United States Patent [19]

Weglein

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[54] **ACOUSTIC SURFACE WAVE DEVICE WITH REDUCED RF FEEDTHROUGH**

[75] Inventor: **Rolf D. Weglein,** Los Angeles, Calif.

[73] Assignee: **Hughes Aircraft Company,** Culver City, Calif.

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[21] Appl. No.: **430,360**

[52] **U.S. Cl.**..... **333/30 R,** 310/9.8, 333/72

[51] **Int. Cl.**..... **H03h 9/26,** H03h 9/30, H01v 7/00

[58] **Field of Search**..... 333/30 R, 30 M, 72; 310/8, 310/8.1, 9.7, 9.8

[56] **References Cited**

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3,573,673	4/1971	De Vries et al.	333/72
3,723,919	3/1973	Adler	333/30 R X

Primary Examiner—James W. Lawrence
Assistant Examiner—Marvin Nussbaum
Attorney, Agent, or Firm—W. H. MacAllister, Jr.; John Holtrichter, Jr.

[57] **ABSTRACT**

An acoustic surface wave device of the type having a launching transducer and a receiving transducer disposed in relatively close proximity on a substrate of piezoelectric material wherein the dynamic range of the device is increased by the reduction and elimination of spurious responses resulting from undesired, RF feedthrough signals due to direct coupling between the transducers, the device incorporating a radiating element or structure disposed in the vicinity of the launching transducer and fed RF input signal energy in phase opposition to "buck" out the leakage component at the receiving transducer because the bucking signal energy generated by the radiating element is seen at the receiving transducer to be of equal magnitude and out of phase with the directly coupled leakage component thereat.

8 Claims, 7 Drawing Figures

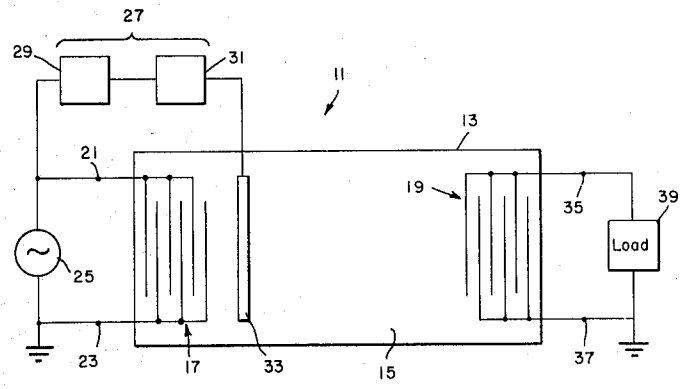


Fig. 1.

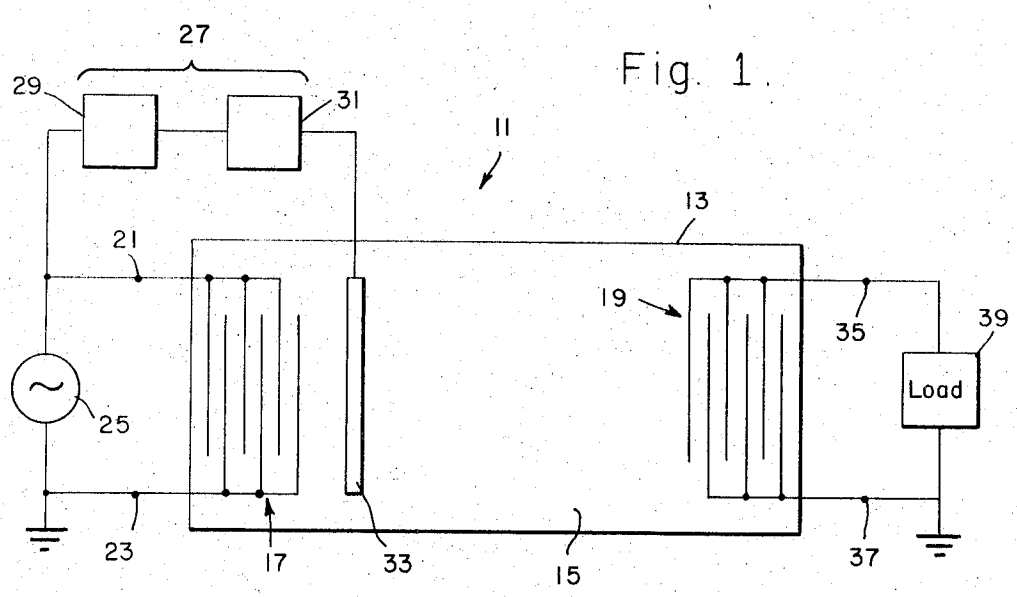


Fig. 2.

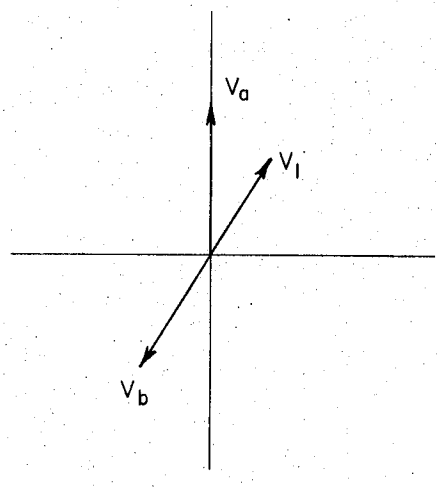


Fig. 3.

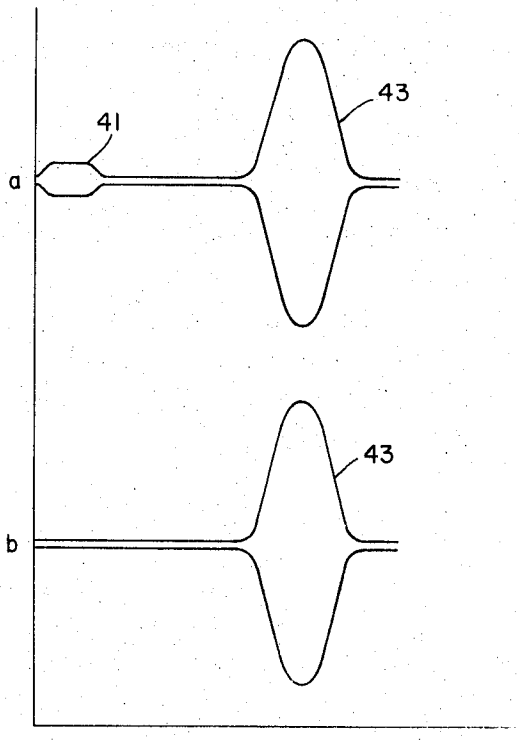


Fig. 4.

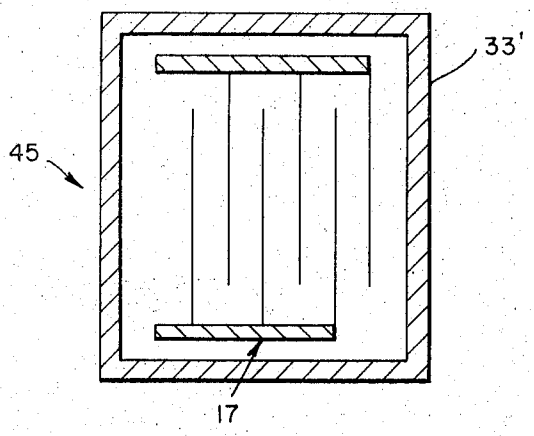


Fig. 5.

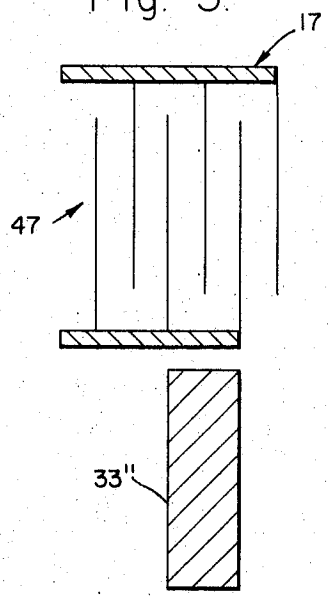


Fig. 6.

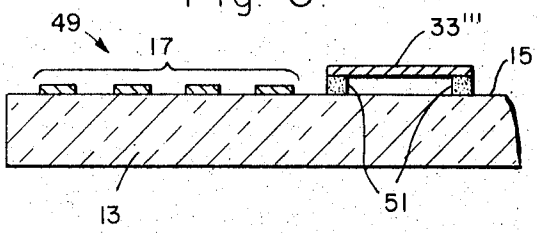
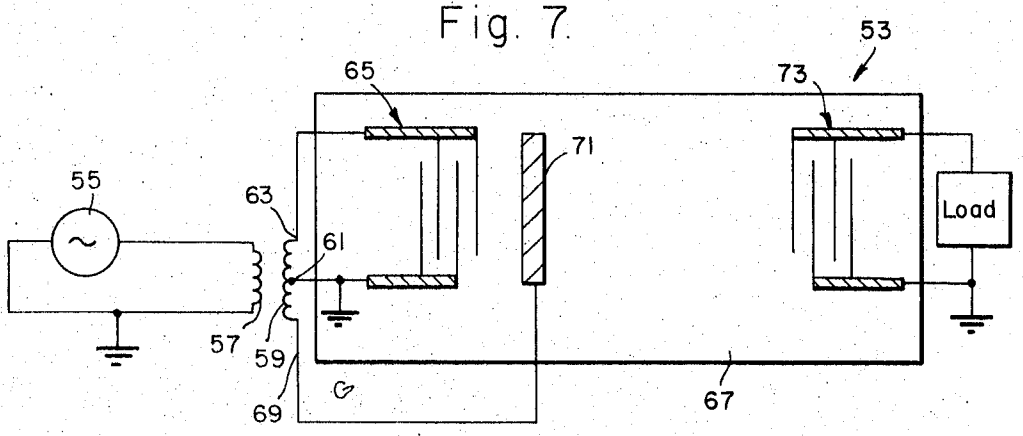


Fig. 7.



ACOUSTIC SURFACE WAVE DEVICE WITH REDUCED RF FEEDTHROUGH

BACKGROUND OF THE INVENTION

The background of the invention will be set forth in two parts.

1. Field of the Invention

This invention relates generally to acoustic surface wave devices and more particularly to such devices incorporating r.f. feedthrough reducing arrangements.

2. Description of the Prior Art

The availability for beneficial use of acoustic waves that propagate along a boundary surface is well known. This phenomenon was first described by Lord Rayleigh in an article entitled "On Waves Propagating Along the Plane Surface of an Elastic Solid," *Proceedings*, London Mathematics Society, Vol. 17, pages 4–11, Nov. 1885. Devices utilizing such acoustic surface waves have the advantage of allowing easy access at all times to the propagating acoustic energy, to sample it, to modify and to interact with it.

The typical particle motion associated with acoustic surface waves is elliptical retrograde and the amplitude decays exponentially with depth into the body of the acoustic surface wave-propagating medium. Thus, acoustic surface waves are localized at the surface of solids, typically of piezoelectric material such as quartz and lithium niobate ($LiNbO_3$), and bismuth germanium oxide ($Bi_{12}Ge0_{20}$), for example.

The advantageous use of acoustic surface wave techniques (elastic waves) has probably been most pronounced in devices operating at very high frequencies (VHF), ultra high frequencies (UHF), and microwave frequencies. It has been found that such operation provides excellent transmission characteristics and relatively low propagating velocities of approximately 5 orders of magnitude less than that of the speed of light or that of electromagnetic waves. As an example, an elastic wave resonator operating at a given frequency is typically 100,000 times smaller than an electromagnetic wave resonator for the same frequency, and the low propagation losses of the acoustic medium allows delay times of about 100 times that possible with low-loss electromagnetic waves.

The basic building block of all surface wave devices is the acoustic surface wave delay line which includes spaced transducers disposed on a surface wave supporting medium. The transducers provide transitions from normal electric circuitry into the acoustic domain.

Transducers designed for operation with piezoelectric media, most commonly are of the interdigital type consisting of a series of conductive electrodes that form a pattern which is disposed on the piezoelectric substrate surface. Such transducers are two-terminal devices having two separate arrays of metal strips resembling interleaved fingers, and convert electrical signals into acoustic surface waves, and also are capable of converting such elastic wave energy incident thereon into electrical signals. In the case of an input signal transducer, an incoming electrical signal is converted by the transducer into a time-dependent spatially varying electrical field pattern which in turn generates and launches an acoustic surface wave directly on the substrate through the piezoelectric action of the substrate material.

In the past, spurious responses in acoustic surface wave delay devices have occurred as a result of undesired r.f. energy feedthrough coupling between the launching and receiving transducers. This type of spurious signal has no delay since it travels in space between the transducers at the speed of light and not through the acoustic medium which has a much slower propagation velocity characteristic.

Several schemes have been developed over the years in an effort to at least reduce such undesired electromagnetic intertransducer coupling. One such scheme is to balance opposite polarity signal components at the launching transducer, as exemplified in U.S. Pat. No. 3,573,763. In this approach, at least one of the transducers, and preferably both, are coupled to their respective source and load by circuitry which causes the signals developed across the transducers to be balanced with respect to ground, both terminals of the launching transducers being above ground potential. Thus, undesired feedthrough signal energy developed at the receiving transducer has two components of equal but opposing values, and hence cancelling polarities.

Another scheme described in the foregoing patent utilizes the shielding effect of a plane or planes of fixed reference potential disposed between a launching and receiving transducer. The shield element is operated at ground potential and has no signal currents thereat in order to minimize the potential of these shielding electrodes that otherwise might create coupling fields to the electrodes in adjacent transducers. This type configuration can be very effective for relatively long delays (greater than 1 μsec) where sufficient space is available between transducers to produce adequate shielding. It should therefore be evident that in applications having relatively short delays (less than 1 μsec), adequate space is generally not available to introduce shielding fixtures. As an example, a time delay of 0.1 μsec spans a distance of 0.3 mm (or 12 mils). The problem is that effective shielding must not only reduce the direct r.f. feedthrough component to tolerable levels, but must simultaneously leave the performance of the surface wave device unaltered. Thus, as the desired delay decreases, the shielding structure must be brought into closer proximity to the transducers, where eventually, interaction with the transducers may impair the electrical perfomance of the device.

SUMMARY OF THE INVENTION

In view of the foregoing factors and conditions characteristic of the prior art, it is a primary object of the present invention to provide an improved acoustic surface wave device with reduced r.f. feedthrough.

Another object of the present invention is to provide a very simple yet efficient construction for an acoustic surface wave device with reduced feedthrough, having relatively short delays.

Yet another object of the present invention is to provide an acoustic surface wave device with reduced direct r.f. feedthrough and incorporating an ungrounded bucking electrode disposed adjacent a launching transducer.

In accordance with an embodiment of the present invention, an acoustic surface wave device includes a substrate of piezoelectric material capable of propagating acoustic surface wave energy and transducer means including at least a launching transducer for converting an electrical input signal into acoustic surface waves

propagating along the substrate. The transducers may also include an associated receiving transducer for converting the acoustic surface waves incident thereon into electrical signals with a delay essentially determined by the propagating velocity characteristic of the substrate material and the distance between the launching and receiving transducers, the distance being sufficiently small that a direct r.f. feedthrough signal coupling exists between the transducers. The device further includes bucking means with a phase shifting electrical arrangement coupled to the electrical input of the launching transducer and with a conductive bucking electrode structure disposed adjacent the launching transducer and coupled to the electrical arrangement for coupling directly to the receiving transducer a bucking signal of equal magnitude and opposite phase than that of the direct r.f. feedthrough signal.

The features of the present invention which are believed to be novel are set forth with particularity in the appended claims. The present invention, both as to its organization and manner of operation, together with further objects and advantages thereof, may best be understood by making reference to the following description taken in conjunction with the accompanying drawings in which like reference characters refer to like elements in the several views.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic plan view of an embodiment of the present invention;

FIG. **2** is a graphical illustration of electrical signals incident on the receiving transducer of FIG. **1**;

FIG. **3** illustrates typical oscilloscope patterns of electrical output signals from the receiving transducer of FIG. **1**, one without a bucking signal applied and one with such a signal applied thereto;

FIG. **4** is a partial schematic plan view of an alternate launching transducer and bucking electrode arrangement in accordance with another embodiment of the invention;

FIG. **5** is a partial schematic plan view of another alternate launching transducer and bucking electrode arrangement, in accordance with still another embodiment of the present invention;

FIG. **6** is an elevational view illustrating yet another embodiment of the present invention; and

FIG. **7** is a schematic illustration of still a further embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT:

Referring now to the drawings and more particularly to FIG. **1**, there is shown an embodiment of the invention in the general form of a simple delay line **11** that includes an elongated slab or substrate **13** of piezoelectric material such as, for example, *y–z* $LiNbO_3$, on a planar surface **15** on which are disposed by any conventional means a launching electro-acoustic transducer **17** and a receiving electro-acoustic transducer **19**.

The launching transducer **17** is a two-terminal device of the interdigital type across which terminals **21** and **23** is coupled a source **25** of r.f. input signal energy, lower terminal **23** being connected to a common return or ground. Also connected to the source **25** is a phase shifting electrical arrangement **27** including a phase shift network **29** and an attenuator **31**, the latter being connected to a conductive bucking electrode structure **33** that is disposed, in this embodiment, on the substrate surface **15** adjacent the launching transducer **17**.

Acoustic surface waves launched along the substrate **13** toward the receiving interdigital transducer **19** in response to r.f. input signal energy, propagate to and are incident on the receiving transducer which converts the surface waves into electrical signals appearing at its terminals **35** and **37** and the load **39** connected thereto. The received electrical signals are delayed an amount essentially determined by the propagating velocity characteristic of the substrate material and by the distance between the launching and receiving transducers.

In the case where relatively short delays (less than 1 μsec) are required, the distance separating the transducers is relatively short and a significantly high level of r.f. feedthrough signal will be coupled either capacitively, inductively, or both, from the launching transducer **17** to the receiving transducer **19**. This directly coupled feedthrough signal represents a serious spurious response having no delay and which, if not reduced, will decrease the dynamic range and/or signal purity of the device **11**. The magnitude and phase of the feedthrough leakage signal, V_1, relative to that of the signal applied to the launching transducer V_a is illustrated in FIG. **2**. The r.f. feedthrough signal is also illustrated at trace *a* in FIG. **3** as the smaller spurious response **41** with no delay as compared to the desired delayed output signal **43**.

In accordance with the invention, a portion of the r.f. input signal is processed in the phase shifting arrangement **27** and is applied to the bucking electrode structure **33** to be directly coupled to the receiving transducer **19** so that there is incident thereat a bucking signal of equal magnitude but opposite phase to the undesired feedthrough signal, as illustrated by the magnitude and direction of the vector labeled V_b in FIG. **2**. With this diametrically opposed signal introduced in conjunction with the feedthrough signal, there occurs a cancellation of these two directly coupled, "no delay" signals without impairment of the desired electrical performance of the device. The desired results of this cancellation is shown in oscilloscope trace *b* of FIG. **3**. The phase shift network **29** and the attenuator **31** are of conventional design and may be adjustable so that maximum cancellation of the spurious feedthrough signal may be obtained by monitoring the output signal of the receiving transducer while varying the amount of phase shift and the magnitude of the bucking signal.

FIGS. **4**, **5** and **6** illustrate differing launching transducer-bucking electrode structure configurations **45**, **47** and **49**, respectively, in accordance with the present invention. In FIG. **4**, the bucking electrode structure **33'** is in the form of a hollow rectangular or square structure surrounding the launching transducer **17**, while the bucking structure **33''** in FIG. **5** is disposed at the side of the transducer **17**, and mounted as electrode **33'''** above the substrate surface **15** on spaced insulating strips **51** downstream of the transducer **17** in FIG. **6**. In all cases, the phase shift and magnitude of the bucking signal radiated by the bucking structure is chosen to cancel the spurious, directly coupled, r.f. feedthrough signal appearing at the receiving transducer **19**.

Referring now to FIG. 7, there is shown another embodiment 53 of the invention. Here, an input r.f. signal source 55 is connected to a primary coil 57 which couples the signal to a center tapped, balanced, secondary coil 59. The input signal developed across the portion of the coil 59 between the center tap 61 and the upper end 63 thereof is connected to a launching transducer 65 disposed on a piezo-electric substrate 67, the center tap and the lower terminal of the transducer being returned to ground as illustrated in the figure. The opposite end 69 of the coil 59 develops a bucking signal of equal magnitude and opposite phase to the input signal coupled to the launching transducer 65 and is connected to a bucking electrode structure 71 so that all directly coupled r.f. feedthrough energy incident on a receiving transducer 73 is cancelled out. In this embodiment, the balanced coil arrangement provides the required opposing phase relationship while the positioning and orientation of the bucking electrode 71 provides the required equal magnitude parameter to cause cancellation of the directly coupled spurious signal.

From the foregoing, it should be evident that there has been described an improved acoustic surface wave device which incorporates simple, yet effective means for cancelling a significant portion of any directly coupled r.f. feedthrough signal energy incident on a receiving transducer. It should also be understood that the materials and structural elements used in fabricating the various embodiments of the invention are not critical and any material and elements or circuitry generally considered suitable for a particular purpose or application may be utilized.

Accordingly, it should be realized that although the present invention has been shown and described with reference to particular embodiments, various changes and modifications are possible within the knowledge of those skilled in the art and are therefore deemed to lie within the spirit, scope and contemplation of the invention.

What is claimed is:

1. An acoustic surface wave device, comprising:

a substrate of piezoelectric material capable of propagating acoustic surface wave energy;

transducer means including at least a launching transducer for converting an electrical input signal into acoustic surface waves propagating along said substrate, and including an associated receiving transducer for converting said acoustic surface waves incident thereon into electrical signals with a delay essentially determined by the propagating velocity characteristic of the substrate material and by the distance between said launching and receiving transducers, said distance being sufficiently small that a direct r.f. feedthrough signal coupling exists between said transducers; and

bucking means including a phase shifting electrical arrangement coupled to the electrical input of said launching transducer and also including a conductive bucking electrode structure disposed adjacent said launching transducer and coupled to said electrical arrangement for coupling directly to said receiving transducer a bucking signal of equal magnitude and opposite phase than that of said direct r.f. feedthrough signal.

2. The device according to claim 1, wherein said phase shifting electrical arrangement includes a phase shift network and an attenuator coupled between said electrical input of said launching transducer and said bucking electrode structure.

3. The device according to claim 2, wherein said phase shift network and said attenuator are adjustable.

4. The device according to claim 1, wherein said bucking electrode structure is an elongated conductive strip disposed on said substrate surface between said launching and receiving transducers.

5. The device according to claim 1, wherein said bucking electrode structure is a hollow rectangular conductive strip disposed on said substrate surface and surrounding said launching transducer.

6. The device according to claim 1, wherein said bucking electrode structure is an elongated conductive strip disposed on said substrate at one side of said launching transducer.

7. The device according to claim 1, wherein said bucking electrode structure is a relatively wide elongated conductive strip disposed in insulative relationship above said substrate surface.

8. The device according to claim 1, wherein said phase shifting electrical arrangement includes a balanced center tapped coil across half of which is coupled said launching transducer and across the other half of which is coupled said bucking electrode structure.

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