

[54] ELECTROMECHANICAL DELAY LINE
WHEREIN CORE EXHIBITS HIGHER MEAN
REFRACTIVE INDEX THAN ENVELOPE

[75] Inventor: Manfred Borner, Ulm/Donau,
Germany
[73] Assignee: Licentia Patent-Verwaltungs-GmbH,
Frankfurt am Main, Germany
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[56] References Cited
UNITED STATES PATENTS
3,421,096 1/1969 Koester..... 350/96 WG

3,659,915 5/1972 Maurer et al. 350/96 WG
3,037,174 5/1962 Bommel et al. 333/30 R

OTHER PUBLICATIONS

Handbook of Chemistry and Physics, The Chemical
Rubber Co., 1965, 46th Edition, pp. E-140, 142 &
143 relied on, QD65C4.

Primary Examiner—Paul L. Gensler
Attorney, Agent, or Firm—George H. Spencer et al.

[57] ABSTRACT

A delay line composed of a filamentary core capable
of supporting the propagation of mechanical energy
and a surrounding envelope. The material of the core
and the envelope are such that the core exhibits a
mean refractive index for the mechanical energy
which is higher than that of the envelope.

14 Claims, 7 Drawing Figures

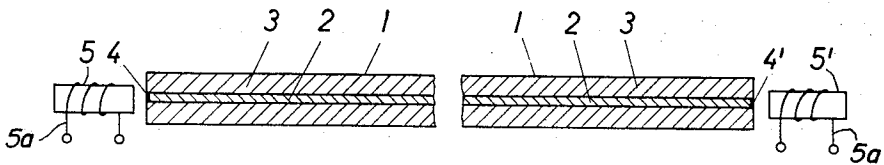


FIG. 1

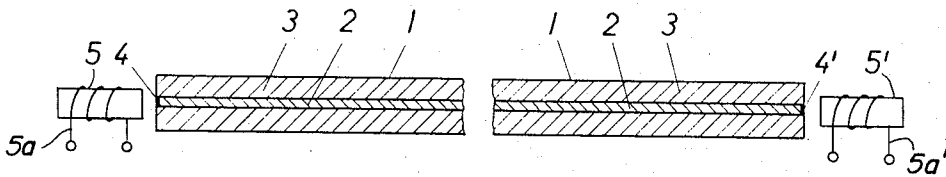


FIG. 2

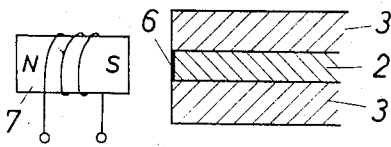


FIG. 3

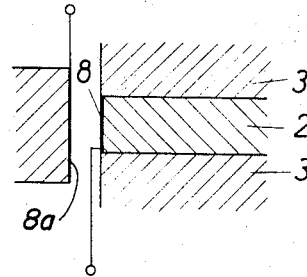


FIG. 4

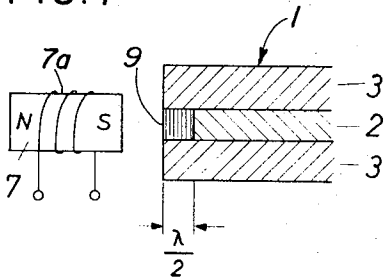


FIG. 5

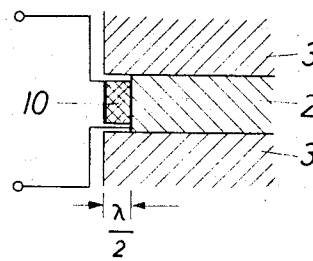


FIG. 6

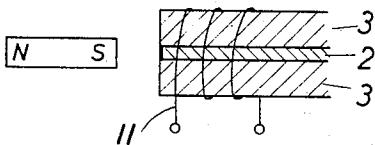
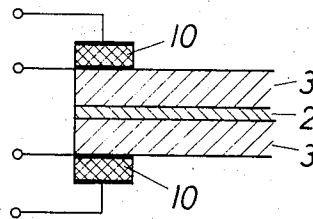


FIG. 7



ELECTROMECHANICAL DELAY LINE WHEREIN CORE EXHIBITS HIGHER MEAN REFRACTIVE INDEX THAN ENVELOPE

The present invention relates to delay lines and it relates more particularly to so-called electro-mechanical delay lines, i.e. to delay lines in which mechanical energy derived via an input transducer from an electrical input signal, is propagated. A second transducer, called the output transducer, is provided to convert the mechanical energy after passage through the delay line, into an electrical output signal.

Some conventional electro-mechanical delay lines, for example filamentary or liquid-type delay lines, tend to suffer from either or both of the following difficulties:

- serious high frequency attenuation (above the MHz band) and
- supports for filamentary-type delay lines introduce signal losses and unwanted reflections.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a delay line in which at least one of the above mentioned difficulties is reduced or overcome.

According to the invention there is provided a delay line comprising a filamentary core, capable of supporting the propagation of mechanical energy, and an envelope around said core, the materials of said core and said envelope being such that said core exhibits a mean refractive index for said mechanical energy which is higher than that of said envelope.

In order that the invention may be clearly understood and readily carried into effect, the same will now be described, by way of example only, with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows, in cross-sectional view, part of a delay line in accordance with one example of the invention together with input and output transducer arrangements, and

FIGS. 2, 3, 4, 5, 6 and 7 show in cross-sectional view, part of a delay line of the kind shown in FIG. 1 and respective alternative transducer arrangements.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1, a delay line 1 consists of a filamentary core 2 which may, for example, be a fiber of glass, around which core is provided an envelope 3. Energy is coupled into the line 1 by means of an electro-mechanical input transducer, shown schematically by a magnetic layer 4 deposited on the cross-section of the input end of the filamentary core 1 and an electromagnet 5 carrying a coil 5a to which the electrical input signals are applied. The reference numerals 4', 5' and 5a' indicate those components of an electro-mechanical output transducer which are similar to the components of the input transducer identified by the corresponding unprimed numerals.

The material of which the core 2 is constructed has a refractive index n_2 for the mechanical energy whereas the material of which the envelope 3 is constructed has a different refractive index, n_3 , for the same energy. The corresponding speeds of sound for said mechanical energy in the core and in the envelope are C_2 and C_3 respectively and it is known that the two ratios C_2/C_3

and n_2/n_3 are equal and the ratios will be termed the refractive power n which is a measure of the discontinuity of refractive index experienced by the mechanical energy on passing from one of said materials to the other. Mechanical energy can be constrained so that it is propagated (e.g. as a longitudinal wave) substantially only within the core provided that $n_2 > n_3$, and it is desirable that the difference between the refractive indices should be as great as possible. The foregoing relationship is especially valid when the diameter d of the core 2 is large compared to the wavelength λ of the mechanical energy.

If, however, d is of the same order of magnitude as λ , the delay line is only capable of propagating mechanical energy in a small number of modes. This gives rise to a predetermined distribution of energy over the cross-section of the delay line, the distribution being such that most of the energy is concentrated in the core 2. The delay line then exhibits a well defined phase velocity pertaining to a given mode. By selection of the dimensions of the core and the envelope, taking into account the effects of bends in the delay line, it can be arranged that substantially the total energy in a given frequency band can be propagated in a single mode. Under these circumstances, pulsed energy propagated through the delay lines undergoes minimal dispersion and distortion so that such an arrangement is advantageous. It is important, however, that the input transducer is capable of exciting the delay line in said single mode.

Some transducer arrangements will now be described with reference to FIGS. 2 to 7.

In FIG. 2 there is shown a small portion of a delay line 1 comprising a core 2 and an envelope 3 as described with reference to FIG. 1. At least at one end of the delay line 1 there is provided a transducer arrangement comprising a magnetically responsive layer 6 deposited or otherwise provided over the cross-sectional area of the end face of the core 2, and an electromagnet 7 which comprises a core which carries a coil to which electrical input signals can be applied or from which electrical output signals can be derived, depending upon whether the arrangement is utilized as an input or an output transducer. The thickness t of the layer 6 is arranged to be considerably less than a wavelength λ of the mechanical energy, and the layer is attracted or repelled by means of the electromagnet 7, which is spaced from the layer 6 by a small air gap. By means of this arrangement it is possible to generate a longitudinal wave which is propagated substantially only in the core 2 of the delay line 1.

The arrangement of FIG. 3 is analogous to that shown in FIG. 2, except that it operates with electrostatic forces instead of electromagnetic forces. An electrostatic layer 8 is deposited or otherwise provided over the cross-sectional area of an end face of the core 2 of delay line 1. The layer 8 and fixed electrode 8a constitute the two input or output electrodes of the arrangement.

FIG. 4 illustrates a transducer arrangement for at least one end of a delay line 1 wherein a magnetically prepolarized, piezomagnetic layer 9, of thickness about $\lambda/2$, is provided over the cross-sectional area of an end face of the core 2. The layer 9 contracts or expands longitudinally in response to electrical input signals applied to coil 7a, assuming that the end of delay line 1 shown in FIG. 4 is the input end. The layer 9 may con-

sist, for example, of a nickel-iron alloy, and although the thickness of the layer 9 must be about $\lambda/2$, the thickness of the airgap is immaterial.

The transformer arrangement shown in FIG. 5 utilizes a piezoelectric layer 10, again of thickness about $\lambda/2$, which is set into thickness oscillations by electrical input signals applied to opposite faces thereof as shown. Conversely, if the transducer arrangement shown in FIG. 5 is used at the output end of the delay line 1, the longitudinal oscillations propagated through the line 1 cause mechanical compression and expansion of the layer 10 which, in turn, provides an electrical output signal.

It is possible to transmit energy through delay lines such as 1 in forms of oscillation other than the longitudinal form thus far described. In such cases the transducer arrangement can be such that the oscillations set up in the envelope by the transformer can be of different form than the oscillations to be propagated through the delay line. The delay line can, for example, be excited by means of a transverse oscillation. Moreover, as shown in FIGS. 6 and 7, transducer arrangements can be used in which the active element does not act directly upon the core 2, but is effective thereon through the intermediary of the envelope 3. In FIG. 6 a coil 11 is wrapped around the envelope 3 of delay line 1, adjacent one end of the line and in FIG. 7 a piezoelectric ring transducer 10 is provided around the envelope 3 adjacent one end of delay line 1.

A practical example of a delay line in accordance with the invention, was designed to operate at a frequency of 1 GHz (which corresponds to a wavelength of 5μ) and to transmit the mechanical oscillations in substantially a single mode. The delay line 1 comprised a glass fiber of total diameter 100μ and of which the diameter of core 2 was 7μ . The fiber was found to be capable of transmitting a bandwidth of 200 MHz, exhibiting a mean attenuation of 6dB/m. With a length of 10m, the fiber has a storage capacity of 1m bit and a mean access time of 1m sec. The complete delay line, together with the control electrode, can conveniently be accommodated on a plug board.

Although the description in the last preceding paragraph is given by way of example only and is not intended to limit the scope of the invention, it will be observed that the dimensions of the delay line are such as to present difficulties with regard to the provision of the various layers incorporated in the transducer arrangements. These difficulties can be substantially reduced in accordance with another feature of the invention which provides a method of manufacturing a delay line of the kind thus far described, together with layers provided thereon for transducing purposes. In accordance with this method, the capability of a delay line having a glass fiber core to transmit light as well as mechanical energy is utilized.

The first step of the method is to provide, on the cross-sectional end faces at the input and output ends of the delay line, a photo-sensitive layer. When a photo-positive layer is used, light is injected into the envelope of the delay line and is focused thereby into the core. The light travels along the core and impinges on the inner surface of one or other of the photo-sensitive layers, so that the layers are only exposed at their interfaces with the fiber core. By means of an etching process, the exposed parts of the photosensitive layers, together with a thin layer of the fiber core adjacent each

of the exposed parts, is removed, thus providing ring-shaped depressions, colinear with the core, at either end of the delay line. The whole cross section of both end faces of the delay line is then provided with the active layer of the transducer, for example by means of an evaporation/deposition process or preferably by electroless plating. These layers are then ground or polished until only the active layers deposited in the depressions formed colinearly with the core remain. If desired, the active layers covering the annular end surfaces of the envelope of the delay line need not be completely removed.

It will be appreciated that it is desirable for the core at least of the delay line to consist of material of low acoustic attenuation. It is also desirable for the change in refractive index between the core and the envelope to be a discrete change.

What we claim is:

1. Apparatus for transmitting mechanical energy comprising in combination: a delay line including a filamentary core, capable of supporting the propagation of mechanical energy, and an envelope of a solid material around said core, the materials of said core and said envelope being such that said core exhibits a mean refractive index for said mechanical energy which is higher than that of said envelope; first mechanical transducer means having an output coupled to one end of said delay line for causing mechanical oscillations to be stimulated within said delay line; and second mechanical transducer means coupled to the other end of said delay line for sensing the mechanical oscillations propagated within said delay line.
2. An arrangement according to claim 1, in which the core consists of a material of low acoustic attenuation.
3. An arrangement according to either of claim 1 in which the core consists of glass.
4. An arrangement according to claim 3, in which the difference in refractive index between the core and the envelope is discrete at least throughout the greater part of the length of the line.
5. An arrangement according to claim 1, in which the diameter of the core is comparable in order of magnitude with the wavelength of the mechanical energy.
6. An arrangement according to claim 1, in which the core is so dimensioned that a small number of oscillation modes are capable of propagation therein.
7. An arrangement according to claim 1, in which at least one longitudinal wave is capable of being propagated in the core.
8. An arrangement according to claim 1, in which at least one of said first and second transducer means includes a magnetically active layer provided at least in the area of the core.
9. An arrangement according to claim 1, in which at least one of said first and second transducer means includes an electrostatically active layer provided at least in the area of the core.
10. An arrangement according to claim 1, wherein at least one of said first and second transducer means is a magnetically pre-polarized piezomagnetic transformer.
11. An arrangement according to claim 1, wherein at least one of said first or second transducer means is a piezoelectric transformer.
12. A delay line according to claim 1, in which said first transducer means stimulates the core in a different oscillation mode from the envelope.

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13. A delay line according to claim 12, in which said first transducer means is coupled to the core via the envelope and stimulates an oscillation mode in the envelope, the oscillation mode in the envelope being constituted by transverse contractions which stimulates oscillations on the core which are propagated along the

length of the core.

14. A delay line according to claim 1, in which said first and second transducer means are coupled to the core via the envelope.

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