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SURFACE WAVE RESONATOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a free edge reflective-type surface wave resonator using SH-type surface ~~{wave}~~ waves such as BGS ~~{wave,}~~ waves, Love ~~{wave}~~ waves or the like, and particularly to a free edge reflective-type surface wave resonator in which plural resonance units are fabricated as a single unitary element.

2. Description of Related Art

A television receiver, a video tape recorder, ~~{etc.}~~ and other similar devices have been required to sufficiently attenuate signals at ~~{the}~~ an adjacent channel video signal frequency f_{vp} ~~{(31.9MHz)}~~(31.9 MHz in European PAL system) and the adjacent channel audio signal frequency f_{ap} ~~{(40.4MHz)}~~(40.4 MHz in European PAL system) at a picture intermediate frequency stage thereof in order to avoid any obstruction between adjacent channels. Fig. 1 is a graph showing an attenuation-frequency characteristic at the picture intermediate frequency stage~~{, and it}~~. It is apparent from Fig. 1 that the attenuation is ~~{kept to be}~~ relatively large at the adjacent channel video signal frequency f_{vp} and the adjacent channel audio signal frequency f_{ap}.

In order to keep the attenuation ~~{to be}~~ large at the adjacent channel video signal frequency f_{vp} and the adjacent channel audio signal frequency f_{ap} as

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described above, ~~{there have been conventionally used two traps, one having}~~ two conventional traps have been used. One of the conventional traps has a large attenuation at the adjacent channel video signal frequency f_w and the other ~~{having}~~ conventional trap has a large attenuation at the adjacent channel video signal frequency f_{uu}. Each ~~{trap}~~ of the conventional traps is constructed by an LC resonance circuit, a piezoelectric resonator, etc.

With respect to the piezoelectric resonator which is used for the above purpose, much attention has been paid to a piezoelectric resonator using SH-type surface ~~{wave}~~ waves such as BGS ~~{wave}~~ waves. Fig. 2 is a perspective view showing a free edge reflective-type surface wave resonator using BGS ~~{wave}~~ waves.

A free edge reflective-type surface wave resonator 1 is constructed by a piezoelectric substrate 2 having a substantially rectangular flat surface. The piezoelectric substrate 2 is formed of piezoelectric material such as piezoelectric ceramic of lead titanate zirconate, $LiNbO_3$ piezoelectric monocrystal, $LiTaO_3$ monocrystal or the like. When ~~{it}~~ the substrate 2 is formed of piezoelectric ceramic, ~~{it}~~ the substrate 2 is subjected to a polarization treatment in a direction as indicated by an arrow P in Fig. 2. A pair of comb-shaped electrodes 3 and 4 are ~~{formed}~~ provided on the upper surface 2a of the piezoelectric substrate 2 to form an interdigital transducer (hereinafter referred to as "IDT"). Each of the comb-shaped ~~{electrode}~~ electrodes 3 ~~{(4)}~~ and 4 has plural electrode fingers 3a to 3c ~~{(}~~and 4a to 4c, respectively~~{)}~~.

By applying an alternating voltage through the comb-shaped electrodes 3 and 4, BGS ~~{wave is}~~ waves are excited on the free edge reflective-type surface wave

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resonator 1, and the BGS ~~{wave propagates}~~ waves propagate in a direction as indicated by an arrow X in Fig. 2. The BGS ~~{wave is}~~ waves are reflected between the free edges 2b and 2c of the piezoelectric substrate 2. The free edge reflective-type surface wave resonator 1 can obtain an effective resonance characteristic by ~~{making a coincidence between}~~ setting the frequency determined by the IDT and the frequency determined by the dimension between the free edges to be substantially equal to each other.

However, the free edge reflective-type surface resonator ~~{has}~~ only has a single resonance characteristic like an LC resonance circuit and other types of piezoelectric resonators. Accordingly, two surface wave resonators must be prepared and connected to each other to achieve a trap characteristic at the two frequency positions (the adjacent channel video signal frequency f_{vs} and the adjacent channel audio signal frequency f_{as}).

An elastic surface wave resonator using Rayleigh ~~{wave}~~ waves has been known as another type surface wave resonator. This elastic surface wave resonator has two resonance characteristics although it uses a single resonator, as disclosed in "INTERNATIONAL ELECTRICAL TECHNOLOGY REPORT", No. 16, ~~{pp1}~~ pp. 1-7, 1992, for example. That is, there is known a double mode resonator using a zero-order longitudinal mode (fundamental mode) and a second-order longitudinal mode in a surface wave resonator filter using Rayleigh ~~{wave}~~ waves, and two resonance characteristics are obtained by this resonator. However, the double mode resonator needs two or more IDTs and a reflector. Further, in the double mode resonator, the resonance characteristics are

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determined on the basis of the characteristic of reflection coefficient ~~{-}~~and the frequency of the reflector~~{, and}~~. Furthermore, a frequency range where a large reflection coefficient is obtained is narrow. Therefore, the difference between the two resonance points is a very small value, for example, about ~~[1MHz]~~ 1 MHz in a range where an excellent resonance characteristic is obtained~~{, and thus}~~. Thus, it is impossible ~~{that}~~ to construct a double mode resonator including two trap resonators which have such a characteristic as shown in Fig. 1 and which have a large frequency gap therebetween ~~{is constructed by only the double mode resonator}~~. Therefore, it may be considered that if two IDTs are ~~{formed}~~ provided on the piezoelectric substrate to form two resonance units in the free edge reflective-type surface wave resonator using BGS ~~{wave}~~ waves as described above, two resonance characteristics can be obtained. However, in the free edge reflective-type surface wave resonator using SH-type surface ~~{wave}~~ waves such as BGS ~~{wave}~~ waves, schematically shown in Fig. 3, the following relationship is satisfied between the wavelength ~~{1}~~λ of the IDT and the distance L of the two confronting free edges where the surface wave of the piezoelectric substrate is reflected:

$$L = \{(1/2)\}(\lambda/2) \times N \quad (N \text{ represents an integer})$$

Since the frequency difference between f_{ap} and f_{as} is large, the wavelengths ~~{1}~~λ of the respective IDTs ~~{are}~~ differ greatly ~~{different}~~ from each other. For example, assuming the sound velocity of the PZT substrate to be equal to 2400m/s, ~~{lap}~~λap for f_{ap} = ~~{75.2m}~~ 75.2 μm and ~~{lac}~~λas for f_{as} = ~~{59.4m}~~ 59.4 μm in case of the

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PAL system. Accordingly, the value of the distance L between the two confronting free edges is different between the resonance unit having a resonance point at the adjacent channel video signal frequency f_{vp} and the resonance unit having a resonance point at the adjacent channel audio signal frequency f_{ap}. That is, with respect to the free edge reflective-type surface wave resonator using SH-type surface ~~{wave, it has been considered as being very}~~ waves, it is extremely difficult to form two resonance units having different resonance frequencies on the same substrate.

SUMMARY OF THE INVENTION

~~{An object of the}~~ The preferred embodiments of present invention ~~{is to}~~ provide a free edge reflective-type surface wave resonator using SH-type surface ~~{wave}~~ waves in which at least two resonance units having different resonance frequencies are fabricated as a single unitary element.

~~{In order to attain the above object}~~ More specifically, according to the preferred embodiments of the present invention, a free edge reflective-type surface wave resonator for reflecting SH-type surface ~~{wave}~~ waves between two confronting free edges of a piezoelectric substrate, includes a piezoelectric substrate having ~~{the}~~ two confronting free edges, and an IDT ~~{which is not only}~~ provided on the piezoelectric substrate ~~{but also is}~~ including a plurality of electrode fingers being weighted by a cross width weighting method or an electrode thinning method, wherein the weighting is performed so that an attenuation pole of a main lobe is located ~~{out}~~ outside of the frequency of an attenuation pole of a ~~{normal type IDT having the}~~

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~~number of electrode-finger pairs which is determined by~~ "normal" IDT (wherein "normal" refers to an unweighted IDT having equal cross widths between electrode fingers) having the same number of electrode ~~(-finger pairs or the same inter-substrate dimension of electrode)~~ finger pairs, and a resonance characteristic ~~due to~~ determined by the main lobe and a resonance characteristic ~~due to~~ determined by the attenuation pole of the normal ~~type~~ IDT are obtained.

That is, in the surface wave resonator of the preferred embodiments of the present invention, two or more resonance characteristics are obtained with only a single element by using the attenuation pole of the normal ~~type~~ IDT which is originally suppressed. The SH-type surface wave in this specification is broadly defined as containing not only BGS ~~wave~~ waves, but also surface ~~wave~~ waves like Love ~~wave~~ waves having a component whose displacement is substantially perpendicular to the propagation direction of the surface ~~wave~~ waves.

Further, the surface resonator of the preferred embodiments of the present invention is preferably used to constitute a trap circuit at the picture intermediate frequency stage of a television receiver or a video tape recorder. That is, the positions of the respective attenuation poles as described above are set so that one of the plural resonance characteristics is set as the adjacent channel video signal frequency (f_φ) and another resonance characteristic having a higher frequency is set as the adjacent channel video signal frequency (f_α), whereby a trap circuit having traps at the adjacent channel video signal frequency and the adjacent channel

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audio signal frequency can be constructed by a single unitary element.

As described above, the resonance frequency f_r of the free edge reflective-type surface wave resonator using BGS ~~{wave}~~ waves is determined as follows:

$f_r = $ ~~{v/λ (1)}~~ v/λ (λ represents the wavelength of surface wave excited by the IDT, and v represents the sound velocity of the piezoelectric substrate)

Further, the dimension L connecting the two confronting free edges of the piezoelectric substrate ~~{must be}~~ is preferably determined so as to satisfy the equation:

$L = $ ~~{(1/2)}~~ $(\lambda/2) \times n$ (n represents an integer). Accordingly, when a resonator constituting a trap for the adjacent channel video signal frequency and a resonator constituting a trap for the adjacent channel audio signal frequency, which are used at the picture intermediate frequency stage, are constructed by a free edge reflective-type surface wave resonator, the value of the dimension L is different between the above two resonators because they have greatly different wavelengths ~~{λ}~~ λ. Therefore, it has been hitherto considered as being difficult to form two resonators on the same chip or substrate.

On the other hand, according to the preferred embodiments of the present invention, the weighting is performed so that the attenuation pole of the main lobe of the weighted IDT is located ~~{out}~~ outside of the frequency position of the attenuation pole of the normal ~~{type}~~ IDT having the same number of electrode ~~{-}~~finger pairs. Accordingly, plural resonance characteristics are obtained, which are the resonance characteristic determined by the substrate dimension L as described

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above, that is, the resonance characteristic ~~due to~~ determined by the attenuation pole of the normal ~~type~~ IDT and the resonance characteristic ~~due to~~ determined by the main lobe of the weighted IDT. That is, as is apparent from the foregoing description, by using the resonance characteristic ~~due to~~ determined by the weighted IDT and the characteristic determined by the substrate dimension L, the free edge reflective-type surface wave resonator having plural resonance characteristics can be constructed ~~in spite of its~~ despite the fact that it has a single-element unitary structure.

As described above, according to the preferred embodiments of the present invention, a free edge reflective-type surface wave resonator which achieves plural resonance characteristics ~~in spite of~~ despite its single-element unitary structure can be provided by weighting the IDT as described above, and ~~the~~ an optimum surface wave resonator can be provided ~~to a field which needs~~ for use in devices requiring two resonance characteristics ~~like~~ such as a trap circuit ~~at the~~ for a picture intermediate frequency stage. Since two resonance characteristics are achieved and provided by a single unitary element, the circuit construction of a trap circuit~~, etc.~~ and other devices can be simplified and ~~a~~ cumbersome connection work of several circuit elements can be omitted. In addition, ~~a space for~~ the size of the trap circuit~~, etc.~~ and similar devices can be effectively reduced.

For the purpose of illustrating the invention, there is shown in the drawings several preferred embodiments which are presently preferred, it being understood that the present invention is not limited to

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the precise structural arrangements and instrumentalities shown in the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a graph showing an attenuation-frequency characteristic at a picture intermediate frequency stage of a television receiver;

Fig. 2 is a perspective view showing a conventional free edge reflective-type surface wave resonator using BGS ~~{wave}~~ waves;

Fig. 3 is a cross-sectional view showing ~~{a}~~ the conventional free edge reflective-type surface wave resonator;

Fig. 4 is a diagram showing the frequency spectrum of a normal ~~{type}~~ IDT;

Fig. 5 is a diagram showing the frequency spectrum of a weighted IDT and the normal ~~{type}~~ IDT;

Fig. 6 is a diagram showing a free edge reflective-type surface wave resonator of ~~{an}~~ a preferred embodiment of the present invention;

Fig. 7 is a diagram showing an impedance-frequency characteristic of the free edge reflective-type surface wave resonator of the preferred embodiment; and

Fig. 8 is a diagram showing an attenuation-frequency characteristic of a trap filter which is constructed by the free edge reflective-type surface wave resonator of the preferred embodiment.

DETAILED DESCRIPTION OF ~~{THE}~~ PREFERRED ~~{EMBODIMENT}~~ EMBODIMENTS

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~~[A preferred embodiment]~~ Preferred embodiments according to the present invention will be described with reference to the accompanying drawings.

Fig. 4 is a diagram showing the resonance frequency spectrum of a normal ~~[type]~~ IDT in a free edge reflective-type surface wave resonator using BGS ~~[wave]~~ waves. The resonance frequency spectrum of the IDT is described in "Lecture Papers of Japan Acoustic Society", ~~[pp351]~~ pp. 351-352, issued on March, 1976~~[, and it has been well known]~~. The axis of the abscissa of Fig. 4 represents the frequency, and 2N, 2N-1, ~~[...]~~ etc. on the axis of abscissa represent resonance points of a 2N-order mode, (2N-1)-order mode, ~~[...]~~ etc. The axis of the ordinate represents an attenuation amount when the peak of a main lobe is set to 0 dB.

As is apparent from Fig. 4, when a normal ~~[type]~~ IDT is used, the resonance mode of 2N-order (N represents an integer) can be excited by forming an IDT having N pairs of electrode ~~[-finger]~~ fingers on the surface of the piezoelectric substrate. Further, odd-number modes out of the other high-order modes, that is, modes of (2N-1)-order, (2N-3)-order, (2N+1)-order and (2N+3)-order are not excited due to symmetry of the electrode. With respect to the even-number modes, as is apparent from Fig. 4, the resonance frequency is coincident with the attenuation pole of the frequency characteristic of the IDT having N pairs of electrode fingers so that these modes are not excited. That is, the even-number modes of (2N-2)-order, (2N-4)-order, (2N+2)-order, (2N+4)-order, etc. are not excited. Accordingly, only the 2N-order mode is excited in the free edge reflective-type surface wave resonator on which the normal ~~[type]~~ IDT is formed as shown in Fig. 2, and

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thus a resonator ~~{which is}~~ having relatively little spurious can be formed. However, as described above, only a single resonance characteristic can be obtained by the surface wave resonator shown in Fig. 2.

On the other hand, according to the preferred embodiments of the present invention, plural resonance characteristics can be obtained by weighting the IDT as described. A weighting method will be hereunder described with reference to Fig. 5.

A solid line A of Fig. 5 represents the frequency spectrum of the IDT when the IDT is subjected to a cross width weighting according to the preferred embodiments of the present invention, and a broken line B of Fig. ~~{B}~~ 5 represents the frequency spectrum of a normal ~~{type}~~ IDT having the same number of electrode ~~{ }~~finger pairs as the cross width weighted IDT. 2N, 2N-1, etc. represent the positions of resonance points of the 2N-order mode, the (2N-1)-order mode, etc. The attenuation pole of the main lobe of the IDT which is subjected to the cross width weighting as described above is formed out of the attenuation poles 2N+2, 2N-2 of the main lobe of the normal ~~{type}~~ IDT.

In the cross-width weighted frequency spectrum A, the attenuation amount is relatively small in the (2N-2)-order and (2N+2)-order modes, and thus it is apparent that the excitation can be achieved in these modes. In ~~{this}~~ the preferred embodiments of the present invention, plural resonance characteristics are achieved by using the nearest resonance characteristics in the excited even-number modes.

~~{Fig.6}~~ Fig. 6 shows an example of the weighting of the IDT having the frequency spectrum indicated by the solid line A in Fig. 5. The free edge

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reflective-type surface wave resonator 11 shown in Fig. 6 has a pair of comb-shaped electrodes 13 and 14 ~~{formed}~~ provided on a piezoelectric substrate 12. An IDT is constructed by these comb-shaped electrodes 13 and 14. As is apparent from Fig. 6, the IDT electrode is subjected to the cross width weighting. The degree of the weighting is selected so as to provide the frequency spectrum indicated by the solid line A in Fig. 5 as described above~~{, however}~~. However, the manner of the weighting to achieve the frequency spectrum indicated by the solid line A is not limited to that of Fig. 6. That is, the IDT having the frequency spectrum indicated by the solid line A of Fig. 5 may be formed by another electrode having a different shape from that of the comb-shaped electrodes 13 and 14 shown in Fig. 6. The weighting may be performed by a thinning electrode method. This weighting method has been well known, and it is described at pages 66 to 68 of "ELASTIC SURFACE WAVE ENGINEERING" supervised by Inuo Shibayama (Electrical Information Communication Society Corporation), for example.

The free edge reflective-type surface wave resonator 11 shown in Fig. 6 has ~~{the same}~~ a similar construction as the free edge reflective-type surface wave resonator shown in Fig. 2, except that the IDT is weighted in the manner as described above. Therefore, the same description of the same or corresponding elements as that of Fig. 2 is applied, and thus the detailed description thereof is omitted.

Fig. 7 is a graph showing an impedance-frequency characteristic of the free edge reflective-type surface wave resonator 11 using the cross-width weighted IDT as indicated by the solid line A

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of Fig. 5. As is apparent from Fig. 7, three resonance characteristics as represented by FR1, FR2 and FR3 are obtained. The FR1 represents the resonance point due to "spurious" corresponding to the (2N-2)-order mode in the frequency spectrum of the normal ~~{type}~~ IDT which is determined by the substrate dimension as described above, the FR2 represents the resonance point of a resonance characteristic of the 2N-order mode of the main lobe of the cross-width weighted IDT, and the FR3 represents the resonance point of a resonance characteristic of the (2N+2)-order mode. As is apparent from Fig. 7, three resonance characteristics can be obtained. Two traps can be constructed by using any two resonance points, for example, the resonance points FR1 and FR2.

For example, if the free edge reflective-type surface wave resonator 11 is constructed so that the FR1 corresponds to the adjacent channel video signal frequency at the picture intermediate stage and the FR2 corresponds to the adjacent channel audio signal frequency at the picture intermediate stage, the attenuation-frequency characteristic shown in Fig. 8 can be achieved.

That is, the wavelength of the IDT is determined in accordance with the adjacent channel audio signal frequency, and the number of electrode ~~{-}~~finger pairs is determined in accordance with the adjacent channel video signal frequency. Further, the IDT is weighted so that the attenuation poles are located ~~{out}~~ <u>outside</u> of the attenuation poles of the normal ~~{type}~~ IDT having the same number of pairs, whereby a resonator having two resonance characteristics with a single element can be provided.

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While preferred embodiments of the present invention have been disclosed, various modes of carrying out the principles described herein are contemplated as being within the scope of the following claims. Therefore, it is understood that the scope of the present invention is not to be limited except as otherwise set forth in the claims.

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WHAT IS CLAIMED IS

1. A free edge reflective-type surface wave resonator for reflecting SH-type surface ~~{wave}~~ waves between two confronting free edges of a piezoelectric substrate, ~~{including}~~ the free edge reflective-type surface wave resonator comprising:

a piezoelectric substrate having two confronting free edges; and

an interdigital transducer ~~{which is formed}~~ provided on said piezoelectric substrate~~{, and subjected to a weighting operation by a cross width weighting method or an electrode thinning method, wherein the weighting operation is performed}~~ and having a plurality of interdigitated electrode fingers having cross widths that are weighted so that an attenuation pole of a main lobe is located ~~{out}~~ outside of ~~{the}~~ a frequency position of an attenuation pole of a main lobe of ~~{a normal type}~~ an unweighted interdigital transducer having ~~{the number of electrode-finger pairs which is determined by}~~ the same number of electrode ~~{-}~~finger pairs as said interdigital transducer or the same inter-substrate dimension as said interdigital transducer, ~~{and}~~ said cross widths of said electrode fingers being weighted such that a resonance characteristic ~~{due to the}~~ of a main lobe and ~~{the}~~ a resonance characteristic ~~{due to the}~~ of an attenuation pole of the ~~{normal type}~~ unweighted interdigital transducer are obtained.

2. The surface wave resonator as claimed in claim 1, wherein said surface wave resonator comprises a

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resonator which constitutes a trap circuit at a picture intermediate frequency stage of a television receiver, and one of ~~{plural}~~ a plurality of frequency characteristics corresponds to an adjacent channel video signal frequency and another of the ~~{plural}~~ plurality of frequency characteristics which has a higher frequency than said one of the plurality of frequency characteristics corresponds to an adjacent channel audio signal frequency.

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ABSTRACT OF THE DISCLOSURE

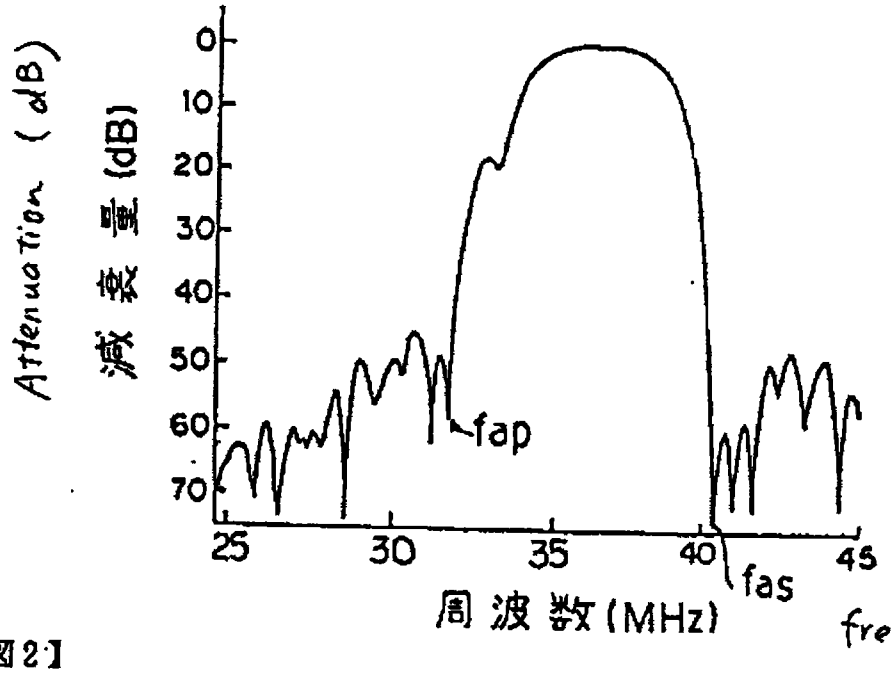
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~~{FIGURES~~
~~FIGS. 1, 4, 5, 6~~
~~ATTENUATION (dB), FREQUENCY~~
~~FIG. 7~~
~~IMPEDANCE, FREQUENCY}~~

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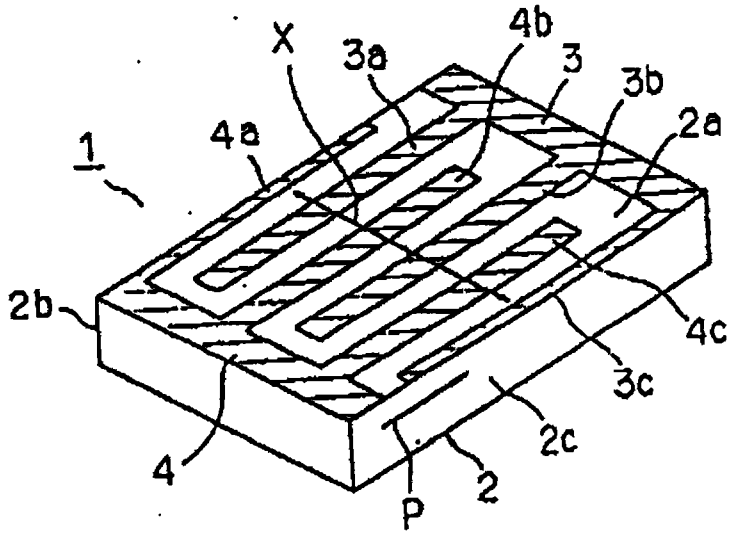
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【図1】 Fig. 1



【図2】

Fig. 2

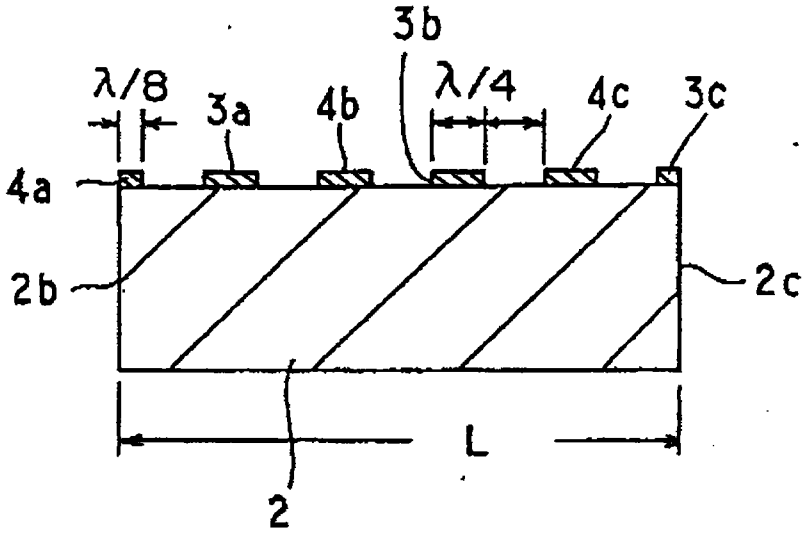


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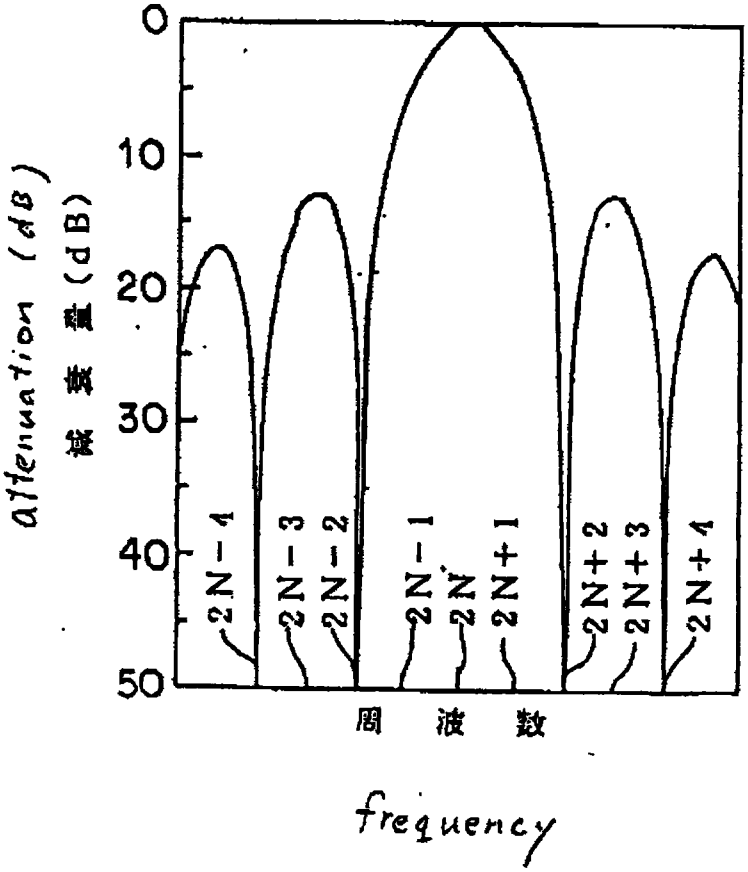
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Fig. 3



【図4】

Fig. 4

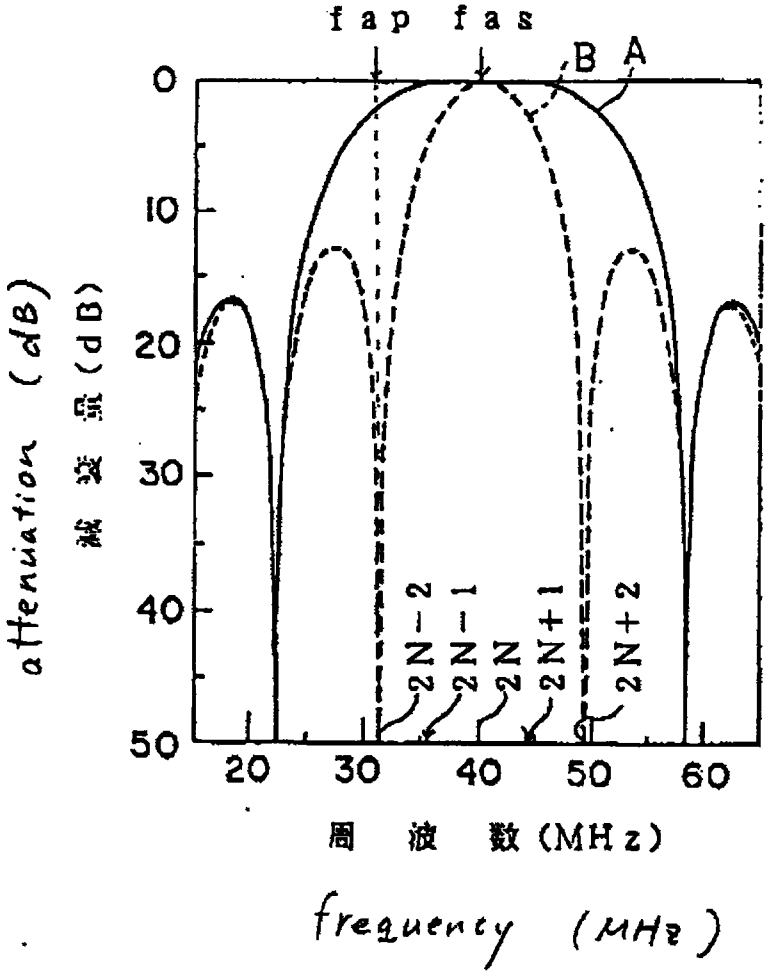


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【図5】

Fig. 5

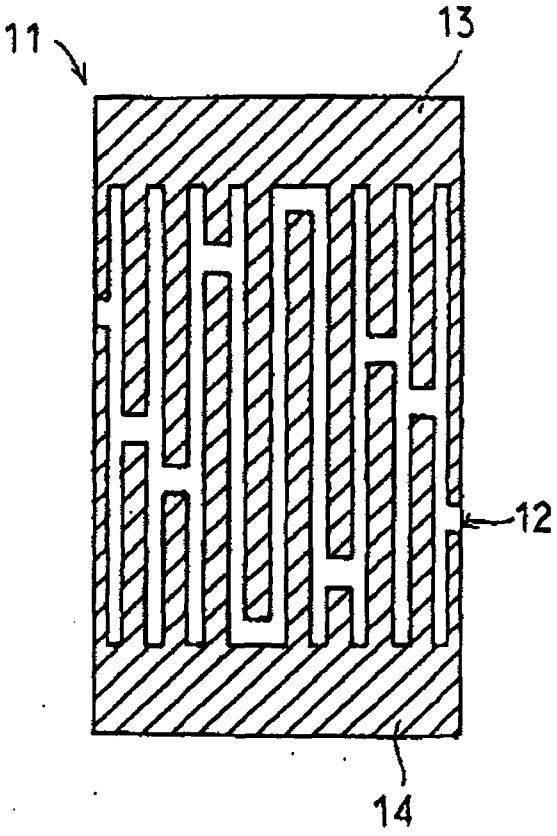


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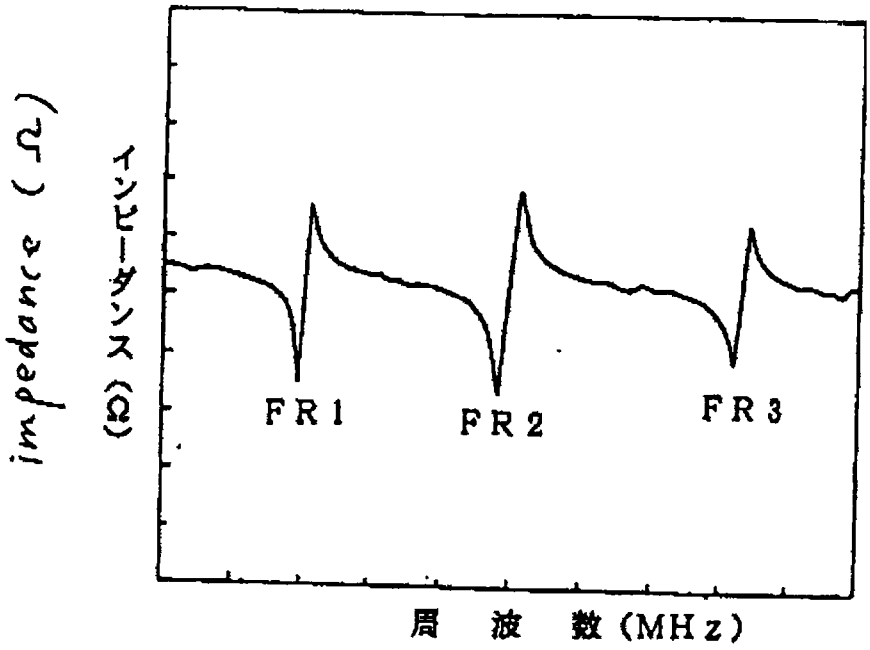
【図6】

Fig. 6

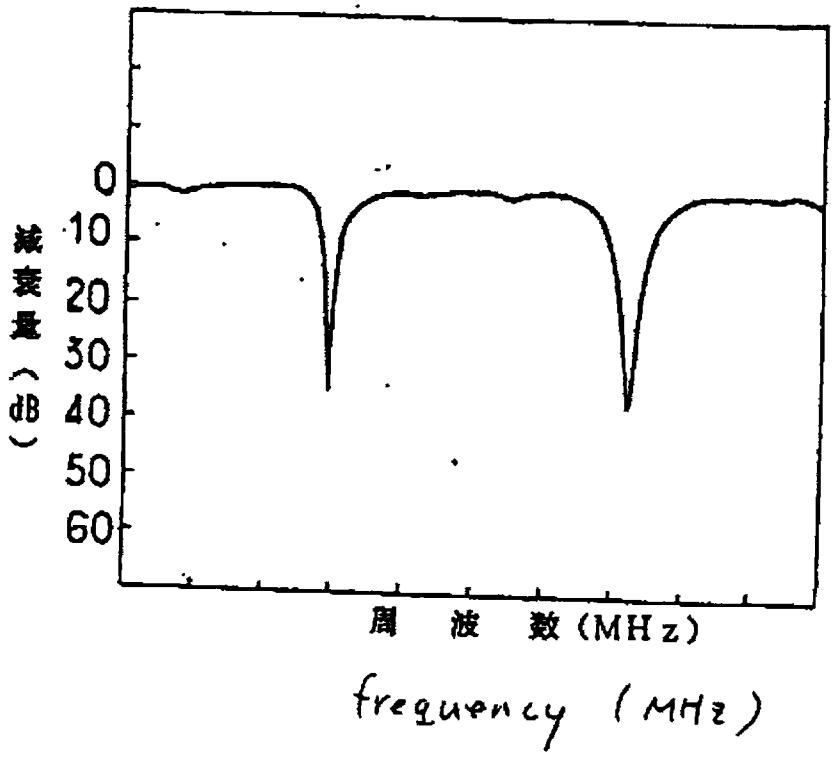


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【図7】 Fig. 7



【図8】 Fig. 8



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SURFACE WAVE RESONATOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a free edge reflective-type surface wave resonator using SH-type surface waves such as BGS waves, Love waves or the like, and particularly to a free edge reflective-type surface wave resonator in which plural resonance units are fabricated as a single unitary element.

2. Description of Related Art

A television receiver, a video tape recorder, and other similar devices have been required to sufficiently attenuate signals at an adjacent channel video signal frequency f_{ap} (31.9 MHz in European PAL system) and the adjacent channel audio signal frequency f_{as} (40.4 MHz in European PAL system) at a picture intermediate frequency stage thereof in order to avoid any obstruction between adjacent channels. Fig. 1 is a graph showing an attenuation-frequency characteristic at the picture intermediate frequency stage. It is apparent from Fig. 1 that the attenuation is relatively large at the adjacent channel video signal frequency f_{ap} and the adjacent channel audio signal frequency f_{as}.

In order to keep the attenuation large at the adjacent channel video signal frequency f_{ap} and the adjacent channel audio signal frequency f_{as} as described above, two conventional traps have been used. One of the conventional traps has a large attenuation at the adjacent channel video signal frequency f_{ap} and the other conventional trap has a large attenuation at the adjacent channel video signal frequency f_{as}. Each of the conventional traps is constructed by an LC resonance circuit, a piezoelectric resonator, etc.

With respect to the piezoelectric resonator which is used for the above purpose, much attention has been paid to a piezoelectric resonator using SH-type surface waves such as BGS waves. Fig. 2 is a perspective view showing a free edge reflective-type surface wave resonator using BGS waves.

A free edge reflective-type surface wave resonator 1

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is constructed by a piezoelectric substrate 2 having a substantially rectangular flat surface. The piezoelectric substrate 2 is formed of piezoelectric material such as piezoelectric ceramic of lead titanate zironate, $LiNbO_3$ piezoelectric monocrystal, $LiTaO_3$ monocrystal or the like. When the substrate 2 is formed of piezoelectric ceramic, the substrate 2 is subjected to a polarization treatment in a direction as indicated by an arrow P in Fig. 2. A pair of comb-shaped electrodes 3 and 4 are provided on the upper surface 2a of the piezoelectric substrate 2 to form an interdigital transducer (hereinafter referred to as "IDT"). Each of the comb-shaped electrodes 3 and 4 has plural electrode fingers 3a to 3c and 4a to 4c, respectively.

By applying an alternating voltage through the comb-shaped electrodes 3 and 4, BGS waves are excited on the free edge reflective-type surface wave resonator 1, and the BGS waves propagate in a direction as indicated by an arrow X in Fig. 2. The BGS waves are reflected between the free edges 2b and 2c of the piezoelectric substrate 2. The free edge reflective-type surface wave resonator 1 can obtain an effective resonance characteristic by setting the frequency determined by the IDT and the frequency determined by the dimension between the free edges to be substantially equal to each other.

However, the free edge reflective-type surface resonator only has a single resonance characteristic like an LC resonance circuit and other types of piezoelectric resonators. Accordingly, two surface wave resonators must be prepared and connected to each other to achieve a trap characteristic at the two frequency positions (the adjacent channel video signal frequency f_{ap} and the adjacent channel audio signal frequency f_{as}).

An elastic surface wave resonator using Rayleigh waves has been known as another type surface wave resonator. This elastic surface wave resonator has two resonance characteristics although it uses a single resonator, as disclosed in "INTERNATIONAL ELECTRICAL TECHNOLOGY REPORT", No. 16, pp. 1-7, 1992, for example. That is, there is known a double mode resonator using a zero-order longitudinal mode (fundamental mode) and a second-order longitudinal mode in a surface wave resonator

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filter using Rayleigh waves, and two resonance characteristics are obtained by this resonator. However, the double mode resonator needs two or more IDTs and a reflector. Further, in the double mode resonator, the resonance characteristics are determined on the basis of the characteristic of reflection coefficient and the frequency of the reflector. Furthermore, a frequency range where a large reflection coefficient is obtained is narrow. Therefore, the difference between the two resonance points is a very small value, for example, about 1 MHz in a range where an excellent resonance characteristic is obtained. Thus, it is impossible to construct a double mode resonator including two trap resonators which have such a characteristic as shown in Fig. 1 and which have a large frequency gap therebetween. Therefore, it may be considered that if two IDTs are provided on the piezoelectric substrate to form two resonance units in the free edge reflective-type surface wave resonator using BGS waves as described above, two resonance characteristics can be obtained. However, in the free edge reflective-type surface wave resonator using SH-type surface waves such as BGS waves, schematically shown in Fig. 3, the following relationship is satisfied between the wavelength λ of the IDT and the distance L of the two confronting free edges where the surface wave of the piezoelectric substrate is reflected:

$$L \approx (\lambda/2) \times N \text{ (N represents an integer)}$$

Since the frequency difference between f_{ap} and f_{as} is large, the wavelengths λ of the respective IDTs differ greatly from each other. For example, assuming the sound velocity of the PZT substrate to be equal to 2400m/s, λap for f_{ap} = 75.2 μm and λas for $f_{as} \approx$ 59.4 μm in case of the PAL system. Accordingly, the value of the distance L between the two confronting free edges is different between the resonance unit having a resonance point at the adjacent channel video signal frequency f_{ap} and the resonance unit having a resonance point at the adjacent channel audio signal frequency f_{as}. That is, with respect to the free edge reflective-type surface wave resonator using SH-type surface waves, it is extremely difficult to form two resonance units having different resonance frequencies on the same substrate.

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SUMMARY OF THE INVENTION

The preferred embodiments of present invention provide a free edge reflective-type surface wave resonator using SH-type surface waves in which at least two resonance units having different resonance frequencies are fabricated as a single unitary element.

More specifically, according to the preferred embodiments of the present invention, a free edge reflective-type surface wave resonator for reflecting SH-type surface waves between two confronting free edges of a piezoelectric substrate, includes a piezoelectric substrate having two confronting free edges, and an IDT provided on the piezoelectric substrate including a plurality of electrode fingers being weighted by a cross width weighting method or an electrode thinning method, wherein the weighting is performed so that an attenuation pole of a main lobe is located outside of the frequency of an attenuation pole of a "normal" IDT (wherein "normal" refers to an unweighed IDT having equal cross widths between electrode fingers) having the same number of electrode finger pairs, and a resonance characteristic determined by the main lobe and a resonance characteristic determined by the attenuation pole of the normal IDT are obtained.

That is, in the surface wave resonator of the preferred embodiments of the present invention, two or resonance characteristic are obtained with only a single element by using the attenuation pole of the normal IDT which is originally suppressed. The SH-type surface wave in this specification is broadly defined as containing not only BGS waves, but also surface waves like Love waves having a component whose displacement is substantially perpendicular to the propagation direction of the surface waves.

Further, the surface resonator of the preferred embodiments of the present invention is preferably used to constitute a trap circuit at the picture intermediate frequency stage of a television receiver or a video tape recorder. That is, the positions of the respective attenuation poles as described above are set so that one of the plural resonance characteristics is set as the adjacent channel video signal frequency (f_{ap}) and another resonance characteristic having a higher frequency is set

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as the adjacent channel video signal frequency (f_{as}), whereby a trap circuit having traps at the adjacent channel video signal frequency and the adjacent channel audio signal frequency can be constructed by a single unitary element.

As described above, the resonance frequency f_r, of the free edge reflective-type surface wave resonator using BGS waves is determined as follows:

$f_r = v/\lambda$ (λ represents the wavelength of surface wave excited by the IDT, and v represents the sound velocity of the piezoelectric substrate)

Further, the dimension L connecting the two confronting free edges of the piezoelectric substrate is preferably determined so as to satisfy the equation:

$L = (\lambda/2) \times n$ (n represents an integer).

Accordingly, when a resonator constituting a trap for the adjacent channel video signal frequency and a resonator constituting a trap for the adjacent channel audio signal frequency, which are used at the picture intermediate frequency stage, are constructed by a free edge reflective-type surface wave resonator, the value of the dimension L is different between the above two resonators because they have greatly different wavelengths λ. Therefore, it has been hitherto considered as being difficult to form two resonators on the same chip or substrate.

On the other hand, according to the preferred embodiments of the present invention, the weighting is performed so that the attenuation pole of the main lobe of the weighted IDT is located outside of the frequency position of the attenuation pole of the normal IDT having the same number of electrode finger pairs. Accordingly, plural resonance characteristics are obtained, which are the resonance characteristic determined by the substrate dimension L as described above, that is, the resonance characteristic determined by the attenuation pole of the normal IDT and the resonance characteristic determined by the main lobe of the weighted IDT. That is, as is apparent from the foregoing description, by using the resonance characteristic determined by the weighted IDT and the characteristic determined by the substrate dimension L, the free edge reflective-type surface wave resonator having plural resonance characteristics

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can be constructed despite the fact that it has a single-element unitary structure.

As described above, according to the preferred embodiments of the present invention, a free edge reflective-type surface wave resonator which achieves plural resonance characteristics despite its single-element unitary structure can be provided by weighting the IDT as described above, and an optimum surface wave resonator can be provided for use in devices requiring two resonance characteristics such as a trap circuit for a picture intermediate frequency stage. Since two resonance characteristics are achieved and provided by a single unitary element, the circuit construction of a trap circuit and other devices can be simplified and cumbersome connection work of several circuit elements can be omitted. In addition, the size of the trap circuit and similar devices can be effectively reduced.

For the purpose of illustrating the invention, there is shown in the drawings several preferred embodiments which are presently preferred, it being understood that the present invention is not limited to the precise structural arrangements and instrumentalities shown in the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a graph showing an attenuation-frequency characteristic at a picture intermediate frequency stage of a television receiver;

Fig. 2 is a perspective view showing a conventional free edge reflective-type surface wave resonator using BGS waves;

Fig. 3 is a cross-sectional view showing the conventional free edge reflective-type surface wave resonator;

Fig. 4 is a diagram showing the frequency spectrum of a normal IDT;

Fig. 5 is a diagram showing the frequency spectrum of a weighted IDT and the normal IDT;

Fig. 6 is a diagram showing a free edge reflective-type surface wave resonator of a preferred embodiment of the present invention;

Fig. 7 is a diagram showing an impedance-frequency characteristic of the free edge reflective-type surface wave

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resonator of the preferred embodiment; and

Fig. 8 is a diagram showing an attenuation-frequency characteristic of a trap filter which is constructed by the free edge reflective-type surface wave resonator of the preferred embodiment.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Preferred embodiments according to the present invention will be described with reference to the accompanying drawings.

Fig. 4 is a diagram showing the resonance frequency spectrum of a normal IDT in a free edge reflective-type surface wave resonator using BGS waves. The resonance frequency spectrum of the IDT is described in "Lecture Papers of Japan Acoustic Society", pp. 351-352, issued on March, 1976. The axis of the abscissa of Fig. 4 represents the frequency, and 2N, 2N-1 etc. on the axis of abscissa represent resonance points of a 2N-order mode, (2N-1)-order mode, etc. The axis of the ordinate represents an attenuation amount when the peak of a main lobe is set to 0 dB.

As is apparent from Fig. 4, when a normal IDT is used, the resonance mode of 2N-order (N represents an integer) can be excited by forming an IDT having N pairs of electrode fingers on the surface of the piezoelectric substrate. Further, odd-number modes out of the other high-order modes, that is, modes of (2N-1) - order, (2N-3)-order, (2N+1)-order and (2N+3)-order are not excited due to symmetry of the electrode. With respect to the even-number modes, as is apparent from Fig. 4, the resonance frequency is coincident with the attenuation pole of the frequency characteristic of the IDT having N pairs of electrode fingers so that these modes are not excited. That is, the even-number modes of (2N-2)-order, (2N-4)-order, (2N+2)-order, (2N+4)-order, etc. are not excited. Accordingly, only the 2N-order mode is excited in the free edge reflective-type surface wave resonator on which the normal IDT is formed as shown in Fig. 2, and thus a resonator having relatively little spurious can be formed. However, as described above, only a single resonance characteristic can be obtained by the surface wave resonator shown in Fig. 2.

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On the other hand, according to the preferred embodiments of the present invention, plural resonance characteristics can be obtained by weighting the IDT as described. A weighting method will be hereunder described with reference to Fig. 5.

A solid line A of Fig. 5 represents the frequency spectrum of the IDT when the IDT is subjected to a cross width weighting according to the preferred embodiments of the present invention, and a broken line B of Fig. 5 represents the frequency spectrum of a normal IDT having the same number of electrode finger pairs as the cross width weighted IDT. 2N, 2N-1, etc. represent the positions of resonance points of the 2N-order mode, the (2N-1)-order mode, etc. The attenuation pole of the main lobe of the IDT which is subjected to the cross width weighting as described above is formed out of the attenuation poles 2N+2, 2N-2 of the main lobe of the normal IDT.

In the cross-width weighted frequency spectrum A, the attenuation amount is relatively small in the (2N-2)-order and (2N+2)-order modes, and thus it is apparent that the excitation can be achieved in these modes. In the preferred embodiments of the present invention, plural resonance characteristics are achieved by using the nearest resonance characteristics in the excited even-number modes.

Fig. 6 shows an example of the weighting of the IDT having the frequency spectrum indicated by the solid line A in Fig. 5. The free edge reflective-type surface wave resonator 11 shown in Fig. 6 has a pair of comb-shaped electrodes 13 and 14 provided on a piezoelectric substrate 12. An IDT is constructed by these comb-shaped electrodes 13 and 14. As is apparent from Fig. 6, the IDT electrode is subjected to the cross width weighting. The degree of the weighting is selected so as to provide the frequency spectrum indicated by the solid line A in Fig. 5 as described above. However, the manner of the weighting to achieve the frequency spectrum indicated by the solid line A is not limited to that of Fig. 6. That is, the IDT having the frequency spectrum indicated by the solid line A of Fig. 5 may be formed by another electrode having a different shape from that of the comb-shaped electrodes 13 and 14 shown in Fig. 6. The weighting may be performed by a thinning electrode method. This

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weighting method has been well known, and it is described at pages 66 to 68 of "ELASTIC SURFACE WAVE ENGINEERING" supervised by Inuo Shibayama (Electrical Information Communication Society Corporation), for example.

The free edge reflective-type surface wave resonator 11 shown in Fig. 6 has a similar construction as the free edge reflective-type surface wave resonator shown in Fig. 2, except that the IDT is weighted in the manner as described above. Therefore, the same description of the same or corresponding elements as that of Fig. 2 is applied, and thus the detailed description thereof is omitted.

Fig. 7 is a graph showing an impedance-frequency characteristic of the free edge reflective-type surface wave resonator 11 using the cross-width weighted IDT as indicated by the solid line A of Fig. 5. As is apparent from Fig. 7, three resonance characteristics as represented by FR1, FR2 and FR3 are obtained. The FR1 represents the resonance point due to "spurious" corresponding to the (2N-2)-order mode in the frequency spectrum of the normal IDT which is determined by the substrate dimension as described above, the FR2 represents the resonance point of a resonance characteristic of the 2N-order mode of the main lobe of the cross-width weighted IDT, and the FR3 represents the resonance point of a resonance characteristic of the (2N+2)-order mode. As is apparent from Fig. 7, three resonance characteristics can be obtained. Two traps can be constructed by using any two resonance points, for example, the resonance points FR1 and FR2.

For example, if the free edge reflective-type surface wave resonator 11 is constructed so that the FR1 corresponds to the adjacent channel video signal frequency at the picture intermediate stage and the FR2 corresponds to the adjacent channel audio signal frequency at the picture intermediate stage, the attenuation-frequency characteristic shown in Fig. 8 can be achieved.

That is, the wavelength of the IDT is determined in accordance with the adjacent channel audio signal frequency, and the number of electrode finger pairs is determined in accordance with the adjacent channel video signal frequency. Further, the IDT is weighted so that the attenuation poles are located outside

of the attenuation poles of the normal IDT having the same number of pairs, whereby a resonator having two resonance characteristics with a single element can be provided.

While preferred embodiments of the present invention have been disclosed, various modes of carrying out the principles described herein are contemplated as being within the scope of the following claims. Therefore, it is understood that the scope of the present invention is not to be limited except as otherwise set forth in the claims.

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WHAT IS CLAIMED IS

1. A free edge reflective-type surface wave resonator for reflecting SH-type surface waves between two confronting free edges of a piezoelectric substrate, the free edge reflective-type surface wave resonator comprising:-

a piezoelectric substrate having two confronting free edges; and

an interdigital transducer provided on said piezoelectric substrate and having a plurality of interdigitated electrode fingers having cross widths that are weighted so that an attenuation pole of a main lobe is located outside of a frequency position of an attenuation pole of a main lobe of an unweighted interdigital transducer having the same number of electrode finger pairs as said interdigital transducer or the same inter-substrate dimension as said interdigital transducer, said cross widths of said electrode fingers being weighted such that a resonance characteristic of a main lobe and a resonance characteristic of an attenuation pole of the unweighted interdigital transducer are obtained.

2. The surface wave resonator as claimed in claim 1, wherein said surface wave resonator comprises a resonator which constitutes a trap circuit at a picture intermediate frequency stage of a television receiver, and one of a plurality of frequency characteristics corresponds to an adjacent channel video signal frequency and another of the plurality of frequency characteristics which has a higher frequency than said one of the plurality of frequency characteristics corresponds to an adjacent channel audio signal frequency.

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Surface Wave Resonator

ABSTRACT OF THE DISCLOSURE

A free edge reflective-type surface wave resonator for reflecting SH-type surface waves between two confronting free edges of a piezoelectric substrate includes a piezoelectric substrate having two confronting free edges and an interdigital transducer having a plurality of electrode fingers having cross widths which are weighted by a cross width weighting method or an electrode thinning method. The weighting of the cross widths is performed so that an attenuation pole of a main lobe is located outside of a frequency of an attenuation pole of a normal non-weighted IDT which has the same number of electrode finger pairs as the weighted IDT, and plural resonance characteristics. Consequently, a resonance characteristic determined by the main lobe and a resonance characteristic determined by the attenuation pole of the normal IDT are obtained.

Figure 6.

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Fig. 1

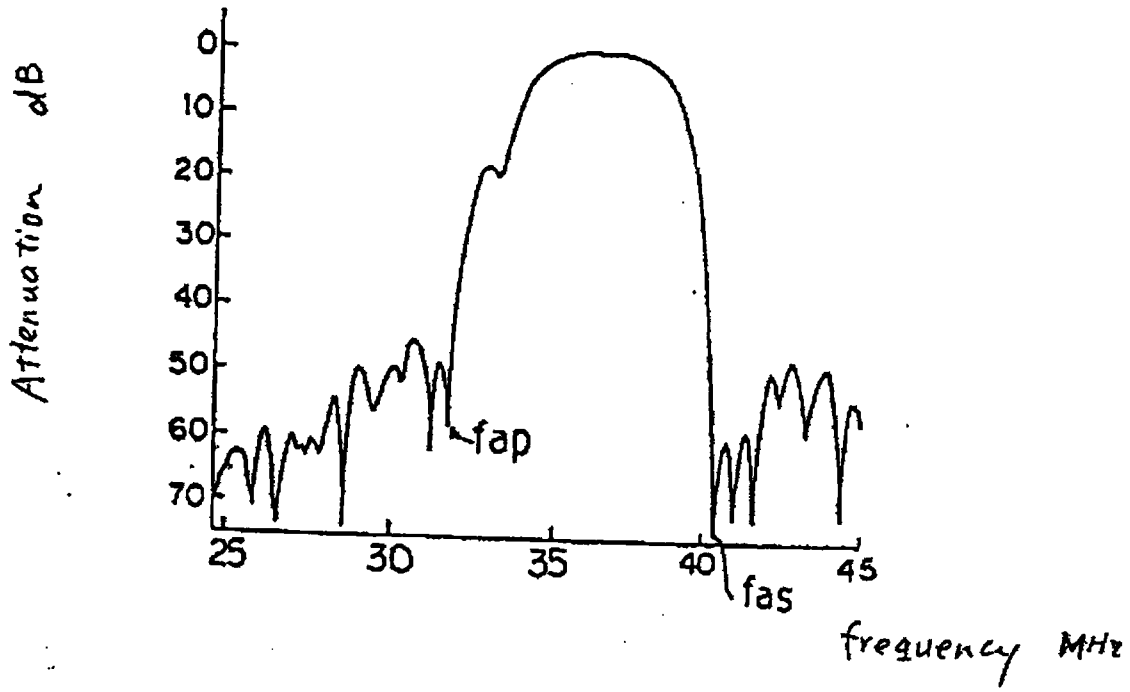
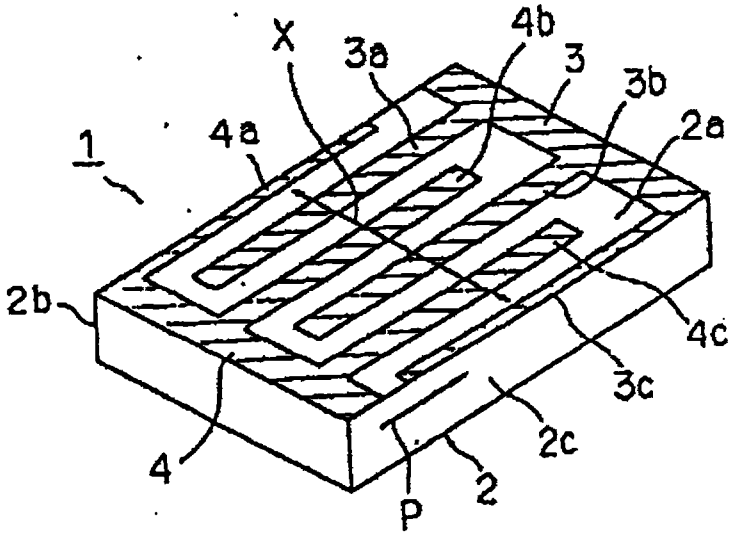


Fig. 2



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Fig. 3

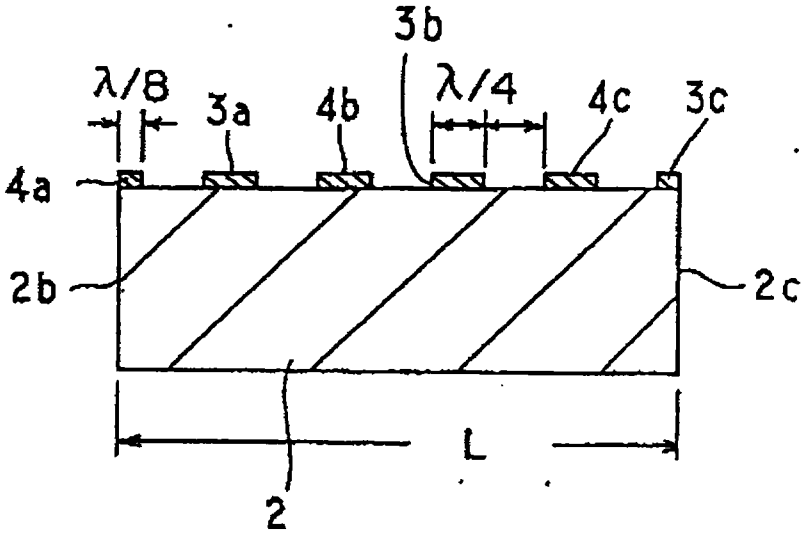
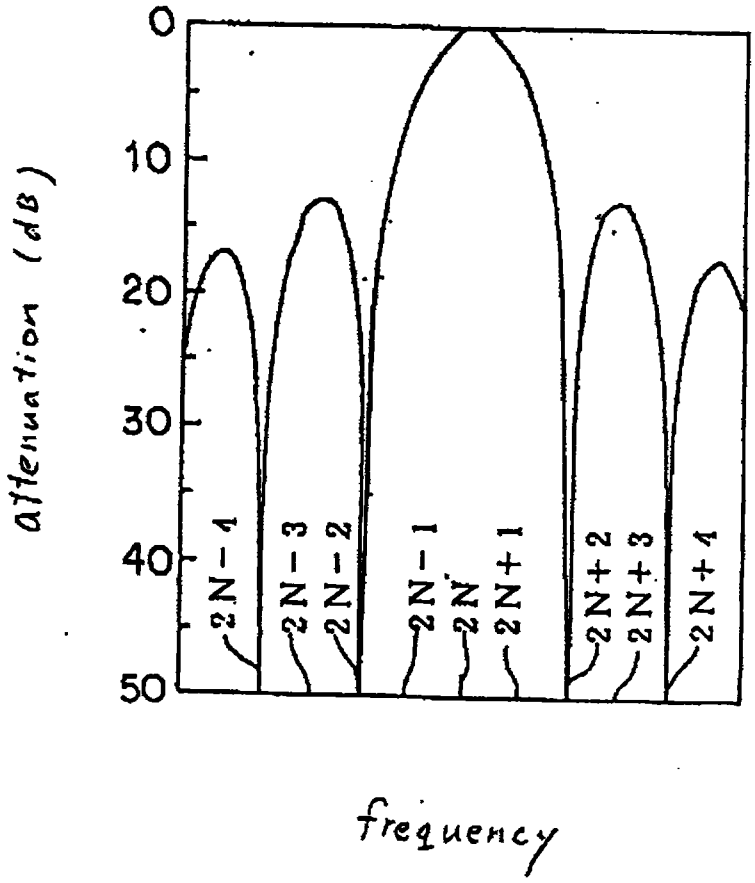


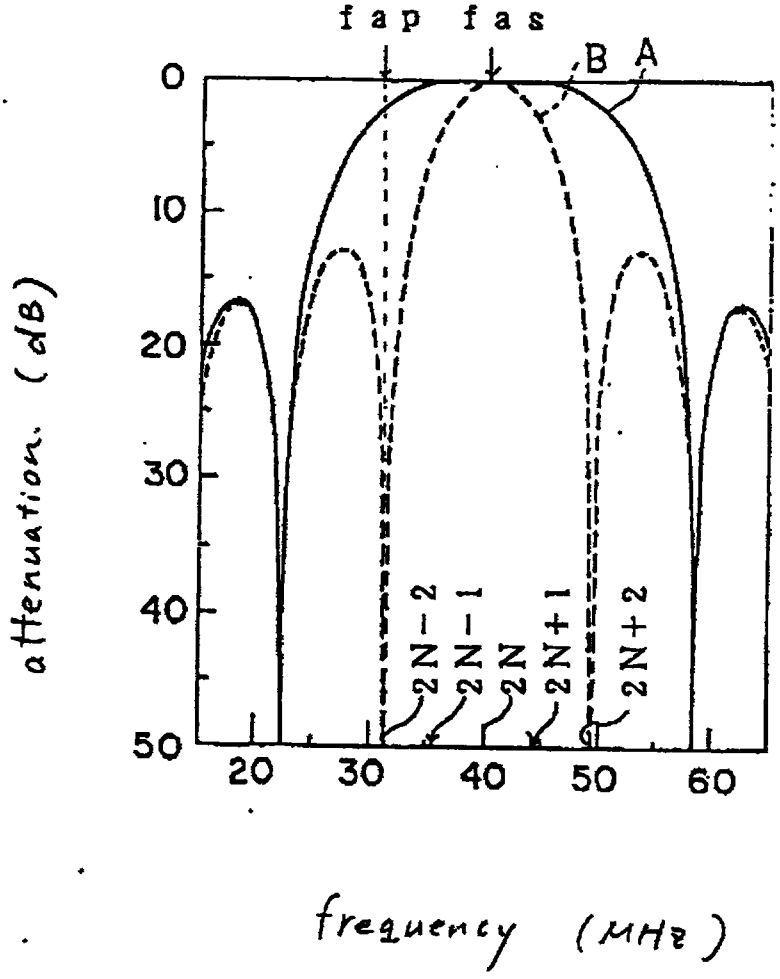
Fig. 4



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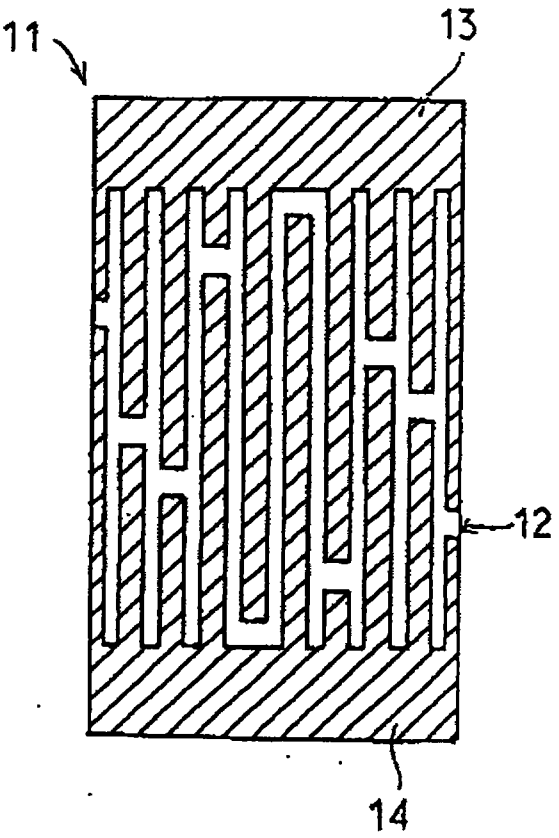
Fig. 5



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Fig. 6



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Fig. 7

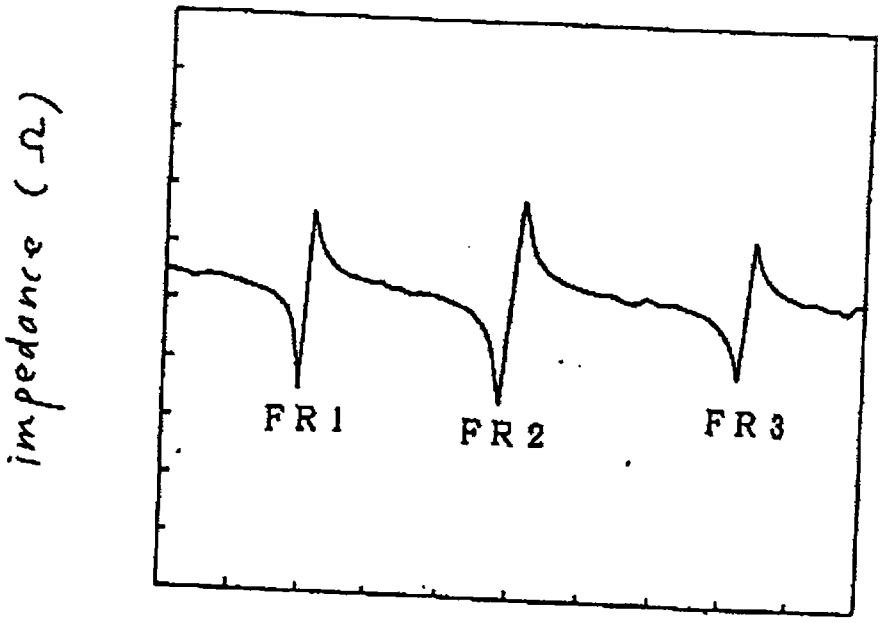
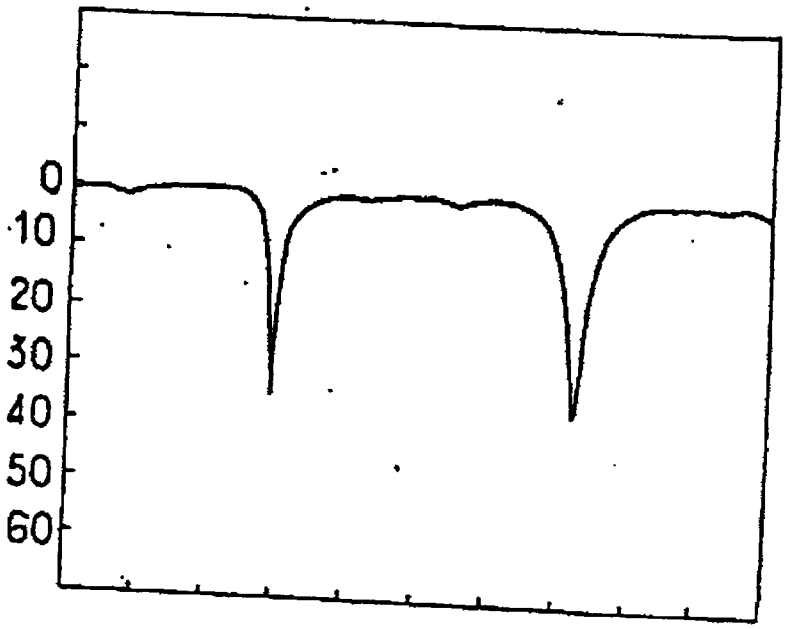


Fig. 8



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