June 20, 1967 G. H. HARE 3,327,252

VIBRATORY DELAY LINE HAVING NOVEL SUPPORT

Original Filed Oct. 28, 1963 3 Sheets-Sheet 1

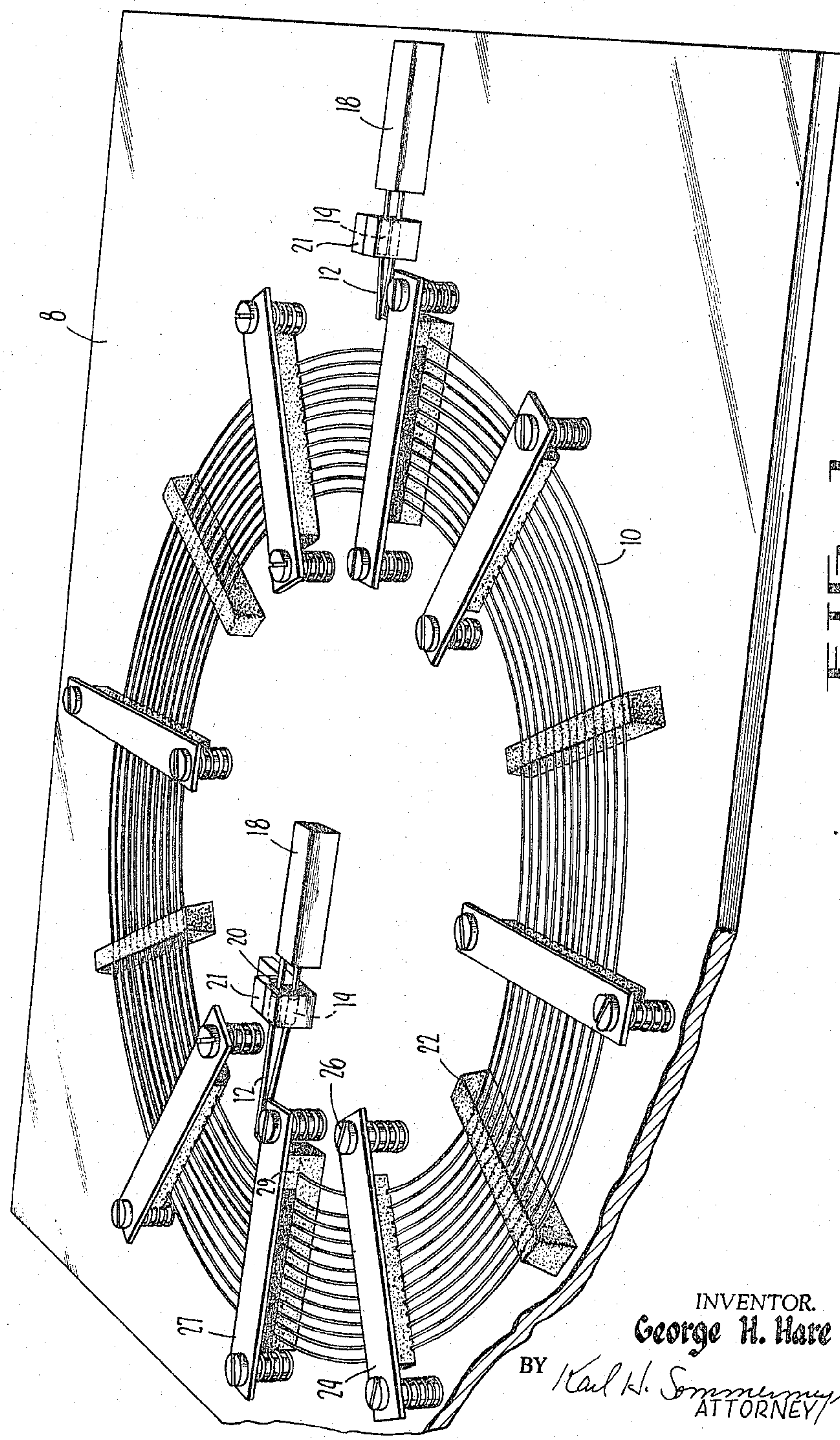

FIG. 1

INVENTOR.
George H. Hare

BY Karl H. Sommermeyer
ATTORNEY

June 20, 1967 G. H. HARE 3,327,252

VIBRATORY DELAY LINE HAVING NOVEL SUPPORT

Original Filed Oct. 28, 1963 3 Sheets-Sheet 2

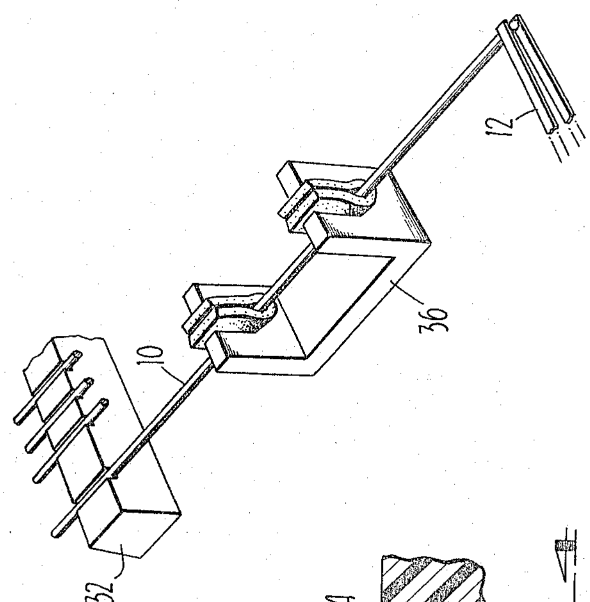

FIG. 3

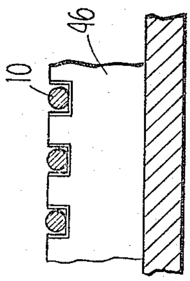

FIG. 7

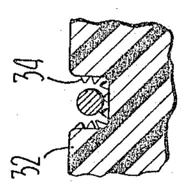

FIG. 4

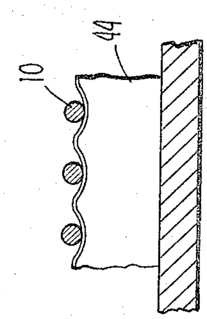

FIG. 6

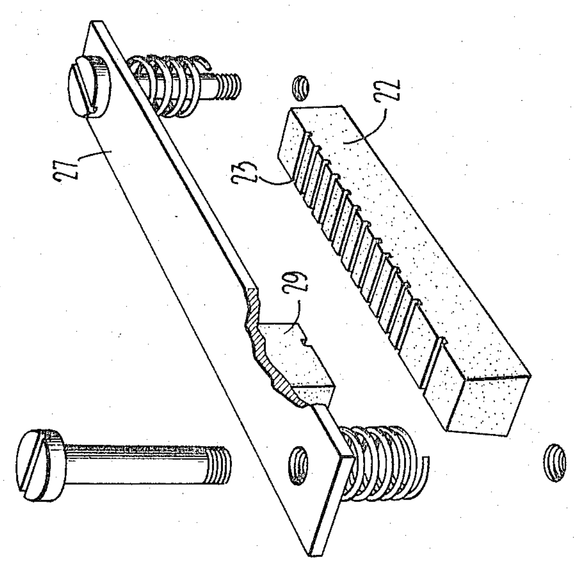

FIG. 2

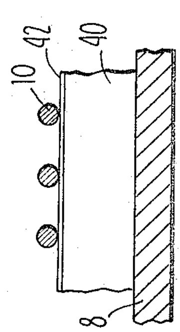

FIG. 5

June 20, 1967 G. H. HARE 3,327,252

VIBRATORY DELAY LINE HAVING NOVEL SUPPORT

Original Filed Oct. 28, 1963 3 Sheets-Sheet 3

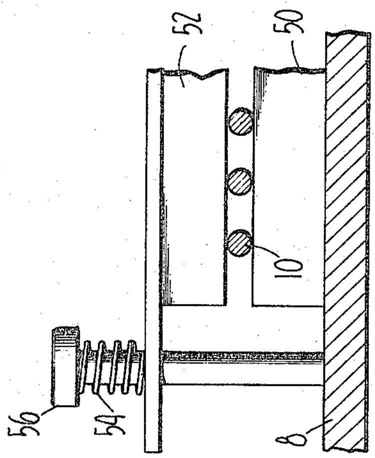

FIG. 9

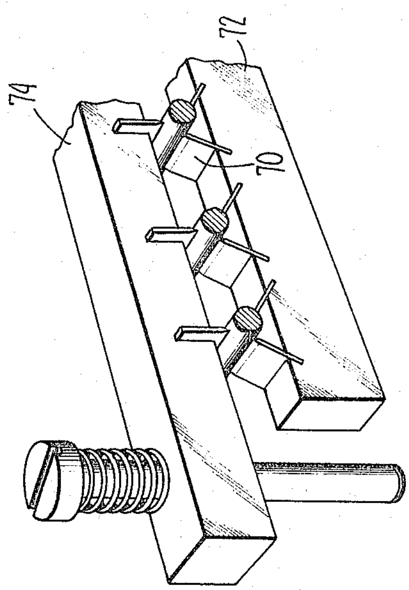

FIG. 11

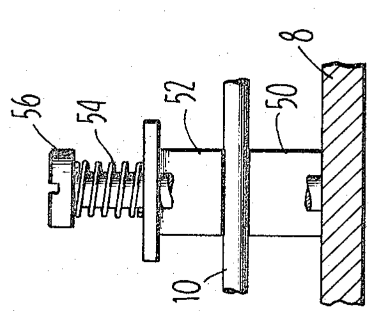

FIG. 8

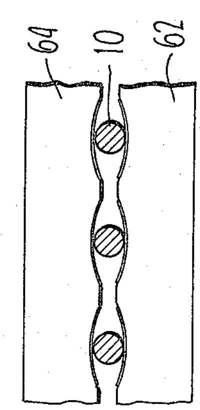

FIG. 10

United States Patent Office

3,327,252

Patented June 20, 1967

1

3,327,252
VIBRATORY DELAY LINE HAVING NOVEL SUPPORT

George H. Hare, Oakland, Calif., assignor to Friden, Inc., a corporation of Delaware

Continuation of application Ser. No. 319,197, Oct. 28, 1963. This application Feb. 2, 1966, Ser. No. 533,750
23 Claims. (Cl. 333—30)

The present invention relates to elastic, or acoustic, delay lines. This application is a continuation of my copending application for Delay Line, Ser. No. 319,197, filed Oct. 28, 1963, and now abandoned.

A delay line may include a rod or wire, along which an elastic signal wave travels. Such a line may be slender, with a length several thousand times its diameter, and so may require numerous supports along its length. Heretofore, supports for such lines have exhibited a coupling with said lines, and have markedly affected their transmission characteristics. Such supports have added reactive loading, have caused attenuation, and have imposed frequency dispersion. Furthermore, such signal distortions and losses have increased with the pressures that the supports exerted on the lines. Consequently, a tight grip on the line by a support produced large distortion, and any acceleration forces, such as those of shock and vibration, imposed unwanted modulation on the signals.

It is an object of the present invention to overcome the foregoing difficulties, and to provide a delay line with minimum distortion, and with operating characteristics that have a minimum susceptibility to change in response to shock, vibration, acceleration or spinning motions.

A further object is the provision of a support for a delay line which does not affect the operating characteristics of the line, or distort the signals thereon.

A further object is the provision of a support for firmly holding a delay line while remaining operationally uncoupled therefrom, for supporting it without participating in its operation.

It is a further object to provide a construction for a delay line in which the elongate elastic line may be firmly clamped for supporting it against shock, vibration, acceleration, and centrifugal forces.

A further object is the provision of a clamping structure and material therefor which will firmly support an elastic delay line without restricting its operation or imposing distortions of the signals.

Still a further object is the provision of a delay line that is decoupled from, and numb, to its supports.

These and other objects and advantages of the present invention will be apparent from the following description of specific embodiments thereof, taken in connection with the accompanying drawings, wherein:

FIG. 1 is a perspective view of a delay line embodying my present invention.

FIG. 2 is an exploded perspective view of one of the support members shown in FIG. 1.

FIG. 3 is a partial perspective view of a modification of the structure of FIG. 1.

FIG. 4 is an elevational sectional detail of FIG. 3.

FIGS. 5, 6 and 7 are partial elevational views of other support structures for the delay lines of FIGS. 1 and 3.

FIGS. 8, 9 and 10 are partial elevational views of clamping supports for the delay line of FIG. 1; and

FIG. 11 is a pictorial view of a knife-edge clamping support for a delay line.

The delay line as shown in FIGS. 1 and 2 includes a spirally coiled wire **10** in which the wire is about .025 inch in diameter and thirty feet long, and the coil has a mean diameter of about eight inches. The wire **10** is composed of a nickel-iron alloy known as "NiSpan," and is

2

here operated in the torsional mode. At each end of the wire **10**, two magnetostrictive ribbons **12**, each about .002 by .020 inch, are welded to the wire at diametrically opposite points of its cylindrical surface. Each of these ribbons extends through a transducer coil **14** and then through an absorbing pad **18** composed of pieces of rubber clamped against it. Permanent magnets **20** in holders **21** provide a bias magnetization of the ribbons **12** within the coils **14**. A signal in the form of an electric current applied to the pair of transducer coils **14** at one end of the wire **10** exerts opposite actions, contraction and expansion, on the two magnetostrictive ribbons **12**, which actions are transmitted as waves along the ribbons. These opposite actions operate as a couple on the wire **10** and generate a torsional strain which travels as an elastic torsional wave along the wire **10**. At the other end of wire **10**, the wave is transmitted as opposite effects, contraction and expansion, to the ribbons **12** of the receiving transducer, and induces voltage signals in the coils of the receiving transducer in a known manner.

It is well-known that certain materials, when laid against the elastic transmission member of a delay line, will alter the transmission characteristics thereof. For example, rubber pads, such as pads **18** in FIG. 1, are commonly clamped to the extreme ends of such a line for absorbing the signal and thereby preventing the appearance of end-reflected signals in the output. While it has been necessary to support the elongate transmission line, usually a metal wire, the contact of the supports with the wire has altered the output signal. Therefore, such supports have been arranged heretofore to exert as little pressure as possible on the wire and the number of such supports has been kept to a minimum. The wire has lain loose in such supports without being clamped, and has been dependent on its own slight stiffness for holding itself in place. Delay lines so constructed have lacked mechanical ruggedness, and consequently have been incapable of resisting severe vibration, shock, or other forces.

In accordance with my present invention I support the line with a faineant material and structure, that is, a material and structure capable of clamping the wire without substantially affecting its signal transmission characteristics. Such a material, though it may be firmly clamped against the wire, or elastic delay element, remains substantially uncoupled therefrom with respect to its operation as an elastic signal line. Though the support material firmly engages the line, it does so with a protective or buoyant touch.

I have found that there are several materials and structures with various degrees of faineance. One highly faineant material is dry colloidal silica, specifically "CAB-O-SIL" type M–5 sold by Cabot Corporation, 125 High St., Boston 10, Mass., U.S.A. This is an extremely fine powdery material weighing about one-half pound per cubic foot. If a small quantity of this material is pressed between two polished surfaces, such as glass plates, it will spread out into a semitransparent smudge about 0.001 inch thick. This surface, or smudge, of colloidal silica will then provide a faineant support for a delay line. Two such plates, when clamped to said line, smudge sides toward the elastic line, show no observable effects on the transmission characteristics of the line even at a high pressure, say ten pounds to a three-inch length of line.

I have found that a piece of balsa wood, such as is used for model airplanes, imposes no distortion on the signal of a delay line such as that of FIG. 1, operating in the torsional mode, when clamped against the line with the fibers of its grain parallel to the wire of the line. With the delay line **10** vibrating, or transmitting signals, in the torsional mode, its vibration is circular about the axis of the wire. Thus the surface of the wire moves parallel to itself and transverse the fibers of balsa that lie parallel to the wire. Similarly, fibrous glass filaments imposed no distortion on such a delay line when used as a support therefor with the glass fibers lying parallel to the torsional elastic line.

I have discovered that some other highly faineant materials are sandpaper, emery paper and the like. Specifically, I have employed two sheets of a 240-grit sandpaper, clamped with the grit sides toward the wire of a delay line of .025 inch NiSpan operating in the torsional mode, and have observed substantially no change in the amplitude or shape of the output signal. I have found equally good results with such sandpaper having paper and cloth backings, and with silicon carbide grit glued to a block of methyl methacrylate. However, sandpaper with larger and smaller grits, for example, 160-grit and 400-grit, were slightly less faineant on such a line in that, when clamped to the wire, they imposed barely perceptible phase distortions on the signals thereon. Other grits including alumina, silica, and garnet, and also diamond dust are also suitable.

In the construction of FIGS. 1 and 2, the wire **10** of the delay line is supported on twelve faineant pads **22**. Alternate pads are fastened to the supporting plate **8** and lie under the wire. The others are supported over the wire by bars **24** which are adjustably supported by screws **26**. The screws **26** are turned down to deflect the wires sufficiently to develop the desired pressure between the wire **10** and the supports. Each end of the wire **10** overhangs one of the lower supports and, at each of these positions, a clamping bar **27** carries an additional small piece **29** of the faineant material which, as best seen in FIG. 2, is clamped directly against the wire for providing the position control required by the ribbons **12**.

The supporting pads **22** may have a flat surface, but preferably I provide a series of grooves **23**, as shown in FIG. 2, for receiving the turns of the wire **10**. These grooves facilitate the assembly and provide assurance against accidental displacement of the wires in the completed device.

The pads **22** may consist of blocks of bonded grit, such as silicon carbide, alumina, silica, garnet or diamond, or a piece of balsa.

Alternative constructions for the faineant supports for use in the structure of FIG. 1 are shown in FIG. 3 to FIG. 11. In FIGS. 3 and 4, a support includes a block **32** of metal, glass, porcelain, methyl methacrylate or the like, having rectangular grooves lined with a grit **34**, such as silicon carbide, silica, alumina, garnet or diamond. The grit **34** may be applied to the base **32** by means of a glue or it may be applied by pressing it into the softer material for thereby "charging" the block **32** with the grit. Similar blocks with the grit-lined grooves are provided for both the upper and lower pads as in the structure of FIG. 1. As an alternative to clamping the ends of the wire **10** in the faineant supports as in FIG. 1, a guide and positioner **36** of known construction is provided.

In FIG. 5 a block of metal, glass, porcleain, methyl methacrylate, or other plastic, **40** has applied thereto a surface **42** of colloidal silica, sandpaper, glass filaments, or balsa for supporting the coils of the wire **10**. The colloidal silica is a self-adhering smudge. The sandpaper, glass filaments, or balsa, may be laid loose on the block **40** but preferably is held by glue. Alternatively, the block of the supporting pad may be supplied with shallow grooves for the wire **10** as shown in FIG. 6 or deeper grooves as shown in FIG. 7. The wire-supporting surfaces of the blocks **44** and **46** of FIGS. 6 and 7 may carry a surface of colloidal silica, sandpaper, glass filaments, or balsa. In each of FIGS. 5, 6 and 7, the glass filaments and the balsa are arranged with the filaments and the grain oriented parallel to the wire **10**.

Instead of utilizing beam-like stresses in the wire **10** for developing the support pressures, clamping supports as shown in FIGS. 8 and 9 may be provided. As there shown, the coils of the wire **10** are clamped between two blocks **50** and **52**, the clamping force being controlled by a spring **54** and adjusted by a screw **56**. The surfaces of the blocks **50** and **52** which engage the wire **10** carry colloidal silica, grit, sandpaper, glass filaments, or balsa. Alternatively, the blocks used in clamps of FIG. 9 may be grooved as shown in FIG. 10 to improve the security of the structure against lateral displacement of the wires **10**. The grooves should be shallow enough that the blocks **62** and **64** do not themselves touch, so that the clamping forces are applied to the wires. The clamping surfaces consist of a faineant material, such as colloidal silica, grit, sandpaper, glass filaments, or balsa.

In FIG. 11, short, steel blades **70** with knife edges are molded into blocks **72** and **74** of a rigid plastic material for supporting the wire **10** of the delay line of FIG. 1. The knife edges engage and support the wire **10**, extend parallel to the axis of the wire **10**, and preferably are from one-sixteenth to a quater of an inch long.

I believe the characteristic that makes these materials and structures highly faineant is the presentation to the wire **10** of the delay line, of many contact elements of small area, which elements are highly compliant to the vibratory excursions of the wire surface, and small enough that negligible inertia is associated with the movement. I believe that the particles of the colloidal silica act as rolling elements. I believe that the grit of the sandpaper, the grit glued to blocks, and the thin knife edges accommodate the rotary motion of the wire surface by deflection. I believe that the glass filaments and the cellular strands or fibers of the balsa, which present striate surfaces to the wire, accommodate the movement of the wire surface by a lateral rolling movement of the striae, or strands. I believe that the superior performance of the 240-grit over that of the larger and smaller grits results from an optimum balance between opposing effects. I think that in the finer grits the increase in number of contact points is greater than the increase in compliance of the smaller particles, and that in the larger grits the increase of stiffness of the larger particles is greater than the reduction of the number of contact points.

In a structure such as that of FIG. 1, the support material extends along approximately five percent of the total length of the wire **10** and, within that small total length, actually touches the wire only at spaced, small-area, contact points.

I think that a firm contact is required between the wire and the support and that the supporting surfaces should be small enough to develop contact pressures that develop stresses at, or just below, half of the yield point. This condition places the static stress in the middle of the elastic range and permits maximum vibratory forces without reaching either zero contact pressure or the yield point.

Preferably, in the normal operation of a delay line, neither the support material nor the surface of the wire should be stressed to its yield point. However, the structure can be "set" by carrying the stresses above the yield point. For example, a delay line such as is shown in FIG. 1 with grit-surfaced supports, when initially constructed and tested, will show a low signal distortion. If the structure is then subjected to high accelerations under vibration, for example, accelerations of fifty times the acceleration of gravity, the distortion is thereby increased somewhat, and the increased distortion of the signal persists when the line is thereafter operated without vibration. I believe that the "set" occurs because the high acceleration forces cause the material to be stressed beyond the yield point with consequent small permanent deformations, and that these deformations impair the sharpness and small area character of the contact between the line and support material. The deformation may occur in either the wire **10** or its support. A delay line so "set" will be stable when subjected to acceleration forces up to the value of the forces that caused the set.

Although the balsa may appear to have characteristics markedly different from the grits. I believe it provides the faineant support for the delay line for the same reason, namely, that it provides numerous small-area, contacting portions with high compliance and low inertia.

It will be apparent that the invention may be employed in embodiments other than those herein specifically shown and described and is to be limited only within the scope of the appended claims.

I claim:

1. In combination in a delay line, an elongate member, means for propagating elastic waves along said member, and a support for said member comprising dry colloidal silica in engagement with said elongate member.

2. The combination of claim **1** wherein said support comprises a rigid member having a thin surface layer of dry colloidal silica in engagement with said elongate member.

3. The combination of claim **1** wherein said support comprises two rigid members each having a thin surface layer of dry colloidal silica between which said elongate member is clamped.

4. In combination in a delay line, an elongate member, means for propagating elastic waves along said member, and a faineant support for said member including a support member having a surface of grit in engagement with said elonagte member.

5. The combination of claim **4** wherein said support member includes a surface of hard grit in engagement with said elongate member.

6. The combination of claim **4** wherein the surface of said support member comprises a grit of hard material glued to said support member.

7. The combination of claim **4** wherein said support comprises a sheet o fsandpaper with the grit side in contact with said elongate member.

8. The combination of claim **4** wherein said grit consists of silicon carbide.

9. The combination of claim **4** wherein there are two support members with surfaces of hard grit between which said elongate member is clamped.

10. An acoustic delay line comprising a round wire of a nickel-iron alloy, approximately .03 inch in diameter along which an elastic wave is propagated, and a support for said wire having a surface of sandpaper of approximately 240-grit engaging said wire.

11. In combination in a delay line, an elongate member, means for propagating an elastic wave along said member, a support member for said elongate member, said support member having small surface protuberances for providing a supporting contact with said elongate member at small areas, said supporting protuberances being compliant to the surface vibration of said elongate member and having low inertia.

12. The combination of claim **11** wherein said protuberances are composed of a hard material.

13. The combination of claim **11** wherein said protuberances make substantially point contacts with said elongate member.

14. The combination of claim **11** wherein said protuberances make substantially line contact with said elongate member.

15. A faineant support for an acoustic delay line wherein an elastic signal wave is propagated along an elongate member, said support comprising a member having surface protuberances of a hard material making contact with said member substantially only at many small points.

16. A support for an acoustic delay line wherein an elastic signal wave is propagated along an elongate member, said support having a surface of hard, granular, material touching the elongate member at small sharp points.

17. In combination in a delay line, an elongate elastic member, means for propagating elastic waves along said member in the torsional mode, and a faineant support for said member comprising narrow, elongate elements oriented longitudinal to said elastic member and engaging it along narrow elongate areas.

18. The combination of claim **17** wherein said elongate elements of said support comprise fiber-like strands.

19. The combination of claim **17** wherein said faineant support includes a surface of balsa with the fibers of the grain thereof engaging, and lying parallel to, said elongate plastic member.

20. In combination in a delay line, an elongate elastic member, means for propagating elastic waves along said member in a predetermined vibratory mode of said member, and a faineant support for said member comprising narrow, elongate elements engaging a surface of said member, which surface moves parallel to itself when said member carries an elastic wave in said predetermined mode, said elements being oriented transverse the direction of vibratory motion of said surface when said member carries an elastic wave in said predetermined mode, said elements engaging said member along narrow, elongate areas and presenting a striate surface to said elongate elastic member.

21. The combination of claim **20** wherein said support has a surface of fiber-like material which includes said elongate elements and which engages and supports said elastic member.

22. The combination of claim **20** wherein said support has a surface of balsa engaging and supporting said elastic member, the fibers of the balsa constituting said elongate elements.

23. In combination in a delay line, an elongate elastic member, means for propagating elastic waves along said member in a predetermined torsional vibratory mode of said member, and a faineant support for said member comprising narrow, elongate elements engaging a surface of said member, which surface moves parallel to itself when said member carries an elastic wave in said predetermined torsional mode, said narrow, elongate elements engaging said elastic member along narrow, elongate areas, said elements and areas being oriented transverse the direction of vibratory motion of said surface when said member carries an elastic wave in said predetermined torsional mode, said elements and areas being narrow compared to the dimensions of said member.

References Cited

UNITED STATES PATENTS

2,629,770	2/1953	Sproule	333—30
2,727,214	12/1955	McSkimin	333—30
2,837,721	6/1958	Millership	333—30
2,842,687	7/1958	Van Dyke	310—9.1
2,861,248	11/1958	Beistle et al.	333—30
3,011,136	11/1961	Scarrott	333—30
3,113,223	12/1963	Smith et al.	310—9.1 X
3,155,926	11/1964	Meitzler	333—30
3,241,090	3/1966	Bastian	333—30

FOREIGN PATENTS

1,199,735 6/1959 France.

OTHER REFERENCES

Scarrott, G. C., and Naylor, R., "Wire-Type Acoustic Delay Lines for Digital Storage," in Proceedings of the Institution of Electrical Engineers, London, vol. 103, part B, Supplement No. 3, 1956, page 500 relied on.

HERMAN KARL SALLBACH, *Primary Examiner.*

ELI LIEBERMAN, *Examiner.*

L. ALLAHUT, *Assistant Examiner.*