21 may be made to be substantially equal to the cross-sectional configuration and area of the beam of principal signal components incident thereon.

The aforementioned feature with respect to the reflection surfaces 21, 21 may be incorporated in the embodiments shown in FIGS. 3 to 5 as well.

It will be appreciated that it is possible to effectively eliminate the unnecessary signal components in the present invention by providing the principal signal component propagation zone in the interior of the solid medium 10 which is defined by the reflection surfaces 21, 21, . . . for the principal signal components, so as to cause the unnecessary signal components to be expelled from the principal signal component propagation zone.

The unnecessary signal components which have been expelled from the principal signal component propagation zone in the interior of the solid medium 10 are subjected to multiple reflection between a plurality of reflection surfaces 26, 26, . . . for the unnecessary signal components provided in the solid medium 10 but outside the principal signal component propagation zone and outer walls of the solid medium 10. Thus, the unnecessary signal components are gradually deprived of their energy and finally cease to exist.

The reflection surfaces 26, 26, . . . for the unnecessary signal components are formed by the openings 22, 22, . . . in the first embodiment shown in FIG. 1 and its modification shown in FIG. 2, and by the grooves 23, 23, . . . in the second and third embodiments shown in FIGS. 3 and 4 respectively and the modification of the third embodiment shown in FIG.

5. It should be noted that in all the embodiments and their modifications the reflection surfaces 26, 26, . . . for the unnecessary signal components are provided in the solid medium but outside the path of propagation for the principal signal components.

The reflection surfaces 26, 26, . . . for the unnecessary signal components are of such size, shape and construction and disposed in positions such that the unnecessary signal components reflected by reflection surfaces 27 in the outer walls of the solid medium 10 shown in FIGS. 3 and 4 are reflected by the particular reflection surfaces 26 facing such reflection surfaces 27 to move in a direction in which the unnecessary signal components are deflected from the principal signal component propagation zone and subjected to multiple reflection between the reflection surfaces 27 in the outer walls of the solid medium and the reflection surfaces 26.

The aforementioned action of the reflection surfaces 26 for the unnecessary signal components is illustrated in FIGS. 3 and 4.

By providing such reflection surfaces 26 for the unnecessary signal components in the solid medium, there is provided, adjacent the aforementioned principal signal propagation zone, an unnecessary signal component trap zone which captures unnecessary signal components expelled from the principal signal component propagation zone to ensure that they never return to the principal signal component propagation zone. The provision of such unnecessary signal component trap zone in the solid medium adjacent the principal signal component propagation zone is conducive to increased efficiency in eliminating the unnecessary signal components.

The dimensions (external dimensions) of the modification of the first embodiment shown in FIG. 2 are 46 millimeters in transverse width, 40 millimeters in longitudinal width and three millimeters in thickness. The dimensions (external dimensions) of the modification of the third embodiment shown in FIG. 5 are 40 millimeters in transverse width, 45 millimeters in longitudinal width and six millimeters in thickness. The openings 22 and grooves 23 in all the embodiments are about 10 millimeters in length.

While particular embodiments and modifications thereof of this invention are shown and described, it will be understood, of course, that the invention is not to be limited thereto, since

many other modifications and changes may be made and it is contemplated, therefore, by the appended claims, to cover any such modifications as fall within the true spirit and scope of this invention.

What is claimed is:

1. An ultrasonic wave delay device comprising a solid medium for propagating an ultrasonic wave signal; an electro-acoustic transducer element attached to an outer wall of said solid medium for converting an input electric signal into an ultrasonic wave signal; a plurality of reflection surfaces for principal components of the ultrasonic wave for forming a path of propagation for the principal components of the ultrasonic wave signal radiated from said electro-acoustic transducer element into the interior of said solid medium, at least one of said reflection surfaces for the principal components being provided in the interior of said solid medium; an acousto-electric transducer element attached to an outer wall of said solid medium for converting into an output electric signal only the principal components transmitted through the path of propagation; and at least one reflection surface provided in the interior of said solid medium for unnecessary components of the ultrasonic wave signal transmitted in said solid medium through paths other than the path of propagation for the principal components, said reflection surface for the unnecessary components being provided in a portion of said solid medium other than the path of propagation for the principal components and forming an unnecessary signal component trap zone between the reflection surface for unnecessary components and an outer wall of said solid medium.

2. An ultrasonic wave delay device as defined in claim 1 wherein said at least one of the reflection surfaces for said principal components of said ultrasonic wave signal and said at least one reflection for said unnecessary components of said ultrasonic wave signal are provided in said solid medium by forming an opening or openings therein.

3. An ultrasonic wave delay device as defined in claim 1 wherein said at least one of the reflection surfaces for said principal components of said ultrasonic wave signal and said at least one reflection surface for the unnecessary components of said ultrasonic wave signal are provided in said solid medium by forming a groove or grooves in the solid medium by cutting inwardly from outer walls thereof.

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