

[54] **DUAL WIRE INTRUDER DETECTOR**

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 244,540, April 17, 1972, abandoned.

[52] U.S. Cl. **340/258 R**, 174/126 CP, 340/261, 340/272

[51] Int. Cl. **G08b 13/22**

[58] Field of Search..... 340/258 R, 261, 272, 17; 174/115, 126 CP, 113 R, 128, 117 R

References Cited

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[57]

ABSTRACT

A perimeter security system comprising a strain sensitive line sensor in the form of dual magnetostrictive thin film plated wires having uniaxial anisotropy. The plated wire line sensor is preferably buried in a shallow trench or the like and detects intrusion in the vicinity of the line as the line sensor is stressed by the intruder causing a displacement of the earth. One of the dual plated wires is made to have a different degree of magnetostrictiveness than the other. The detection system is selectively sensitive to the motion of a mass on a surface, but tends to reject magnetic disturbances which effectively produce the same signal.

3 Claims, 16 Drawing Figures

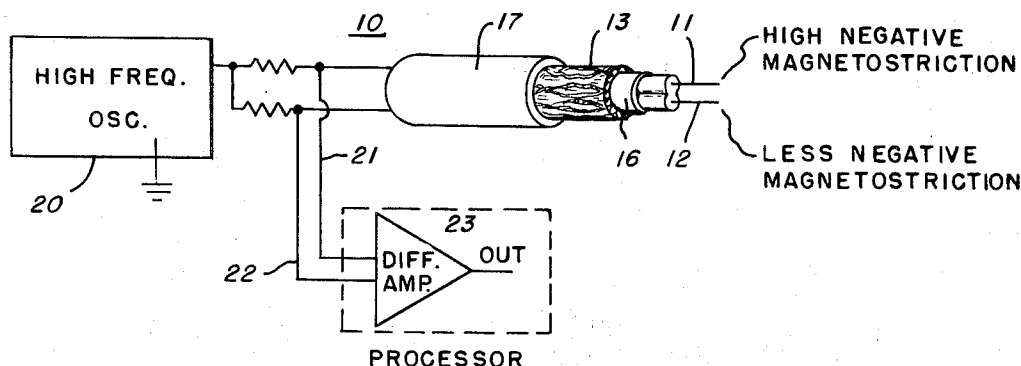


FIG. 1

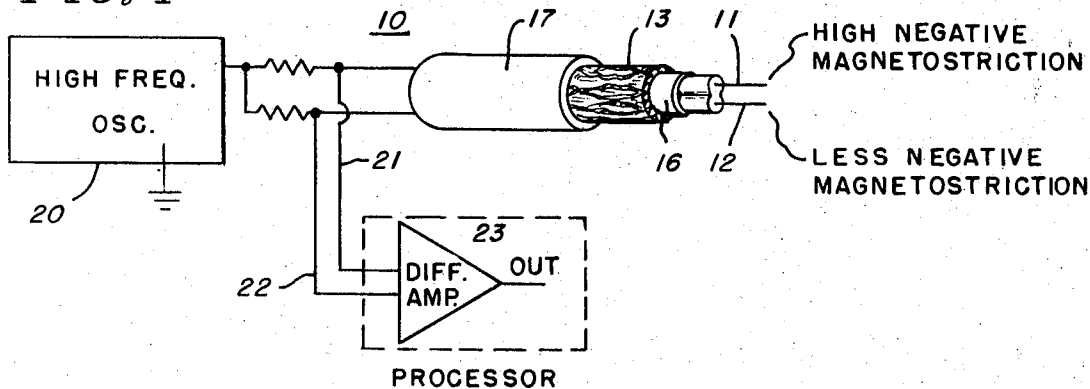


FIG. 1a

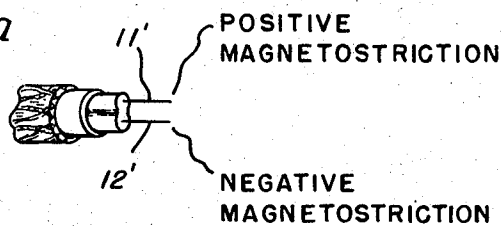


FIG. 2

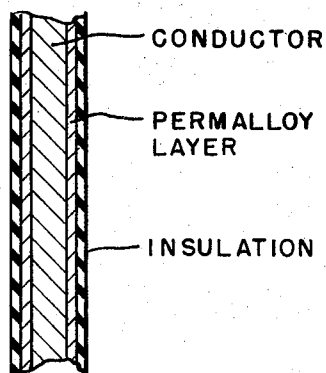


FIG. 3

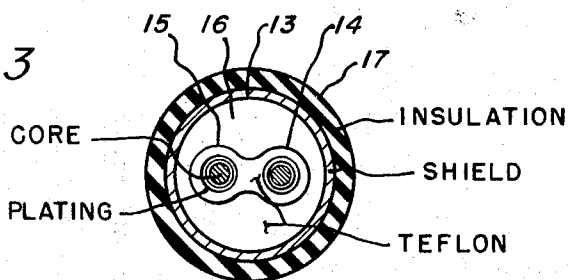
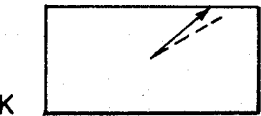
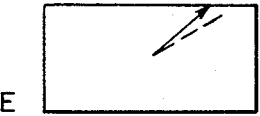
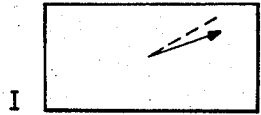
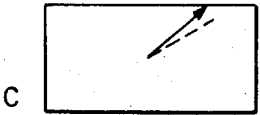
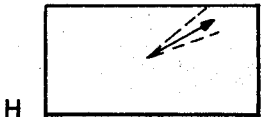
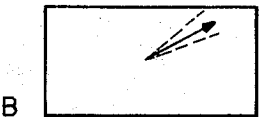
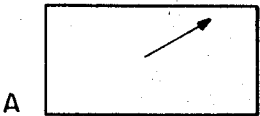


FIG. 4



DUAL WIRE INTRUDER DETECTOR

BACKGROUND OF THE INVENTION

This is a continuation-in-part of application Ser. No. 244,540 filed Apr. 17, 1972 and now abandoned.

The strain sensitive line sensor consists of a magnetostrictive plated wire having uniaxial anisotropy which acts as a transducer converting displacement of movement of the earth to an electrical signal. The extended length of plated wire line can be placed on the floor of a shallow trench and covered for camouflage. It will detect intrusion in the immediate vicinity of the line. In principle, the weight of the intruder or that of any other moving load on the surface of a semi-infinite solid like the ground, physically disturbs the load supporting medium. The line sensor embedded in the medium is stressed by the displacement. The resulting strain on the wire generates a signal.

The term magnetostriction is used to describe any dimensional change of a material which is associated with its magnetic behavior. Ferromagnetic bodies in particular are susceptible to dimensional changes, for instance, as a result of changes in temperature or a magnetic field. In the following description, the phenomenon of interest is the converse, where change in strain on a magnetostrictive material induces a change in its magnetic behavior.

In operation, an alternating current, sinusoidal or otherwise, is fed into the plated wire which generates an alternating magnetic field in the permalloy plating around the circumference of the wire. The alternating current magnetic field sets the magnetization vector in the plating into oscillation. This, in turn generates an alternating current electromotive force in the substrate core of the wire, which may be copper-beryllium. The voltage output or signal is alternating and constant in amplitude. Changes in the equilibrium orientation of the magnetization vector results in changes in the envelope of the signal amplitude. This appears as a modulation of a carrier similar in appearance to an amplitude modulation of a radio wave carrier.

In practice, the magnetostrictive plated wire is contained in an insulating flexible tube, such as a teflon tube. The wire and tubing are within a metallic shielded braid which, in turn, is protected by electrical insulation. The current flow through the plated wire may find its return through the metallic shield. The transducer output is detected, filtered through a low pass-band filter, and amplifier to produce an analogue signal.

The output of the transducer is a function of the orientation of the magnetization vector relative to the easy axis. In a zero magnetostrictive anisotropic plated wire, the equilibrium orientation of the magnetization vector is determined by the component of the ambient magnetic field parallel to the hard axis of the wire. If the wire plating is also magnetostrictive, the same re-orientation of the magnetization vector can also be achieved by straining of the wire under stress. The output of the transducer, therefore, measures either the state of the ambient magnetic field or the state of strain to which the plated wire is subjected, or both. There is no differentiation between the phenomena in the electrical output signal produced. In a short length of magnetostrictive wire, the disturbing effect of strain upon the magnetization vector dominates the effect of ambient changes of magnetic field. In a long cable, however,

the cumulative effect of magnetic field changes on the wire appear to mask the effect of the strain.

A satisfactory security system must minimize the false alarm rate. A strain responsive line sensor designed to detect ground pressure changes must be immune to changes in magnetic fields. In the low frequency spectrum of magnetic disturbances, the fluctuations in field amplitude are large and the cumulative effect over the length of the line may be large relative to the strain generated signal. The present invention provides apparatus for minimizing the geomagnetic and electromagnetic noise in a line sensor and emphasizing the magnetostrictive response thereby providing further capability for increased sensitivity and range.

SUMMARY OF THE INVENTION

An extended length of cabled anisotropic plated wire having magnetostrictive response is buried to provide strain detection of a perimeter being guarded. Two plated wires having similar magnetic properties but differing magnetostriction properties are in the cable, and the signals from the wires are connected to an amplifier such that the magnetically generated signals are canceled out but the magnetostrictively generated signals are summed.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a diagrammatic representation of a preferred embodiment of the invention;

FIG. 1a is another embodiment;

FIG. 2 is a cross-section illustration of a short length of a plated wire utilized in the invention;

FIG. 3 is intended to show an end view of the strain sensitive cable having the two plated wires therein; and

FIGS. 4A-4L shows the magnetization vector under several conditions of operation.

DESCRIPTION

Referring now to the drawing there is disclosed a cable 10 comprising dual magnetostrictive thin film plated wires 11 and 12 within a shield 13, which cable is intended for shallow burial in the ground for perimeter protection of an area from intruders. The anisotropic plated wires 11 and 12 may be, for example, a 5 mil diameter beryllium-copper substrate wire which has been plated with an anisotropic magnetic permalloy film, a cross-section of which is shown in FIG. 2. During deposition of the ferromagnetic film, a magnetic field is applied so that a preferred axis, called the easy axis, is obtained which is oriented circumferentially about the wire or with some degree of skew. The magnetization vector may lie along this line in the absence of external fields and strain on the wire, and makes a loop of magnetic flux around the wire.

In my application, Ser. No. 45,466, filed June 11, 1970, now U.S. Pat. No. 3,657,641 and assigned to the same assignee as the present invention, I have described in more detail anisotropic thin film plated wire of this nature. In that application the permalloy film is described as being of approximate composition of 80 percent Ni and 20 percent Fe, which composition has a low or zero magnetostrictive effect. In the present invention which is a strain detector and which depends on the magnetostrictive response of the wire, it is desirable rather to enhance the magnetostrictive effect. The two anisotropic plated wires 11 and 12 are of similar

magnetic properties, i.e. comparable H_c and H_k but each has a different degree of magnetostrictiveness. Thus in a preferred embodiment wire 11 may have a nickel rich plating composition, Ni content greater than 80 percent and has a high negative magnetostriction. Wire 12 may also have a nickel rich plating composition but to a lesser amount and the wire has a lesser or weaker negative magnetostriction than does wire 11. As shown in FIG. 3, both wires 11 and 12 are contained in a pair of flexible dielectric insulating tubings 14 and 15, such as teflon, fully attached on the side. A further inner insulation 16 may be provided, the plated wires being enclosed by the braid of shield 13 and an outer insulation 17.

In another embodiment shown in FIG. 1a wire 12' may have a nickel rich plating composition, Ni content greater than 80 percent, and has negative magnetostriction. Wire 11', on the other hand, may have an iron rich plating composition where the Fe is greater than 20 percent and the wire has a positive magnetostriction.

A high frequency sine wave oscillator 20 is connected to drive both plated wires in parallel. The return path for the current may be the common metallic shield 13. The two output conductors 21 and 22 are connected to the input of a differential amplifier 23. The processor also contains a detector, a conventional low pass-band filter and amplifier such that the signal from the differential amplifier is detected, filtered through the low pass-band filter and amplified to produce an analogue signal in the processor.

The magnetic properties of wires 11 and 12 (or wires 11' and 12') being alike, other than their degree of magnetostriction, changes in the ambient magnetic field produce equal signals in each of the wires which are applied by conductors 21 and 22, respectively, to the differential amplifier inputs. Equal signals are also produced as a result of electromagnetic disturbances. In either case the signals are nulled out by the differential amplifier 23.

If the wires are subjected to identical strains, however, the signal from each of the wires is significantly different from the other. The output of the differential amplifier is then proportional to the product of the strain and the algebraic difference of the magnetostrictive coefficients of the plated wires. Thus the apparatus which has been described is effective to cancel out signals resulting from magnetic fluctuations and to provide a report of signals generated due to strain of the plated wires.

FIG. 4 is illustrative of the magnetic response and the magnetostrictive response of the two wires of FIG. 1a. A similar presentation could be made for the embodiment of FIG. 1. In FIG. 4 the rectangles represent a peeled layer of anisotropic permalloy plating from a short segment of wire. The easy axis lies in the general direction of the X axis. The magnetization vector M is shown making a small angle with the easy axis. FIG. 4A and 4G are similar and show a typical direction of the magnetization vector M in the wires. It is not necessary that the direction in 4A and 4G be identical. The sine wave oscillator 20 which preferably is a high frequency, such as 10 megahertz, is connected in energizing or driving relation to the wires 11' and 12', the wires 11' and 12' being energized in parallel. As a result of the alternating driving currents from the oscillator the di-

rection of magnetization responds in an alternating manner as is shown in FIGS. 4B and 4H.

In FIGS. 4C and 4I a strain has appeared on the wires 11' and 12' due to the approach of an intruding object or body. The weight of an intruding body on the surface of a "semi-infinite" solid like the ground, physically disturbs the body supporting medium in which the line sensor is embedded. The line sensor is stressed by the displacement. Since wire 11' has a positive magnetostriction the strain of the wire causes an upward movement of the rotation vector from that of FIG. 4A. Since wire 12' has a negative magnetostriction the equal strain of this wire causes a downward movement of the rotation vector from that of FIG. 4G, as is clearly depicted in FIGS. 4C and 4I. FIGS. 4D and 4J show the effect of the alternating current drive on the strained wires. It is clear that the signals generated in the two wires because of a strain are manifestly different one from the other. These strain generated signals are summed by the differential amplifier 23 to provide a suitable output indicating the presence of an intruder.

FIGS. 4E and 4K reproduce in broken lines the magnetization vectors as shown in FIGS. 4A and 4G and depict in solid lines the additional rotation due to a change in the magnetic field. The magnetic field causes both wires to respond in the same direction. FIGS. 4F and 4L superimpose the alternating drive current and again it may be seen that both are alike. The magnetically generated alike signals from the two wires are balanced out or nulled out in the differential amplifier and provide a zero output from the system. Thus it may be appreciated that an improved magnetostrictive plated wire line sensor system has been provided.

The embodiments of the invention in which an exclusive property or right is claimed are defined as follows:

1. A strain sensitive line sensor detection system which senses local movement of a medium being intruded upon, the system comprising:

an extended length of a first wire on which is plated an anisotropic thin film having a first composition of nickel-iron alloy plating exhibiting a first degree of magnetostrictive response; an extended length of a second wire on which is plated an anisotropic thin film having a different composition of nickel-iron alloy plating exhibiting a different degree of magnetostrictive response, said first and second wires each having the same response to a magnetic field, said wires having an insulative covering;

means energizing said first and second plated wires from a source of alternating type current; said first and second plated wires being positioned in a side by side relation in said medium so that while magnetic field changes cause equal signals on said first and second wires, movement of said medium which strains said wires causes differing signals in one wire than the other because of the differing degrees of magnetostrictive response; and

means connecting the signals from said first and second plated wires to first and second differential inputs of a differential amplifier whereby said equal signals on said wires such as caused by a magnetic disturbance cancel one another out in the amplifier while the differing strain produced signals are summed and amplified.

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2. The invention according to claim 1 wherein said first composition of nickel-iron alloy plating has more than 80 percent Ni and exhibits a negative magnetostrictive response and wherein said second composition of nickel-iron alloy plating has less than 80 percent Ni and exhibits a positive magnetostrictive response.

3. The invention according to claim 1 wherein said

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first composition of NiFe permalloy plating has more than 80 percent Ni and exhibits a relatively high negative magnetostrictive response and wherein said second composition of NiFe permalloy plating has somewhat more than 80 percent Ni and exhibits a lesser negative magnetostrictive response.

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