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(54) **Antenna arrangement with two operating frequency bands**

(57) An antenna arrangement comprises a radiating antenna element (101), feed point (304, 703, 804) for connecting the radiating antenna element to a radio apparatus, and a ground plane (303, 705, 808). There is between the feed point and ground plane a certain shortest distance which is substantially greater than 1.5 mm. The antenna arrangement has two different operating frequency bands. Preferably the construction comprises an electrically conductive connecting component (105, 603, 801) for connecting the radiating antenna element to the feed point, a functional part (110, 809) in the radio apparatus for transmitting and receiving electromagnetic radiation through an antenna, and a transmission line (306, 604, 605) for providing an electrical connection between the connecting component and the functional part in the radio apparatus. The transmission line comprises in succession a first portion (307, 604) and a second portion (308, 605) such that the longer the distance between a given reference point in the first portion and the interface between the first portion and second portion, the greater the shortest distance between the reference point and the ground plane, and the shortest distance between a given reference point in the second portion and the ground plane is independent of the distance between the reference point and said interface.

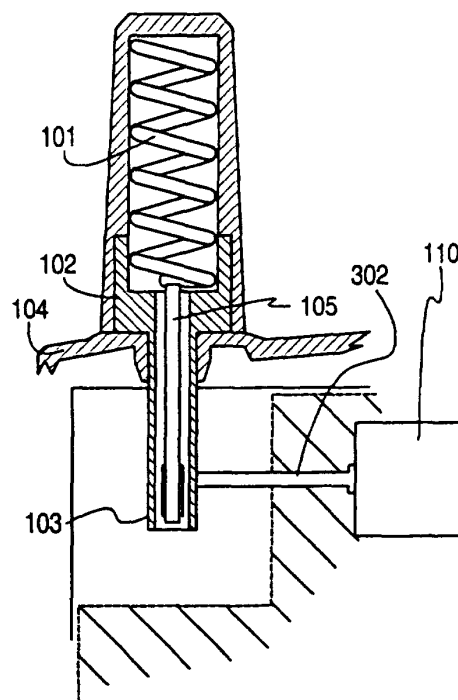


Fig. 4

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Description

[0001] The invention relates in general to antenna arrangements of radio apparatus, comprising a radiating antenna element or elements, their attachment to the radio apparatus, and antenna feed, i.e. electrical connection to the functional parts of the radio apparatus. In particular the invention relates to an antenna arrangement having at least two clearly distinct operating frequency bands.

[0002] Figs. 1a, 1b and 1c show a known antenna arrangement of a radio apparatus with one operating frequency band. The radiating antenna element is a helix 101 which is attached by its lower end to a socket 102 made of plastic of some other insulating material. At the lower end of the socket there is a sleeve 103 by means of which the antenna is mechanically attached to a hole in the housing 104 of the radio apparatus and within which there is a connector spring 105 which is part of the antenna feed. The upper end of the connector spring 105 is galvanically or capacitively coupled to the lower end of the helix 101. The lower end of the connector spring 105 has a bend that sticks out from a hole on the side of the sleeve 103. The radio apparatus includes a printed circuit board 106 which has a feed pad 107 on a first surface and a ground plane 108 on a second surface. A transmission line 109 exists on the first surface of the printed circuit board between the antenna feed pad 107 and a functional component in the radio apparatus, say, a duplex filter 110. "A transmission line" means in this description and patent claims the other conductor of the whole transmission line. Fig. 1c depicts the printed circuit board 106 without the antenna and duplex filter, showing a conductive pattern that comprises the antenna feed pad 107, transmission line 109 and coupling pad 111 to which the antenna port of the duplex filter is connected. In accordance with Figs. 1a and 1b the helix 101 is protected by a dielectric covering 112 which also gives the antenna the desired appearance.

[0003] Fig. 1d is an electrical representation of the antenna arrangement according to Figs. 1a and 1b, comprising an antenna 120, a duplex filter 121 in a radio apparatus, and a connection between them that comprises a first transmission line 122 and a second transmission line 123. The first transmission line 122 corresponds to the connector spring that couples the lower end of the radiating antenna element to the feeding pad on the printed circuit board. It may also be regarded as part of the radiating antenna element, in which case only the second transmission line 123 would exist between the antenna 120 and duplex filter 121. The first transmission line 122 is therefore depicted by a broken line.

[0004] In addition to the feed arrangement based on a connector spring and a coupling pad on the surface of a printed circuit board, antenna arrangements are known in which a flexible and electrically conductive clip is attached to the printed circuit board such that a certain part of the radiating antenna element is pressed against

it as the antenna is attached to the radio apparatus. Moreover, several other radiating antenna elements are known, such as e.g. a straight conductor, or a whip antenna, straight or winding pattern on a surface of a printed circuit board and a thick monopole.

[0005] Figs. 2a and 2b show a known variation of the antenna arrangement described above, having two operating frequency bands. The difference from the antenna arrangement depicted in Figs. 1a, 1b and 1c is that the helix 201 comprises a first portion 202 and second portion 203 such that the pitch, or the distance between the turns of the helix, in the first portion is considerably greater than the pitch in the second portion. Two operating frequency bands are especially required of antenna arrangements of mobile phones intended to operate in at least two different cellular radio systems. The first operating frequency band may be around 900 MHz and the second operating frequency band around 1800 MHz, for example. In each operating frequency band the antenna must have a sufficient impedance bandwidth, i.e. a frequency band in which the matching of the antenna to the antenna port of the radio apparatus is good.

[0006] The structure depicted in Figs. 2a and 2b has some disadvantages. It is technically difficult to manufacture a helix in which the pitch changes at a given location: the proportions of the antenna have to be exactly correct, which reduces the yield in the manufacturing process. In addition, the antenna arrangement according to Figs. 2a and 2b has a relatively small impedance bandwidth, which results losses in radio signal when the radio apparatus is operating at the peripheral areas of its operating frequency band. Fig. 2c depicts a measurement result showing the reflection loss of the antenna arrangement according to Figs. 2a and 2b as a function of frequency. The reflection loss has to be as small as possible within an operating frequency band. Fig. 2c shows that the antenna arrangement has a first operating frequency band A-B around 900 MHz and a second operating frequency band C-D around 1800 MHz.

[0007] An object of the invention is to provide an antenna arrangement for a radio apparatus, having at least two operating frequency bands, being easy to manufacture and having a sufficient impedance bandwidth for each of the operating frequency bands.

[0008] Another object of the invention is that the antenna arrangement according to the invention can be easily adapted to desired operating frequency bands.

[0009] The objects of the invention are achieved by arranging the antenna feed such that the ground plane is located relatively far from the feed point of the antenna.

[0010] The antenna arrangement according to the invention is characterized in that there is a certain shortest distance between the feed point and ground plane, substantially greater than 1.5 mm, whereby the antenna arrangement has two different operating frequency bands.

[0011] The invention is also concerned with a radio apparatus which is characterized in that it comprises a

transmission line in order to provide an electrical connection between the feed point and a functional component in the radio apparatus, which transmission line comprising, in succession, a first portion and second portion such that the longer the distance between a certain reference point located arbitrarily in the first portion and the interface between the first portion and second portion, the greater the shortest distance between the reference point and the ground plane, and that the shortest distance between a reference point located arbitrarily in the second portion and the ground plane is independent of the distance between the reference point and said interface, and that there is a certain shortest distance between the feed point and ground plane, substantially greater than 1.5 mm.

[0012] The present invention is based on the observation that the distance between the ground plane and antenna feed point affects the operating frequency bands and bandwidths of an antenna. "Antenna feed point" in this case refers to the outer end of the transmission line that connects the antenna with the functional components in the radio apparatus. "Ground plane" refers to a relatively large electrically conductive component connected to a fixed potential, having a substantial effect on the electrical operation of the antenna. In practical implementations the feed point and ground plane are usually located on one and the same printed circuit board which also includes most of the functional parts of the radio apparatus.

[0013] In prior-art solutions a typical distance between the feed point and ground plane is 1.5 mm. According to the invention the distance between the ground plane and antenna feed point is set substantially greater than that, whereby the antenna arrangement can have two operating frequency bands even if the radiating antenna element were identical with those used in prior-art antennas with one operating frequency range. The research that led to the invention also showed that a sufficient distance between the antenna feed point and ground plane also produces a relatively great impedance bandwidth for each operating frequency band.

[0014] The invention is below described in more detail referring to the preferred embodiments presented by way of example and to the accompanying drawings in which

Fig. 1a is a side view of a partial longitudinal section of a known antenna arrangement,
 Fig. 1b is a front view of a partial longitudinal section of the antenna arrangement of Fig. 1a,
 Fig. 1c shows a printed circuit board used in an antenna arrangement according to Figs. 1a and 1b,
 Fig. 1d is an electrical representation of the antenna arrangement according to Figs.

Fig. 2a 1a and 1b,
 is a side view of a partial longitudinal section of a second known antenna arrangement,
 Fig. 2b is a front view of a partial longitudinal section of the antenna arrangement of Fig. 2a,
 Fig. 2c shows the operating frequency bands of the antenna arrangement according to Figs. 2a and 2b,
 Fig. 3 shows a printed circuit board that can be used in an antenna arrangement according to the invention,
 Fig. 4 is a front view of a partial longitudinal section of an antenna arrangement according to an embodiment of the invention,
 Fig. 5 shows the operating frequency bands of the antenna arrangement according to Fig. 4,
 Fig. 6 is an electrical representation of an antenna arrangement according to the invention,
 Figs. 7a-7e show alternative printed circuit board patterns,
 Fig. 8 shows an alternative embodiment of the invention, and
 Fig. 9 schematically shows a radio apparatus according to the invention.

[0015] Above in connection with the description of the prior art reference was made to Figs. 1a to 2c, so below in the description of the invention and its preferred embodiments reference will be made mainly to Figs. 3 to 9. Like elements in the drawings are denoted by like reference numerals.

[0016] Fig. 3 shows part of a printed circuit board 301 on the first surface of which there is an electrically conductive pattern 302 for connecting the antenna feed point to a duplex filter in the radio apparatus, and on the second surface (in the position depicted, at the back side of the printed circuit board) of which there is an electrically conductive ground plane 303. The conductive pattern 302 can be produced on the circuit board by means of photolithography or some other known method. It comprises an antenna feed pad 304 for connecting to the antenna, a coupling pad 305 for connecting to the antenna port of the duplex filter and a transmission line 306 between these two. In Fig. 3 the transmission line is shown straight and having a uniform width, but it may comprise bends and portions of varying width. The ground plane 303 may be located at the other side of a two-sided printed circuit board or on any layer of a multilayer board except the layer on which the conductive pattern 302 is located. The ground plane need not be solid but it may be netlike, for example.

[0017] Fig. 3 shows a first portion 307 of the transmission line 306, at the position of which there is no ground

plane on the other side of the printed circuit board, and a second portion 308 of the transmission line 306, at the position of which there is a ground plane on the other side of the circuit board. Fig. 3 shows that the length of the first portion 307 of the transmission line and at the same time the shortest distance between the ground plane 303 and antenna feed pad 304 is 10 mm. Research that led to the invention showed that the distance of 10 mm produces advantageous electrical characteristics for a 900/1800-MHz antenna arrangement, but the invention does not, however, require that the distance be exactly 10 mm. When the operating frequency ranges and bandwidths of the antenna arrangement are known, the best distance between the ground plane and feed pad can be found by experimenting. Fig. 3 also shows part of the housing 104 of the radio apparatus, which is made of an insulating material and may be in accordance with the prior art.

[0018] Fig. 4 shows an antenna arrangement using a printed circuit board according to Fig. 3. The radiating antenna element 101, socket 102 and sleeve 103, the housing 104 of the radio apparatus and the connector spring 105 may be identical with those used in the prior-art single-frequency antenna arrangement depicted in Figs. 1a and 1b. The invention does not limit the positioning of the duplex filter 110 on the printed circuit board 301 as long as it is positioned such that the antenna port (not shown) of the duplex filter can be connected to the coupling pad in the conductive pattern 302. The outer body of the duplex filter is galvanically coupled in a known manner to the ground plane of the radio apparatus using e.g. a via through the printed circuit board. From the manufacturing standpoint it is significant that the radiating antenna element may be a conventional helix which has a uniform pitch along the whole length of the helix. This eliminates the problems typical of the prior art that are caused by a varying pitch in the helix. However, the invention does not require that the radiating antenna element be a conventional helix.

[0019] In the antenna arrangement according to Fig. 4 the length, pitch and diameter of the helix 101 determine the optimal distance between the antenna feed pad and ground plane. Since a helix with a uniform pitch is the most advantageous one from the manufacturing standpoint, one design principle could be to choose the distance between the antenna feed pad and ground plane such that a helix with a uniform pitch functions well as a matched antenna at two (say, 900 and 1800 MHz) frequency bands. When a helix with a uniform pitch is chosen as the radiating antenna element, the optimal distance can be found by experimenting. If some other than a helix with a uniform pitch is selected as the radiating antenna element, the optimal distance for that radiating antenna element can similarly be found by experimenting.

[0020] Fig. 5 shows a measurement result depicting the reflection loss of an antenna arrangement according to Fig. 4 as a function of the frequency. Comparing Fig.

5 to Fig. 2c, one can see that the smallest reflection loss of the antenna arrangement according to the invention is smaller than the smallest reflection loss of the antenna arrangement according to the prior art in both operating frequency ranges. In addition, the impedance bandwidth of the antenna arrangement according to the invention is greater than in the prior art, especially in the lower operating frequency band, which can be seen e.g. from the fact that the frequency band in which the reflection loss is smaller than -10 dB is wider.

[0021] Fig. 6 is an electrical representation of the antenna arrangement according to Fig. 4. Fig. 6 shows an antenna 601 and a duplex filter 602 of a radio apparatus and a circuit between them that comprises three successive transmission lines 603, 604 and 605. Transmission line 603 corresponds to the connector spring that connects the lower end of the radiating antenna element to the feeding pad on the printed circuit board. It can also be regarded as part of the radiating antenna element, in which case only transmission lines 604 and 605 would remain between the antenna 601 and duplex filter 602. Transmission line 603 is therefore depicted in Fig. 6 using a broken line.

[0022] Transmission line 604 corresponds to the first portion 307 of the transmission line 306 in Fig. 3, and transmission line 605 corresponds to the second portion 308 of the transmission line 306 in Fig. 3. These transmission lines have different characteristic impedances since at the location corresponding to the location of the first portion there is no ground plane on the second surface of the printed circuit board (or on an intermediate layer of a multilayer board) and the distance between the whole length of the second portion and the ground plane is no more than the thickness of the circuit board (or if the board has multiple layers and the ground plane is on an intermediate layer, the total thickness of all the layers located between the ground plane and the conductive pattern used for the antenna feed). In the antenna arrangement according to the invention, changing the distance between the ground plane and antenna feed point corresponds to changing the lengths of transmission lines 604 and 605 so as to produce electrical characteristics of the antenna arrangement that are the best possible for the application in question. It should be noted that the optimal lengths of transmission lines 604 and 605 depend on the radiating antenna element used. The research that led to the invention shows that the best electrical characteristics of the antenna arrangement are achieved when the radiating antenna element is a helix with a uniform pitch and the lengths of the transmission lines 604 and 605 (the distance between the antenna feed pad and ground plane) are chosen right.

[0023] Fig. 7a shows an alternative printed circuit board pattern in which a conductive pattern 701 has bends in it and the ground plane edge closest to the antenna feed point is shaped curvilinear. In Fig. 7b the conductive pattern 702 has bends in it such that it alternately

includes portions at the location of which there is a ground plane on the other side of the printed circuit board and portions at the location of which there is no ground plane on the other side of the printed circuit board. In Fig. 7c the antenna feed pad 703 is not located in a corner of the circuit board but close to an edge of the board so that the ground plane edge closest to the antenna feed point may be shaped like a semi-circle or rectangle, for example. In Fig. 7d the conductive pattern 704 and ground plane 705 are located on the same surface of the printed circuit board, whereby that portion of the conductive pattern that is not surrounded by the ground plane corresponds to transmission line 604 in Fig. 6, and that portion of the conductive pattern that is surrounded by the ground plane corresponds to transmission line 605. In Fig. 7e the conductive pattern and ground plane are on the same surface of the circuit board and the conductive pattern 706 comprises three portions of which the one closest to the antenna feed pad is not at all surrounded by the ground plane, the next portion is close to the ground plane by one of its edges, and the last portion is surrounded by the ground plane. In addition, embodiments of the invention can be disclosed in which the transmission line between the antenna feed pad and antenna port coupling pad in the duplex filter travels through a via partly through the printed circuit board at one location or through a plurality of vias through the printed circuit board such that some of the vias may be partial vias between different layers of a multilayer board.

[0024] Fig. 8 shows an embodiment of the invention in which the construction of the antenna is slightly different from the above. The lower end of the radiating antenna element 101 is galvanically or capacitively coupled to an electrically conductive insert 801 which together with an insulating socket 802 constitutes a means for attaching the antenna to the radio apparatus. A printed circuit board 803 in the radio apparatus has a first connecting pad 804 and second connecting pad 805, interconnected by a transmission line 806. Attached to the first connecting pad 804 there is a clip 807 which is pushed against the edge of the insert 801 when the antenna is attached to the radio apparatus. On the other side of the circuit board 803 there is a ground plane 808 which is shaped such that the shortest distance between the first connecting pad 804 and ground plane is chosen such that when the radiating antenna element is a helix with a uniform pitch, the antenna arrangement operates in the desired two operating frequency ranges. In that case the distance may be about 10mm, for example. To the second connecting pad 805 there is connected the antenna port of the duplex filter 809.

[0025] Above it was described an antenna arrangement according to the invention in which the radiating element is connected through a transmission line to a duplex filter. However, depending on the construction and intended usage of the radio apparatus the functional component connected to the antenna may be other than

a duplex filter, say, some other filter or an amplifier. As far as the invention is concerned, it does not matter which functional component of the radio apparatus the antenna is connected to. Neither does it matter, as far as the invention is concerned, what kind of a radiating antenna element is used: instead of or in addition to a helix the radiating antenna element may comprise patterns formed on a printed circuit board or some other mechanically supportive insulating material, whip components made from a conductor so rigid that it stays erect by itself, or other radiating antenna element structures known per se. Moreover, it is insignificant, as far as the invention is concerned, which operating frequency bands are selected for the antenna arrangement; however, the invention is preferably applied to a case in which the operating frequency bands differ by several hundreds megahertz.

[0026] Fig. 9 illustrates a radio apparatus according to the invention. By way of example it can be assumed that the radio apparatus according to Fig. 9 is a mobile terminal of a cellular radio network, applicable in two different frequency bands of one and the same cellular radio system, or as a mobile terminal of two different cellular radio systems when the systems have different operating frequency bands. The mobile terminal may function as a mobile phone, data terminal equipment and as a paging device, for example.

[0027] There is connected to the antenna 901 a filtering block 902 which passes signals of different operating frequencies in such a manner that to a first radio-frequency block 903 the filtering block passes in the downlink direction the receive-frequency signals of a first frequency band and in the uplink direction the transmit-frequency signals of the first frequency band. Conversely, to a second radio-frequency block 904 the filtering block passes in the downlink direction the receive-frequency signals of a second frequency band and in the uplink direction the transmit-frequency signals of the second frequency band. The radio-frequency blocks are connected to a common baseband and control block 905 which is further connected to application blocks 906, 907 and 908 according to the different operating modes. In addition, there are control connections between block 905 and the radio-frequency blocks 903 and 904.

[0028] The connection between the antenna 901 and filtering block 902 is arranged in the above-described manner according to the invention: the distance between the ground plane 910 of the radio apparatus and the feed point is substantially greater than 1.5 mm. This way several advantages are achieved in terms of operation of the radio apparatus. The requirements on the frequency response characteristics of the filtering block 902 need not be as strict as in the solutions according to the prior art because the antenna arrangement for its own part decreases losses especially at the peripheral areas of the operating frequency bands. Furthermore, a disadvantageously high adaptability in regard to gain and linearity is not required of the radio-frequency

blocks 903 and 904, unlike typically in prior-art solutions in which the amount of the losses caused by the antenna arrangement varies to a great extent according to where in the operating frequency band the frequency used is located.

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Claims

1. An antenna arrangement comprising

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- a radiating antenna element (101),
- a feed point (304, 703, 804) for connecting the radiating antenna element to a radio apparatus, and
- a ground plane (303, 705, 808),

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characterized in that there is between the feed point and ground plane a certain shortest distance which is substantially greater than 1.5 mm, whereby the antenna arrangement has two different operating frequency bands.

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2. An antenna arrangement according to claim 1, **characterized** in that the shortest distance between the feed point and ground plane is substantially 10 mm.

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3. An antenna arrangement according to claim 1, **characterized** in that it comprises

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- an electrically conductive connecting component (105, 603, 801) for connecting the radiating antenna element to the feed point,
- a functional component (110, 809) of a radio apparatus for transmitting and receiving electromagnetic radiation through an antenna, and
- a transmission line (306, 604, 605) for providing an electrical connection between the connecting component and the functional component of the radio apparatus, whereby the transmission line comprises in succession a first portion (307, 604) and a second portion (308, 605) such that the longer the distance between a given reference point in the first portion and the interface between the first portion and second portion, the greater the shortest distance between the reference point and the ground plane, and that the shortest distance between a given reference point in the second portion and the ground plane is independent of the distance between the reference point and said interface.

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4. An antenna arrangement according to claim 3, **characterized** in that it comprises a printed circuit board (301, 803) having a first planar surface and a second planar surface such that

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- the ground plane (303, 803) is located on the first planar surface of the printed circuit board,
- the transmission line (306) is located on the second planar surface of the printed circuit board, and
- the second portion of the transmission line is located on the second planar surface in such a manner that the corresponding location on the first planar surface of the printed circuit board is covered by the ground plane.

5. An antenna arrangement according to claim 3, **characterized** in that it comprises a printed circuit board having a first planar surface, whereby the ground plane (705) and transmission line are located on the first planar surface of the printed circuit board and the ground plane surrounds or borders the second portion of the transmission line.

6. An antenna arrangement according to claim 3, **characterized** in that the first portion of the transmission line is located between the connecting component and said interface, and the second portion of the transmission line is located between said interface and the functional component of the radio apparatus.

7. An antenna arrangement according to claim 3, **characterized** in that the transmission line also comprises other portions, whereby the first portion of the transmission line is located between the connecting component and said interface, and the second portion of the transmission line is located between said interface and some other portion of the transmission line.

8. An antenna arrangement according to claim 1, **characterized** in that the radiating antenna element (101) is a helix with a uniform pitch.

9. A radio apparatus having two operating frequency ranges and comprising

- a radiating antenna element (901),
- a feed point (911) for connecting the radiating antenna element to the radio apparatus,
- a ground plane (910), and
- a functional component (902) galvanically coupled to the ground plane for transmitting and receiving electromagnetic radiation through an antenna,

characterized in that it comprises a transmission line for providing an electrical connection between the feed point and the functional component of the radio apparatus, whereby the transmission line comprises in succession a first portion and a second portion such that

the longer the distance between a given reference point in the first portion and the interface between the first portion and second portion, the greater the shortest distance between the reference point and the ground plane, and that the shortest distance between a given reference point in the second portion and the ground plane is independent of the distance between the reference point and said interface, and that there is a certain shortest distance between the feed point and ground plane, substantially greater than 1.5 mm.

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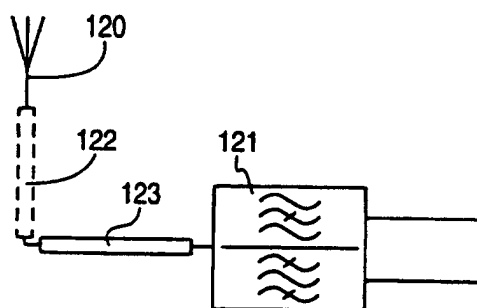
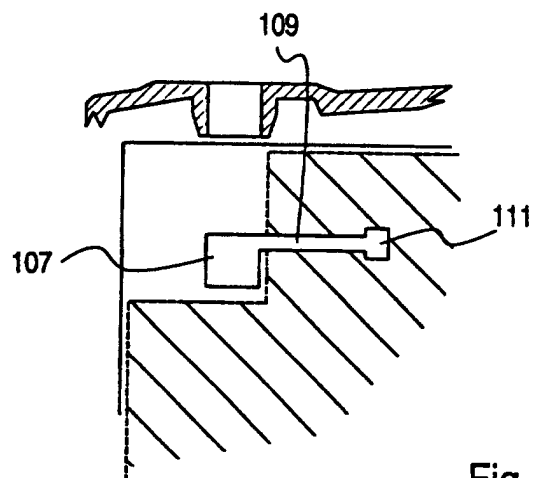
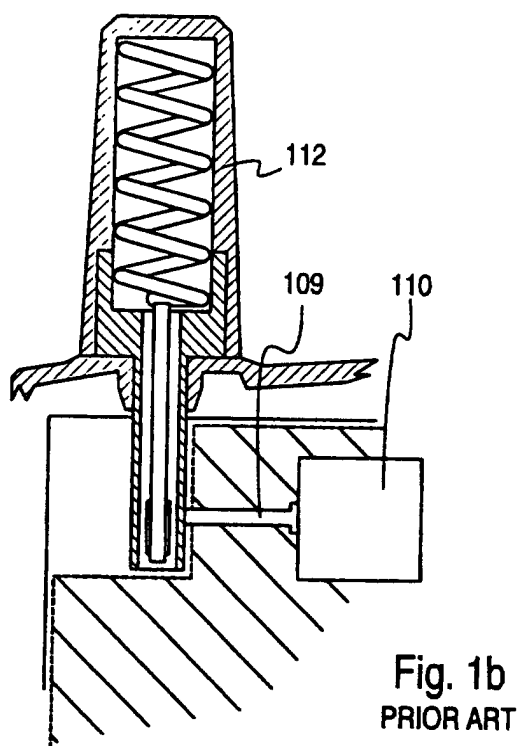
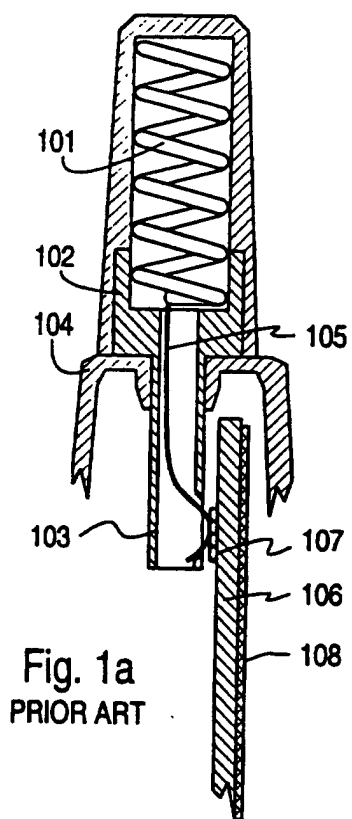
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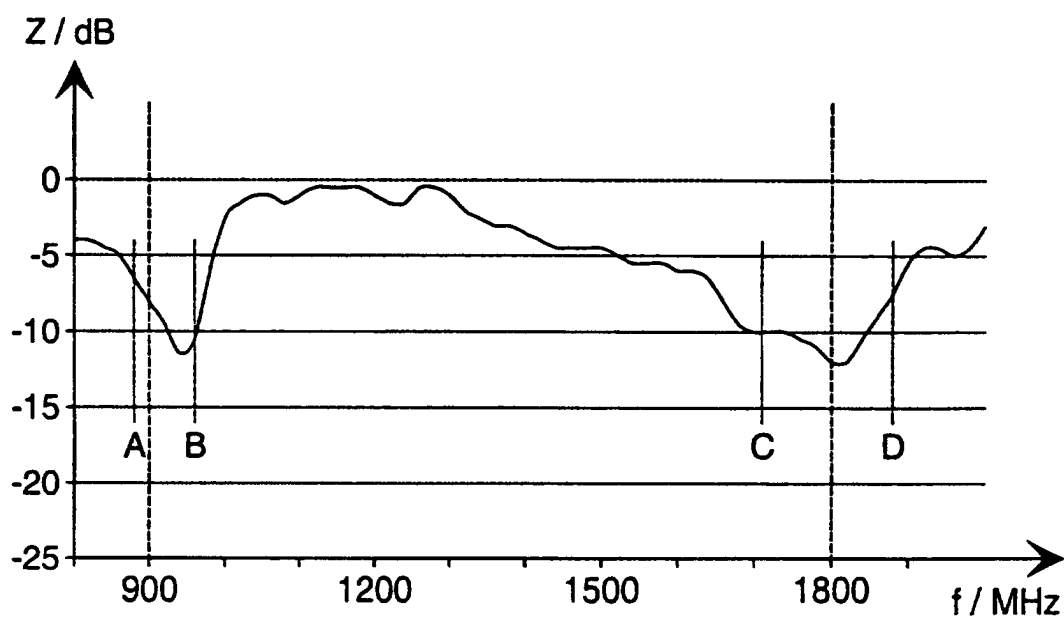
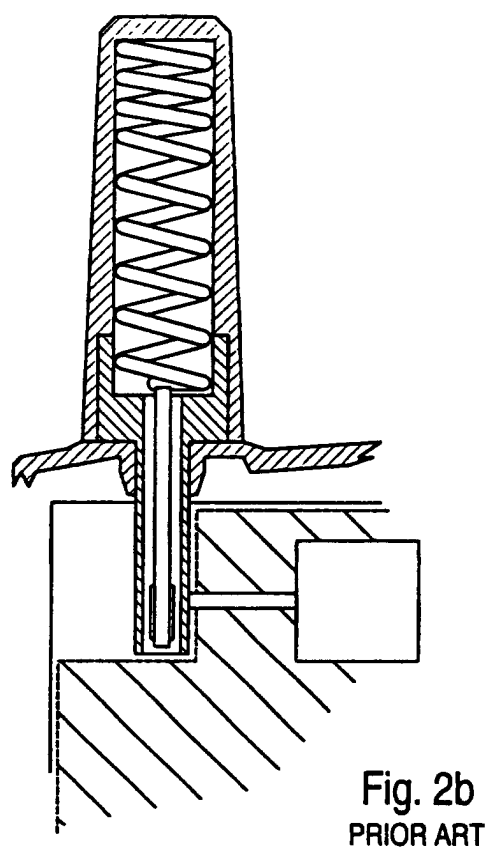
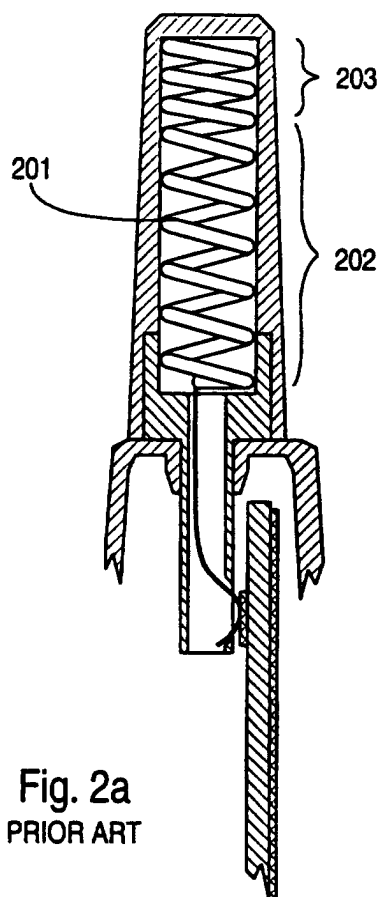
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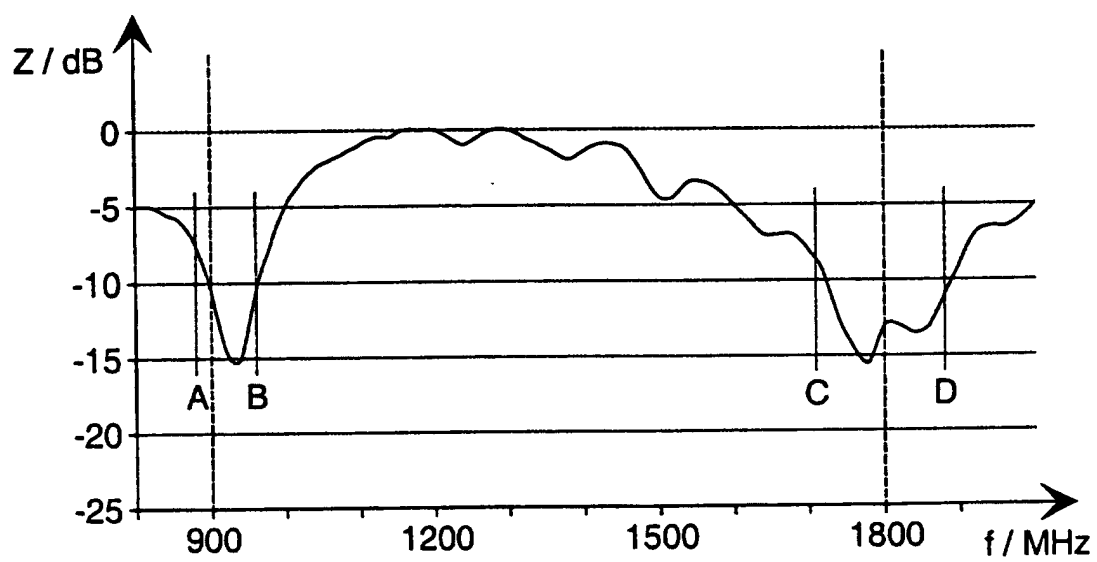
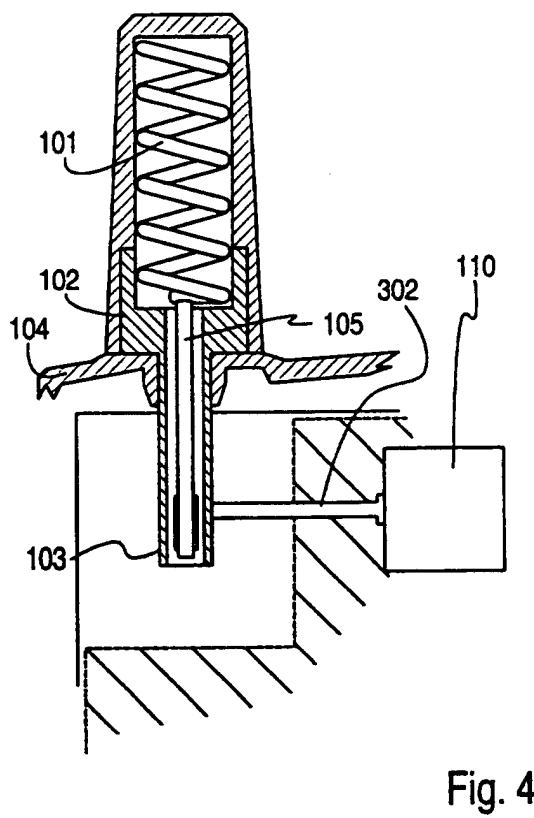
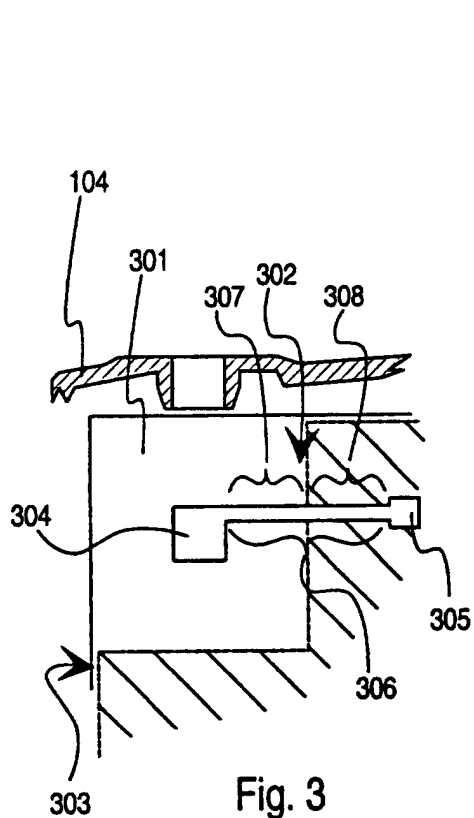
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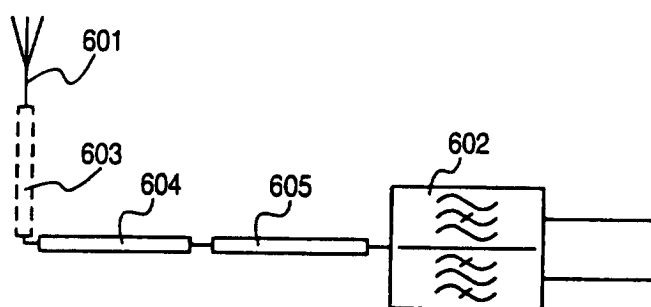


Fig. 6

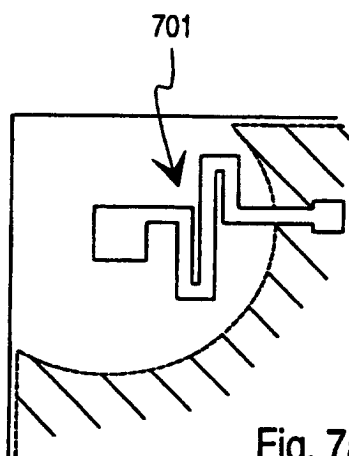


Fig. 7a

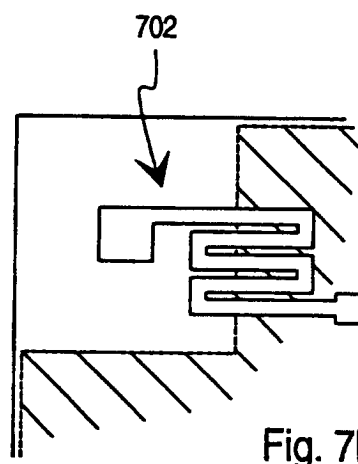


Fig. 7b

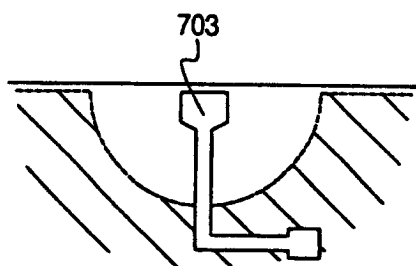


Fig. 7c

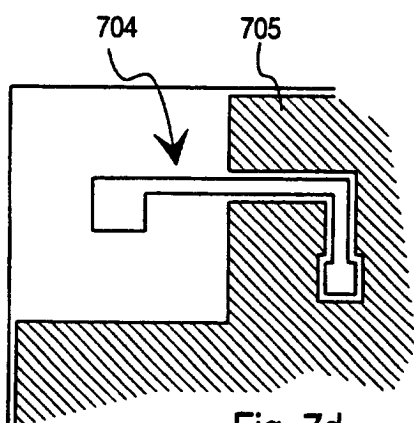


Fig. 7d

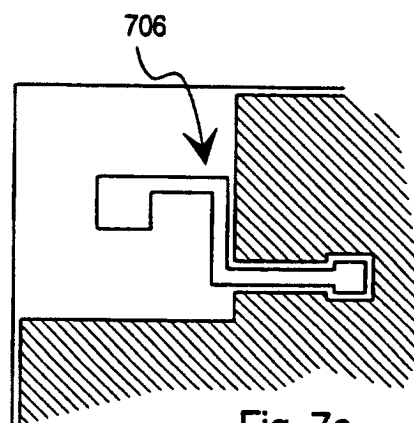


Fig. 7e

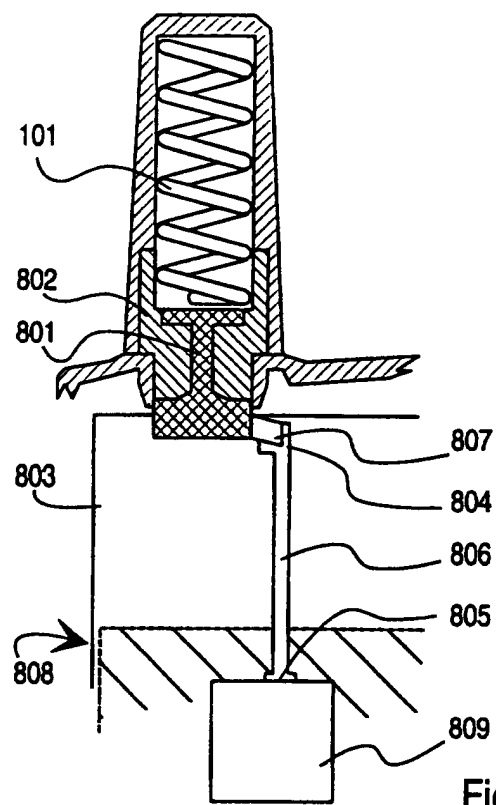


Fig. 8

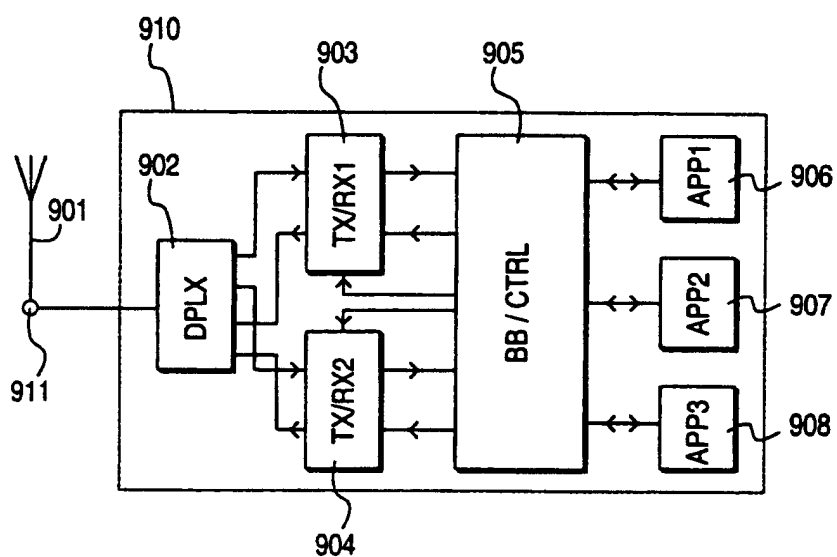


Fig. 9