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(54) **Title:** NARROW BAND BULK ACOUSTIC WAVE FILTER

(57) **Abstract:** Thin-film bulk acoustic wave filters based on piezoelectric resonators operating in the thickness extensionally mode achieve relative band-widths in the order of to 4 % at a center frequency of 2 GHz. According to an exemplary embodiment of the present invention, a filter is provided, comprising a plurality of low coupling coefficient bulk acoustic wave resonators forming a mixture of lattice- and laddersections. Advantageously, this may result in a low filter band-width of 6 MHz for a center frequency of 1 GHz and a high out-of-band rejection of more than 40 dB. Thus, a filter according to the present invention may be used in a TV up-conversion tuner.

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Narrow band bulk acoustic wave filter

The present invention relates to the field of filtering electronic signals. In particular, the present invention relates to a filter comprising a plurality of low coupling-coefficient bulk acoustic wave resonators, to the use of a respective narrow-band filter in a TV up-conversion tuner and to a method of fabricating such a filter.

Thin-film bulk acoustic wave (BAW) filters which are based on piezoelectric resonators operating in the thickness extensional mode are used today for filtering signals both in the receive path and in the transmit path of mobile radio front ends. Frequencies are typically in the 1-2 GHz range and, for the most commonly used thin-film piezoelectric material aluminium nitrate (AlN), the relative band-width is in the order of 3 – 4 % (band-width at 2 GHz approx. 60 MHz). BAW filters have been demonstrated with low pass-band insertion loss, steep roll-off and very good rejection outside the pass-band. They are small in size and can be flip-chip mounted or integrated on silicon. These filters are therefore well suited for mobile applications.

There are, however, also filter applications where significantly narrower band-width is required. In TV up-conversion tuner architectures, intermediate frequency (IF) filters are required which select only a single TV channel.

It is an object of the present invention to provide for an improved filter performance.

According to an exemplary embodiment of the present invention as set forth in claim 1, the above object may be solved by a filter, comprising a plurality of low coupling-coefficient bulk acoustic wave resonators, a first group of resonators of a plurality of low coupling-coefficient bulk acoustic wave resonators and a second group of resonators of the plurality of low coupling-coefficient bulk acoustic wave resonators, wherein the first group forms a lattice section and wherein the second group forms a ladder section.

In other words, a filter is provided which comprises a mixture of lattice- and ladder-sections of low coupling-coefficient thin-film BAW resonators. Advantageously, this may result in a narrow band-width, a high out-of-band rejection and an efficient rejection at the "image" or "mirror" frequency and therefore in an improved filter performance.

According to another exemplary embodiment of the present invention as set forth in claim 2, the filter is an electrically balanced filter, wherein the filter is adapted for use in a TV up-conversion tuner.

Advantageously, this may allow for an effective suppression of mirror frequencies and for a good rejection of adjacent channel frequencies.

According to another exemplary embodiment of the present invention as set forth in claim 3, each first group resonator of the first group which forms the lattice section has a first surface area and each second group resonator of the second group which forms the ladder section has a second surface area, wherein the second surface area is a predetermined fraction of the first surface area.

For example, according to an aspect of the present invention, the second surface area is the first surface area times ($1/\sqrt{2}$). This factor may provide for optimum electrical impedance-matching between ladder and lattice sections, and therefore maximum power transfer at the filter centre frequency. The filter response may be adjusted by changing this factor, e.g. to modify the stop-band.

According to another exemplary embodiment of the present invention as set forth in claim 4, the filter is an electrically unbalanced filter, wherein the filter comprises a third group of resonators which are shunt resonators and wherein the filter comprises a fourth group of resonators which are series resonators.

Such an unbalanced arrangement may be advantageous at RF (Radio Frequency) where the filter may be directly connected to other unbalanced devices such as antennas or power amplifiers.

According to another exemplary embodiment of the present invention as set forth in claim 5, the filter is at least one of a narrow band filter, a narrow band RF filter, and a narrow band IF filter.

According to another exemplary embodiment of the present invention as set forth in claim 6, each resonator of the plurality of resonators comprises a first layer occupying a first volume, a second layer and a resonant cavity, which occupies a second volume, wherein the first layer and the second layer are inside the resonant cavity, which may also include a top electrode layer above the first and second layers and a bottom electrode layer below the first and second layers. The first volume is significantly smaller than the second volume, such that an effective coupling coefficient of the resonator is significantly reduced. The first layer is a piezoelectric layer.

Advantageously, this may provide for a narrow band bulk acoustic wave filter with a simple layer sequence and an improved filter performance. Production costs may thus be reduced relative to alternative methods of reducing band-width, such as the addition of a capacitor in parallel with each resonator.

According to another exemplary embodiment of the present invention as set forth in claim 7, the second layer is one of a non-piezoelectric layer, a non-piezoelectric dielectric layer, part of a bottom electrode and part of a top electrode.

For example, the second layer may be formed of the same material as the bottom electrode thus increasing the thickness of the bottom electrode. At the same time the thickness of the piezoelectric layer is reduced correspondingly, resulting in a reduction of the effective coupling coefficient of the resonator by reducing the percentage of the resonant cavity occupied by the piezoelectric layer to much less than 100 %.

Another exemplary embodiment of the present invention as set forth in claim 8.

According to another exemplary embodiment of the present invention as set forth in claim 9, at least one of the first layer and the second layer comprises a material with a positive temperature dependence of elastic constants and at least one of the second layer and the first layer comprises a material with a negative temperature dependence of elastic constants.

Advantageously, this may result in a minimization of the temperature dependence of the resonant frequency of the BAW resonators.

Other exemplary embodiments, advantages and aspects of the present invention are set forth in the further independent claims or sub-claims.

According to another exemplary embodiment of the present invention as set forth in claim 11, a method of fabricating a filter is provided, the method comprising the steps of providing a substrate, providing an acoustic decoupling between a resonator and the substrate, providing a bottom electrode, providing a second layer which is one of a non-piezoelectric and a non-piezoelectric dielectric layer, providing a first layer which is a piezoelectric layer and providing a top electrode wherein the first layer is one of on top of the second layer and beneath of the second layer.

Advantageously, this method may provide for the production of an improved narrow- band bulk acoustic wave filter.

Another exemplary embodiment of the present invention is set forth in claim 12, where the acoustic decoupling is provided by at least one of an acoustic Bragg reflector on top of the substrate, by locally etching away the substrate, and by providing an air gap between the resonator and the substrate. The bottom electrode comprises a material selected from the group of materials consisting of Al, Pt, W, Mo, Au, and Cu; the first layer comprises a material selected from the group of materials consisting of AlN, ZnO, PZT, La doped PZT, KnO_3, and Li Niobate. The second layer comprises a material selected from the group of materials consisting of Si_3N_4, SiO_2, Pt, and Ta_2O_5 and the top electrode comprises a material selected from the group of materials consisting of Al, Pt, W, Mo, Au, and Cu. It is particularly advantageous to employ a very dense metal such as Pt, W or Au for the top electrode as discussed below in relation to mass-loading.

Another exemplary embodiment of the present invention is set forth in claim 13.

It may be seen as the gist of an exemplary embodiment of the present invention that an IF- or RF-filter for example for use in a TV up-conversion tuner is provided which comprises a plurality of thin-film low coupling-coefficient bulk acoustic wave resonators. According to an exemplary embodiment of the present invention, the filter comprises a mixture of lattice- and ladder-sections, resulting in a low filter band-width of 6 MHz for a center frequency of 1.2 GHz and a high out-of-band rejection of more than 40 dB.

These and other aspects of the present invention will become apparent from and will be elucidated with reference to the embodiments described hereinafter.

Exemplary embodiments of the present invention will be described in the following, with reference to the following drawings:

Fig. 1 shows an architecture of an un-balanced thin-film BAW filter.

Fig. 2 shows a measured performance of an un-balanced narrow-band thin-film BAW channel filter.

Fig. 3 shows three alternative cross-sections of a resonator of a narrow-band thin-film BAW channel filter according to the present invention.

Fig. 4 shows an architecture for a balanced narrow-band thin-film BAW implementation of a TV up-conversion tuner IF filter according to an exemplary embodiment of the present invention.

Fig. 5 shows a specification for a TV up-conversion tuner IF filter.

Fig. 6 shows a simulation of a response of a BAW TV up-conversion tuner IF filter.

Fig. 7 shows a layout design of the filter of Fig. 4 according to an exemplary embodiment of the present invention.

For the description of Figs. 1 – 7, the same reference numerals are used to designate the same or corresponding elements.

Fig. 1 shows an architecture of a thin-film narrow-band acoustic wave channel filter. Low coupling-coefficient bulk acoustic wave resonators 10, 11, 12, 13 are series resonators and low coupling-coefficient BAW resonators 14, 15, 16 are shunt resonators. Series resonator 10 is electrically connected to an input signal 30 on its first side and to the neighbouring series resonator 11 and shunt resonator 14 on its second side. The respective sides of the shunt resonators 14, 15, 16 which are not connected to the respective series resonators 10, 11, 12, 13 are on ground potential 32, 33, 34. The last series resonator 13 is connected to a filter output 31.

The filter architecture shown in Fig. 1 is an example of an unbalanced ladder filter employing four series resonators 10, 11, 12, 13 and three shunt resonators 14, 15, 16. The measured response of the filter is shown in Fig. 2.

Fig. 2 shows the measured performance of a narrow-band thin-film BAW filter depicted in Fig. 1. S11 is the reflection coefficient to a power source and S21 is the through coefficient as measured at an output port. All three diagrams represent the same measured data. The top diagram shows S11 and S21 from 10 MHz to 10 GHz. The middle diagram shows S11 and S21 from 1.17 to 1.2 GHz and the bottom diagram depicts a close up view of the pass-band S21.

As can be seen from Fig. 2, the filter has an insertion loss of approx. 5 dB, a 3 dB band-width of 8 MHz, and a close-in rejection of better than 50 dB. The temperature variation of the center frequency of the filter is smaller than –4 ppm/K which is much better than conventional wide-band AlN BAW filters which achieve typically –20 ppm/K.

Fig. 3 shows three alternative cross-sections of a resonator of a narrow-band thin-film BAW filter according to exemplary embodiments of the present invention. The resonators comprise a substrate 1, for example silicon, on top of which is an acoustic decoupler 2 which, for example, may be an acoustic Bragg reflector. After the acoustic decoupler 2 follows a bottom-electrode 3 followed by a layer sequence comprising a non-piezoelectric layer 4 and a piezoelectric layer 5. On top of this layer sequence 4, 5 is a top-electrode 6.

The three alternative layer sequences between the bottom electrode layer 3 and the top electrode layer 6 are as follows. The upper resonator 300 comprises a non-piezoelectric layer 4 underneath the piezoelectric layer 5. The middle resonator 301 comprises the non-piezoelectric layer 4 on top of the piezoelectric layer 5 and the bottom resonator 302 comprises the non-piezoelectric layer 4 sandwiched by two separated piezoelectric layers 5.

The acoustic Bragg reflector 2 of SiO_2 and Ta_2O_5 is deposited on the silicon substrate 1. A bottom electrode 3 of 140 nm Pt is patterned on top of the reflector 2. Then a piezoelectric layer 5 of AlN is deposited. On top of layer 5 the dielectric layer 4 is deposited. The top electrode 6 consists of 100 nm Al and 30 nm Pt. Mass loading of the shunt resonators P (see Fig. 1) may be done by adding a thin SiO_2 layer on top of the structure. For low coupling-coefficient resonators it may be advantageous to use a very dense metal such as Pt, W or Au in the top electrode. This may make the resonant frequency of the resonator less sensitive to the thickness of the mass-loading layer, thus reducing the tolerance on the thickness of this layer, and so increasing manufacturability. Typically of the order of 30 nm of SiO_2 may be required for mass-loading where the top electrode is Pt, compared to of the order of 10 nm where the top electrode is Al. In the filter architecture shown in Fig.1 resonators 14-16 are mass-loaded. In the filter architecture shown in Fig.4 resonators 14-17, 22-25 are mass-loaded.

The acoustic Bragg reflector 2 may consist of $\lambda/4$ layers of materials with high and low acoustic impedance. The substrate 1 may, for example, be silicon, glass, ceramic, or gallium arsenide. The materials with low acoustic impedance may be silicon dioxide, porous silicon dioxide, low K dielectrics, low density polymers, aerogels, or xerogels. The materials with high acoustic impedance may be Ta_2O_5, B, AlN, or HF-oxide.

Alternatively, the acoustic decoupling of the resonators from the substrate may be realized by etching away the substrate locally (micromachining), or by creating an air gap underneath the resonators.

The bottom electrode 3 may be Al, Pt, B, Mo, Au, Cu with an adhesion layer of Cr or Ti. The non-piezoelectric dielectric material 4 may be Si_3M_4, SiO_2, Ta_2O_5. The dielectric material 4 may be underneath the piezoelectric material 5, or on top of the piezoelectric material 5. Also other sequences of materials 4, 5 may be possible. For narrow-band filters piezoelectric materials with fairly low piezoelectric coupling coefficient, such as AlN of ZnO are preferred. However, the proposed methods of fabricating a filter may also be used to reduce effective resonator coupling coefficient k_{eff} for BAW devices based on strongly piezoelectric materials such as lead zirconate titanate (PZT) with or without La doping, $KnbO_3$, Li Tantalite, Li Niobate.

A further benefit of introducing a non-piezoelectric layer 4 adjacent to the piezoelectric layer 5 may be that the choice of non-piezoelectric dielectric 4 may be made such that the temperature dependence of the resonant frequency of the BAW resonator is minimized.

For example, if SiO_2 is chosen as the non-piezoelectric material 4 its temperature dependence compensates the negative slope of the frequency-temperature curve associated with the temperature dependence of the elastic constants of AlN. For the non-piezoelectric dielectric layer 4 the preferred choice may be SiO_2, or any other material which has a positive temperature dependence of its elastic constants.

According to an aspect of the present invention, the filter band-width may be reduced by one of three different methods. In the first method a non-piezoelectric layer 4 is introduced adjacent to the piezoelectric layer 5. In the second method the combination of layers which make up the top electrode is substantially increased in thickness. In the third method the combination of layers which make up a bottom electrode is substantially increased in thickness. Therefore, in the second method the non-piezoelectric layer 4 is omitted and the top electrode 6 is thickened. In third method, the non-piezoelectric layer 4 is omitted and the bottom electrode 3 is thickened.

The use of a dense metal for the top electrode may allow for the use of a thicker mass-loading layer. This may improve manufacturability with the thickness tolerance required.

For a given frequency the thickness of the piezoelectric layer must be correspondingly reduced. The principle involved is the same in all three cases, namely that of reducing effective coupling coefficient k_{eff} of the resonator by reducing the percentage of the resonant cavity occupied by the piezoelectric layer to much less than 100 %. These techniques allow for a filter band-width of, for example, as small as 6 MHz for a center frequency of 1 GHz. At the same time the insertion loss is moderate (typically of the order of 5 dB) and out-of-band rejection may be high (typically bigger than 40 dB).

Intermediate relative band-widths may also be achieved using non-adjacent piezoelectric and non-piezoelectric layers. Both electrically balanced and unbalanced filters may be realized based on lattice and ladder architectures respectively.

More general architectures based on combinations of lattice and ladder sections may also be possible. Balanced filters may be in particular advantageous at IF.

Fig. 4 shows an exemplary filter architecture for a thin-film BAW implementation of a TV up-conversion tuner IF filter. The filter depicted in Fig. 4 comprises a first group of resonators 18 to 25 of a plurality of low coupling-coefficient bulk acoustic wave resonators 10 to 25. Furthermore, the filter comprises a second group of resonators 10 to 17 of the plurality of low coupling-coefficient bulk acoustic wave resonators 10 to 25, a filter input 30 for an input signal and a filter output 31 for an output signal. The first group of resonators 18 to 25 forms two lattice sections and the second group of resonators 10 to 17 forms two ladder sections. The depicted mix of lattice and ladder geometry may improve the filter performance. In particular, by combining lattice- and ladder-sections as depicted in Fig. 4, a mirror frequency of a TV signal may be effectively suppressed and adjacent channel frequencies may effectively be rejected.

The filter which is depicted in Fig. 4 is a balanced IF filter designed for a TV up-conversion tuner which meets the specification shown in Fig. 5.

Fig. 5 shows the specification for a TV up-conversion tuner IF filter. The horizontal axis 50 depicts the frequency in MHz and the vertical axis 51 depicts the relative attenuation of the filter in dB.

The required filter has a 3 dB channel band-width of 6 MHz centered on 1.2 GHz (IF1) with an out-of-band rejection of 40 dB (indicated by horizontal line 52) at the adjacent channel N+1 (8.5 MHz from the wanted channel IF1) and 60 dB at the "image" or "mirror" frequency (20 MHz from the wanted channel IF1 and indicated by reference numeral 53).

This specification may be met by the architecture in Fig. 4, where the lattice-section resonators 18 to 25 are of equal area A and the balanced ladder-section resonators 10 to 17 are of equal area $(1/\sqrt{2})A$. The response for such a filter comprising an additional SiO_2 layer in the first case, a thick Pt bottom electrode in the second case and a thick Pt top electrode in the third case are shown in Fig. 6.

Fig. 6 shows a predicted response of a BAW TV up-conversion tuner IF filter implemented using each of the three proposed layer structures for reducing effective piezoelectric coupling. As may be seen from Fig. 6, the predictions for all three layer structures are very similar, showing that in principle any of the three methods may be used. Where thickened electrodes are used it may be important that the area of the thinner electrode is smaller, so that there are no very severe mechanical discontinuities at resonator edges (edges of areas of overlap of top and bottom electrodes).

Fig. 7 shows a layout design of the filter of Fig. 4 according to an exemplary embodiment of the present invention.

In practice an architecture may be employed which is electrically equivalent to the architecture shown in Fig.4. The four resonators 14-17 are each implemented as two resonators in series, each of double the original area. This allows an implementation without vias between top and bottom layers, thus simplifying the manufacture. The factor of √2 may be optimal for electrical impedance-matching between lattice and ladder sections. The mask layout of top and bottom electrode layers in such an implementation is shown in Fig. 7. The areas of overlap of the two electrode layers form the resonators. The two connection pads at the bottom corners form one port, and the two connections at the top corners form the other port. Input and output ports are interchangeable.

It should be noted that Fig. 4 shows a circuit diagram. It describes which resonators are connected to which other resonators, and does not describe implementation. Angles and lengths of lines do not signify anything.

It should be noted, that the term "comprising" does not exclude other elements or steps and the "a" or "an" does not exclude a plurality. Also elements described in association with different embodiments may be combined.

It should also be noted that any reference signs in the claims shall not be construed as limiting the scope of the claims.

CLAIMS:

1. A filter, comprising:

a plurality of low coupling-coefficient bulk acoustic wave resonators (10 – 25);

wherein the filter comprises a first group of resonators (18 – 25) of the plurality of low coupling-coefficient bulk acoustic wave resonators;

wherein the filter comprises a second group of resonators (10 – 17) of the plurality of low coupling-coefficient bulk acoustic wave resonators;

wherein the first group forms a lattice section; and

wherein the second group forms a ladder section.

2. The filter of claim 1,

wherein the filter is an electrically balanced filter; and

wherein the filter is adapted for use in a TV up-conversion tuner.

3. The filter of claim 1,

wherein each first group resonator of the first group which forms the lattice section has a first surface area;

wherein each second group resonator of the second group which forms the ladder section has a second surface area; and

wherein the second surface area is a predetermined fraction of the first surface area.

4. The filter of claim 1,

wherein the filter is an electrically unbalanced filter;

wherein the filter comprises a third group of resonators which are shunt resonators; and

wherein the filter comprises a fourth group of resonators which are series resonators.

5. The filter of claim 1,

wherein the filter is at least one of a narrow band filter, a narrow band RF filter, and a narrow band IF filter.

6. The filter of claim 1,

wherein each resonator of the plurality of resonators comprises:

a first layer (5) occupying a first volume;

a second layer (4);

a resonant cavity occupying a second volume;

wherein the first layer (5) and the second layer (4) are inside the resonant cavity;

wherein the first volume is significantly smaller than the second volume, such that an effective coupling coefficient of the resonator is significantly reduced; and

wherein the first layer (5) is a piezoelectric layer.

7. The filter of claim 6,

wherein the second layer (4) is one of a non-piezoelectric layer, a non-piezoelectric dielectric layer, part of a bottom electrode, and part of a top electrode.

8. The filter of claim 6,

wherein the first layer (5) comprises a material selected from the group of materials consisting of AlN, ZnO, PZT, La doped PZT, KnO_3, and Li Niobate; and

wherein the second layer (4) comprises a material selected from the group of materials consisting of Si_3N_4, SiO_2, Pt, and Ta_2O_5.

9. The filter of claim 6,

wherein at least one of the first layer (5) and the second layer (4) comprises a material with a positive temperature dependence of elastic constants; and wherein at least one of the first layer (5) and the second layer (4) comprises a material with a negative temperature dependence of elastic constants.

10. Use of a filter of claim 1 in a TV up-conversion tuner.

11. A method of fabricating a filter, the method comprising the steps of:

providing a substrate (1);

providing an acoustic decoupling (2) between a resonator (3, 4, 5) and the substrate (1);

providing a bottom electrode (3);

providing a second layer (4) which is one of a non-piezoelectric and a non-piezoelectric dielectric layer;

providing a first layer (5) which is a piezoelectric layer;

providing a top electrode (6);

wherein the first layer (5) is one of on top of the second layer (4) and beneath of the second layer (4).

12. The method of claim 11,

wherein the acoustic decoupling is provided by at least one of an acoustic Bragg reflector (2) on top of the substrate (1), by locally etching away the substrate (1), and by providing an air gap between the resonator and the substrate (1);

wherein the bottom electrode (3) comprises a material selected from the group of materials consisting of Al, Pt, W, Mo, Au, and Cu;

wherein the first layer (5) comprises a material selected from the group of materials consisting of AlN, ZnO, PZT, La doped PZT, KnO_3, and Li Niobate;

wherein the second layer (4) comprises a material selected from the group of materials consisting of Si_3N_4, SiO_2, Pt, and Ta_2O_5; and

wherein the top electrode (6) comprises a material selected from the group of materials consisting of Al, Pt, W, Mo, Au, and Cu.

13. The method of claim 11,

wherein the top electrode (6) comprises a dense metal selected from the group consisting of Pt, W, and Au.

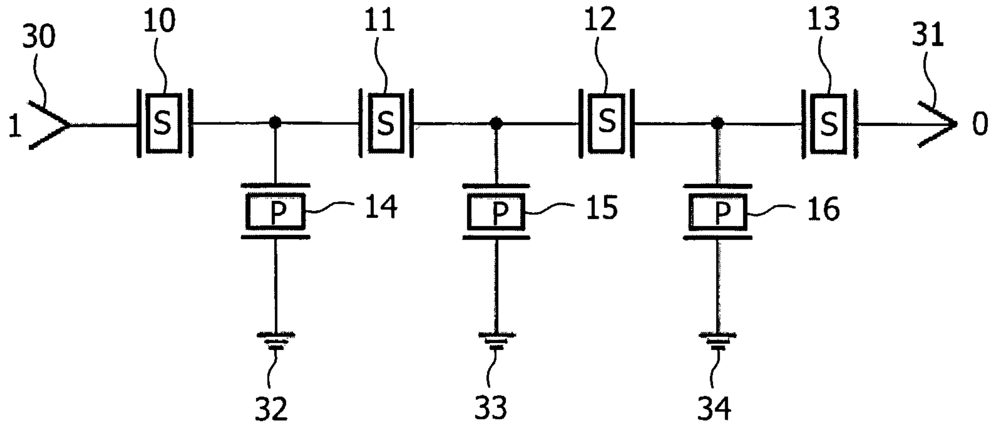

FIG.1

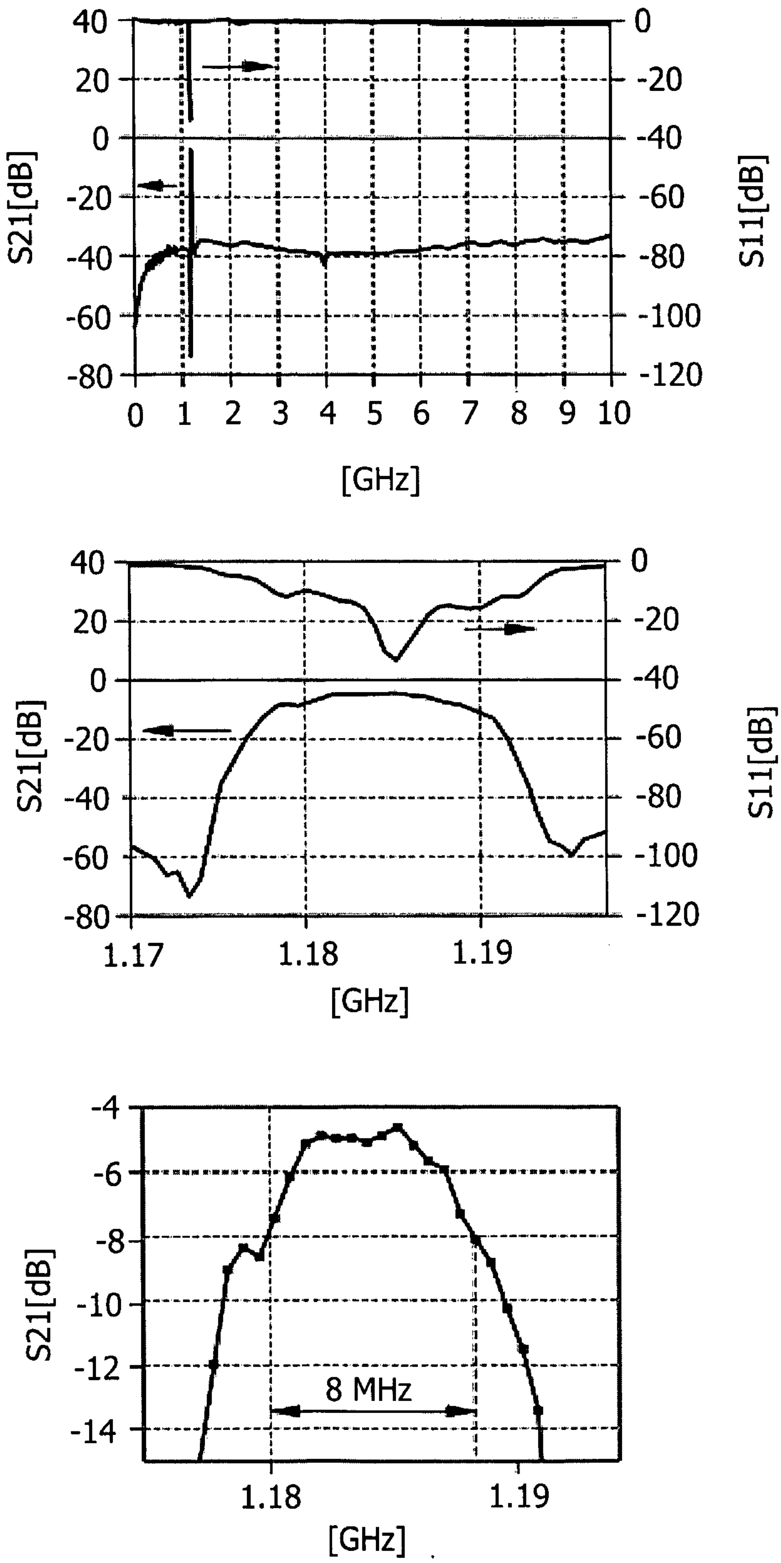

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FIG.2

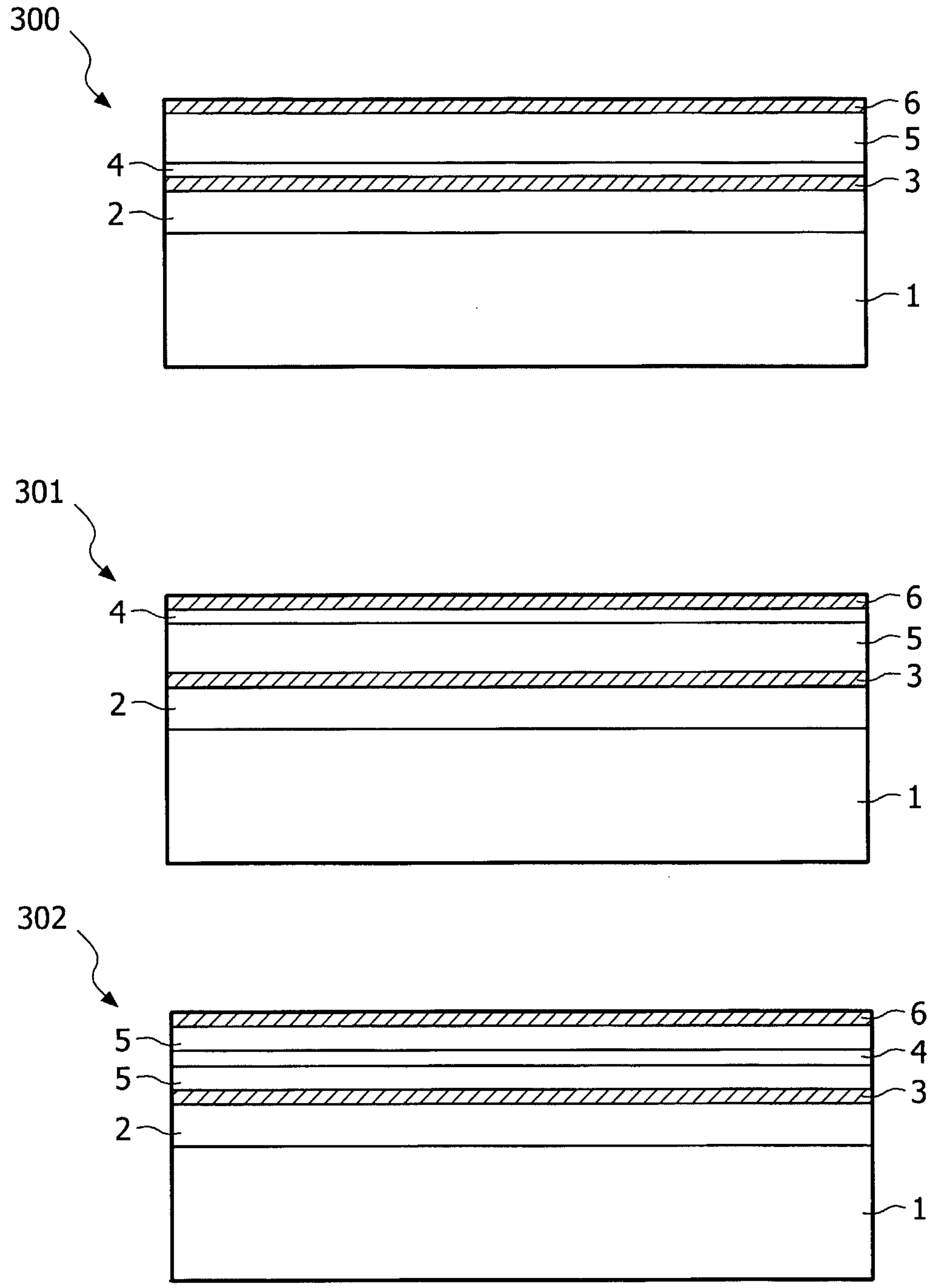

FIG.3

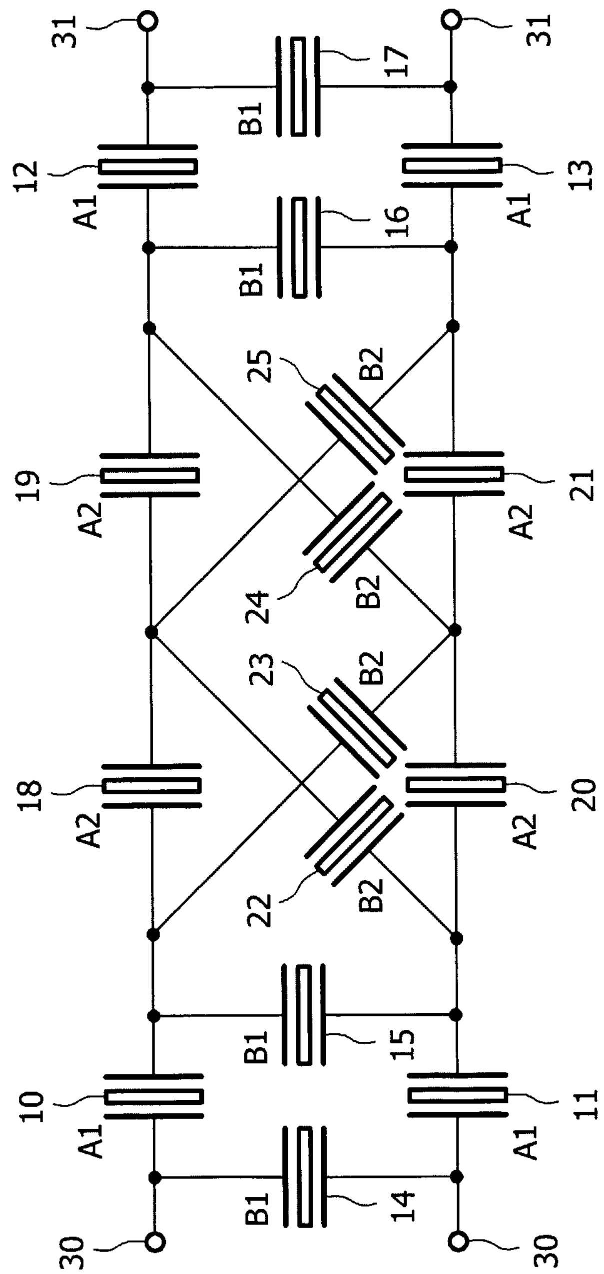
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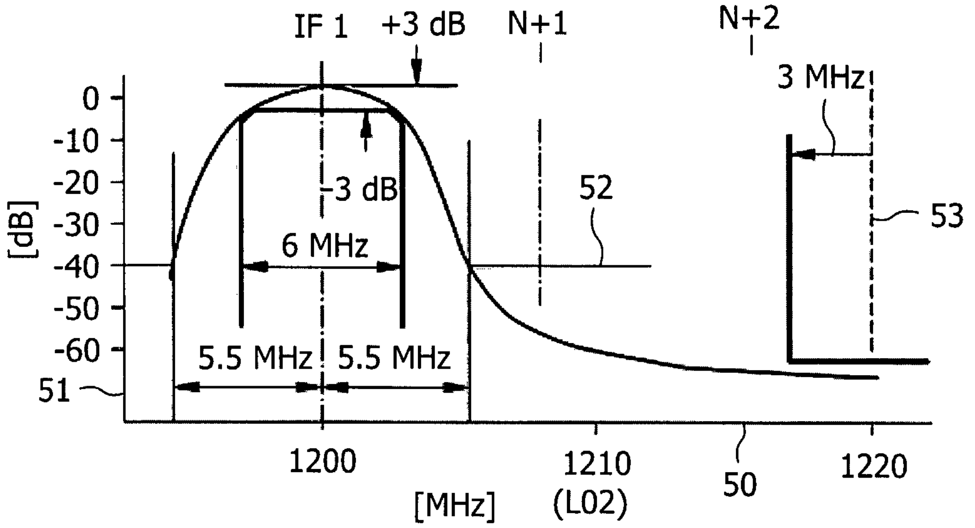
FIG.4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50
1220
[MHz]

FIG.5

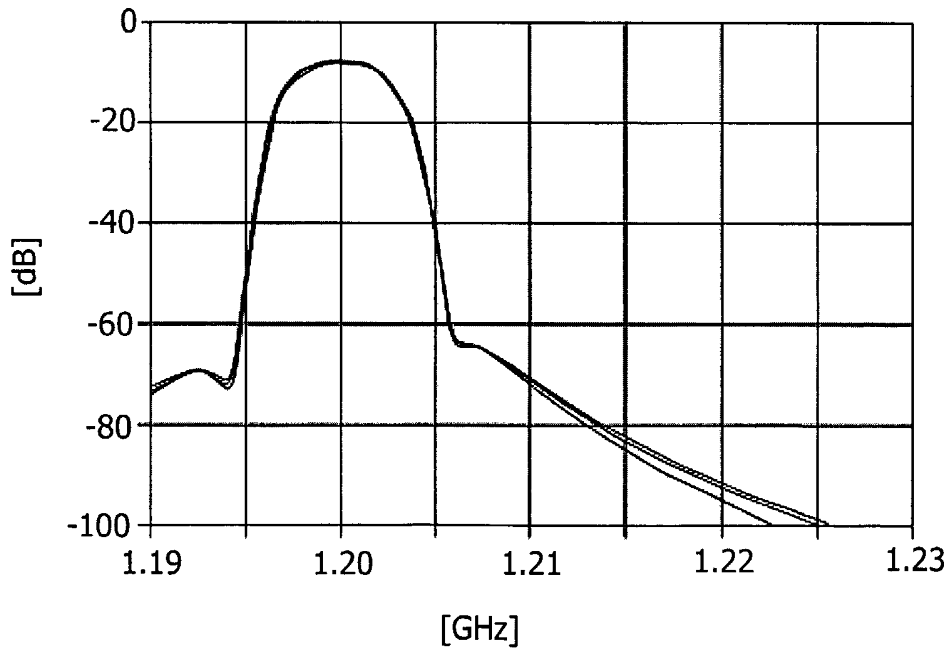
0
-20
-40
-60
-80
-100
[dB]
1.19
1.20
1.21
1.22
1.23
[GHz]

FIG.6

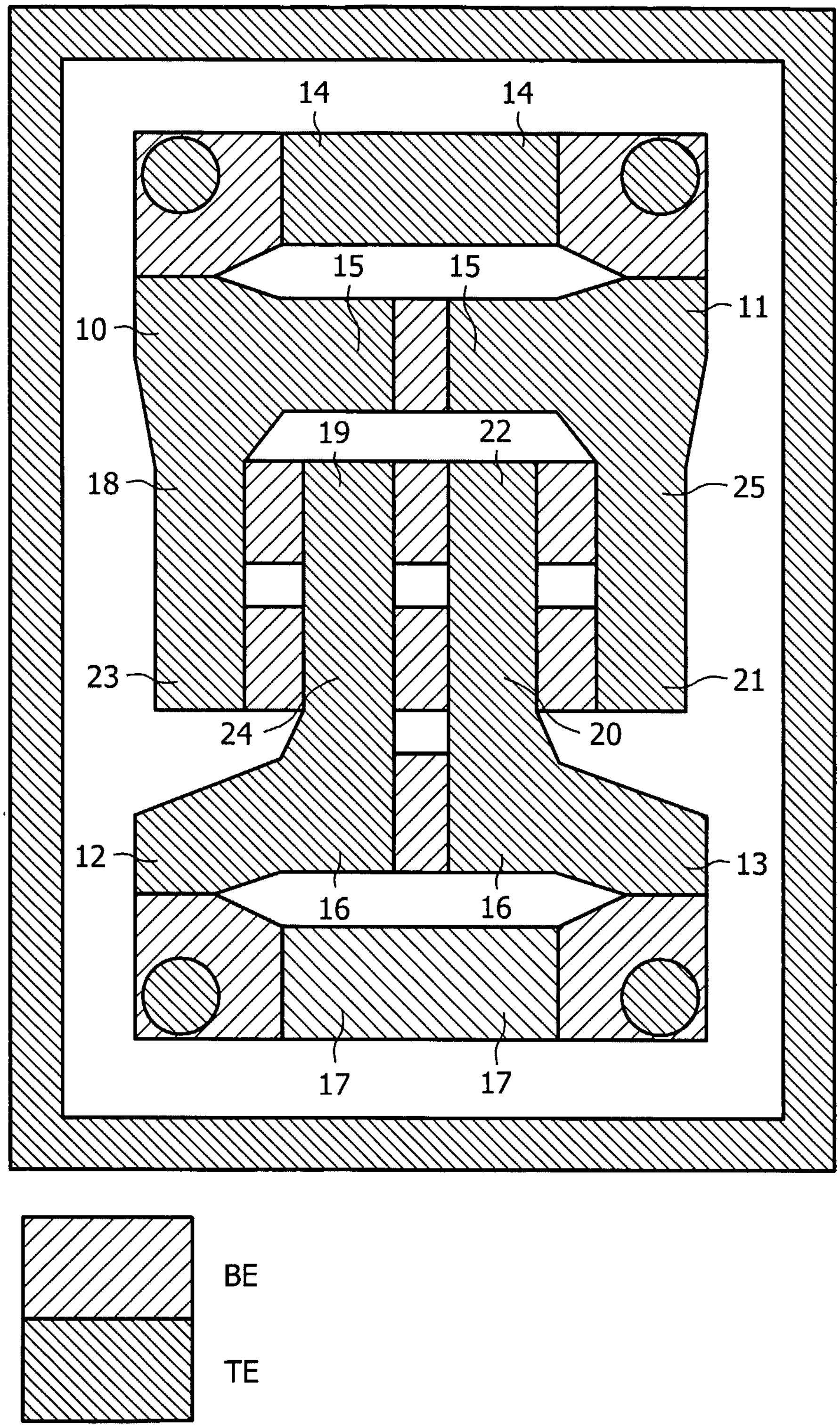

FIG.7

INTERNATIONAL SEARCH REPORT

International Application No
PCT/IB2005/052636

A. CLASSIFICATION OF SUBJECT MATTER
H03H3/04 H03H9/02 H03H9/17 H03H9/58

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H03H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	KRISHNASWAMY S V ET AL: "Film bulk acoustic wave resonator technology" 1990 ULTRASONICS SYMPOSIUM, 4 December 1990 (1990-12-04), pages 529-536, XP010010079 the whole document -----	1-13
X	TEN DOLLE H K J ET AL: "Balanced lattice-ladder bandpass filter in bulk acoustic wave technology" MICROWAVE SYMPOSIUM DIGEST, 2004 IEEE MTT-S INTERNATIONAL FORT WORTH, TX, USA JUNE 6-11, 2004, PISCATAWAY, NJ, USA,IEEE, vol. 1, 6 June 2004 (2004-06-06), pages 391-394, XP010727322 ISBN: 0-7803-8331-1	1-7,10
Y	the whole document -----	8,9

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
9 January 2006	19. 01. 2006

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Maget, J

INTERNATIONAL SEARCH REPORT

Inte al Application No
PCT/IB2005/052636

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2003/179053 A1 (AIGNER ROBERT ET AL) 25 September 2003 (2003-09-25) abstract; figures 1,3,4,6 paragraphs '0009!, '0021! - '0023!, '0037! - '0046!	1,4-7,11
A		8,9
X	WO 03/056699 A (EPCOS AG; UNTERBERGER, MICHAEL; TIKKA, PASI) 10 July 2003 (2003-07-10)	1,3,5-7, 11-13
A	abstract; figures 1,2A-E,3A-C,4-6,9A,B page 1, line 13 - page 2, line 34 page 6, lines 19-24 page 10, lines 1-11 page 5, lines 8-29	2,4,8-10
A	MEIER H ET AL: "Miniaturization and advanced functionalities of saw devices" ULTRASONICS SYMPOSIUM, 2000 IEEE OCT 22-25, 2000, PISCATAWAY, NJ, USA,IEEE, vol. 1, 22 October 2000 (2000-10-22), pages 395-401, XP010541625 ISBN: 0-7803-6365-5 1. Introduction 3. Multimedia Applications figures 9,10	2,5,10
Y	EP 1 434 346 A (TDK CORPORATION) 30 June 2004 (2004-06-30)	8,9
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A	paragraphs '0027!, '0028!, '0120! - '0122! paragraphs '0116! - '0119!; figures 1,2,9	13
A	LAKIN K M: "Thin Film Resonators and High Frequency Filters" TECHNICAL REPORT TFR TECHNOLOGIES, XX, XX, 1 June 2001 (2001-06-01), pages 1-18, XP002276553 the whole document	1-13
X	EP 1 202 454 A (AGILENT TECHNOLOGIES, INC.) 2 May 2002 (2002-05-02) the whole document	1-7,10

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	LARSON J D ET AL: "Power handling and temperature coefficient studies in FBAR duplexers for the 1900 MHz PCS band" ULTRASONICS SYMPOSIUM, 2000 IEEE OCT 22-25, 2000, PISCATAWAY, NJ, USA,IEEE, vol. 1, 22 October 2000 (2000-10-22), pages 869-874, XP010541724 ISBN: 0-7803-6365-5 Tx FILTER DESIGN; figures 1,3	5
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X	EP 1 120 909 A (TEXAS INSTRUMENTS INCORPORATED) 1 August 2001 (2001-08-01)	11,12
A	paragraphs ‘0007!, ‘0009! - ‘0011!, ‘0015!, ‘0026! - ‘0036!; figures 3,4	10,13
X	LAKIN K M ED - INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS: "Thin film resonator technology" PROCEEDINGS OF THE 2003 IEEE INTERNATIONAL FREQUENCY CONTROL SYMPOSIUM& PDA EXHIBITION JOINTLY WITH THE 17TH. EUROPEAN FREQUENCY AND TIME FORUM. TAMPA, FL, MAY 4 - 8, 2003, IEEE INTERNATIONAL FREQUENCY CONTROL SYMPOSIUM, NEW YORK, NY : IEEE, US, 4 May 2003 (2003-05-04), pages 765-778, XP010688892 ISBN: 0-7803-7688-9	11,12
A	Table on page 765; Sections IV,V,VI,VIII; figures 5-7,9,13	1-10,13
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X	WO 03/052928 A (INFINEON TECHNOLOGIES AG; AIGNER, ROBERT; ELBRECHT, LUEDER; HANDTMANN,) 26 June 2003 (2003-06-26)	11,13
A	page 7, line 35 - page 13, line 14; figure 3	12

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	TAY K-W ET AL: "INFLUENCE OF PIEZOELECTRIC FILM AND ELECTRODE MATERIALS ON FILM BULK ACOUSTIC-WAVE RESONATOR CHARACTERISTICS" JAPANESE JOURNAL OF APPLIED PHYSICS, JAPAN SOCIETY OF APPLIED PHYSICS, TOKYO, JP, vol. 43, no. 3, March 2004 (2004-03), pages 1122-1126, XP001232135 ISSN: 0021-4922 the whole document	11-13
A		6-8
X	PATENT ABSTRACTS OF JAPAN vol. 004, no. 148 (E-030), 18 October 1980 (1980-10-18) & JP 55 100722 A (MURATA MFG CO LTD), 31 July 1980 (1980-07-31) abstract	11-13
X	EP 1 225 695 A (NOKIA CORPORATION) 24 July 2002 (2002-07-24) paragraphs ‘0018! - ‘0021!; figure 7	11,12
X	KIRBY P B ET AL: "PZT thin film bulk acoustic wave resonators and filters" PROCEEDINGS OF THE 2001 IEEE INTERNATIONAL FREQUENCY CONTROL SYMPOSIUM& PDA EXHIBITION. SEATTLE, WA, JUNE 6 - 8, 2001, IEEE INTERNATIONAL FREQUENCY CONTROL SYMPOSIUM, NEW YORK, NY : IEEE, US, 6 June 2001 (2001-06-06), pages 687-694, XP010561650 ISBN: 0-7803-7028-7 Device Fabrication	11-13
X	PATENT ABSTRACTS OF JAPAN vol. 008, no. 247 (E-278), 13 November 1984 (1984-11-13) -& JP 59 125114 A (FUJITSU KK), 19 July 1984 (1984-07-19) abstract	11-13

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2005/052636

Box II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-10

   circuit arrangement of baw resonators where ladder and lattice sections are combined

   ---

2. claims: 11-13

   layer stack of a resonator in a filter

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/IB2005/052636

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