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Bert et al.

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[54] **PIEZOELECTRIC DELAY LINE FOR STORING HIGH FREQUENCY SIGNALS**

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[52] **U.S. Cl.** ..... **340/173 CR;** 310/8.1; 313/394; 315/55; 340/173 MS

[51] **Int. Cl.** **G11c 27/00;** G11c 13/00

[58] **Field of Search** 340/173 CR, 173 RC, 173 MS, 340/174 MS; 310/8.1; 313/394; 315/55

[56] **References Cited**

UNITED STATES PATENTS

3,662,355	5/1972	Kazan	340/173 RC
3,750,043	7/1973	Epsztein	330/43

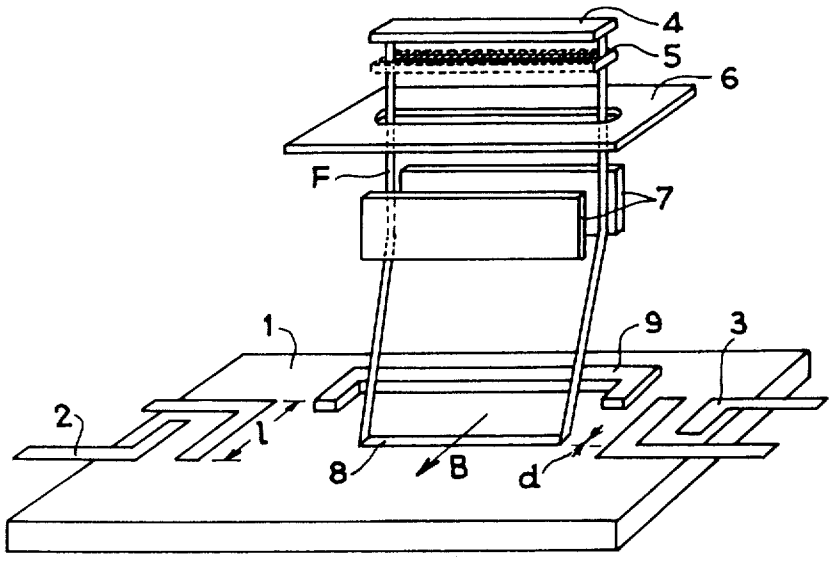
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[57] **ABSTRACT**

A device for storing high frequency signals. High frequency electrical signals to be stored are applied to a piezoelectric delay line, where they are transduced into an acoustical wave traveling along a surface of the delay line. An electron beam sweeps this surface and interacts with the line and the wave stimulating emission of secondary electrons which form an electrostatic image of the acoustical waves along this surface, thereby recording the signal or wave. Read out is accomplished by a subsequent beam sweep of the surface. The beam write and read-out sweeps may be identical, or different in time, direction, or variable, to compress/expand, reverse, or modulate the signal when read-out.

9 Claims, 2 Drawing Figures



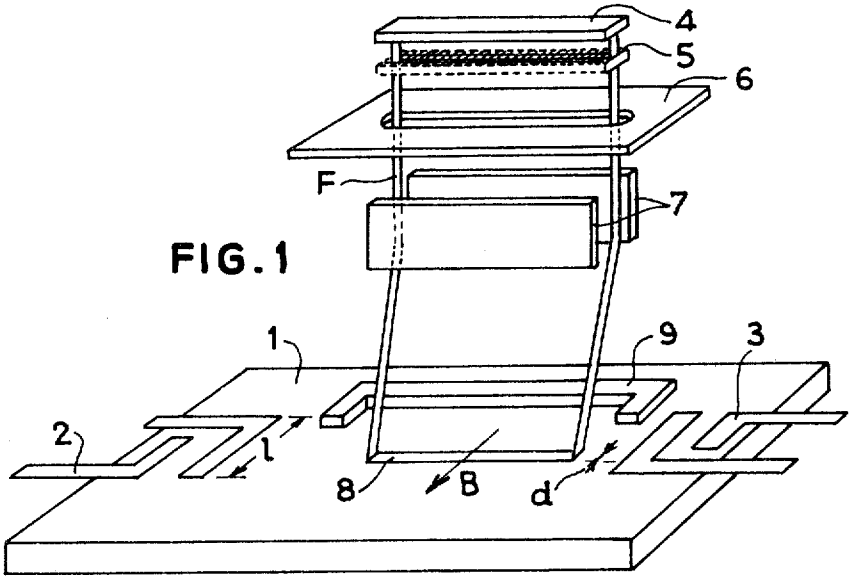


FIG. 1

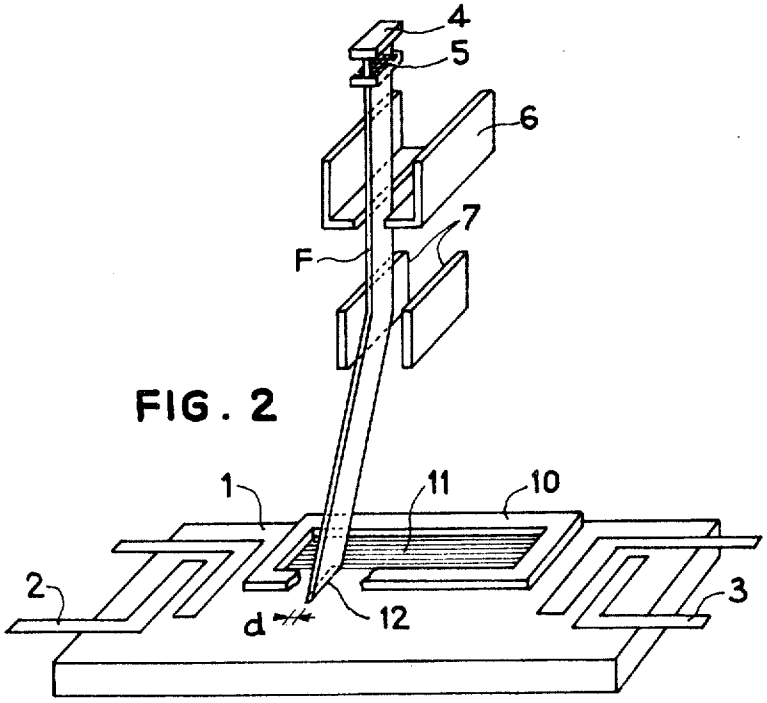


FIG. 2

PIEZOELECTRIC DELAY LINE FOR STORING HIGH FREQUENCY SIGNALS

The present invention relates generally to high frequency signal storage devices, and particularly to the use of acoustic delay lines to store high frequency signals.

Devices of this type are described in U.S. Pat. No. 3,750,043 filed on July 13, 1971 and assigned to the same assignee as the present application.

While U.S. Pat. No. 3,730,043 describes amplifying devices and storage devices; the present invention relates to storage devices only.

The storage devices described in the cited patent include a vacuum-tight chamber containing a delay-line of piezoelectrical material along which the waves to be stored are propagated and an electron gun delivering a beam of electrons striking the surface of the line where said waves are propagated.

For example, the delay line is made of a substrate of insulating piezoelectrical material, emitting secondary electrons in relatively large quantities when struck by primary electrons issuing from an electron gun. One end has an input transducer transforming the high frequency electrical signals which are to be stored, into elastic waves traveling along the surface of the substrate. The other end has an output transducer effecting the transformation in reverse when the signals thus stored are read.

The beam of primary electrons delivered by the gun at the time of recording or reading is a flat beam, intense and of short duration, striking at the same time the entire work surface of the line along the propagation surface between the two transducers.

This beam of primary electrons stimulates the emission of secondary electrons on the work surface of the line and they redistribute themselves on this surface according to the distribution potential of the surface.

When a recording is made, these secondary electrons are subjected to the influence of an electrical field related to the surface acoustic wave, the amplitude of which is sufficient to modify their trajectory. They are attracted to the zones of greatest positive potential and remain trapped on the surface where they almost immediately, form an electrostatic image of the signal. This image remains fixed to the surface indefinitely so long as the work surface of the line is sufficiently insulating.

Whenever a reading is desired, it is the reverse piezoelectrical effect which unblocks the stored signal. In fact, the static charges of the electrostatic image presented on the work surface create mechanical stresses in the material. The secondary electrons produced when the primary electron beam strikes the work surface of the line are attracted to the zones of greatest positive potential along the surface and rapidly nullify the amplitude of the wave of electrostatic potential recorded, as well as cancel related mechanical stresses. This rapid variation involves the stimulation of two electrical surface waves which travel in opposite directions. The wave traveling in the same direction as the wave initially recorded, and collected at the output transducer, is the exact reproduction of that wave, whereas the wave traveling in the opposite direction and collected in the input transducer is the reproduction of the recorded wave but reversed in time.

Such devices are particularly valuable in the construction of static storage analogs, with frequencies and transmission ranges heretofore unobtainable in previous devices.

However, in order to obtain a proper reproduction in the recorded waves, these devices require that the duration of the strike of the primary electron beam be short in comparison to the period of the recording phenomenon represented by the acoustical wave being propagated. The duration of the strike must be equal to or less than one quarter of this period. For example, in order to record a signal with a 100 MHz frequency, an unblocking time of 2.5 nanoseconds is required for the primary electron beam. This necessitates ultra-rapid electronic systems which are difficult to implement when the frequencies are greatly increased.

An object of the present invention is to produce devices for storing signals using the above process (for the emission of secondary electrons by piezoelectric materials) but requiring less rapid electronics, while allowing an exact reproduction of the recorded signals.

Among other objects of this invention are the creation of storage devices allowing the processing of signals to be recorded at the same time as they are stored. These processes include inversions in time, compressions, frequency modulations.

In order to obtain these objects, the devices of the present invention make use of a thin beam of primary electrons associated with a deflection device. This device allows for a progressive sweep of the surface of the line by the primary electrons rather than a beam striking the entire surface at once.

Other purposes and characteristics of the present invention will appear in the course of the ensuing description, submitted by way of non-limitative examples and illustrated by the attached drawings in which:

FIG. 1 is a diagrammatic view, in perspective, of a storage device according to a first embodiment of this invention;

FIG. 2 is a diagrammatic view in perspective of a storage device according to a second embodiment of this invention.

In the drawings, like elements in both Figures bear like legends. FIGS. 1 and 2 show two different embodiments of the present invention. Both use a thin electron beam to sweep a delay line. As shown in both Figures, there is a block 1 of a strongly piezoelectric material which constitutes the delay line, and on which there are two transducers 2 and 3. One transducer is the input bringing a signal that is to be stored, and the other is the output to which is delivered a signal being read-out.

An electron gun 4, 5, 6 delivers a thin beam F of primary electrons. It has a cathode 4 for emitting electrons; an electrode or grid 5, for controlling the intensity of the electron beam from the cathode; an electrode or anode 6 for accelerating this beam, and a deflection system for deflecting the electron beam F and which is shown as having two electrostatic deflection plates 7.

All the elements which make up this storage device are arranged in a vacuum-tight enclosure (not shown), which can be a metal chamber, and through which pass electrical circuits (not shown) and over which are applied voltages and electrical signals required for the proper functioning of these elements.

In the embodiment of FIG. 1 which will now be more specifically described, beam F is a flat beam whose area

of impact on the surface of the delay line **1** is a rectangle **8.** The length of this rectangle is parallel to the direction of propagation of the acoustical waves travelling between the two transducers.

An electrode **9** placed, for example, on or near the surface of line **1** is struck by the beam, and is raised to a positive potential in relation to cathode **4,** and close to the acceleration electrode **6,** collects electrons which have not been picked up by the work surface of line **1** at the time of its bombardment by beam F and at the time of the production of secondary electrons along the surface. This electrode also regulates the equilibrium potential of this surface.

Said electrode **9,** represented here in the form of a metal grill can be replaced by a grid such as the one on FIG. **2** which is made of thin wires **11** parallel to the direction of acoustical wave propagation and carried by a metal grid **10,** this grid being carried to the same potential indicated for electrode **9.** This grid can be arranged directly on the surface.

It is also possible to eliminate this electrode, since the metal chamber in which the elements are enclosed is perfectly capable of carrying out its function. In that case it would be better if the chamber has a zero potential or reference potential so that the cathode can then be carried to a negative potential in relation to its reference potential.

The deflection plates **7** arranged parallel to the length of a transverse cross section of beam F (as shown in The Figures) are controlled by a saw-toothed voltage which permits the area of impact **8** of the beam F on line **1** (FIG. **1**) to sweep the work-surface of this line in a direction perpendicular to the one in which the acoustical waves are travelling.

The off position of beam F, i.e. when not recording and reading, is such that the beam, or at least the residual current of the beam — which is normally blocked by grid **5** on which a blocking current with a negative potential in relation to the cathode is applied, — does npt strike the work surface of the line **1,** in order to prevent previously recorded signals from being erased. This residual current can be collected by electrode **9** for example, or even by the device's chamber.

Different modes of operation of this storage device are possible.

In a first mode of operation, the electrical signal gathered after reading is an exact reproduction of the signal recorded. The electrical signal which is to be stored is applied to transducer **2** which then serves as the input transducer. The corresponding acoustical wave travels toward transducer **3** or the output transducer. Beam F is then unblocked by control grid **5** while a saw-tooth voltage is applied between plates **7** so that the area of impact **8** of the beam F sweep along the work surface of the line **1,** in the direction indicated by arrow B. When this sweeping of the work surface is completed, beam F is blocked once again and restored to its rest position.

The redistribution of electrical charges along the surface of line **1,** due to secondary electrons emitted and collected by this surface, is produced according to a mechanism described in the above cited U.S. patent. In the present device, the redistribution takes place only in the region of the surface of the line struck by the beam, that is the area swept by **8.**

If the total duration tB of a transversal sweep (arrow B) is not weak during the acoustical wave period, such as is the case with devices of the present invention, the signal is not recorded in perpendicular lines in the direction of propagation, but along lines which are oblique to this direction.

Indeed, if l is the width along the transducer, then the acoustical wave fronts, (i.e. the points of the work surface corresponding to the waves having the same potential and emitted at the same time along the width l of transducer **2**) are situated along lines parallel to l, i.e. lines which are perpendicular to the direction of wave propagation.

The various points along width l of these wave fronts are not recorded at the same time; if the first part of this wave front is recorded at a time of $t = 0$ (beginning of the sweep along B), the last part will be recorded at a time of $t = t_B$ (end of the sweep along B.) The elastic waves having continued to travel during the duration t_B of the sweep, the points recorded on a line parallel to B no longer have the same amplitude as the acoustical wave. The recorded lines having the same amplitude as the acoustical wave are oblique lines; the end of these lines, recorded at the end of the sweep, is closer to transducer **3** than their beginning.

Once the recording has been made, read-out is done by a sweep identical to the recording sweep. The waves, created consecutively, by the secondary electrons' cancellation of mechanical stresses, are added in phase. The two sweeps compensate each other, and reproduce the initial signal on the output transducer **3.**

In this device, when the beam simultaneously strikes the entire length of surface section **8,** the propagating waves, the thickness of the beam, and thus the width d of the area of impact **8,** are not critical.

The width d is determined by taking into consideration speed V of the beam movement on the crystal's surface.

Let d' be the width of the zone of action of the beam on line **1**; — d' is in fact slightly larger than d because the width of this zone of action takes into consideration the redistribution of secondary electrons along the outside of impact area **8** of the primary electron beam.

In devices of the present invention, one condition that must be fulfilled if the read-out signal is to accurately reflect the recorded signal is that the time during which the secondary electrons redistribute themselves along each point of the work surface of the line be equal to or less than one-quarter of the period T of the signal to be recorded, i.e. one must have:

$$d'/V < T/4$$

If this condition is compared to that required for the storage device of the earlier patent, it becomes clear that beam F remains unblocked longer (in l/d' relation) in the present device than in earlier devices. Indeed, this is one of the aims of the present invention.

One may note further that in both cases, the density of the current at the point of beam impact on the work surface of line **1** has the same value. But, in prior devices in which the bombardment simultaneously involves the entire surface a bombardment of very short duration must be used, in the present devices, this bombardment takes a longer period of time. Obviously the beam's density is the same in both cases. Moreover, in the present invention, the command of the beam is greater and leads to a more convenient modulator and grid circuit design. Also there is no criticality on the

wave fronts; and obtaining a saw-tooth sweep for the devices under consideration presents no problem.

In a second mode of operation, the device in FIG. 1 produces an output signal which is the reproduction of the input signal, except that it is inverted in time.

In order to achieve this mode of operation the recording process should be carried out in the same way as described above; the read-out can be done by allowing the work surface of line 1 to be swept by beam F in the direction opposite to direction B used for the recording. The output signal can be collected on the same transducer 2 which was used as the input transducer.

In the operation of FIG. 2, beam F is a flat beam whose area of impact on delay line 1 is a rectangle 12 the length of which is perpendicular to the direction of propagation of the acoustical waves between the two transducers, while its width d is parallel to this direction.

The deflection plates 7 cause a sweep of the work surface of line 1 by beam F, (unblocked by control grid 5) whenever a signal applied to the input transducer 2 is to be recorded, or whenever a signal is to be read-out on the output transducer 3. The sweep takes place in a direction parallel to the direction of acoustical wave propagation.

The procedures for recording and read-out are the same as before.

The condition relating to the width d of the beam, and d' of its zone of action, are exactly the same as in Flg. 1.

But, in the mode of operation with which we are concerned here, the length of the wave of the recorded phenomenon may not be equal to the length of the acoustical wave; its value depends on the relationship between the speed with which beam F sweeps the target and the speed at which the acoustical wave travels along line 1.

Indeed, if Va is the speed at which the acoustical wave is propagated, and Vf is the speed of the electron sweep and No the length of the acoustical wave, the wave lengths N of the recorded phenomenon are transformed by a Doppler effect according to the relation

$$N = \left| Vf/(Vf - Va) \right| No$$

It is important to note that this relation holds no matter what the relative direction of Vf and Va since the sweep can be effected from transducer 2 toward transducer 3 or vice versa.

Thus, depending on the direction and the speed of sweep Vf, the recording will be either a faithful reproduction with $N \approx No$, or a recording accompanied by a spatial compression of the signal ($N<No$), or a recording accompanied by a frequency modulation of the signal.

For example, in order to obtain on output transducer 3, a signal corresponding to that applied on input transducer 2, beam F ought to sweep the work surface in the same direction as the propagation of acoustical waves; the condition relating to its width d defined in connection with FIG. 1 will give the minimum speed V min of this sweep:

$$V \min = 4\, d\, f$$

f being the frequency of the signal applied at 2, for example, 100MHz.

For a beam whose width d (not very different from the zone of action d') is on the order of 0.1 mm one obtains V min = 4 cm/μs.

This speed is greater than the speed of propagation Va of the acoustical wave. In fact, on a quartz crystal for example, a Rayleigh wave is propagated at a speed of $Va = 0.3$ cm/μs. Under these conditions, the apparent wave length of the recorded wave is very close to the actual wave length.

The signal obtained on transducer 3 after read-out by a beam identical to the writing beam is an obviously close reproduction of the signal applied on 2.

By sweeping the crystal in the same direction as the elastic waves travel, but at a slower speed than the one described above, the wave length of the one which is recorded increases, and the recorded signal is expanded or dilated in relation to the signal applied at the input transducer. If a read-out is then done with a reading beam having a speed of Vf raised in relation to Va, such as the one defined above, the signal restored on the output transducer is dlated dilated relation to the input signal in essentially the same proportions as was the recorded signal. If a reading is made with a reading beam identical to the recording beam, then the output signal is even more dilated than the recorded signal.

By sweeping always in the same direction as the waves are propagated, but with a variable speed Vf in the recording sweep and/or in the reading sweep, it is possible to obtain a frequency modulation of the signal restored after read-out.

Finally, if the crystal is swept upon recording in a direction opposite to the propagation of acoustical waves, the recorded signal is compressed in relation to the input signal and it becomes possible to record on the line a signal which is longer than the transit time of the acoustical wave between the two transducers.

If the read-out is then accomplished with a reading beam sweeping the crystal in a direction opposite to the recording sweep and at a high speed of Vf, such as the speed defined above, the output signal is compressed in relation to the input signal, in about the same proportions as was the recorded signal. If however, the read-out is done with a reading beam identical to the recording beam, then the output signal essentially reproduces the input signal.

Thus, by choosing the sweep speed Vf of the recording beam, as well as of the reading beam, and the direction of the sweep in relation to the direction of propagation of the elastic waves on the crystal, it is possible, in addition to the storage of this signal, to process it in many ways such as compression, expansion, or frequency modulation. All these are a part of the present invention.

We claim:

1. A device for storing travelling surface waves comprising, inside a vacuum tight enclosure;

a delay line made of an elongated block of piezoelectric material producing secondary electrons when struck by primary electrons;

two transducers, each one being mounted at an extremity of said elongated block, for transducing high frequency electrical signals into acoustic waves and vice-versa, said acoustic waves propagating between said two transducers along a propagation path defining a substantially rectangular work surface;

an electron gun for emitting a thin beam of primary electrons towards said work surface, said electron gun being designed and controlled for providing for said electron beam a substantially rectangular cross-section smaller than said work surface, in such a way that said electron-beam strikes said work surface along a substantially rectangular impact surface which is a narrow band of said work surface;

and deflection means for deflecting said electron beam so that said beam substantially sweeps the whole surface of said work surface.

2. A device according to claim 1 wherein said electron gun is so designed and controlled that the rectangular impact surface on said work surface of the thin beam it delivers has its longest side parallel to the direction of acoustical wave propagation on said work surface, said deflecting means displacing said beams so that said impact surface sweeps said work surface perpendicular to the direction of acoustical wave propagation.

3. A device, according to claim 2, wherein one of said transducers includes means for receiving the high frequency electric signals to be stored, said deflecting means displacing said beam so said impact surface sweeps said work surface while the acoustic wave from said high frequency electric signal is propagating thereon, and for subsequently displacing said beam in an identical sweep restoring said acoustic wave, whereby the electric signals delivered by the other transducer being substantially the same as those applied to said one transducer.

4. A storage device, according to claim 2, wherein one of said transducers includes means for receiving the high frequency electric signals to be stored, said deflecting means for displacing said beam so said impact surface sweeps said work surface while the acoustic wave is propagating thereon, and for subsequently displacing said beam in a reverse sweep restoring said acoustic wave, whereby the electric signals delivered by said one transducer being reversed from those applied to said one transducer.

5. A storage device according to claim 1 in which the said electron gun delivers a thin beam whose surface of impact on the said work surface is rectangular, its length being perpendicular to the direction of acoustical wave propagation on said work surface, said deflection means displacing the beam so said impact surface on the said work surface sweep parallel to the said direction of acoustical wave propagation.

6. A device according to claim 5, wherein the deflection means displacing said beam in a reverse direction to the direction of the propagation of acoustical waves on the said work surface.

7. A device according to claim 5, wherein the deflecting means displacing said beam in the same direction as the direction of acoustical wave propagation on the said work surface, with the speed of this sweep being variable.

8. A storage device according to claim 5 wherein one of said transducers includes means for receiving the electrical signals to be stored, and the other of the transducers includes means for delivering the restored electrical signals.

9. A storage device, according to claim 8, wherein said deflecting means for displacing said beam so said impact surface sweeps said work surface while the acoustic wave is propagating thereon and in the same direction as the direction of the propagation of acoustical waves on the said work surface, with the speed of this sweep being superior to the speed of the said propagation of acoustical waves; and for subsequently displacing said beam in an identical sweep restoring said acoustic wave, whereby the electric signals delivered by the other transducer are substantially the same as those applied to said one transducer.

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