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(54) A combined duplex filter and antenna

(57) The invention relates to a combined structure of an antenna (1) and a duplex filter (2b), in which said antenna (1) at its input point is connected directly to the duplex filter (2b) at an antenna connection point. Then it is not possible that an exceptional situation would occur, in which no radiating element would be connected to the duplex filter, for instance due to a damaged antenna, to the replacement action of a replaceable antenna, or due to an retractable antenna being in a position between the extreme positions. This prevents the transmit signal from reflecting at a high power level to the receive branch (RX), so that the receive branch (RX) can be dimensioned for a much lower power level that earlier, and it can utilize for instance current surface acoustic filters (7). Further the transmission line losses between the duplex filter and the antenna are minimized, and a filter designer is provided with the possibility to design the impedance of the duplex filter at its antenna connection point (3) so that it is directly matched to the input impedance of the antenna.

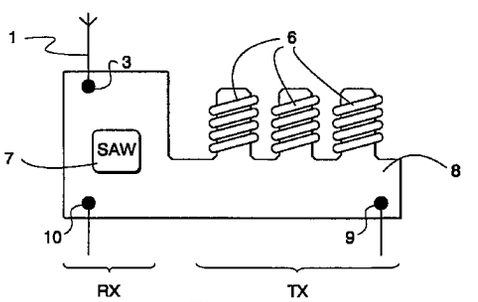

Fig. 2a

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Description

The invention relates generally to filter and antenna structures of radio equipment, and particularly to the connection of a duplex filter to the antenna of a radio device.

Duplex filters are generally used for separating the transmit and receive signals in radio devices, where the transmission and the reception are made at different frequencies via the same antenna. A duplex filter is a three-port circuit element comprising a transmitter port, a receiver port, and an antenna port. A radio signal supplied to the transmitter port at the transmit frequency sees the signal path towards the reception port as a high impedance, so that the radio power is not substantially directed to the receiver port, but it is directed through the antenna port to the antenna, where it is radiated as a radio signal to the environment. Correspondingly, a radio signal received through the antenna and the antenna port at the receive frequency sees the transmitter port as a high impedance, so that it is directed to the receiver port and further to the receiver sections of the radio device. The difference between the transmit frequency and the receive frequency is called the duplex interval. As distinguished from an antenna switch, the function of the duplex filter is not generally based on a switching function, in which the signal is controlled by e.g. semiconductor switches, but on different frequency response characteristics of the filter components.

In the description below a mobile phone is treated as an illustrative radio device. In a modern mobile phone the duplex filter is generally realized by transmission line resonators, which for instance can be helix, coaxial, micro-strip or ceramic resonators. The desired operation is achieved by combining resonators constructed for different resonance frequencies, and by arranging the connections between them in a suitable way. When an antenna is connected to the antenna port, it is provided with impedance matching which adapts the impedance of the antenna port to the impedance of the antenna itself.

The transmit branch of the duplex filter, i.e. the signal path from the transmitter port to the antenna port, must be designed so that it can tolerate the transmit power of the radio device, which in a typical mobile phone application is e.g. 0.6 to 1.2 W (in the DAMPS system, Digital Advanced Mobile Phone system), or 0.8 to 2 W (the GSM system, Group Spéciale Mobile). The receive branch, i.e. the signal path from the antenna port to the receiver port, would not require nearly as high power ratings regarding the received radio power, but for certain exceptional situations the receive branch of conventional solutions had to be dimensioned for almost as high power ratings as the transmit branch. Exceptional situations refer particularly to a situation when, for some reason or other, no antenna or corresponding radiating element is connected to the antenna port, which means that in the worst case the transmitted radio signal will see the antenna port as an open terminal, whereby it is reflected and tries to reach the receive branch. If the reflected signal reaches such components of the receiver section which are dimensioned for the normally received radio power of only a few milliwatts, it can destroy these components.

An exceptional situation can occur for instance in a mobile phone when its retractable antenna comprises a separate helix part and a whip part, of which one is connected to the antenna port when the antenna is retracted within the cover of the phone, and correspondingly the other is connected to the antenna port when the antenna is extracted. In an intermediate state it may happen that neither of these is connected to the antenna port. In a mobile phone provided with a detachable antenna there might also occur a situation where the telephone transmits, even if the antenna is detached. An exceptional situation can also result if the antenna is broken, or if the antenna connector is damaged as a result of the telephone being dropped or due to inappropriate handling. The impedance seen by the transmit signal in an exceptional situation will depend on the length of the transmission line between the filter and the antenna, on the location and connection of any impedance matching elements, and on the quality and location of the fault in a fault situation.

Regarding the filter technique it would be advantageous, if it would not be necessary to design the duplex filter to withstand high power. For instance, it would be advantageous to use small-size acoustic filters (SAW, Surface Acoustic Wave) in mobile phones, but currently these filters withstand a power of only 0.04 to 0.1 W.

In the prior art there are solutions in which the duplex filter comprises a power impeding circuit or attenuator, which is located between the antenna port and the receive filter and dimensioned for a low power, and the function of which in an exceptional situation is to attenuate the radio power reflected from the antenna port to the receive branch so much that it will not damage the SAW filter used as the receive filter. However, these solutions have the disadvantage that a power impeding or attenuating circuit always also to some degree attenuates the received signal, whereby the signal-to-noise ratio is worsened.

One potential outcome of this invention is an antenna and duplex filter structure, in which the components of the receive branch can be dimensioned for a substantially lower power than the transmit power, without any risk for these components to be damaged in an exceptional situation like those described above. Another potential outcome is to present an antenna and a duplex filter structure, where it is possible to use surface acoustic filters in the receive branch, without a separate power impeding or attenuating circuit. Another potential outcome is further to present an antenna and duplex filter structure, which due to its size, characteristics and manufacturing costs is suitable for series production of modern mobile phones. Another potential outcome is to present an antenna and duplex filter

structure where transmission line losses and space requirement is minimized.

Preferred aspects of the invention are attained with an integrated solution, in which the antenna has a fixed connection to the antenna port of the duplex filter structure.

The antenna and duplex filter structure may suitably be characterized in that said antenna at its input point is connected directly to the duplex filter.

In order to avoid a situation where the transmit power is reflected from an open antenna port to the duplex filter it must preferably be secured in a way or other that the antenna port is never open. The arrangement of the invention preferably takes care of this so that the radiating antenna element has a fixed connection at its input point, directly to the duplex filter, without any transmission lines or coaxial lines. Further the structure according to the invention preferably means the antenna impedance is matched in the duplex filter itself.

The combined antenna and duplex filter structure according to the invention comprises a duplex filter having a transmitter port and a receiver port, and an antenna connected directly to the duplex filter at an antenna connection point. From the standpoint of the invention it is not necessarily essential in which technology the filter is realized or which antenna structure is used. In the preferred embodiment the filter may comprise helix or ceramic resonators. Because it is not necessary to design the receive branch to tolerate a high power level, it can preferably comprise a surface acoustic filter. The antenna can also be a planar antenna (PIFA, Planar Inverted F-Antenna), a radiation coupled antenna (RCDLA, Radiation coupled Double L-Antenna) or a micro-strip antenna (micro-strip/patch antenna). According to the preferred embodiment the structure according to the invention is placed in a mobile phone or in a corresponding device so that the outer covering of the device protects the antenna, or at least the connection between the input point of the antenna and the duplex filter, against mechanical stress.

Because the transmit power is not reflected towards the receiver port in any situation, the receive filter can be dimensioned for a substantially lower power level than hitherto, whereby it is for instance possible to utilize the characteristics of SAW filters. The invention may provide an advantage compared to prior art, in that the impedance matching required by the antenna can be made directly in the duplex filter by using partly components already present in the filter. The components of the duplex filter can also be designed so that the impedance of the duplex filter at the antenna connection point directly corresponds to the input impedance of the antenna, so that no separate impedance matching is required. The structure according to the invention may also reduce or minimize transmission line losses which are typical in a prior art mobile phone, in which the antenna is connected to the duplex filter via a coaxial line or a transmission line.

The invention is described in more detail below with reference to the preferred embodiments shown as examples and to the enclosed figures, in which

figure 1a shows schematically a prior art antenna and duplex filter structure;

figure 1b shows schematically an antenna and duplex filter structure according to the invention;

figure 2a shows a preferred embodiment according to the invention;

figure 2b shows another preferred embodiment according to the invention;

figure 3a shows a third preferred embodiment according to the invention;

figure 3b shows a fourth preferred embodiment according to the invention;

figure 4 shows a fifth preferred embodiment according to the invention;

figure 5 shows in more detail a way to realize a mechanical connection, which can be used to realize the structure according to the invention;

figures 6a to 6c schematically show preferred ways to locate the structure according to the invention in a mobile phone;

figure 7a shows in more detail another way to realize a mechanical connection, which can be used to realize the structure according to the invention;

figure 7b shows the structure according to figure 7a, when the movable part of the antenna is retracted;

figures 8a and 8b show schematically a preferred way to locate the structure according to figures 7a and 7b in a mobile phone;

figure 9 shows a sixth embodiment of the structure according to the invention; and

figure 10 shows schematically a preferred way to locate the structure according to figure 9 in a mobile phone.

The same reference numerals have been used in the figures for corresponding parts.

Figure 1a shows schematically a prior art antenna and duplex filter structure, where the antenna 1 is connected via a coaxial line 4 to the antenna port 3 of the duplex filter 2a. Further the structure comprises an impedance matching circuit 5 close to the junction of the

coaxial line 4 and the antenna 1. It has to be noted that because a person skilled in the art regards the transmission line 4 between the antenna and the duplex filter and the impedance matching circuit 5 as self-evident parts of a radio apparatus, they are frequently omitted from schematic circuit diagrams and block diagram representations (this practice is comparable to that of leaving the operating voltage connections of integrated circuits out of circuit diagrams to enhance graphical clarity). Figure 1b shows a corresponding structure according to the invention, in which the input point of the antenna 1 is connected directly to the duplex filter 2b at an antenna connection point 3, which can also be nominated as an antenna port. The structure according to the invention requires no separate transmission lines between the filter and the antenna, and no separate impedance matching circuits.

Figure 2a shows a structure according to the invention, in which the filter TX of the transmit branch of the duplex filter comprises helix resonators 6, and in which the filter RX is a surface acoustic filter 7. The substrate of the filter is a circuit board 8 made of low-loss material and with comb-like branches supporting the helix resonators 6. A structure where a circuit board with branches supports the helix resonators is called a helix filter with a comb structure, and it is per se a filter type known by a person skilled in the art. With a method known per se the surface of the circuit board 8 is provided with strip lines for wire connections and terminal pads to attach the required discrete components, such as switching diodes.

For the sake of clarity the figures do not show strip lines, terminal pads and discrete components, which are not relevant for the invention. The surface acoustic filter 7 of the receive branch RX is attached on the surface of the circuit board 8, and required connections are arranged as strip lines. The surface acoustic filter 7 of the receive branch RX is attached on the surface of the circuit board 8, on which required wire connections are made as strip lines. In order to achieve the correct function of the resonators and to prevent electromagnetic interference the filter is protected according to a practice known by a person skilled in the art by a cover made of electrically conducting material, which for the sake of clarity is not shown in figure 2a.

The antenna connection point 3, the transmitter port 9 and the receiver port 10 of the duplex filter shown in figure 2a are connection points made on the circuit board 8. According to the invention the antenna 1 is connected directly to the filter at an antenna connection point 3. The duplex filter's impedance at the antenna connection point 3, which in the preferred embodiment of the invention is matched directly to the input impedance of the antenna, is determined in a way known per se to a person skilled in the art by the dimensioning the strip lines made on the circuit board surface and any discrete components connected to the strip lines, and by their mutual location on the circuit board.

The antenna and duplex filter structure shown in figure 2b corresponds to that of figure 2a, but here the filter section of the transmit branch TX is realized with ceramic resonators. The body of the resonators is a block 11 made of a dielectric ceramic material, and the resonators 12 are holes made in the block and coated with an electrically conducting material. The ceramic body 11 is fastened on a substrate or a circuit board 8 made of low-loss material, the surface of which is used to form strip lines and connection patches, in the same way as described in connection with figure 2a. The antenna port 3, the transmitter port 9 and the receiver port 10 are also terminal points made on the circuit board 8. According to the invention the antenna 1 is connected directly to the antenna port 3. Also this structure is protected by a cover made of generally electrically conducting material.

In the embodiments of figures 2a and 2b a part of the helix or ceramic resonators can be used in the receive branch, whereby the filter of the transmit branch comprises only resonators and the filter of the receive branch comprises both resonators and a surface acoustic filter 7.

Figure 3a shows a filter structure, in which the filter section of both the transmit branch TX and the receive branch RX comprise only helix resonators 6. Filters of this type do not have the same power tolerance problems as surface acoustic filters, but when the antenna 1 is connected directly to the filter at an antenna connection point 3 we achieve the other advantages of the invention, i.e. the transmission line losses are low and the space requirements are small, and the filter's impedance at the antenna connection point can be designed so that it directly corresponds to the input impedance of the antenna. The structure of figure 3b corresponds to that of figure 3a, but here ceramic resonators 12 are used as filter resonators.

With advances in technology it is probable that in the future it is possible to manufacture surface acoustic filters having so high power ratings that they can also be used in the transmit branch of the duplex filter. Figure 4 shows a combined antenna and duplex filter structure according to the invention, in which a surface acoustic filter 7, 13 is used as the filter in both the transmit branch TX and the receive branch. Then the size of the structure can probably be made substantially smaller than with the current filter technology. Even if the power rating requirements do not restrict the realization of the structure, it is useful to make according to the invention the connection of the antenna 1 directly to the antenna port 3 of the filter, in order to minimize transmission line losses and in order to arrange the impedance matchings as advantageously as possible.

Figure 5 shows an arrangement to attach the antenna to the filter. Figure 5 corresponds to the structure of figure 2b, in that there the filter of the transmit branch TX is realized by ceramic resonators 12, and the filter of the receive branch RX is a surface acoustic filter 7. Required wire connections are made as strip lines 14 on the surface of the circuit board 8. The antenna con-

nector 15 has a fixed connection to the filter structure, in this case to the circuit board 8. In the neighborhood of the connector there can be matching elements (not shown in the figure) for the matching of the filter's impedance to the input impedance of the antenna 1. The outline of the electrically conducting and protecting cover 16 placed on the filter is shown with a broken line in figure 5.

The structure according to the invention is preferably placed in a mobile phone or other radio device so that the outer covering of the device protects both the filter and at least partly also the antenna, and particularly the junction between the antenna and the duplex filter, against bending and impacts. The figures 6a to 6c show different exemplary alternative locations. The reference numeral 17 denotes the circuit board of the mobile phone and the reference numeral 18 denotes the outer covering of the telephone, which can be designed in many different ways. In figure 6a a helix antenna 1a is used as the antenna, whereby the combination according to the invention formed by the antenna and the duplex filter 2b is quite small and compact. It can be located in the top part of the mobile phone so that the duplex filter 2b is fastened to the telephone's circuit board 17 and the helix antenna 1a is directed upwards, or in the position shown in the figure, away from the circuit board 17. The outer covering 18 of the mobile phone is designed in this embodiment so that it encloses all components, whereby the structure is very compact, and viewed from the outside it is elegant in a simple way.

The embodiment of figure 6b utilizes a whip antenna 1b having a substantially greater length in the direction of its longitudinal axis than the helix antenna of a corresponding electrical length. Then it is usually not worth wile to enclose the whole antenna 1b within the outer covering 18, but a part of the antenna is left visible. The task of the telephone's outer covering 18 is to protect the base of the antenna 1b and the junction between it and the duplex filter 2b. The visible part of the antenna is made flexible, so that it withstands bending an other mechanical stresses. Figure 6c shows a modification of the same structure, where the antenna port of the duplex filter 2b due to its structure is located at one end of its longitudinal shape. Then the filter 2b can be mounted on the circuit board 17 in a vertical direction as seen in the figure. Other mounting directions are also possible.

The structure according to the invention can be used also when the antenna of the radio device is retractable or otherwise movable. Such a solution comes often into question in mobile phones, which in the portable state must occupy as little space as possible, but which require a rather long antenna for the best communication quality. In the prior art several retractable antennas are known which have both helix and whip parts Particularly reference is made to the antenna structure presented in the Finnish patent application FI-952742 (LK-Products Oy: Kaksitoiminen antenni (Double-acting antenna)), in which the antenna structure comprises a fixed helix part and a whip part which can be moved in relation to the helix part, whereby the extracted whip part forms a series connection with said helix part. Figure 7a illustrates a way to connect such an antenna to be a part of a combined antenna and duplex filter structure according to the invention. The filter utilizes a ceramic filter 12 in the transmit branch and a surface acoustic filter 7 in the receive branch. The antenna connector 15 has a fixed connection to the low-loss circuit board 8 of the filter, and the required conductor connections between the connector and the other parts of the filter are made by strip lines 14. The antenna helix part 19 has a fixed connection to the antenna connector 15, which in the center has a hole, in which the whip part 20 can move back and forth. The electrically conducting and protecting cover 16 of the duplex filter covers in the embodiment of figure 7a only the filters 12 and 7, but it could also be designed so that the antenna connector 15 is within the cover. In the situation of figure 7a the whip part 20 is extracted, whereby it forms a series connection with the helix part 19. In figure 7b the whip part 20 is retracted, whereby only the helix part 19 acts as the antenna of the telephone. The presented structure, in which the helix part 19 has a fixed connection to the antenna connector 15, is advantageous in that when the antenna is moved there occurs no such situation in which no radiating element would be connected to the antenna port of the filter.

Figures 8a and 8b correspond to the figures 7a and 7b and show an example of how the structure presented there is located in a mobile phone, when the antenna whip part 20 is extracted (figure 8a) and retracted (figure 8b). The telephone's outer covering is preferably designed so that it covers the helix part 19. The cover has a hole, in which the whip part 20 can move back and forth. Other alternatives for the location and design are also possible.

Figure 9 shows schematically an alternative to use a planar antenna as a part of the combined antenna and duplex filter structure according to the invention. The figure shows a duplex filter 2b enclosed by an electrically conducting cover, and a PIFA antenna 21 (Planar Inverted F-Antenna) known per se to a person skilled in the art, which is connected to one corner of the cover. The casing of the filter acts as an essentially shorting element, which is essential to the function of the antenna, and the antenna input is at the connection point of the antenna port 3 at the center of the filter. Instead of the PIFA structure shown in the figure also other planar antennas known per se can be used, such as micro strip antennas and RCDLA antennas (Radiation coupled Double L-Antenna).

Figure 10 shows an exemplary way to locate the structure of figure 9 in a mobile phone. The probable position of the mobile phone in use must be observed when the planar antenna is placed the mobile phone's case, because the whole planar antenna is preferably located within the case so that the antenna should oper-

ate in the best possible way, and so that as little as possible of its radiation would be directed to the telephone user. A preferred location is in the upper part of the mobile phone, and on its back side, so that in a normal position of use the antenna is located as far as possible from the body and the head of the user, and so that the user's hand has as little influence as possible on the radiation characteristics of the antenna. The radiation pattern of the planar antenna is directional, and the direction of the strongest amplification should point away from the body of the user.

Above it was discussed how the structure according to the invention is placed mainly in a mobile phone. However, the presented examples are not intended to be limiting, but to a person skilled in the art it is clear that the invention can be applied in many different filter and antenna structures in radio devices of all kinds, preferably at the UHF and VHF frequencies, but also at other frequencies.

The invention presents a potential solution to the receive branch power tolerance problem of a duplex filter, so that very small-sized filters can be used, for instance surface acoustic filters. The invention preferably does not require any particular and exact manufacturing steps, and no particularly expensive components or materials, so aspects of the invention are well suited for series production of radio devices, such as mobile phones.

Claims

1. A combined antenna (1; 1a; 19, 20) and duplex filter (2b) structure, in which the antenna comprises an input point and the duplex filter comprises

   - an antenna connection point (3) to direct the transmit signal to the antenna and to direct the received signal from the antenna,
   - a transmitter port (9) for the input of the transmit signal, and
   - a receiver port (10) for the output of the received signal, and

   characterized in that the antenna (1; 1a; 19, 20) at its input point is connected directly to the duplex filter at the antenna connection point (3).

2. A combined structure according to claim 1, characterized in that said duplex filter (2b) comprises a transmit branch (TX) between said transmitter port (9) and said antenna connection point (3), and a receive branch (RX) between said antenna connection point (3) and said receiver port (10), and that said receive branch (RX) comprises a surface acoustic filter (7) (SAW, Surface Acoustic Wave).

3. A combined structure according to claim 2, characterized in that said transmit branch (TX) comprises ceramic resonators (12).

4. A combined structure according to claim 2, characterized in that said transmit branch (TX) comprises helix resonators (6).

5. A combined structure according to claim 2 or 3, characterized in that said receive branch (RX) further comprises ceramic resonators.

6. A combined structure according to claim 2 or 4, characterized in that said receive branch (RX) further comprises helix resonators.

7. A combined structure according to claim 1, characterized in that said duplex filter (2b) is wholly realized in ceramic resonator technology (12).

8. A combined structure according to claim 1, characterized in that said duplex filter (2b) is wholly realized in helix resonator technology (6).

9. A combined structure according to claim 1 or 2, characterized in that said duplex filter (2b) is wholly realized in surface acoustic filter technology (7, 13).

10. A combined structure according to any previous claim, characterized in that said antenna (1) is one of the following: a helix antenna (1a), a whip antenna (1b), a combined helix and whip antenna (19, 20), an extractable antenna (20), a micro-strip antenna, a planar inverted F-antenna (21) (PIFA), a radiation coupled double L-antenna (RCDLA).

11. A radio communication device, which comprises an outer covering (18), an antenna (1) and a duplex filter (2b), in which said antenna comprises an input point and said duplex filter comprises

    - an antenna connection point (3) to direct the transmit signal to the antenna and to direct the received signal from the antenna,
    - a transmitter port (9) for the input of the transmit signal, and
    - a receiver port (10) for the output of the received signal, and

    characterized in that said antenna (1) is at its input point directly connected to the duplex filter at said antenna connection point (3), and that the essential parts of the combined structure so formed by said antenna and said duplex filter is located within said outer covering (18), whereby said outer covering is designed to protect at least the junction between the antenna and the duplex filter.

12. A radio communication device according to claim 11, characterized in that it is a mobile phone of a cellular radio network.

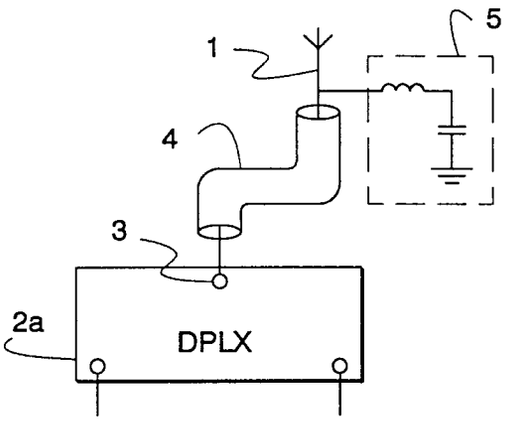

Fig. 1a

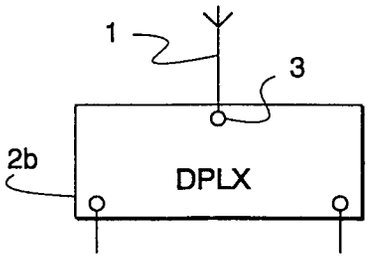

Fig. 1b

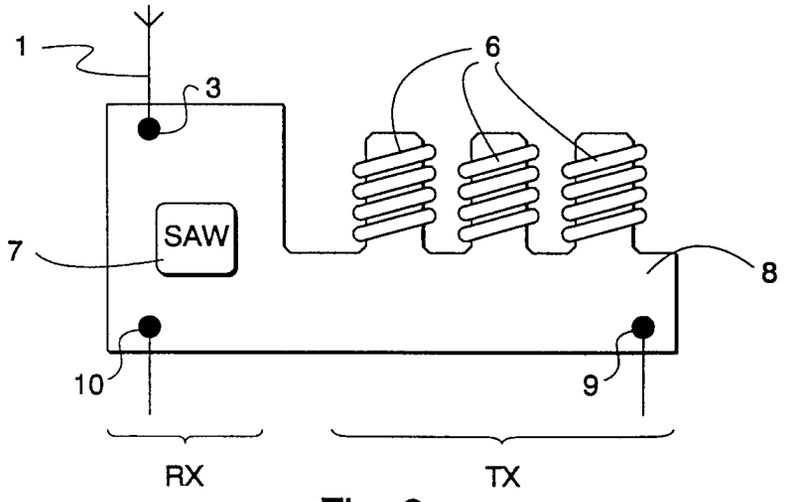

Fig. 2a

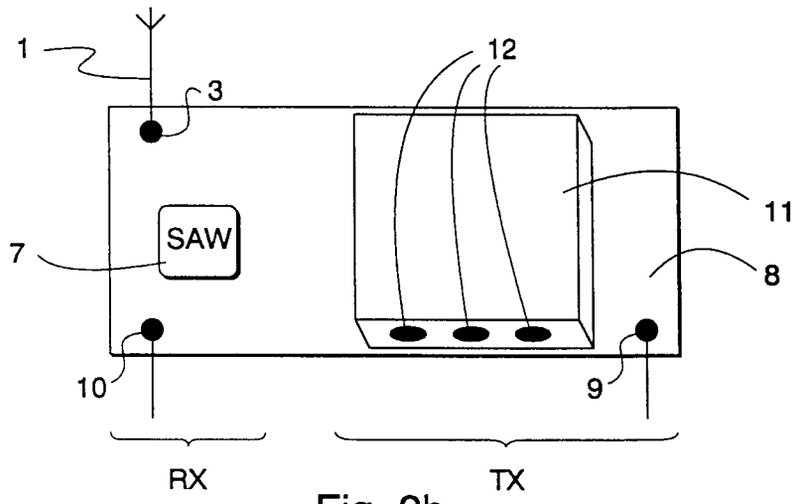

Fig. 2b

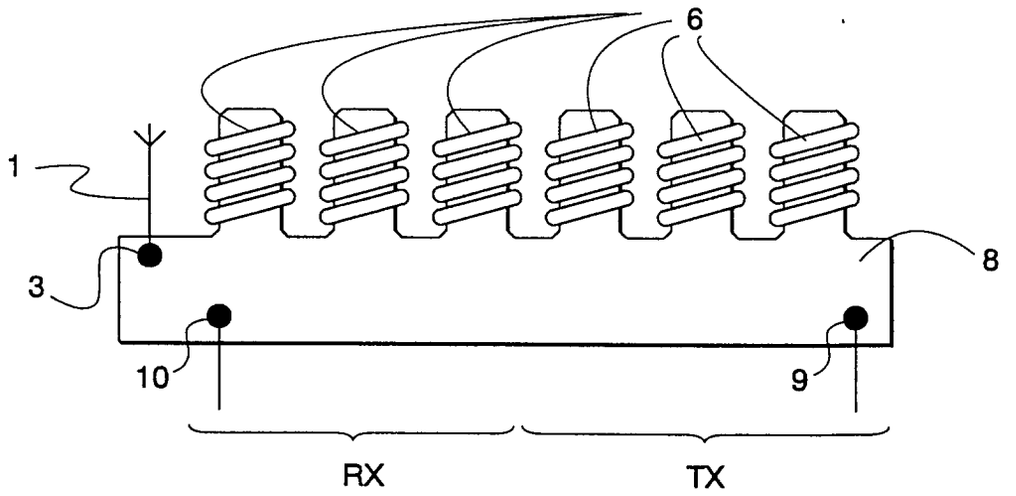

Fig. 3a

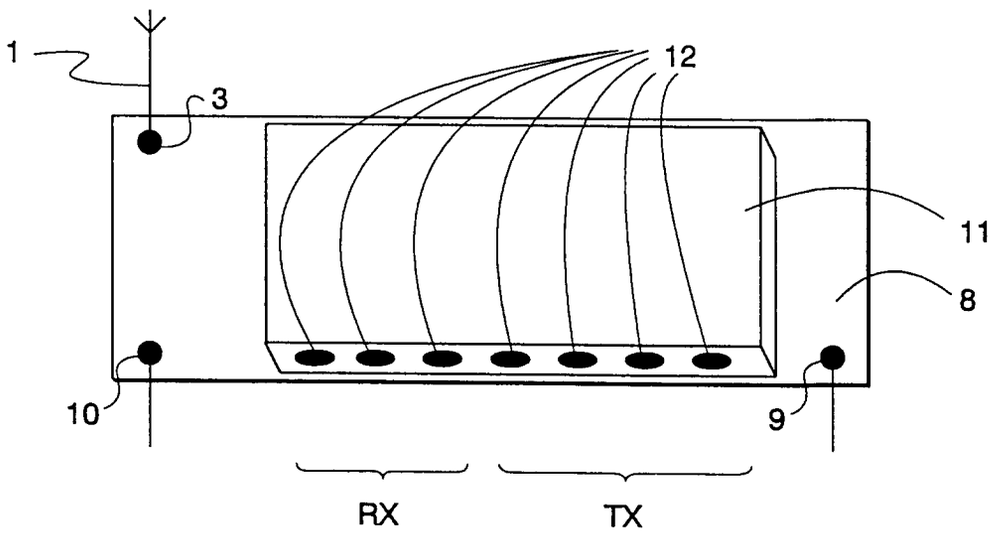

Fig. 3b

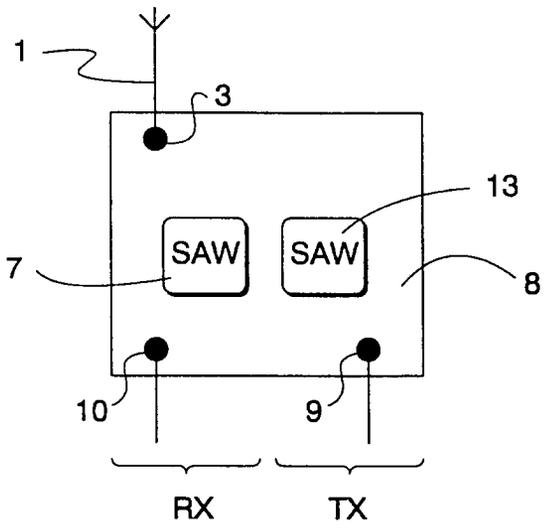

Fig. 4

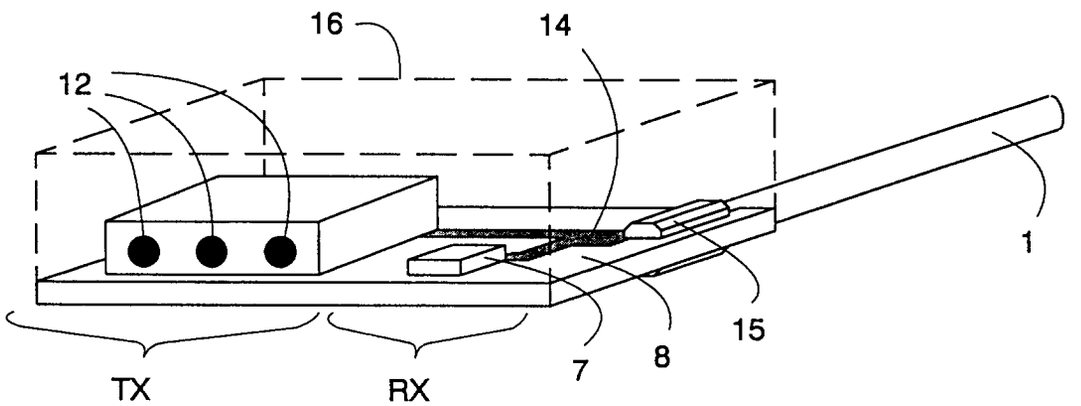

Fig. 5

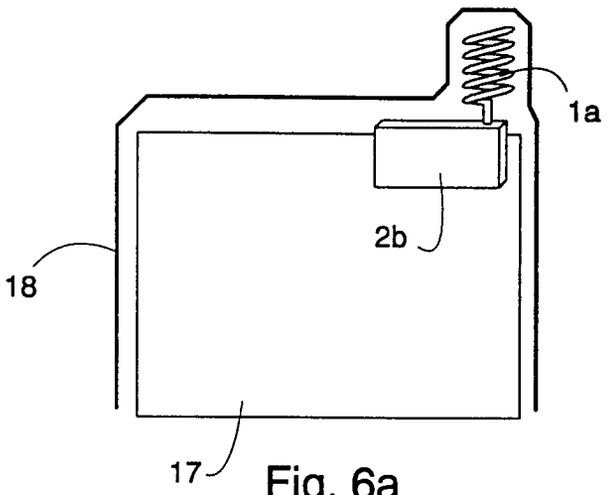

Fig. 6a

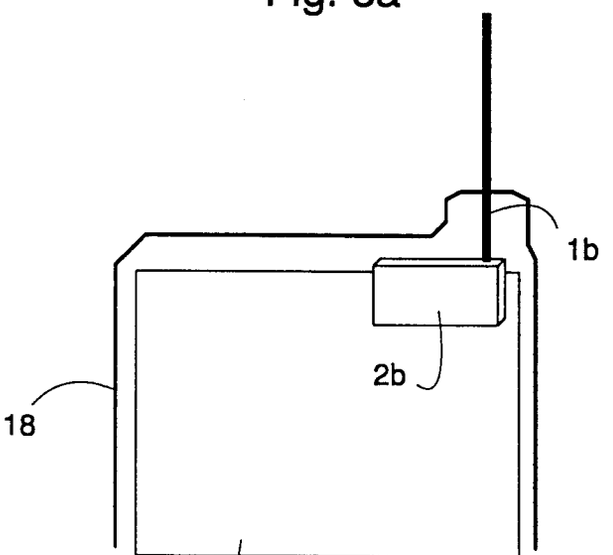

Fig. 6b

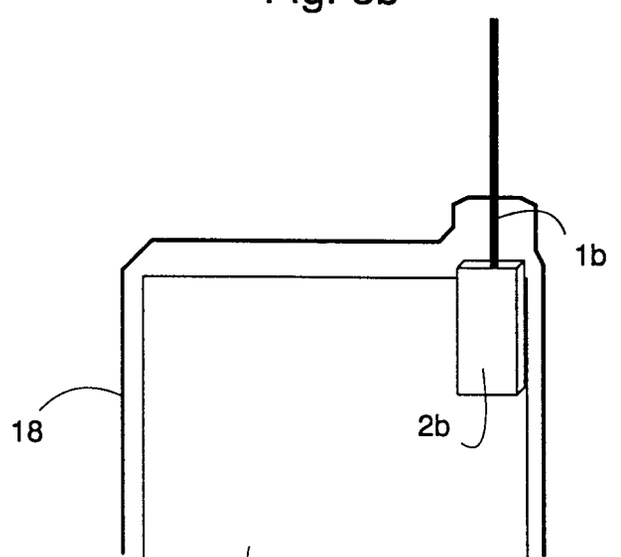

Fig. 6c

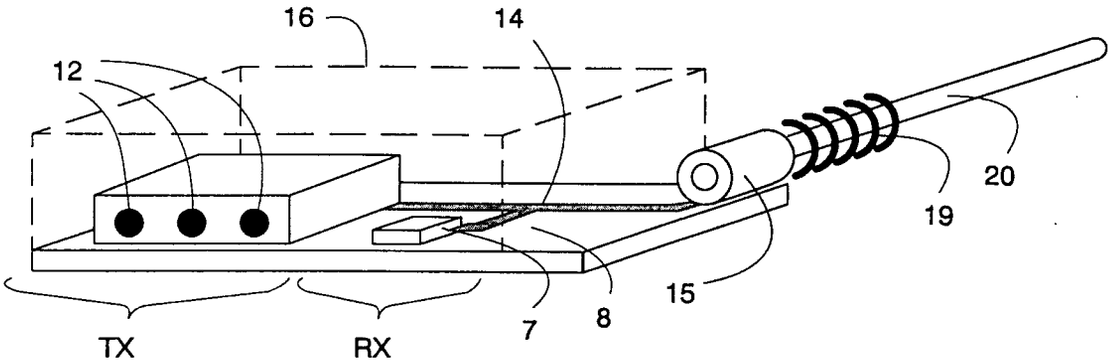

Fig. 7a

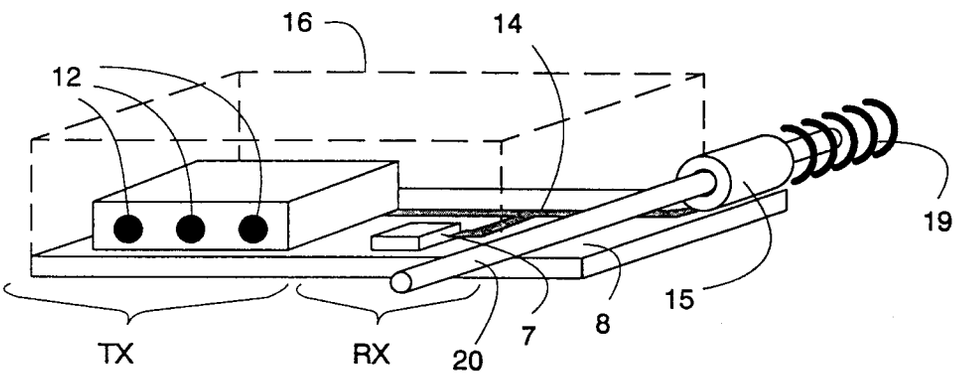

Fig. 7b

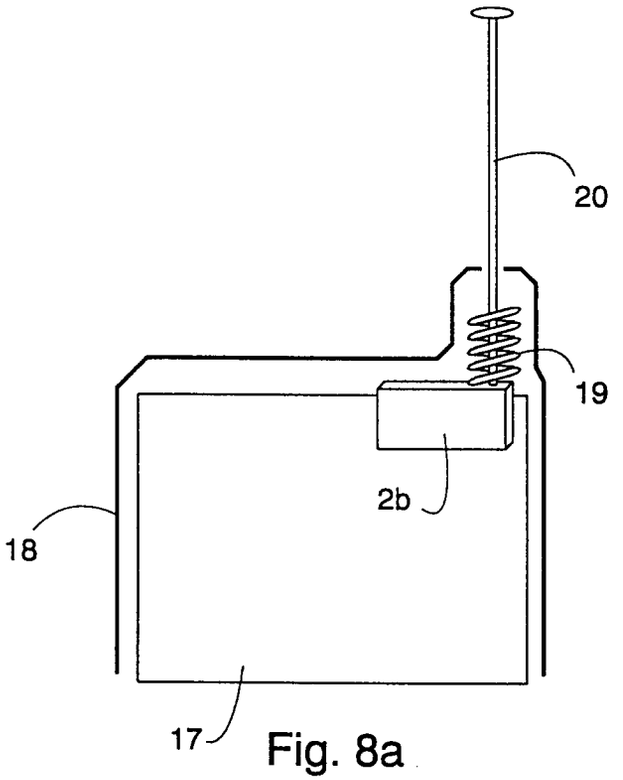

Fig. 8a

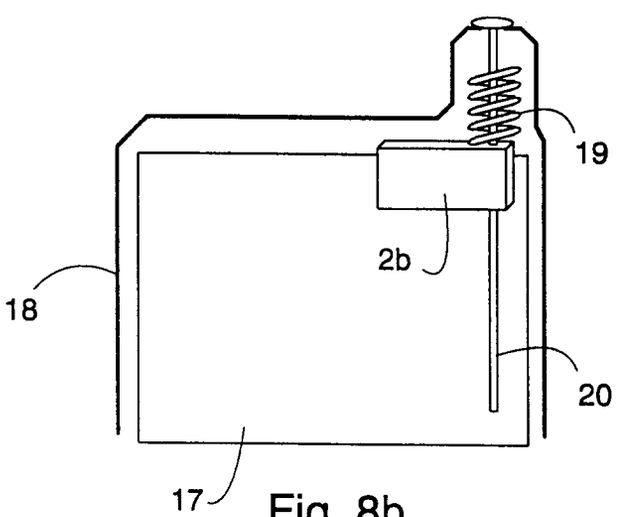

Fig. 8b

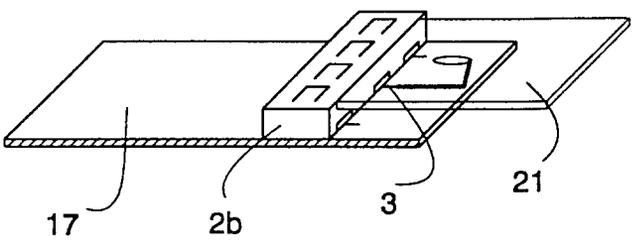

Fig. 9

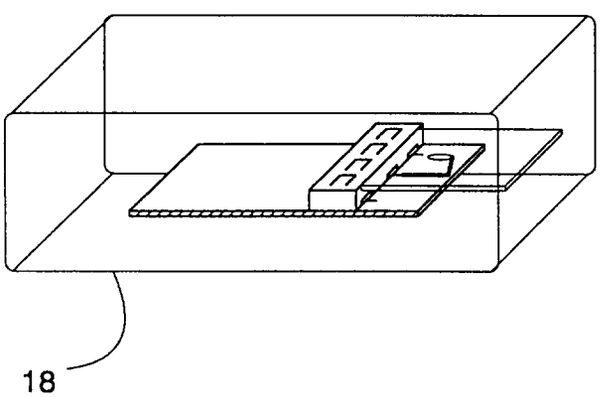

Fig. 10

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 96 30 7644

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X Y	GB-A-2 271 487 (MAXON SYSTEMS) 13 April 1994 * page 4, line 1 - page 6; figures 3,4 *	1 2,9	H01Q1/24 H01Q21/30
X	EP-A-0 259 129 (NEC) 9 March 1988 * abstract; figures 1-2B *	1	
Y A	PROCEEDINGS OF THE ULTRASONICS SYMPOSIUM, BALTIMORE, OCT. 31 - NOV. 3, 1993, vol. 1, 31 October 1993, LEVY M;MCAVOY B R, pages 111-114, XP000473550 IKATA O ET AL: "DEVELOPMENT OF SMALL ANTENNA DUPLEXER USING SAW FILTERS FOR HANDHELD PHONES" * the whole document *	2,9 3-8	
A	US-A-4 792 939 (HIKITA ET AL.) 20 December 1988 * claims 1-12; figures 1-9 *	1-9,11	
A	WO-A-90 05390 (MOTOROLA) 17 May 1990 * page 3, line 15 - page 7, line 9; figure *	1,11,12	TECHNICAL FIELDS SEARCHED (Int.Cl.6) H01Q H03H H04B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	24 January 1997	Angrabeit, F

CATEGORY OF CITED DOCUMENTS

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