United States Patent

Jones et al.

[15] **3,675,054**

[45] **July 4, 1972**

[54] SERIES CONNECTION OF INTERDIGITATED SURFACE WAVE TRANSDUCERS

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[22] Filed: **Dec. 2, 1970**

[21] Appl. No.: **94,305**

[52] **U.S. Cl.** .....**310/9.8,** 310/8.1, 333/30 R, 333/72

[51] **Int. Cl.** **H01v 7/00**

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

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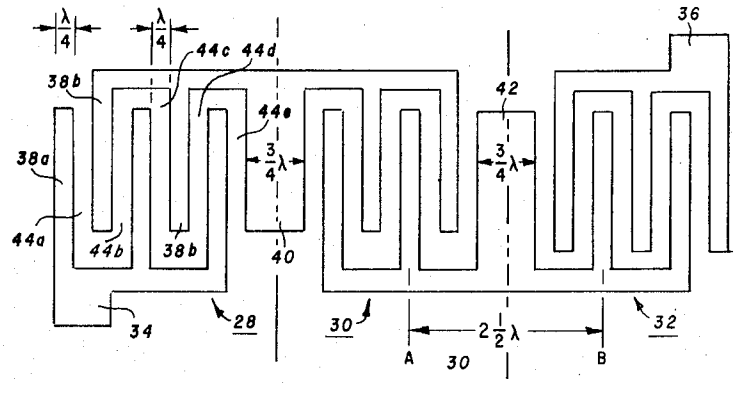
[57] **ABSTRACT**

In a transducer in which a plurality of acoustic sections are cascaded in series, a plurality of electrical sections are also cascaded in series to produce a relatively long interdigitated surface wave transducer having a relatively large input impedance. In one embodiment, electrical cascading is effected so that the interconnected acoustic sections are in phase with each other. In a different embodiment the series electrical cascading produces a phase reversal between the interconnected acoustic sections.

16 Claims, 13 Drawing Figures



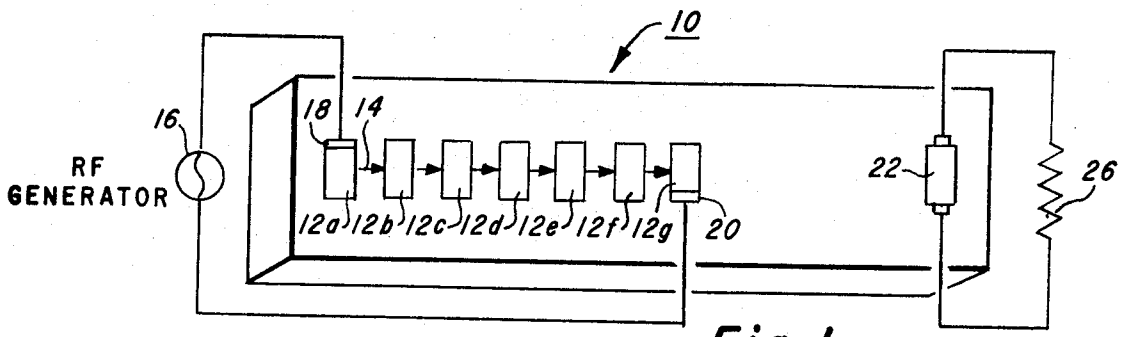


Fig. 1

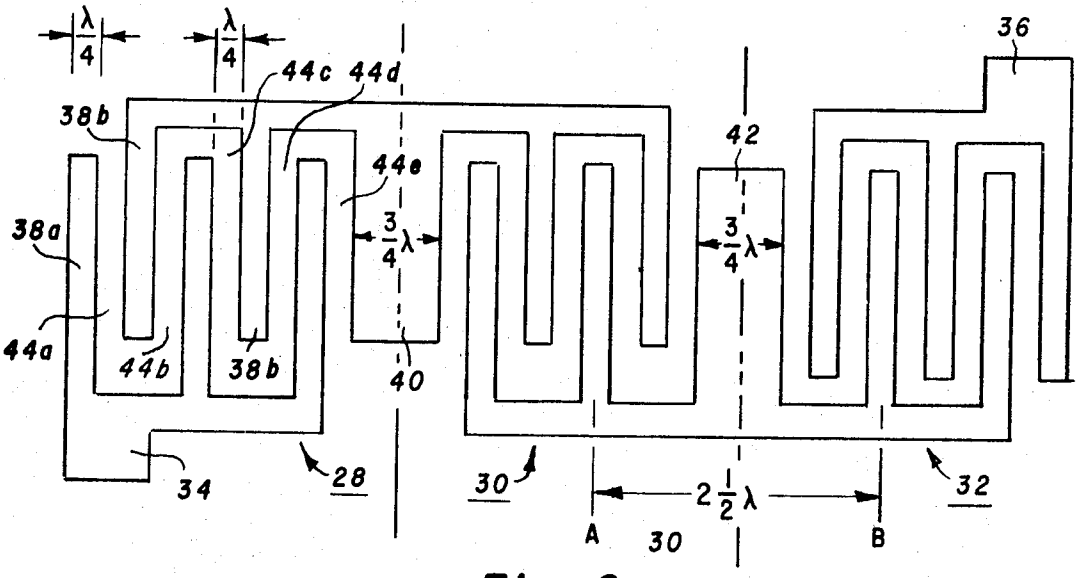


Fig. 2a

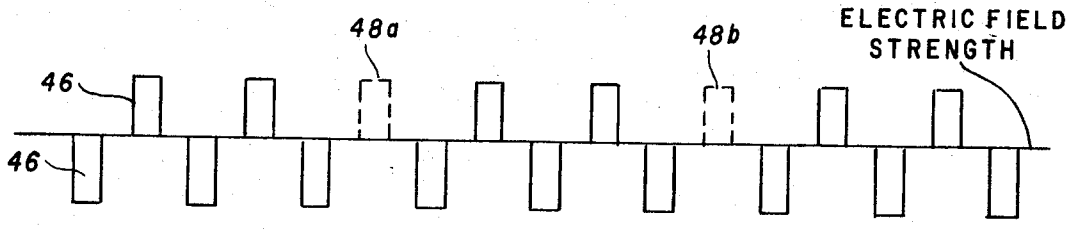


Fig. 2b

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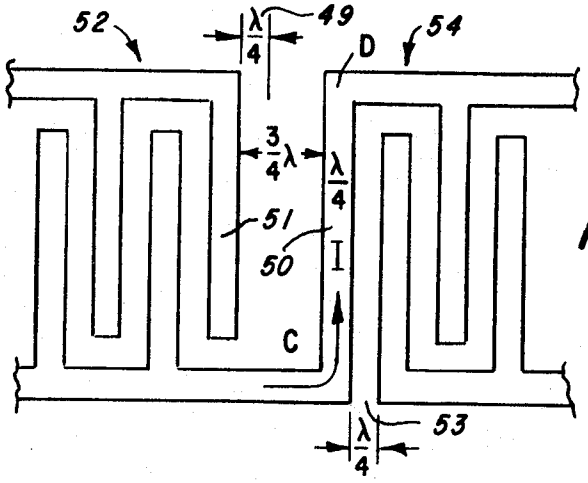

Fig. 3a

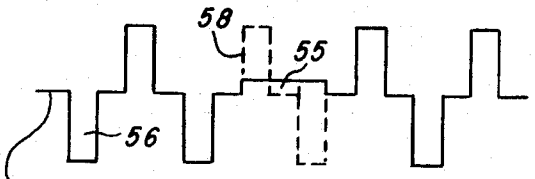

Fig. 3b

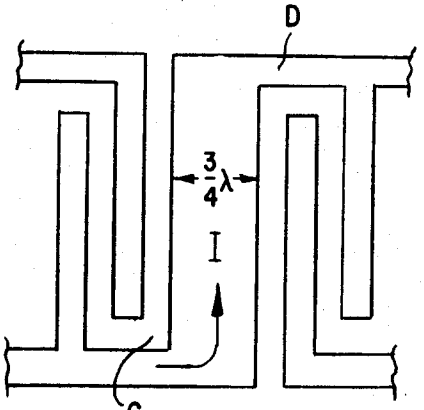

Fig. 4a

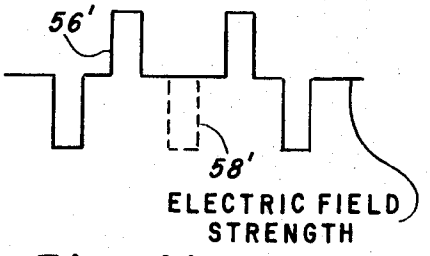

Fig. 4b

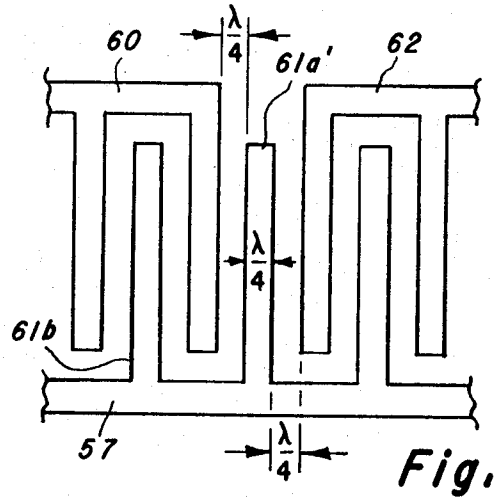

Fig. 5a

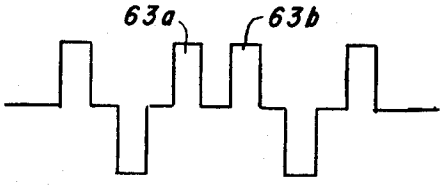

Fig. 5b

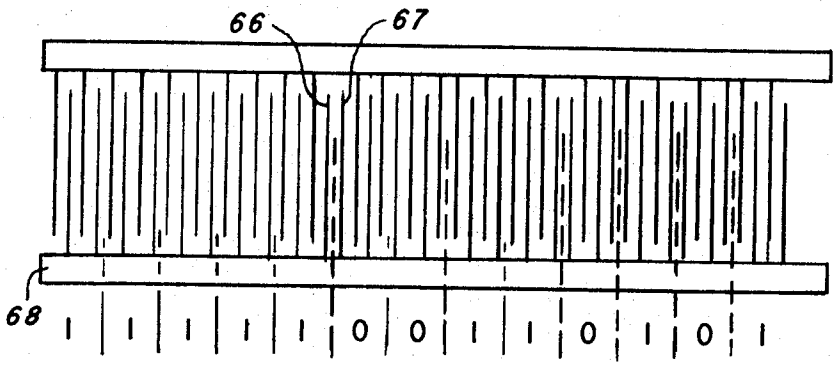

Fig. 7

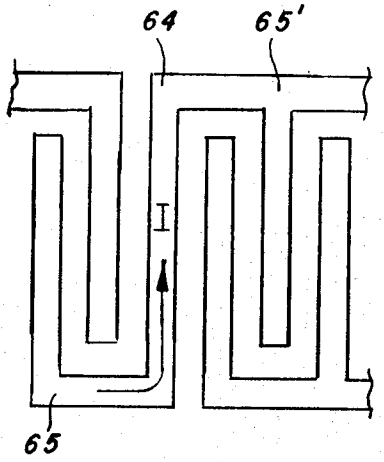

Fig. 6

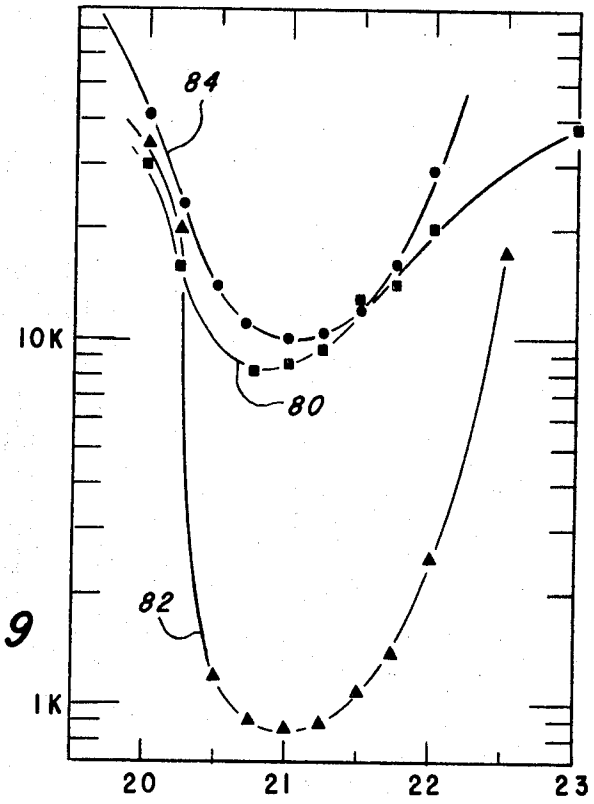

Fig. 9

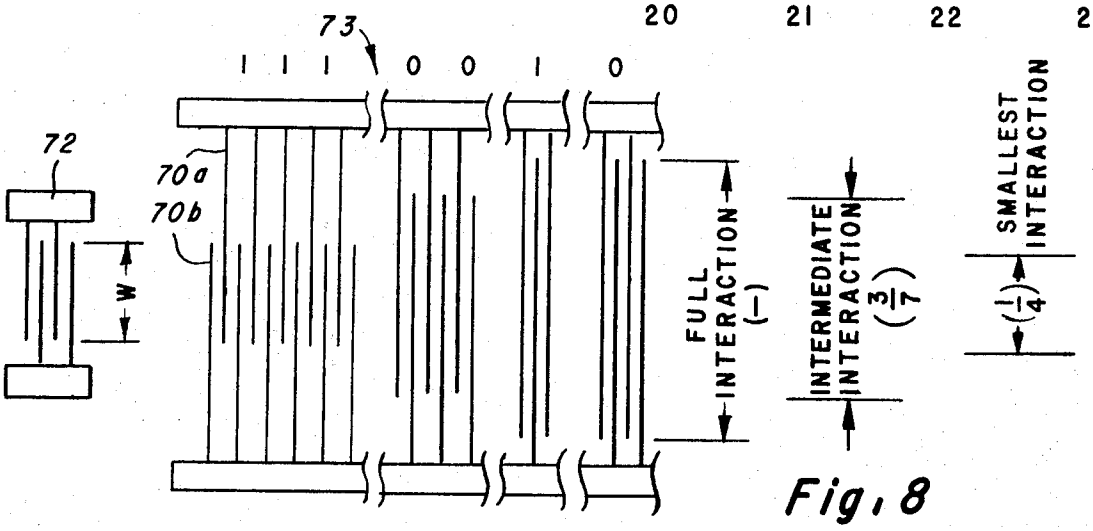

Fig. 8

SERIES CONNECTION OF INTERDIGITATED SURFACE WAVE TRANSDUCERS

This invention pertains generally to surface wave devices and more particularly to interdigitated surface wave transducers electrically cascaded in series.

The surface acoustic wave technology is ideally suited for applications in a wide range of passive and active signal processing systems - delay lines, matched terminations, attenuators, phase shifters, bandpass filters, pulse compression filters, matched filters, amplifiers, oscillators, mixers, and limiters, due to the ability to tap, guide, amplify and otherwise manipulate an acoustic wave as it propagates along the surface of a suitable substrate. Such devices utilize acoustic waves which propagate along a stress free plane surface of an isotropic elastic solid. These acoustic surface waves have an essentially exponential decay of amplitude into the solid and therefore most of the particle displacement of the solid occurs within about one wavelength of the surface. For ease in coupling electrically to the surface waves, piezoelectric anisotropic substrates have generally been used. For such piezoelectric substrates coupling a signal to the surface wave can be accomplished by means of deposited interdigitated metal electrodes spaced apart by one-half wavelength at the resonance frequency desired.

Usually, adjacent electrodes of an interdigitated transducer are electrically connected in parallel and at relatively high frequencies, or when relatively long arrays are required for frequency selectivity or for signal processing, the transducer exhibits an extremely low input impedance. For example, interdigitated transducers having 50 pairs of electrodes at 500 MHz may exhibit an input impedance in the range of about 1–5 ohms on a lithium niobate substrate. Such a low impedance makes it extremely difficult to effectively utilize the transducer.

One technique that has been proposed to increase the electrical input impedance of an interdigitated surface wave transducer is to physically interconnect several interdigitated sections in series so that the electrical series impedance of the respective sections add. A major problem using external bonding wires, however, is the fact that the bonding wires used to interconnect the various sections introduce phase distortion which deleteriously affects the operation of the transducer and renders it inoperable for many applications.

Accordingly it is an object of the present invention to provide an interdigitated surface wave transducer having a relatively high input impedance.

A further object of the present invention is to electrically and acoustically cascade in series a plurality of individual sections to form a relatively long interdigitated surface wave transducer having a relatively high electrical input impedance and uniform phase characteristics along the length thereof.

Another object of the present invention is to provide an electrically and acoustically series cascaded interdigitated surface wave transducer that is compatible with conventional transducer pattern metallization techniques.

Briefly and in accordance with the present invention, an interdigitated surface wave transducer having a relatively large input impedance comprises a plurality of series cascaded acoustic sections and series cascaded electrical sections, in which all electrodes may be formed in a single metallization step. Successive electro-acoustic sections of the transducer may be interconnected by a series "in-phase" connection or alternately successive electro-acoustic sections may be interconnected by a series "phase-reversal" connection. Each electro-acoustic section comprises a plurality of interdigitated electrodes that define a predetermined number of electric field interaction regions, the electrical impedance of each section being relatively small with respect to the desired transducer input impedance. Successive electro-acoustic sections are interconnected by metal electrode coupling means that effectively couple current from one electro-acoustic section to the succeeding electro-acoustic section. When a series "in-phase" interconnection is required, adjacent interaction regions of successive electro-acoustic sections are spaced apart by three-fourths of an acoustic wavelength at the resonance frequency. When a series "phase-reversal" interconnection is desired, adjacent interaction regions of successive electro-acoustic sections are spaced apart by one-fourth of an acoustic wavelength.

The novel features believed to be characteristic of this invention are set forth in the appended claims. The invention itself, however, as well as other objects and advantages thereof may best be understood by reference to the following detailed description of illustrative embodiments when read in conjunction with the accompanying drawings in which:

FIG. **1** depicts an illustrative embodiment utilizing the series cascaded interdigitated transducer of the present invention;

FIG. **2***a* depicts an embodiment of the present invention wherein three acoustic sections are cascaded in phase;

FIG. **2***b* depicts the electric field produced by the interaction of adjacent electrodes of FIG. **2***a*;

FIG. **3***a* depicts an alternate embodiment of successive acoustic sections cascaded in phase;

FIG. **3***b* depicts the electrical field of the alternate embodiment shown in FIG. **3***a*;

FIG. **4***a* depicts a modification of the embodiment shown in FIG. 3a;

FIG. **4***b* depicts the electric field of the modified embodiment illustrated in FIG. **4***a*;

FIG. **5***a* depicts successive acoustic sections cascaded in series to produce a phase reversal between sections;

FIG. **5***b* depicts the electrical field produced by the embodiment of FIG. **5***a*;

FIG. **6** depicts an alternate embodiment for cascading successive acoustic sections in series to produce a phase reversal;

FIG. **7** diagrammatically depicts a surface wave transducer that is phase coded to represent a predetermined binary code;

FIG. **8** diagrammatically depicts a phase coded surface wave transducer that is amplitude weighted so that the various acoustic sections of the transducer exhibit the same effective impedance; and

FIG. **9** depicts in graphical form the theoretical and measured impedance of a series cascaded transducer in accordance with the present invention as compared to the input impedance of a corresponding conventional interdigitated transducer.

With reference now to the drawings and for the present particularly to FIG. **1**, there is depicted partially schematically and partially in block diagram form an illustrative example incorporating a series cascaded interdigitated transducer in accordance with the present invention. This transducer is shown generally at **10** and comprises seven discrete electro-acoustic sections shown at **12***a* through **12***g*. As represented by the arrows shown generally at **14**, these individual electro-acoustic sections are cascaded in series to form a relatively long interdigitated transducer having a relatively large input impedance. The electro-acoustic sections are disposed so that they form a single acoustic channel, i.e., a propagating acoustic surface wave sequentially traverses successive acoustic sections. The use of seven acoustic sections is by way of example only, and any desired number of acoustic sections may be cascaded in accordance with the present invention.

Each of the electro-acoustic sections **12***a* through **12***g* comprises an interdigitated array of electrodes and exhibits a relatively low input impedance with respect to the desired effective input impedance of the transducer **10**. An r.f. generator **16** applies an input signal across an input terminal **18** of acoustic section **12***a* and across an input terminal **20** of the acoustic section **12***g*. An output transducer is shown in block diagram format at **22**. Transducer **22** may, for example, comprise a broadband interdigitated surface wave transducer. Transducers **10** and **22** are formed on a piezoelectric substrate **24** by conventional metallization techniques. In response to a signal from the r.f. generator **16**, the input transducer **10** generates an acoustic surface wave in the surface of the piezoelectric substrate **24**. This surface wave is detected by the output transducer **22** and a signal is generated across the load **26**.

With reference now to FIGS. 2*a* and 2*b*, there is depicted an illustrative embodiment of the present invention wherein three electro-acoustic sections **28**, **30** and **32** are cascaded by series "in-phase" connections. That is, successive electro-acoustic sections such as **28** and **30** are connected in series and are in phase with each other. Individual electrodes of the interdigitated transducer are shown generally at **38***a* and **38***b*. These electrodes are preferably formed to be one-fourth of an acoustic wavelength at the desired resonance frequency in width. Adjacent electrodes **38***a* and **38***b* are spaced apart by one-fourth of a wavelength, defining a center-to-center spacing of adjacent electrodes of one-half of a wavelength. Electrodes **40** and **42** that interconnect successive electro-acoustic sections are respectively formed to be three-fourths of a wavelength in width to maintain the correct phase in cascading two discrete electro-acoustic sections in series and to reduce distortion. This will be explained in more detail hereinafter in the description of FIGS. 3*b* and 4*b*. The electrodes **38***a* and **38***b* and electrical pads or terminals **34** and **36** are formed by conventional metallization techniques on a piezoelectric substrate (not shown).

Responsive to an r.f. signal applied across terminals **34** and **36**, adjacent electrodes **38***a* and **38***b* interact to produce an electric field disturbance in the surface of the piezoelectric substrate. As may be seen with reference to FIG. 2*a*, each electro-acoustic section, such as section **28**, has five regions of electrode interaction shown at **44***a*, **44***b*, **44***c*, **44***d* and **44***e*.

Referring now to FIG. 2*b*, there is depicted the electric field produced by the interaction between adjacent electrodes such as **38***a* and **38***b* of FIG. 2*a*. Regions **48***a* and **48***b* depict the electric field produced by a conventional interdigitated transducer while the solid line **46** depicts the electric field produced by the series cascaded interdigital transducer of the present invention. As may be seen, the wide electrodes **40** and **42** that interconnect successive electro-acoustic sections short out the substrate surface and prevent an electric field disturbance in areas where it would normally occur in conventional interdigitated transducers thus producing a slight distortion. However, it is to be noted that the phase of the electric field remains the same for each of the cascaded electro-acoustic sections **28**, **30** and **32**, since the spacing therebetween is three-fourths of a wavelength.

With reference to FIGS. 3*a* and 3*b*, there is depicted an alternate embodiment of the present invention for effecting "in-phase" series cascading of two acoustic sections. In this embodiment, a crossover or interconnecting electrode **50** physically connects the two electro-acoustic sections **52** and **54** in series. To maintain the electric field produced by section **54** in phase with the electric field of section **52**, the adjacent interaction regions of acoustic sections **52** and **54**, depicted at **49** and **53** respectively, are separated by three-fourths of a wavelength. Or, stated another way, the separation or low interaction region between the crossover electrode **50** and the adjacent electrode **51** is formed to be three-fourths of a wavelength.

As may be seen with reference to FIG. 3b, the series in-phase connection between electro-acoustic sections **52** and **54** introduces some distortion of the electric field due to the three-fourths of a wavelength region of lower interaction. The actual electrical field of the series cascading arrangement shown in FIG. 3*a* is depicted by the solid line **56**. The electric field associated with the low interaction region is shown at **55** and the amplitude there is only about one-third of the amplitude produced in other interaction regions between adjacent electrodes. The reason for this is that the lower interaction region **57** (FIG. 3*a*) is three normal interaction regions in width, thereby producing a correspondingly lower electrical field between the adjacent electrodes **51** and **50**. The dotted portion **58** depicts the electric field obtained with a conventional (i.e., non-cascaded) interdigitated transducer.

With reference to FIGS. 4*a* and 4*b*, there is depicted a modification of the series in-phase cascading arrangement of FIG. 3*a*. In this modified arrangement the crossover electrode **50'** is formed so that it is three-fourths of an acoustic wavelength in width. Forming the crossover electrode in this manner reduces the distortion produced in the electric field as may be seen by comparing the response illustrated in FIG. 4*b* with that depicted in FIG. 3*b*. With reference to FIG. 4*b*, the dotted portion **58'** represents the electric field that is obtained in a conventional interdigitated transducer while the solid line **56'** represents the actual electric field obtained with the arrangement of FIG. 4*a*.

In-phase cascading of discrete electro-acoustic sections is preferably accomplished in accordance with the cascading arrangement depicted in FIG. 2*a*, since the resistive loss is less than that resulting from either of the cascading arrangements depicted in FIG. 3*a* or FIG. 4*a*. This may best be seen by reference to FIG. 2*a* wherein the current I that flows between point A of acoustic section **30** and point B of acoustic section **32** is channeled through the coupling electrode **42**. The distance between points A and B is two and one-half acoustic wavelengths. The resistance between points A and B causes an unrecoverable IR voltage drop that reduces the efficiency of the transducer.

With reference now to FIGS. 3*a* and 4*a*, the current connecting two sections **52** and **54** flows through the crossover electrode **50** from point C to D. The distance between points C and D is significantly greater than the distance between points A and B (FIG. 2*a*) and thus the resistance is much greater, producing a much larger IR drop. For example, a typical distance from C to D may be on the order of 100 wavelengths or greater.

With reference to FIG. 5*a*, two sections **60** and **62** are cascaded in series so that a phase-reversal between the two sections is obtained. A phase reversal is obtained by forming a coupling electrode **61***a'* between adjacent interaction regions of the two electro-acoustic sections, said electrode being one-fourth a wavelength in width and being connected to an electrical pad **57** that is common to both acoustic sections. This phase reversal may be seen by reference generally to FIG. 5*b*, which depicts the electric field produced by interaction of adjacent electrodes **61***a* and **61***b*, and specifically to portions **63***a* and **63***b* of the electric field response.

An alternate arrangement for cascading acoustic sections in series to produce phase reversal is depicted in FIG. **6**. In this embodiment an interconnecting electrode **64** physically connects electrical pad **65** of one acoustic section with electrical pad **65'** of the succeeding acoustic section.

In some applications it is desirable to increase the input electrical impedance of phase-coded interdigitated arrays. One such application, for example, would be a low compression ratio phase-coded correlator on a higher coupling material or a very long phase-coded correlator having a low compression ratio on a lower coupling material.

With reference to FIG. **7**, a 13-bit Barker code of 1111100110101 is depicted. By way of example, only, two electrode pairs are shown as representing each binary bit. The binary state is changed, for example, from a "1" to a "0, by reversing the phase of the surface wave produced by the transducer. This phase reversal may be effected most simply by connecting two adjacent electrodes such as **66** and **67** to the same electrical pad **68**. A binary coded array such as depicted in FIG. **7** may be produced in accordance with the present invention utilizing, for example, the in-phase series cascading depicted in FIG. 2*a* and the phase-reversal series cascading shown in FIG. 5*a*. In producing the phase coded array it may be desirable to series cascade each electro-acoustic section corresponding to a discrete binary bit of the desired binary code. In other words, assuming two electrode pairs are utilized for each binary code, such as is shown in FIG. **7**, each group of two electrode pairs would constitute an electro-acoustic section that is to be cascaded in series with succeeding electro-acoustic sections required to formulate the desired 13 bits. That is, for a 13-bit binary code, 13 acoustic sections would be cascaded in series. This arrangement may be desirable even if adjacent acoustic segments are of the same polarity or phase, since otherwise the acoustic sections would have different im-

pedance values leading to different acoustic contributions. For example, consider the amplitude binary code 1110010. If this code were constructed as follows — 111*00*1*0 — where the asterisks represent series cascading in accordance with the present invention, the **111** acoustic section would have a lower impedance since three groups of electrode pairs are in parallel while the 1 and 0 acoustic sections would both exhibit relatively high impedances. Thus, it may be desirable to represent each binary bit with a separate acoustic segment and form the coded array by interconnecting the acoustic sections as follows: 1*1*1*0*0*1*0, wherein the asterisks denote series cascading. When interconnecting like polarity sections, in-phase series cascading in accordance with the present invention is utilized while phase-reversal series cascading is utilized where the binary state of adjacent acoustic sections is different.

If it is not desired to divide each binary bit into a separate electro-acoustic section, an alternate cascading technique may be utilized wherein the total number of electrode pairs required to represent the binary code is determined. The electrode pairs may then be evenly divided into a convenient number of acoustic sections, thereby ensuring that each acoustic section exhibits the same impedance. The necessary phase coding may then be effected to form the desired binary code by cascading the acoustic sections (to effect a relatively high input impedance) in series "in-phase" or series "phase-reversal" connections, as required. To obtain phase reversals within a discrete acoustic section, conventional phase reversing techniques may be employed, as shown at **66** and **67** in FIG. **7**.

A different technique for ensuring that the effective impedance is the same for different acoustic sections of a phase coded array is depicted in FIG. **8** wherein a portion of a coded array is shown and depicts a binary code of 1110010. By way of example, each binary bit is represented by two electrode pairs, one electrode pair being shown at **70***a* and **70***b*. For increased clarity of description, the phase coded array is illustrated as being formed utilizing "phase-reversal" series cascading in accordance with the embodiments depicted in FIG. 5a. It is to be appreciated, of course, that other techniques for series "phase-reversal" cascading may be utilized.

As illustrated in FIG. **8**, the desired pattern of 1110010 may be obtained by cascading four electro-acoustic sections as follows — 111*00*1*0 — where the asterisk refers to series phase-reversal cascading. The interaction length between adjacent electrodes of each acoustic section is amplitude weighted a predetermined amount so that the effective impedance of each acoustic section is the same. That is, the effective impedance of an electrode pair is inversely proportional to the interaction length. By weighting the acoustic section representing three binary bits "111" so that the interaction length of respective electrode pairs is small, the parallel combination of the electrode pairs of that acoustic section is controlled to be relatively large. With respect to the electro-acoustic section representing the individual binary bits "1" and "0," the interaction length of electrode pairs therein is relatively large, effecting an impedance that is the same as the parallel combination of the acoustic section representing the binary bits "111." Similarly, the interaction length of electrode pairs of the acoustic section representing "**00**" is controlled to an intermediate value so that the effective impedance thereof is the same as the other acoustic sections. For example, assuming that the interaction length of electrode pairs of the acoustic sections representing single binary bits is one unit, the interaction length associated with acoustic sections representing two binary bits and three binary bits may be controlled to be three-sevenths and one-fourth units respectively (given by the number of active electro-acoustic interactions per section). The required acoustic surface wave beam width W is controlled to be the same width as the smallest interaction length so that the correct acoustic energy is contained in that width since the acoustic amplitude has been devised to be constant utilizing this method. This is done by using an interdigitated transducer having an interaction length the same as the smallest interaction length of the weighted coded array **73** as is shown at **72**. Since interdigitated transducers are bi-directional, transducer **72** may be utilized as an input transducer when the coded array **73** is functioning as a detector, or as an output transducer whenever the coded array functions as a generator.

In accordance with the present invention, an interdigitated surface wave transducer comprising three in-phase series cascaded acoustic sections was constructed. Each acoustic section was formed to have seven interaction regions. The electrodes were formed to define a resonance frequency of 21 MHz. Respective interaction regions were formed to have a length of approximately 90 mils, and respective electrodes within a section were formed to be one-fourth of an acoustic wavelength in width (approximately 1 ½ mils). The electrodes were formed on a lithium niobate substrate using conventional photomask and metallization etching techniques. The electrodes were formed of aluminum deposited on a lithium niobate substrate to a thickness of about 2,000 A. The impedance of the in-phase series cascaded interdigitated transducer above described was measured and the results are shown in graphical form at **80** in FIG. **9**. The measured impedance was compared with the theoretical impedance of a conventional interdigital surface wave transducer of the same length. (Such a transducer has 24 interaction lengths.) The impedance was calculated in accordance with the equivalent circuit model described in Smith et al., "Analysis of Interdigital Surface Wave Transducers by Use of an Equivalent Circuit Model," *IEEE Transactions of Microwave Theory and Techniques*, Vol. MTT–17, No. 11, November, 1969. This calculated impedance is shown in FIG. **9** at **82**. The theoretical value of the series cascaded surface wave transducer was also calculated and is shown at **84**. As may be seen, the theoretical impedance of a conventional long interdigital surface wave transducer is approximately 860 ohms; the measured impedance of the series cascaded surface wave transducer in accordance with the present invention is approximately 8,600 ohms, while the theoretical impedance of the series cascaded transducer is approximately 10,000 ohms. As may be seen, cascading three acoustic sections increases the electrical impedance by a factor of approximately nine.

The impulse response of the series cascaded transducers above described was checked to determine whether any unwanted phase shifts were induced by the series cascading; no unwanted phase shifting was observed.

Although specific embodiments of this invention have been described herein, it will be apparent to a person skilled in the art that various modifications to the details of construction shown and described may be made without departing from the scope of the invention.

We claim:

1. A relatively large input impedance interdigital surface wave transducer that is phase coded to correspond to a predetermined binary code, comprising in combination:

a. a piezoelectric substrate;

b. a plurality of spaced apart electro-acoustic sections disposed on said substrate to define a single acoustic channel, each of said sections comprising two electrical pads having at least one interdigitated electrode pair selectively connected thereto and having a relatively small electrical impedance, the relative phase of each of said electro-acoustic sections corresponding to a binary bit of said predetermined binary code; and

c. means for cascading said electro-acoustic sections in series, said means coupling current from an electrical pad of one electro-acoustic section to an electrical pad of the succeeding electro-acoustic section and controlling the phase of respective electro-acoustic sections to correspond to said predetermined binary code, the combination of successive electro-acoustic sections effecting said predetermined binary code and effectively cascading the

electrical impedance of said electro-acoustic sections in series.

2. A relatively large input impedance interdigitated surface wave transducer that is phase coded to correspond to a predetermined binary code comprising in combination:

a. a piezoelectric substrate;

b. a plurality of spaced apart electro-acoustic sections disposed on said substrate to define a single acoustic channel, each of said sections comprising two electrical pads having at least one interdigitated electrode pair selectively connected thereto and corresponding to at least one binary bit of said predetermined binary code, said at least one electrode pair having a relatively small value of electrical impedance, at least one of said electro-acoustic sections having a total number of electrode pairs that is larger than at least one other electro-acoustic section of said plurality of electro-acoustic sections;

c. amplitude weighting means to control the effective impedance of each of said electro-acoustic sections to be substantially the same; and

d. means for cascading said acoustic sections in series, said means effectively coupling current from an electrical pad of one electro-acoustic section to the succeeding electro-acoustic sections and controlling the phase of respective electro-acoustic sections to correspond to respective binary numbers of said predetermined binary code, whereby the effective impedance of each electro-acoustic section is the same and is cascaded in series with the impedance of adjacent electro-acoustic sections to produce a phase coded interdigitated surface wave transducer having a relatively large input impedance.

3. An interdigital surface wave transducer having a relatively large impedance comprising in combination:

a. a piezoelectric substrate;

b. a plurality of spaced apart electro-acoustic sections formed on a surface of said substrate, each section being defined by a first array of electrodes commonly connected to a first electrical pad and a second array of electrodes commonly connected to a second electrical pad, said first and second arrays of electrodes being interleaved to form an interdigitated patterns that defines a preselected number of equal width electric field interaction regions in the surface of said substrate, each of said acoustic sections exhibiting a relatively small impedance, said plurality of electro-acoustic sections disposed in alignment to define an acoustic channel; and

c. means for electrically coupling adjacent acoustic sections whereby the electrical impedance of said plurality of electric sections add in series to produce an interdigital surface wave transducer having a relatively large input impedance.

4. A phase coded transducer as set forth in claim 2 wherein said at least one section having a larger number of electrode pairs has a smaller electrode interaction length than said at least one other section.

5. A phase coded transducer as set forth in claim 2 wherein the acoustic section of said phase coded transducer having the minimum number of electrode pairs has the maximum electrode interaction length and acoustic sections having a larger number of electrode pairs have an electrode interaction length that is a fraction of said maximum length, said fraction corresponding to the number of active electro-acoustic interactions per section.

6. An interdigital surface wave transducer in accordance with claim 3 wherein said coupling means are arranged to interconnect successive electro-acoustic sections acoustically in phase with each other.

7. An interdigital surface wave transducer in accordance with claim 6 wherein said coupling means comprises an electrode three-fourths of an acoustic wavelength in width spaced between adjacent interaction regions of successive electro-acoustic sections, one end of said electrode being connected to an electrical pad common to both of said successive acoustic sections.

8. An interdigital surface wave transducer in accordance with claim 3 wherein said coupling means are operative to reverse the phase of successive electro-acoustic sections.

9. An interdigitated surface wave transducer in accordance with claim 8 wherein said coupling means comprises an electrode one-fourth of an acoustic wavelength in width spaced between adjacent interaction regions of said successive electro-acoustic sections, one end of said electrode being connected to an electrical pad common to both of said successive electro-acoustic sections.

10. An interdigital surface wave transducer in accordance with claim 6 wherein said coupling means comprises an interconnecting electrode, one end of said electrode being electrically connected to an electrical pad of one of said successive electro-acoustic sections and the other end of said electrode being electrically connected to an electrical pad of the other of said successive electro-acoustic sections, adjacent interaction regions of said successive electro-acoustic sections being spaced apart by three-fourths of an acoustic wavelength.

11. An interdigitated surface wave transducer as set forth in claim 10 wherein said interconnecting electrode is one-fourth of an acoustic wavelength in width.

12. An interdigitated surface wave transducer as set forth in claim 10 wherein said interconnecting electrode is three-fourths of an acoustic wavelength in width.

13. An interdigitated surface wave transducer as set forth in claim 8 wherein said coupling means comprises an interconnecting electrode, one end of said electrode being electrically connected to an electrical pad of one of said successive electro-acoustic sections and the other end of said electrode being electrically connected to an electrical pad of the other of said successive electro-acoustic sections, adjacent interaction regions of said successive electro-acoustic sections being spaced apart by one-fourth of an acoustic wavelength.

14. A phase coded transducer system having a relatively large input impedance comprising in combination;

a. a piezoelectric substrate;

b. a first transducer including a plurality of spaced apart electro-acoustic sections disposed on said substrate to define a single acoustic channel, each of said sections comprising two electrical pads having at least one interdigitated electrode pair selectively connected thereto and corresponding to at least one binary bit of a predetermined binary code, said at least one electrical pair having a relatively small value of electrical impedance, at least one of said electro-acoustic sections having a total number of electrode pairs that is larger than at least one other electro-acoustic section of said plurality of electro-acoustic sections, the acoustic section of said phase coded transducer having the minimum number of electrode pairs having a maximum electrode interaction length and acoustic sections having a larger number of electrode pairs having an electrode interaction length that is a fraction of said maximum length, said fraction corresponding to the number of active electro-acoustic interactions per section;

c. means for cascading said acoustic section in series, said means electrically coupling one electro-acoustic section to the succeeding electro-acoustic sections and controlling the phase of respective electro-acoustic sections to correspond to respective binary members of said predetermined binary code, whereby the effective impedance of each electro-acoustic section is the same and is cascaded in series with the impedance with the adjacent electro-acoustic section to produce a phase coded interdigitated surface wave transducer having a relatively large input impedance; and

d. a second transducer on said substrate spaced from said first transducer and aligned with said acoustic channel, said second transducer having an electrode interaction length corresponding to said minimum interaction length of said first transducer.

15. A phase coded transducer system as set forth in claim 14 wherein said means for cascading, selectively includes phase

reversing means comprising an electrode one-fourth an acoustic wave length in width spaced between adjacent interaction regions of successive electro-acoustic sections, one end of said electrode being connected to an electrical pad common to both of said successive electro-acoustic sections.

16. A phase coded transducer system as set forth in claim 14 wherein said means for cascading, selectively includes an interconnecting electrode, one end of said electrode being electrically connected to an electrical pad of one of successive electro-acoustic sections and the other end of said electrode being electrically connected to an electrical pad of the other of successive electro-acoustic sections, adjacent interaction regions of said successive electro-acoustic sections being spaced apart by three-fourths of an acoustic wavelength.

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