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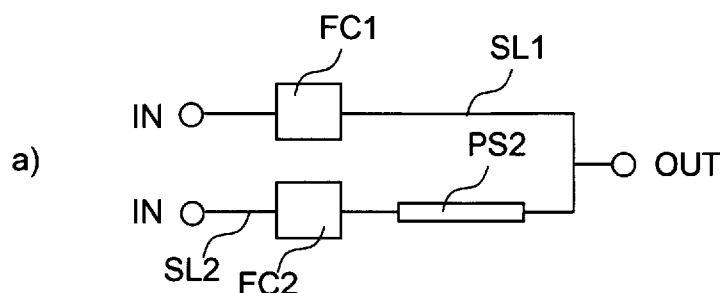
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(54) **Title:** SAW DEVICE WITH SUPPRESSED PARASITIC SIGNAL

Fig 1



(57) **Abstract:** In a SAW device comprises a SAW chip bearing a SAW transducer arranged within a first signal line parasitic signals due to higher harmonics of the operating frequency of the SAW devices are electrically eliminated by compensating means comprising at least one second signal line having means for producing a cancelling signal different in sign or phase to the parasitic signal, or a shunt line to electrically connect the SAW transducer to a back side metallization of the SAW chip.



## Description

SAW device with suppressed parasitic signal

5 In acoustic filters as commonly used in modern communication devices such as mobile phones non-linearities can arise. These non-linearities produce parasitic signals such as second and higher harmonics and mixed products that may cause problems in signal processing like filtering, selectivity or  
10 isolation for instance.

In SAW devices, the second harmonics, referred to as H2, is correlated to a bulk wave that produces a signal at a twofold of the used passband or resonance frequency of the device.  
15 Due to its non-linearity this excitation is undesired in filter applications and therefore, many attempts have been made to suppress this excitation. Notwithstanding the foregoing, this non-linearity has been used in technical applications such as convolvers.

20 Some of the attempts are directed to damping the waves at the back side of the respective SAW chip or to filter them out by a sophisticated filter technology. However, no solution has been found that is usable to effectively suppress H2  
25 harmonics in SAW devices of different design.

Hence, it is an object of the present invention to provide a SAW device that can effectively suppress second harmonics H2 and related mixed products.

30 This and other objects are met by a SAW device according to claim 1. Advantageous and developed embodiments can be taken from further claims.

A SAW device comprises a SAW chip that is a piezoelectric body bearing a SAW transducer on a top surface thereof. The transducer is adapted to work with an operating frequency of the device that usually complies with a resonance frequency of the transducer. The transducer may be part of a filter circuit and is arranged within a first signal line. Besides features adapted to operate at the operating frequency, the invention provides compensating means that are connected to the signal line or are arranged in the signal line to electrically eliminate non-linear parasitic signals that occur at frequencies different from the operating frequency.

The compensating means comprise

- at least a second signal line having means for producing a cancelling signal different in sign or phase to the parasitic signal, or
- a shunt line to electrically connect the SAW transducer to a back side metallization of the SAW chip, or
- a shunt element that makes a short circuit to ground at a frequency where the parasitic signal has to be suppressed, e.g. at about double the resonance frequency for H2 suppression.

In all cases mentioned above the parasitic signal is suppressed in an electrical way either by combining and cancelling the parasitic signal with a symmetrical signal of different sign or by shorting two metallizations carrying the parasitic signal.

A simple solution for the first case is to provide a second signal line having identical components like the first signal line and to combine both signal lines with a mutual phase difference at the parasitic frequency of  $\pi$ . Such a phase

difference may be achieved by inserting a phase shifter into at least one of the signal lines.

A single phase shifter requires producing a phase shift of  $\pi$ , while two or more phase shifters need to add their phase shifts up to a mutual phase difference of  $\pi$  or more general of  $(2n+1)\pi$  where  $n$  is an integer. A possible solution combines a  $+\pi/2$  and a  $-\pi/2$  phase shifter.

A simple solution according to the second case comprises an ordinary conductor line as a shunt line to connect one of the two electrodes of the SAW transducer to a metallization that is arranged on the back side of the SAW chip. Such a shunt line prevents building-up of a voltage between the backside and the transducer on the top surface. Such a voltage may be the result of the parasitic bulk wave according to the second harmonics H2. The bulk wave is reflected at the back side such that a standing wave builds up. This bulk wave produces unwanted signals at different frequencies dependent on the resonant cavity and thus, dependent on the thickness of the SAW chip. Thereby a potential difference arises and a signal may be measured between the both surface i.e. between the metallization thereon like transducer and back side metallization as long as not shorted. Shorting these metallizations eliminates the voltage and suppresses the resulting parasitic signal. It is necessary that the backside metallization is floating and thus has no connection to ground or a signal source.

The back side metallization may be a continuous metallization covering the total area of the back side of the SAW chip. However, it is preferred to structure the back side metallization by separating and electrically isolating

different partial areas thereof. Each area is opposite to just one single element on the top surface for instance opposite to the transducer. A partial area may be restricted in its lateral dimensions to the area of the respective top  
5 surface element.

According to a further embodiment, a shunt resonator having a resonance frequency at or near the parasitic frequency is arranged in the shunt line and the shunt line is connected to  
10 a ground potential. Thereby signals at the parasitic frequency according to the resonance frequency of the shunt resonator are shorted, while signals at the operating frequency not or only negligibly affected.

15 The shunt resonator may be embodied as SAW resonator. Then it can be formed on the top surface of the SAW chip as a further metallization.

Alternatively the shunt resonator may be a BAW resonator or a  
20 resonator embodied in another technology in the form of a separate device.

In the first case (first embodiment), two or more second signal lines are connected in parallel to the first signal  
25 line. Each of the first and the at least one second signal lines comprises the same components such that the amplitudes of the useful signal as well as of the parasitic signals are the same in each signal line. A phase shifter is arranged in at least one of the signal lines, and is adapted to shift the  
30 phase of the parasitic signal in the least one second signal line relative to the first signal line such that the parasitic signals cancel each other due to their phase difference. The useful signals due not suffer the phase shift

and hence, are interfering constructively and add their amplitudes.

In a simple solution, the phase shifter is embodied as a SAW resonator having a resonance frequency at or near the parasitic frequency. The SAW resonator can be arranged on the top surface of SAW chip of the SAW device.

According to a further embodiment, the signal line comprises a resonator that is cascaded. This means that the single original resonator is replaced by a parallel circuit of two series circuits of two resonators respectively. In such a series circuit a phase shift can be achieved if mutually detuning the two resonators against each other. By detuning the two series circuits in a direction opposite to each other a phase shift between the two series circuits results that can be set to  $\pi$  at the parasitic frequency.

As most of today's filter circuits comprise a cascaded resonator the inventive solution does not require any additional component, space, chip area, of effort relative to the state of the art.

In another embodiment, the phase shifter can be embodied as a symmetric pi member of impedance elements chosen from capacitances and inductances. But each other circuit that causes a phase shift is possible too. The phase shifter may be formed as discrete device circuited within the respective signal line. Further, the impedance elements of the phase shifter may be integrated in a carrier substrate that is part of the package of the SAW chip or its housing. The phase shifter works in a small frequency band such that signals at the operating frequency are not affected.

In the second case (second embodiment) the shunt line may be guided through the SAW chip and can be embodied as a via or a through contact. Alternatively, the shunt line comprises a  
5 line conductor that is guided over and around an edge of the SAW chip. Further, the shunt line may have a section that is formed by a housing in which the SAW chip is arranged in. The shunt line may be formed even in total by the housing. Then, one electrode of the transducer needs to be connected to the  
10 housing and the housing needs to be grounded. Independent therefrom the back side metallization may be grounded too such that electrode the back side metallization are shorted.

A further method that can additionally suppress the building  
15 up of a standing wave by parasitic bulk wave excitation is to structure the back side in a manner that achieves a dispersion of the bulk waves impacting onto the back side. Thereby, delayed (reflected) signals can be suppressed. The structuring can comprise a surface treatment of the  
20 piezoelectric chip or a structuring of the back side metallization. The last case can be realized with much lower effort than a surface treatment by roughening, sawing, sandblasting or etching.

25 At last, the proposed methods for suppressing parasitic signals of the mentioned art can be combined in every arbitrary combination. Especially, first and second embodiment do not mutually influence each other and can be implemented in parallel. Thereby, parasitic signals of  
30 different frequencies can be cancelled or suppressed when using respective frequency selective phase shifters in first and second signal line and/or when implementing shunt lines that are frequency selective as already explained above.

The invention can be used to suppress parasitic signals originating from other parasitic effects like from third harmonics H3. In this case, the frequency selective elements (phase shifters and/or shunt elements) should be optimized to the frequency of the third harmonics that is  $3f$  where  $f$  is the operating frequency of the SAW device or the filter circuit.

10 According to different embodiments the SAW device may be or comprise a ladder type filter, a DMS filter or a resonator.

The concept of the shunt element of the third embodiment is not limited to SAW filters. Hence, the idea of providing a short circuit to ground selectively for signals of a frequency to be suppressed like H2 can be applied in other filter techniques as well, e.g. in BAW filters. Even at filters that do not use acoustic signals like LC filters for example the inventive shunt element can be used in addition to the known filter elements.

In the following the invention is explained in more detail with reference to concrete embodiments and the accompanied figures. The figures are schematically only and not drawn to scale. Same elements or elements of the same function are referenced by the same reference symbols.

Figure 1 shows different examples according to the first embodiment

Figure 2 shows an example according to the second embodiment

Figure 3 shows different examples for filter circuits as those used in first and second embodiment

Figure 4 shows a cross sectional view of an arrangement with two SAW chips according first embodiment

Figure 5 shows a cross sectional view of a SAW chip according second embodiment

Figure 6 shows a cross sectional views of different SAW chip with a shunt line according to the second embodiment

Figure 7 compares chip areas that are necessary for forming a resonator of the art and a signal line according to the first embodiment

Figure 8 shows a SAW filter according to the invention including a shunt resonator

Figure 9 compares two transfer functions of a filter circuit with and without an inventive shunt line according to the second embodiment

Figure 10 shows an enlarged section of the S12 matrix element of the same filter circuit according to the second embodiment

Figure 11 explains the excitation of parasitic bulk waves in a SAW device at an H2 frequency

Figure 11 shows a schematic view of a cross-section through a SAW device. Interdigital transducers comprising transducer fingers TRF are arranged on the top surface of a

piezoelectric chip CHP. In a normal finger transducer the transducer fingers TRF are arranged in a mostly regular pattern of  $\pi/2$ . At the resonance frequency  $f$  an applied RF signal causes a deflection of the transducer fingers such that the fingers are alternately moving upward and downward. At a harmonic frequency of the transducer at a frequency of  $2f$  a synchronous movement of all transducer fingers can be regarded as shown in Fig. 11. Such a synchronous up and down movement of all transducer fingers causes a bulk wave that travels versus the back side of the chip CHP to be excited. At the back side of the chip CHP a back side metallization BSM may be applied. In either case the bulk waves BWV are reflected at the back side to form a reflected wave RWV. The reflected wave travels upward to the top surface and may be reflected again at the top surface. Thereby, a standing wave builds up forming a resonance like in a bulk wave resonator. The bulk wave yields parasitic signals at all frequencies fulfilling the resonance conditions for a standing wave in a cavity of a length  $h$  where in the figure,  $h$  is the distance between transducer finger TRF and back side metallization BSM. The parasitic signal can be taken as a potential difference between the back side metallization BSM and the transducer fingers TRF.

It is an object of the invention to suppress these parasitic signals whose origin is a second harmonic vibration of the transducer.

Figure 1 shows different arrangements that can meet this object according to the first embodiment. Figure 1 shows at a) a signal line that is split in two symmetric signal lines SL1 and SL2 that are circuited in parallel between an input IN and an output OUT. Each of the two signal lines SL

comprises a respective first or second filter circuit FC1 and FC2 that are identical and, hence, are operating in the same way. Without further means these two signal lines SL would constructively add their amplitudes at the output OUT.

5 According to the invention, a phase shifter PS2 is inserted between one of the filter circuits FC and the output. In the figure the phase shifter is inserted in the second signal line SL2. The phase shifter PS2 causes a phase shift of  $\pi$  for the frequency of the parasitic signal. Preferably, the phase  
10 shifter PS2 is set to provide a phase shift at least for the frequency of the second harmonics. As a consequence, the signals in the two signal lines SL1 and SL2 interfere at the output OUT, thereby cancelling each other. This way, the parasitic signal can be eliminated in total. Signals of the  
15 operating frequency that is used by the filter circuit are not affected by the phase shifter PS due to the limited bandwidth at which the phase shifter operates.

The variant b) differs only slightly from variant a) by the  
20 fact that the phase shifter PS2 is arranged between input IN and second filter circuit FC2. The interchanged sequence achieves the same result as variant a) and also yields a complete cancellation of the parasitic signal.

25 According to variant c) the claim phase shift of  $\pi$  between the two signal lines SL at a frequency to be suppressed is achieved by a first phase shifter PS1 arranged in the first signal line SL1 and a second phase shifter PS2 arranged in the second signal line SL2. The two phase shifters PS1 and  
30 PS2 cause a phase shift in a mutually opposite direction such that at the output OUT a total phase difference of  $\pi$  and a cancelling of the parasitic signal is achieved. If the parasitic signal to be suppressed has a frequency of  $2f$  where

f is the ground mode of the filter the ground mode shows a phase difference of  $\pm \pi/4$ . First phase shifter PS1, for instance, may cause a phase shift of  $+\pi/2$  and can be combined with a second phase shifter PS2 causing a phase shift of  $-\pi/2$  adding to a total phase difference between the two signal lines of  $\pi$  at the frequency of the parasitic signal to be suppressed.

Variant c) can be extended to variant d) comprising a parallel circuit of n signal lines SL1 to SLn that are circuited in parallel. All of the n signal lines SL comprises the same filter circuit like first filter circuit FC1 and a phase shifter PSn. The phase shifters PS are selected to cause at the output OUT a respective phase shift at the parasitic signal frequency such that all frequency components of the parasitic signal frequency cancel out.

Figure 2 shows an arrangement according to a second embodiment. A filter circuit FC is arranged in a signal line SL between an input IN and an output OUT. The signal line and the filter circuit FC are arranged on the top of the SAW chip. Onto the back side of the SAW chip a back side metallization BSM is applied opposite to the elements of the filter circuit FC. In the figure, the back side metallization BSM is depicted as a conductor line that can assume a potential due to a polarization of the piezoelectric material that is caused by a parasitic wave like the second harmonic. According to the second embodiment, the invention proposes to circuit a shunt line SHL between the signal line SL and the back side metallization BSM. The shunt line can be arranged near the components of the filter circuit FC that is at a location where a maximum potential difference between the filter metallization at the top side and the backside

metallization can build up. By the shunt line SHL the built-up potential equalizes by shorting and is hence eliminated.

According to a further development, further shunt lines SHL  
5 may be arranged at other locations between the signal line SL and the back side metallization BSM. This may be necessary in cases where the back side metallization BSM is separated in partial areas that are electrically isolated against each other. Then, each isolated partial area of the back side  
10 metallization BSM can be connected to the signal line by a respective shunt line SHL.

Figure 3 shows five different examples of circuits FC or of components of a filter circuit to which the invention may be  
15 applied. Figure 3A depicts a schematic filter circuit FC circuited in the signal line between an input and an output. The filter circuit may comprise different elements that are electrically or acoustically connected in series. Figure 3B shows as a necessary component of such a SAW filter circuit  
20 FC an interdigital transducer TRD that is circuited within the signal line. Another component of a filter circuit FC may be a resonator RES schematically shown in Figure 3C. A transducer as shown in Figure 3B may be part of a resonator, a DMS filter or another longitudinally coupled resonator  
25 filter shown in Figure 3D. As an example, the resonator shown in Figure 3C may be part of a resonator filter that is part of a ladder-type arrangement according to figure 3E comprising a series resonator arranged in the signal line and a parallel resonator arranged in a parallel branch that  
30 connects the signal line to a ground potential.

Each filter circuit FC may comprise other components too that may be a combination of the shown examples or may comprise other elements that are not depicted in figure 3.

5 Figure 4 shows an example according to the first embodiment and realized like the filter circuit according to Figure 3E. As shown in Figure 1A the filter circuit FC comprises a first signal line SL1 and a second signal line SL2 circuited in parallel between an input IN and an output OUT. In each of  
10 the signal lines SL a series resonator SR is circuited in series. Further, a parallel resonator PR is circuited in parallel between a respective signal line SL and a ground potential GND. For simplification purpose each of the resonators SR, PR is depicted schematically by three  
15 transducer fingers only that are interdigitated. First and second filter circuits are depicted with a separate chip each that is a first chip CHP1 and a second chip CHP2. As this is for a better understanding only, a real arrangement preferably comprises only one chip on which the two signal  
20 lines and the respective components thereof are arranged. A phase shifter PS2 is arranged in the second signal line SL2 between the respective series resonator SR and the output OUT. Alternatively, the phase shifter PS2 may be arranged between input IN and the series resonator SR. The phase  
25 shifter is adapted to cause a phase shift of  $\pi$  for signals of the parasitic frequency. The band width of the phase shifter PS is selected such that a signal at the operating frequency is not affected in its phase by the phase shifter PS.

30 Figure 5 shows a further variant of the invention according to the second embodiment. Here, the shunt line SHL that is schematically depicted in Figure 2 comprises a shunt resonator SHR circuited between the signal line SL and a

ground potential. The shunt resonator SHR is different from any resonator arranged in the signal line by its resonance frequency which at or near to the frequency of the parasitic signal. As a result of this arrangement, the shunt line

5 including the shunt resonator SHR is active only for frequencies near the resonance frequency of the shunt resonator. Hence, the shunt line is a frequency-selective for the parasitic signal only. Such a shunt resonator SHR may be advantageously be used in a resonator filter according to

10 Figure 3E and may hence be embodied as a further resonator on top of the SAW chip CHP. Alternatively, the shunt resonator SHR may be a separate device that is connected only electrically between signal line and ground GND. The separate device may be any type of resonator like a SAW resonator,

15 bulk acoustic wave resonator or a resonator in another technique, for example an LC resonator. The shunt resonator SHR may be connected to the same ground line GND that the parallel branch with a parallel resonator therein is connected to.

20 Figure 6 shows three examples of how to realize shunt line and backside metallization. In Figure 6A the shunt line SHL connects the signal line, part of which is depicted in the figure as a transducer, and a back side metallization BSM on the opposite surface of the chip CHP. The shunt line SHL is

25 conducted partly on the top surface, guided around the upper edge, along the side surface and around the bottom edge of the chip CHP.

30 Figure 6B shows an example where the shunt line is realized as a via connecting a metallization on the top surface with a back side metallization BSM on the bottom surface or a back side of the chip CHP. The via can be embodied as a through-

going hole through the chip CHP that is metallized at least at its side walls or that is totally filled with an electrically conducting material. The via VIA extends from the metallization on the top surface to the opposite surface  
5 of the chip CHP under the back side metallization BSM.

If a SAW chip CHP has several transducers or several other filter components arranged on the top surface it is possible to provide at least one further via connecting the other  
10 component with the back side metallization BSM. Though the back side metallization BSM is depicted as a unitary layer covering the entire back side of the chip CHP, it may be advantageous to structure the back side metallization and restrict each partial area of the back side metallization to  
15 the opposing area of the transducer to which the back side metallization is connected by the shunt line.

Figure 6C shows a variant where the shunt line is at least partially realized by a metallization of a housing or of the  
20 package the chip is enclosed in. Inside the package, the chip CHP is mounted in a flip-chip arrangement onto a carrier that is, for instance, a printed circuit board. The package for the chip comprises a covering layer applied onto the chip and connecting or sealing to the surface of the carrier such that  
25 a cavity is enclosed and sealed between the chip and the carrier. The covering layer comprises a shaping material and at least an electrically conducting layer allowing to use the covering layer as a shunt line SHL. Inside the carrier the signal line needs to be connected with the electrically  
30 conducting layer forming the shunt line. By this the signal line is shorted to the back side metallization BSM. In this example, the said covering layer must not be connected to ground. Alternatively, a second conducting covering layer is

present above the housing to connect the housing to ground without shorting at same time the shunt line to ground.

Figure 7 compares the necessary chip areas of a resonator RES and a filter circuit according to the first embodiment of the invention. A single resonator working with acoustic waves can be substituted by a cascaded resonator to achieve a higher power durability thereby enhancing the lifetime of the resonator. Cascading a single resonator RES means that it is necessary to provide a series connection of a first resonator and a second resonator, each having double the resonator area or capacity like the original single resonator. Doubling the area or capacity of the cascaded resonator can be achieved by circuiting in parallel two series circuits of a first and a second resonator, each of first and second resonator having the same area like the original single resonator. Figure 7B shows a signal line that is split into two parallel lines that are connected at their two outermost ends. In each partial signal line two resonators are connected in series. Hence, replacing the single resonators as shown by figure 7A by four resonator circuitied as shown in Figure 7B gives a cascaded resonator having the same properties as the single resonator but having an enhanced power durability and reduced non-linearity as known from the art.

Figure 7C shows such a cascaded resonator that split into two signal lines and provided with a phase shifter PS in each of the two signal lines. The two phase shifters are shifting the phase of a respective parasitic signal line in a direction opposite to the direction in the other signal line. By this, a phase difference of about  $\pi$  can be achieved that is effective only for frequencies according to the parasitic signal. As can be seen the necessary chip area for realizing

the invention according to the first embodiment is only slightly greater than the chip area for a cascaded resonator.

Another solution that requires no additional chip area is  
5 already indicated in Figures 7B and 7D. The resonators are referenced by different indices meaning that the two resonators differ slightly. The two series connected resonators are mutually shifted in their resonance frequencies such that a resonator  $RES_A$  and a resonator  $RES_B$   
10 have different resonance frequencies. In the respective other signal line the sequence of the A-referenced resonator and the B-referenced resonator is interchanged. The frequency gap between a respective pair of two series connected resonators is chosen such that a phase shift results for the partial  
15 signal line that is effective for the frequencies of the parasitic signal. In the respective other signal line and due to the interchanged sequence of the different resonators, the respective phase shift is effective in the other direction. Hence, by properly selecting the frequencies of the two  
20 resonators in each partial signal line of Figure 7B the same effect can be achieved as the arrangement shown in Figure 7C. However, no additional area for a phase shifter is required as phase shifting can be achieved here without implementing further components. Similarly and according to Figure 7D  
25 resonators with different frequencies are used in different signal lines but identical resonators are used within one of the signal lines.

Figure 8A and 8B show two exemplary solutions that provide  
30 improvement of properties relative to comparable filter circuits without the invention. Figure 8A shows a T-section of a ladder-type arrangement comprising a first and a second series resonator  $SR1$  and  $SR2$  that are connected in series

within the signal line. Between the two series resonators a first and a second parallel resonator PR1, PR2, each arranged in a parallel branch of the circuit, are coupled to the signal line. Between the second parallel resonator PR2 and the second series resonator SR2 a parallel branch is coupled between the signal line and ground. In this branch, a shunt resonator SHR is arranged whose frequency is selected to be about  $2f$  if the parasitic H2 signal has to be suppressed. If H3 has to be suppressed, the frequency is about  $3f$  and so forth. The two series resonators SR as well as the two parallel resonators form a ladder type arrangement to provide a pass band at a frequency of  $f$ .

Figure 9A shows the amplitude of the second harmonics that produces peaks at a frequency of about  $2f$ . The graph belonging to the structure shown in Figure 8A is depicted as curve 2. As a reference, curve 1 shows the amplitude of the second harmonics of a structure similar to that of Figure 8A but having the shunt resonator omitted. It can easily be seen that the highest signal at about 1870 MHz is reduced by at least 5 dB. This is a result of the shorting of signals according to the invention.

This non-linearity can further be reduced by a structure according to figure 8B. Figure 10 depicts the amplitude of the parasitic signal H2 only and shows the improvement when comparing curve 2 (according to the improvement of figure 8B) to curve 1 (according to the structure of figure 8A as discussed above). The amplitude of the parasitic H2 signal at a frequency of about 1875 MHz is substantially reduced.

The invention has been explained by reference to a limited number of concrete embodiments but is not restricted to these

embodiments. Variations and combination of features depicted in single features are regarded to fall under the scope as well. The scope of the invention shall only be limited by the claims.

## List of terms and reference symbols

|     |                                     |
|-----|-------------------------------------|
| BSM | back side metallization             |
| BWV | bulk wave                           |
| CAR | carrier                             |
| CHP | SAW chip                            |
| FC  | filter circuit                      |
| GND | ground connection                   |
| IN  | input (of the signal line)          |
| OUT | output (of the signal line)         |
| PR  | parallel resonator                  |
| PS  | phase shifter                       |
| RES | resonator                           |
| RWV | reflected waves                     |
| SHL | shunt line                          |
| SHR | shunt resonator                     |
| SL  | signal line                         |
| SR  | series resonator                    |
| TRD | (interdigital) transducer           |
| TRF | transducer finger                   |
| VIA | via                                 |
| 1   | transfer curve of reference example |
| 2   | transfer curve of embodiment        |

## Claims

## 1. SAW device comprising

5       - a SAW chip (CP) bearing a SAW transducer adapted to work with an operating frequency and being arranged within a first signal line,

      - compensating means connected to the signal line to electrically eliminate the non-linear parasitic signal wherein the compensating means are comprising

10       - at least one second signal line (SL2) having means for producing a cancelling signal different in sign or phase to the parasitic signal, or

      - a shunt line (SHL) to electrically connect the SAW transducer to a back side metallization (BSM) of the SAW chip, or

15       - a shunt resonator (SHR) to electrically connect the SAW transducer to a ground potential at a frequency of the parasitic signal to be suppressed.

## 20   2. The SAW device of claim 1,

      - wherein a backside metallization (BSM) is arranged on the back side of the SAW chip (CHP) opposite to the transducer

      - wherein the transducer comprises a first and a second electrode

25       - wherein one of first and second electrode is connected to the backside metallization (BSM) via the shunt line (SHL).

## 3. The SAW device of one of the foregoing claims,

30       - wherein a shunt resonator (SHR) having a resonance frequency at or near the parasitic frequency is coupled between a signal line of the SAW device and ground.

4. The SAW device of one of the foregoing claims, wherein the at least one second signal line (SL2)

- comprises a phase shifter (PS) or accomplishes a phase shift

5 - is connected in parallel to the first signal line (SL1)

- provides a useful signal at the operating frequency and a cancelling signal at the parasitic frequency that is equal in amplitude but different in sign or phase to the parasitic signal.

10

5. The SAW device of one of the foregoing claims, wherein a phase shifter (PS1, PS2) is arranged in the first signal line (SL1) and each of the at least one second signal line (SL), wherein the cancelling is effected by interference of all

15 first and second signal lines.

6. The SAW device of one of the foregoing claims,

- wherein a first and a second signal (SL1, SL2) are circuited in parallel, each signal line comprising a series circuit of a first and a second resonator (RES)

20

- wherein the first resonator (RES<sub>A</sub>) is shifted in its resonance frequency relative to the second resonator (RES<sub>B</sub>) such that a phase shift having a magnitude of  $\pi/2$  results at a frequency of the parasitic signal that is preferably the second harmonics

25

- wherein the sequence of first and second resonator (RES) is interchanged in the first and second signal line (SL1, SL2) such that the two resulting phase shifts of the two signal lines at the frequency of the parasitic signal add to  $\pi$ .

30

7. The SAW device of one of the foregoing claims, wherein the phase shifter (PS) is embodied as a resonator (RES) having a resonance frequency at or near the parasitic frequency.

5 8. The SAW device of one of the foregoing claims, wherein the phase shifter (PS) is embodied as a SAW resonator that is arranged on the SAW chip of the SAW device.

9. The SAW device of one of the foregoing claims, wherein the  
10 shunt line is embodied as a via (VIA) conducted through the SAW chip (CHP).

10. The SAW device of one of the foregoing claims, wherein the shunt line (SHL) comprises a section that is formed by a  
15 housing wherein the SAW chip (CHP) is arranged.

11. The SAW device of one of the foregoing claims, embodied as a ladder type filter, a DMS filter or a resonator.

Fig 1

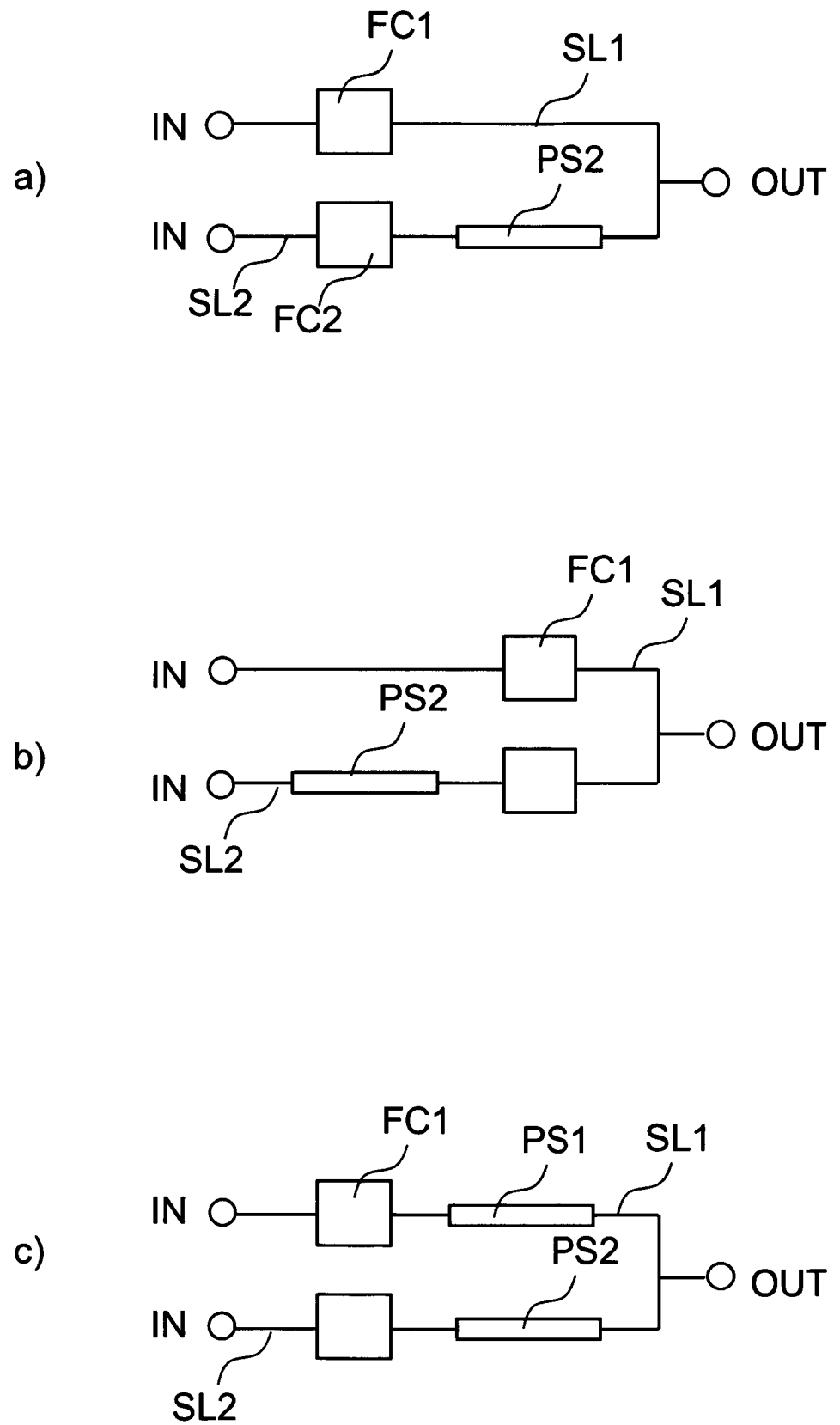


Fig 1

d)

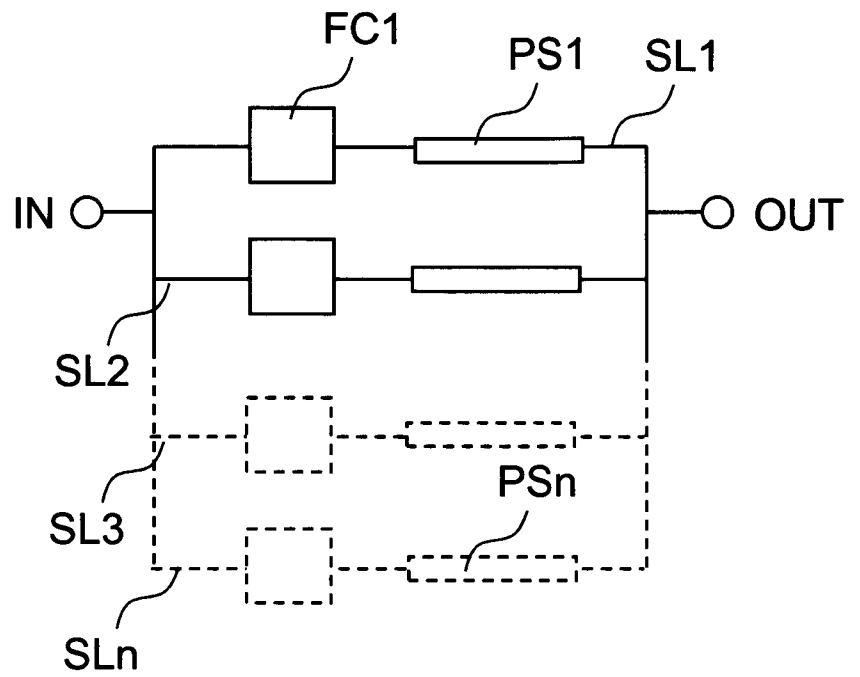
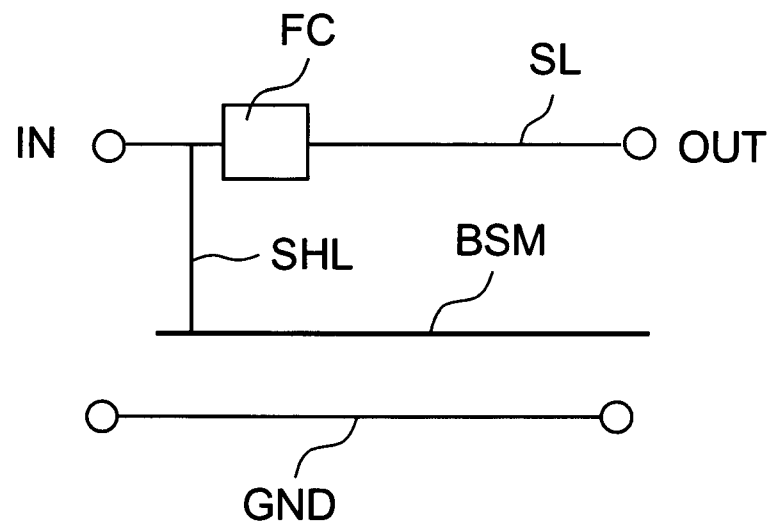
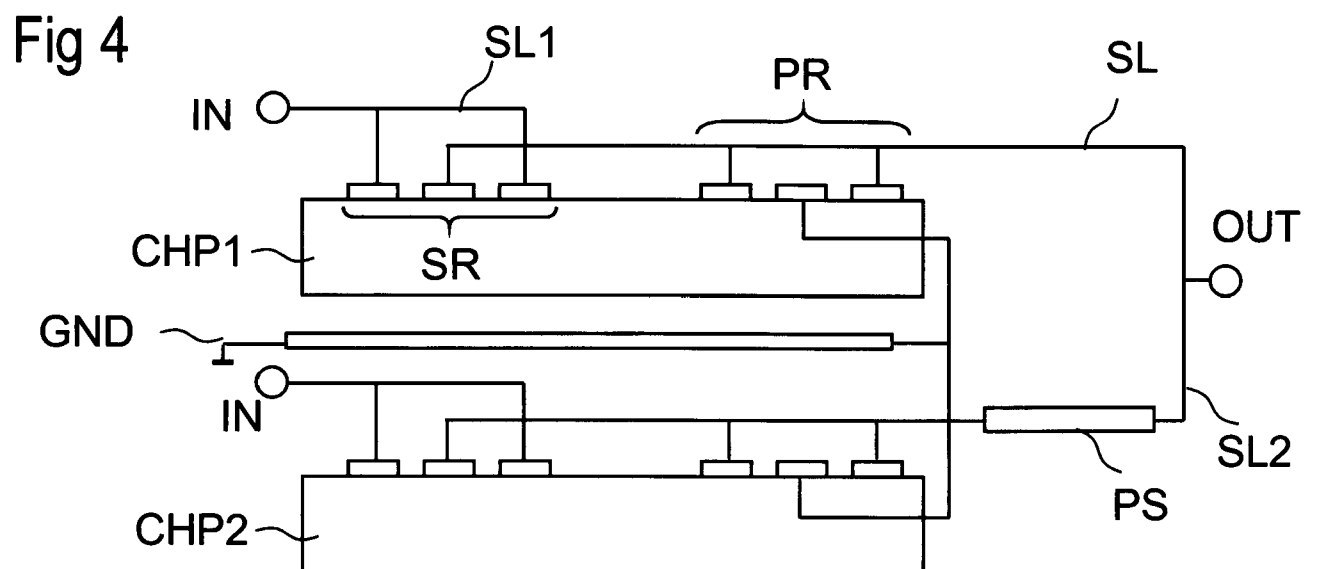
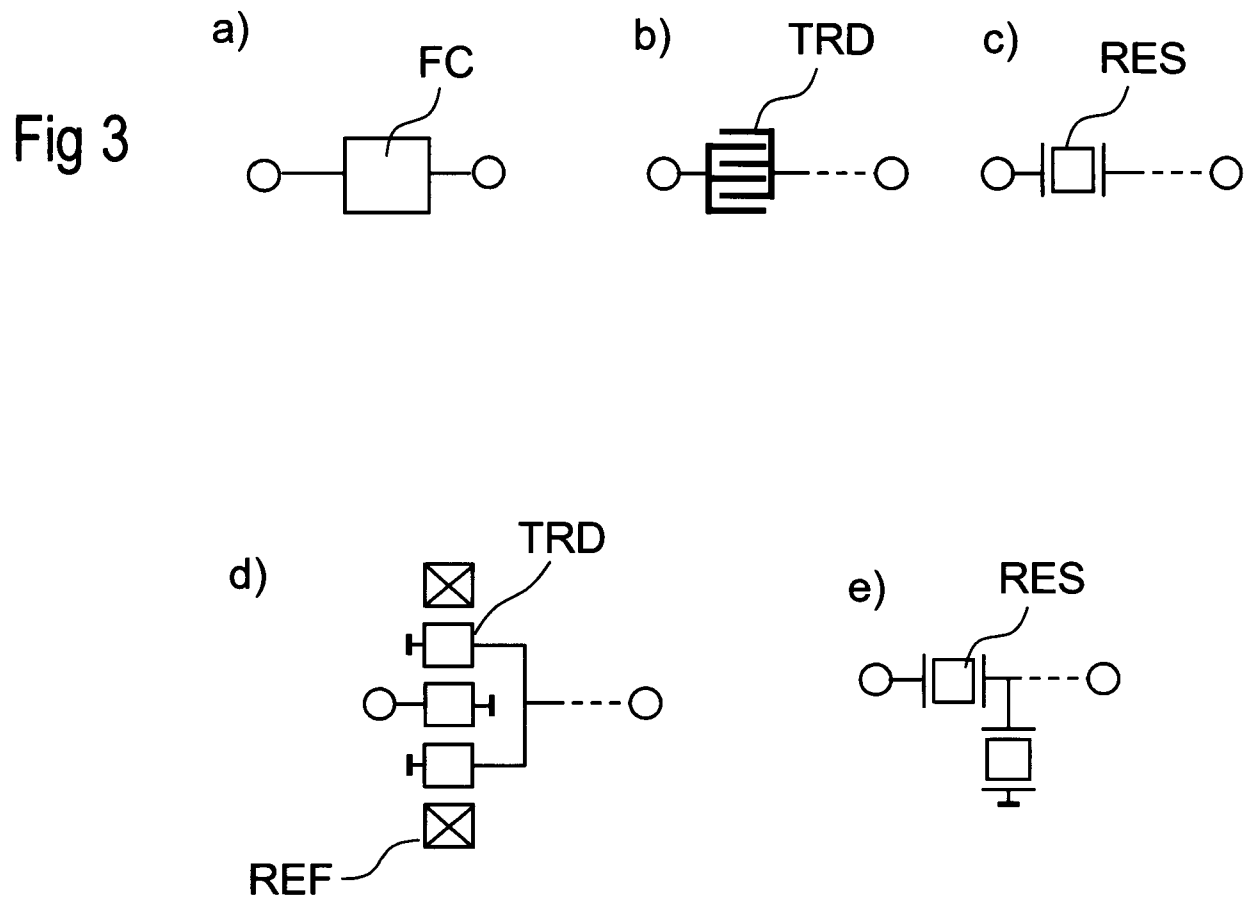


Fig 2





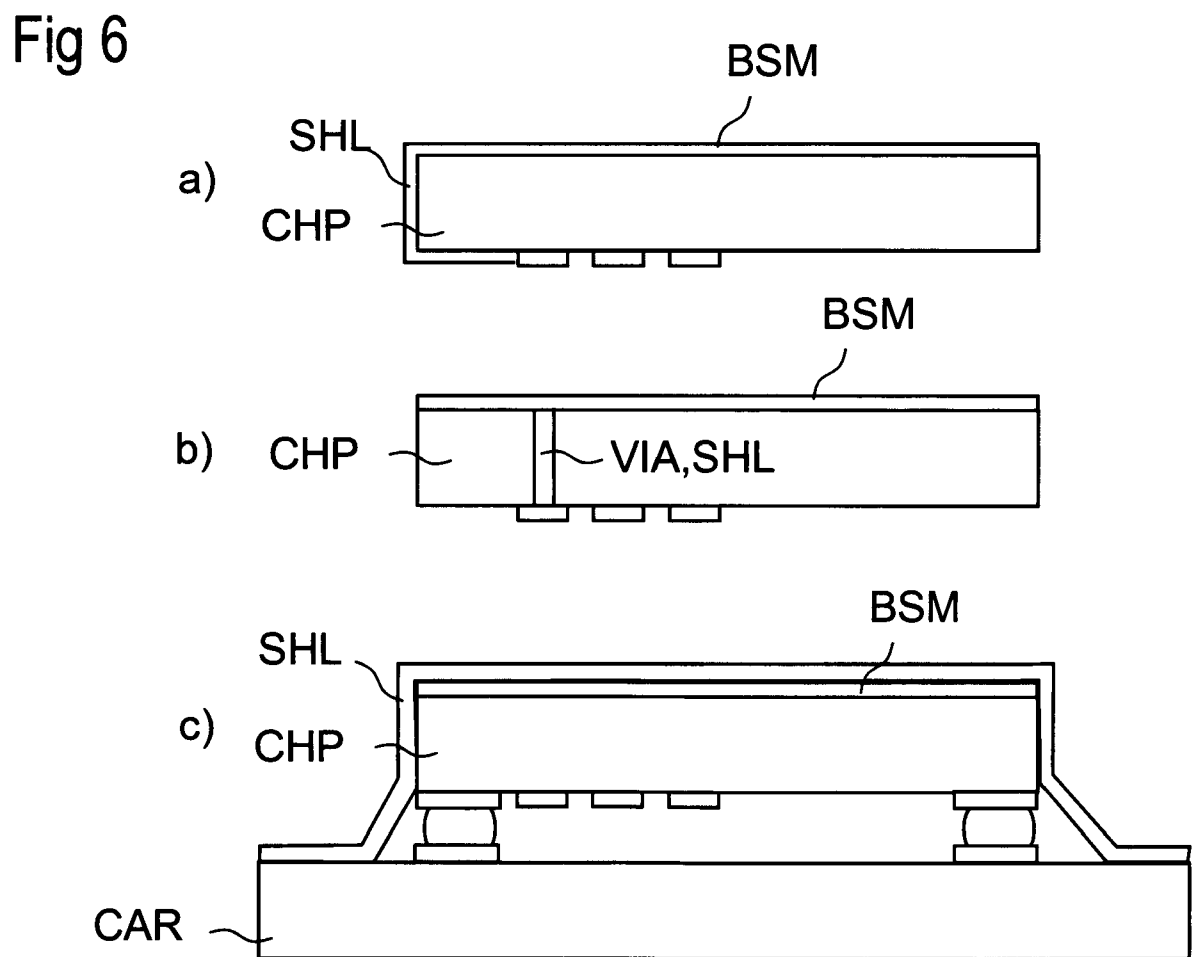
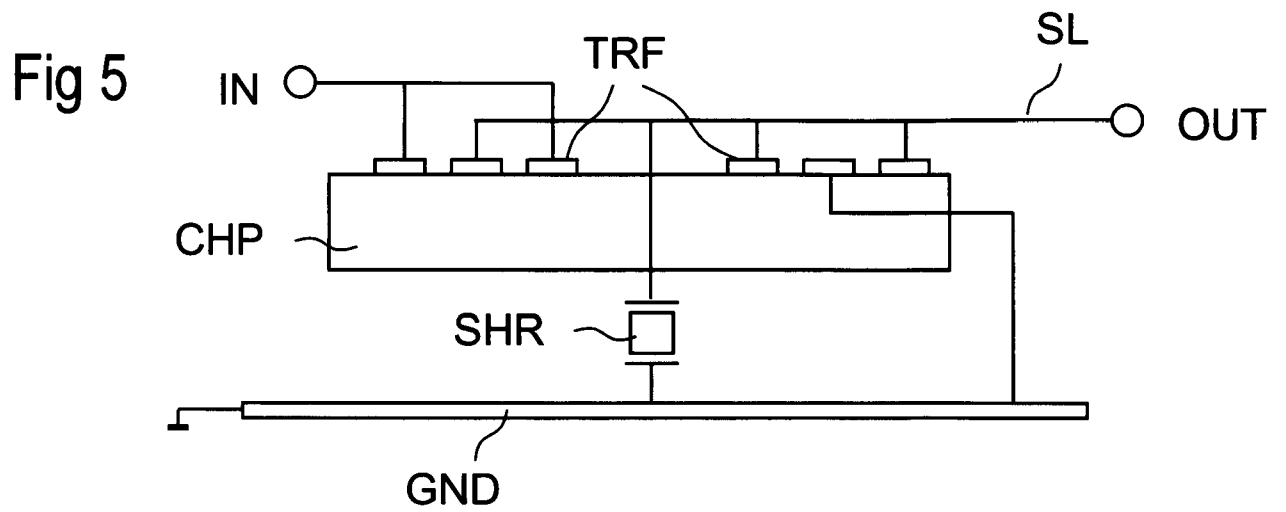


Fig 7

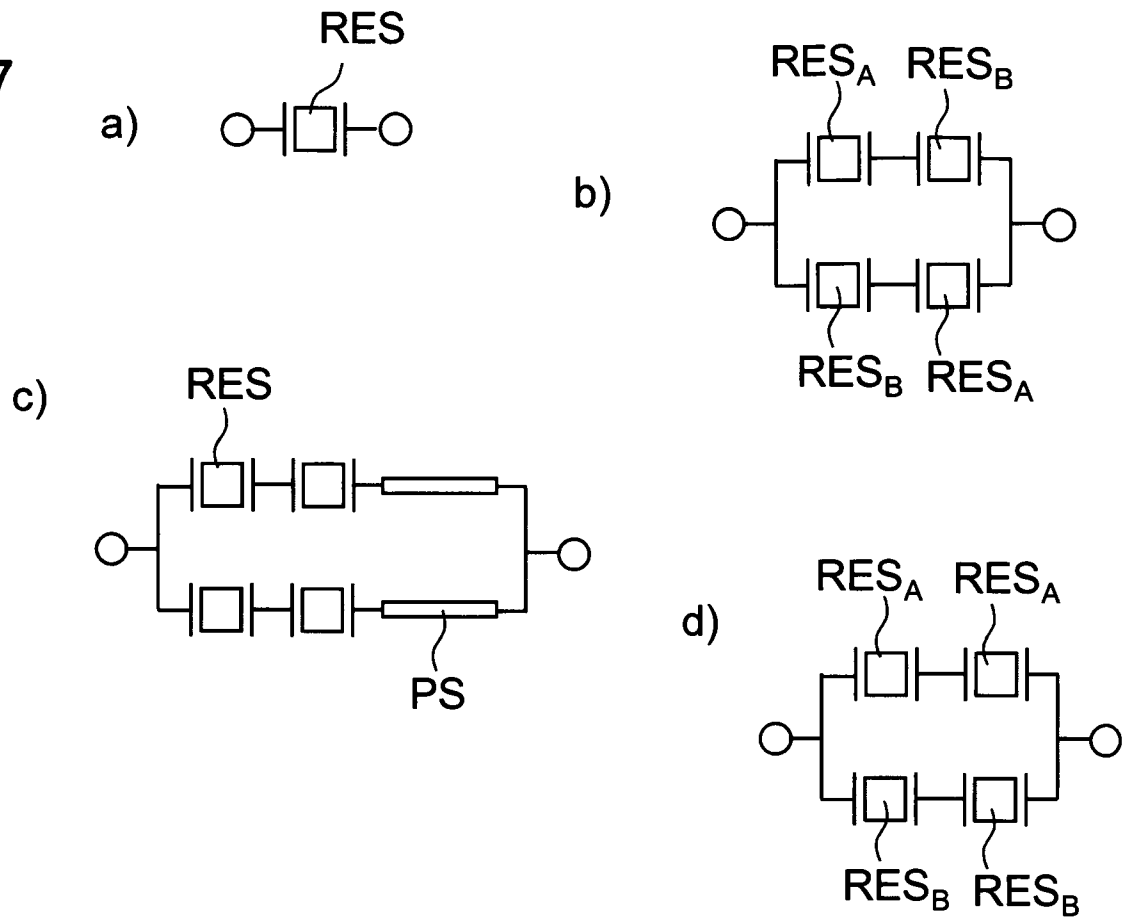


Fig 8A

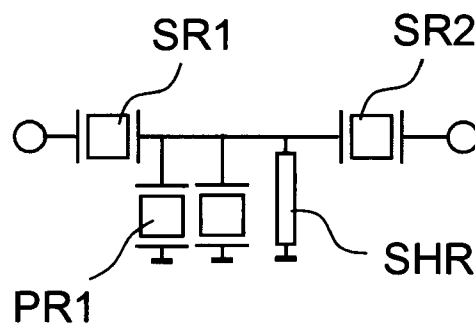


Fig 8B

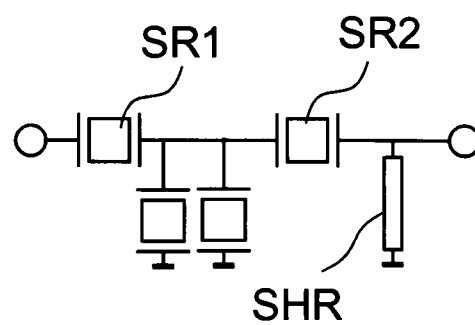


Fig 9A

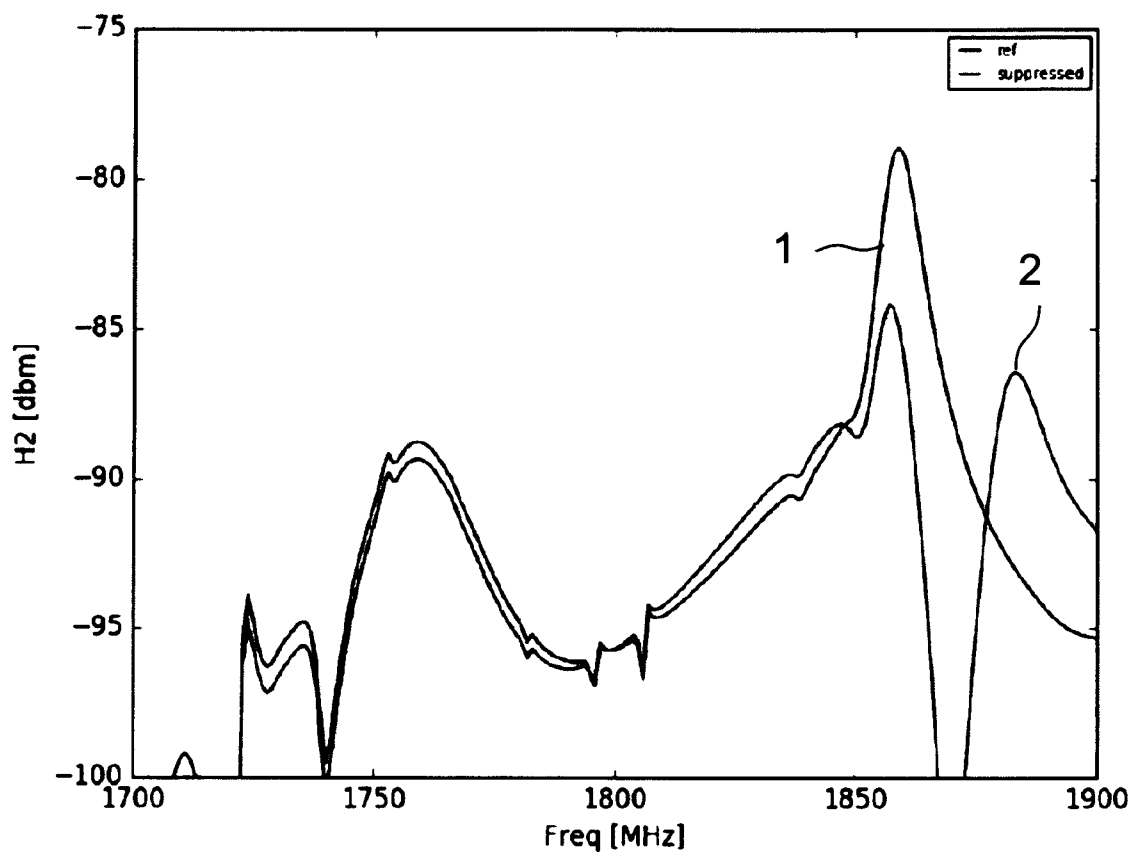


Fig 9B

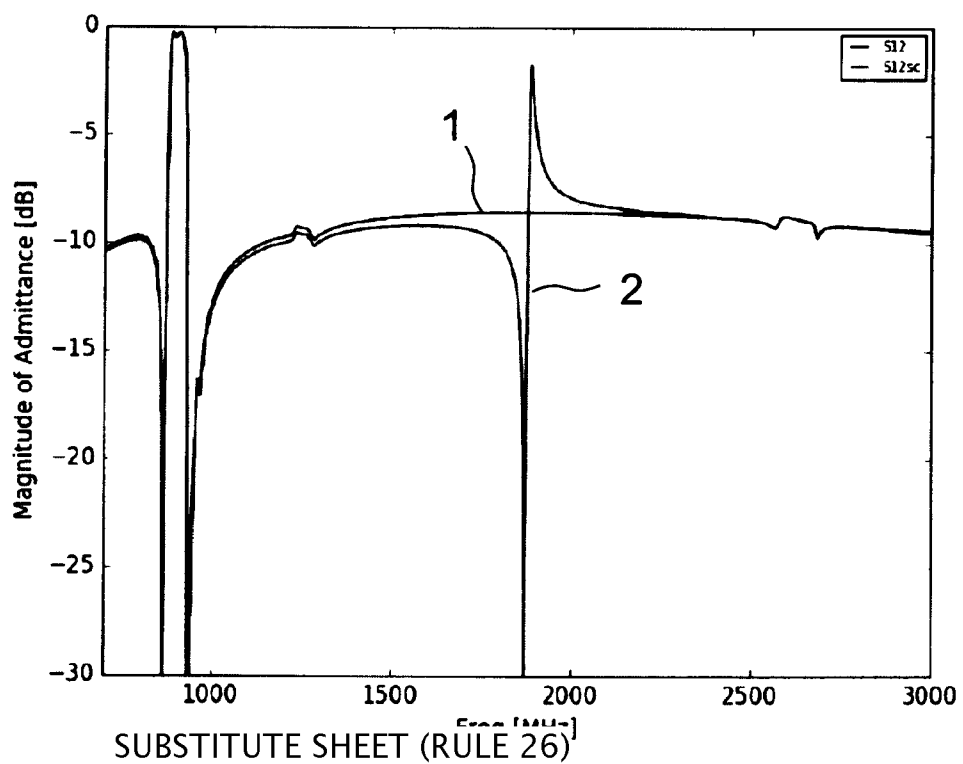


Fig 10

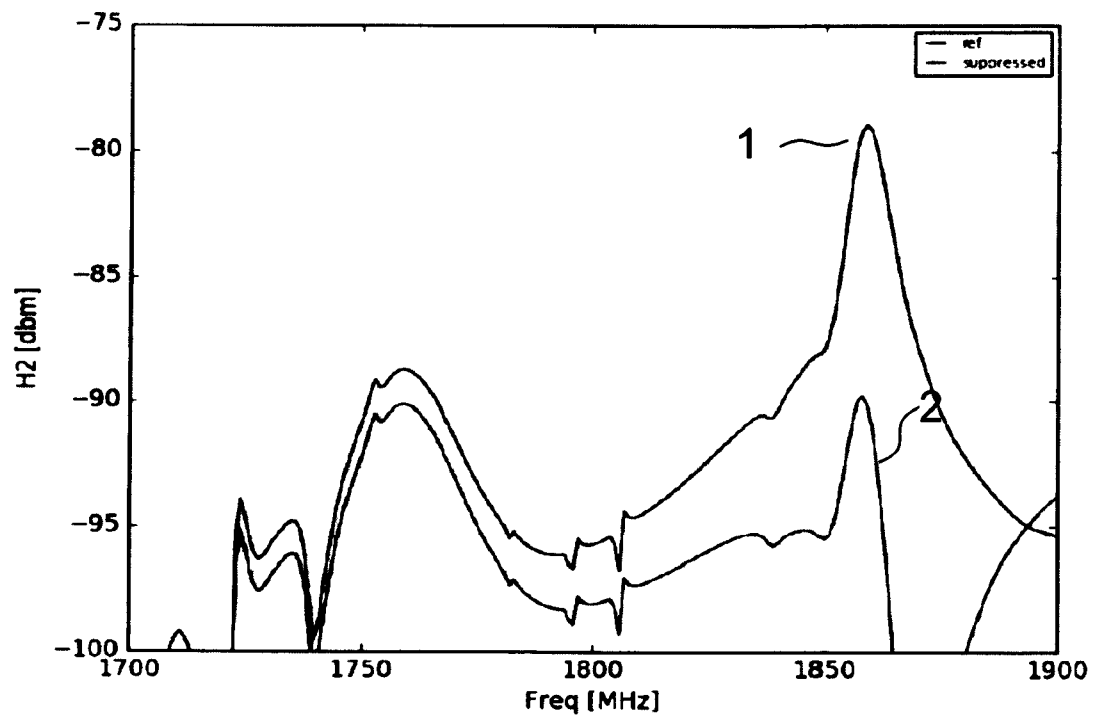
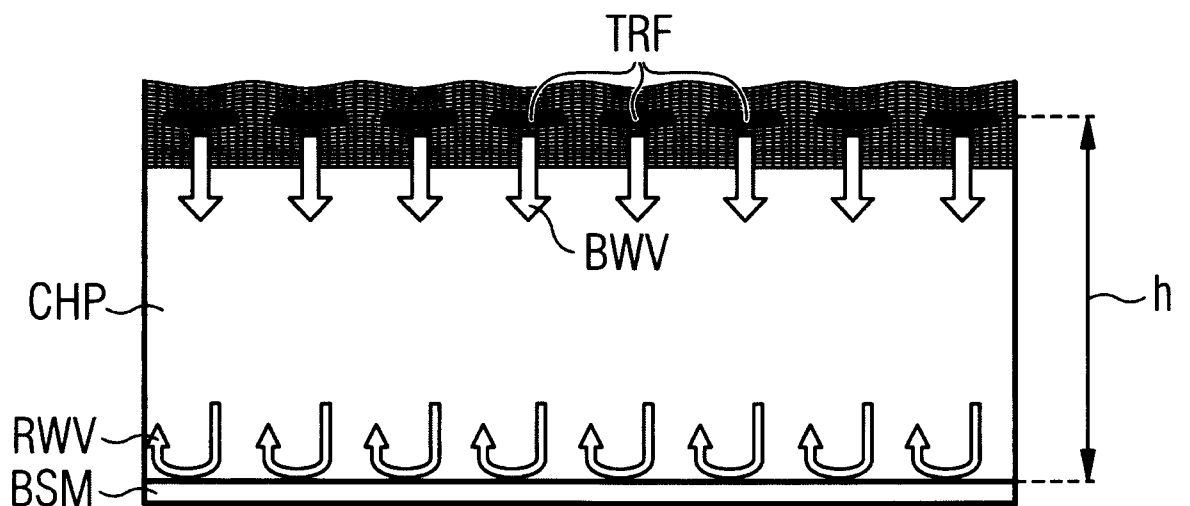


Fig 11



## INTERNATIONAL SEARCH REPORT

International application No  
PCT/EP2018/060085

A. CLASSIFICATION OF SUBJECT MATTER  
INV. H03H9/02 H03H9/64  
ADD.

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 practicable, search terms used)

EPO-Internal, WPI Data, INSPEC, COMPENDEX

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                                                      | Relevant to claim No. |
|-----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| X<br>A    | US 2016/118956 A1 (KIHARA TAKASHI [JP] ET AL) 28 April 2016 (2016-04-28)<br>paragraph [0044] - paragraph [0076];<br>figures 1 - 7<br>paragraphs [0009], [0024]<br>----- | 1,4,7,8,<br>11<br>5,6 |
| X<br>A    | EP 2 963 819 A1 (KYOCERA CORP [JP])<br>6 January 2016 (2016-01-06)<br>paragraph [0017] - paragraph [0083];<br>figures 2 - 5<br>-----                                    | 1,4,7,8,<br>11<br>5,6 |
| X<br>A    | US 2013/169378 A1 (KIM WON KYU [KR] ET AL)<br>4 July 2013 (2013-07-04)<br>paragraph [0079] - paragraph [0114];<br>figures 3, 4<br>-----<br>-/--                         | 1,4,5,11<br>6-8       |



Further documents are listed in the continuation of Box C.



See patent family 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 application or patent 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

3 July 2018

Date of mailing of the international search report

12/10/2018

Name and mailing address of the ISA/

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NL - 2280 HV Rijswijk  
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Fax: (+31-70) 340-3016

Authorized officer

Trafidlo, Renata

## INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2018/060085

| C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT |                                                                                                                                                                                                                                                                                                          |                       |
|------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| Category*                                            | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                                                                                                                                       | Relevant to claim No. |
| X                                                    | JP S62 261211 A (TOYO COMMUNICATION EQUIP)<br>13 November 1987 (1987-11-13)                                                                                                                                                                                                                              | 1,4,11                |
| A                                                    | abstract<br>-----                                                                                                                                                                                                                                                                                        | 5-8                   |
| X                                                    | EP 2 590 326 A2 (TAIYO YUDEN KK [JP])<br>8 May 2013 (2013-05-08)                                                                                                                                                                                                                                         | 1,4,11                |
| A                                                    | paragraph [0028] - paragraph [0040];<br>figures 12 - 17<br>-----                                                                                                                                                                                                                                         | 5-8                   |
| X                                                    | MASAFUMI IWAKI ET AL: "An attenuation<br>improvement technology for ladder SAW/FBAR<br>filters and duplexers employing<br>cancellation circuit",<br>MICROWAVE CONFERENCE (EUMC), 2011 41ST<br>EUROPEAN, IEEE,<br>10 October 2011 (2011-10-10), pages<br>751-754, XP032072782,<br>ISBN: 978-1-61284-235-6 | 1,4,11                |
| A                                                    | II. Principle of Cancellation Circuit;<br>page 751, left-hand column - page 753,<br>right-hand column; figures 1 - 7<br>-----                                                                                                                                                                            | 5-8                   |

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/EP2018/060085

## Box No. 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 No. 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 fees, this Authority did not invite payment of additional fees.
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.:

4-8(completely); 1, 11(partially)

### Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ 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: 4-8(completely); 1, 11(partially)

SAW device comprising a SAW chip having a SAW transducer working at an operating frequency and arranged within a first signal line, compensating means connected to the first signal line to electrically eliminate a non-linear parasitic signal, wherein the compensating means are comprising a second signal line having means for producing a cancelling signal different in sign or phase to the parasitic signal.

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2. claims: 2, 9, 10(completely); 1, 11(partially)

SAW device comprising a SAW chip having a SAW transducer working at an operating frequency and arranged within a first signal line, compensating means connected to the first signal line to electrically eliminate a non-linear parasitic signal, wherein the compensating means are comprising a shunt line to electrically connect the SAW transducer to a back side metallization of the SAW chip.

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3. claims: 3(completely); 1, 11(partially)

SAW device comprising a SAW chip having a SAW transducer working at an operating frequency and arranged within a first signal line, compensating means connected to the first signal line to electrically eliminate a non-linear parasitic signal, wherein the compensating means are comprising a shunt resonator to electrically connect the SAW transducer to a ground potential at a frequency of the parasitic signal to be suppressed.

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# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2018/060085

| Patent document<br>cited in search report | Publication<br>date | Patent family<br>member(s)                                                                                                                                                                | Publication<br>date                                                                                                                      |
|-------------------------------------------|---------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|
| US 2016118956 A1                          | 28-04-2016          | JP W02015002047 A1<br>US 2016118956 A1<br>WO 2015002047 A1                                                                                                                                | 23-02-2017<br>28-04-2016<br>08-01-2015                                                                                                   |
| EP 2963819 A1                             | 06-01-2016          | CN 104995836 A<br>EP 2963819 A1<br>JP 5844939 B2<br>JP 6100852 B2<br>JP 2016001923 A<br>JP 2017118587 A<br>JP W02014133084 A1<br>US 2016049920 A1<br>US 2018048289 A1<br>WO 2014133084 A1 | 21-10-2015<br>06-01-2016<br>20-01-2016<br>22-03-2017<br>07-01-2016<br>29-06-2017<br>02-02-2017<br>18-02-2016<br>15-02-2018<br>04-09-2014 |
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| JP S62261211 A                            | 13-11-1987          | JP S62261211 A<br>JP S62261211 K1                                                                                                                                                         | 13-11-1987<br>13-11-1987                                                                                                                 |
| EP 2590326 A2                             | 08-05-2013          | CN 103107794 A<br>EP 2590326 A2<br>JP 6017868 B2<br>JP 6081650 B2<br>JP 2013118611 A<br>JP 2016220263 A<br>SG 189610 A1<br>US 2013113576 A1<br>US 2016072477 A1                           | 15-05-2013<br>08-05-2013<br>02-11-2016<br>15-02-2017<br>13-06-2013<br>22-12-2016<br>31-05-2013<br>09-05-2013<br>10-03-2016               |