(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 251 930 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
17.11.2010 Bulletin 2010/46

(21) Application number: **09159923.3**

(22) Date of filing: **11.05.2009**

(51) Int Cl.:
H01Q 9/42 *(2006.01)* ***H01Q 5/00*** *(2006.01)*
H01Q 7/00 *(2006.01)* ***H01Q 9/04*** *(2006.01)*
H01Q 9/44 *(2006.01)* ***H01Q 1/24*** *(2006.01)*

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO SE SI SK TR
Designated Extension States:
AL BA RS

(71) Applicant: **Laird Technologies AB**
164 22 Kista (SE)

(72) Inventors:
- **Kaikkonen, Andrei**
  175 48, JÄRFÄLLA (SE)
- **Zhang,, Anrong**
  100176, BEIJING (CN)
- **Kim, Jae sang**
  INCHEON-SI (KR)
- **Lee, Seung Chul**
  SEOUL (KR)
- **Jansson, Daniel**
  Beijing 100176 (SE)
- **von Arbin, Axel**
  183 63, TÄBY (SE)
- **Lindberg, Peter**
  752 29, UPPSALA (SE)

(74) Representative: **Dahnér, Christer et al**
Kransell & Wennborg AB
P.O. Box 27834
115 93 Stockholm (SE)

(54) Antenna device and portable radio communication device comprising such an antenna device

(57) An antenna device (12) operable in at least a first lower frequency band and a second higher frequency band comprises a first radiating element (16), which operates in the first frequency band and has a first and a second (20) opposite end and a second radiating element (21) joined to the first end. Thereby the first end defines a first junction (18). The second element stretches away from the first element. The device also comprises a first feeding connection (FC1) leading to the first junction, a first connection path (P1) between the first feeding connection and a first frequency band signal handling unit, a first tuning element (T1) connected to the first connection path, a first signal passing and blocking arrangement (22), a second connection path (P2) between the first junction and a second frequency band signal handling unit and a second signal passing and blocking arrangement (26).

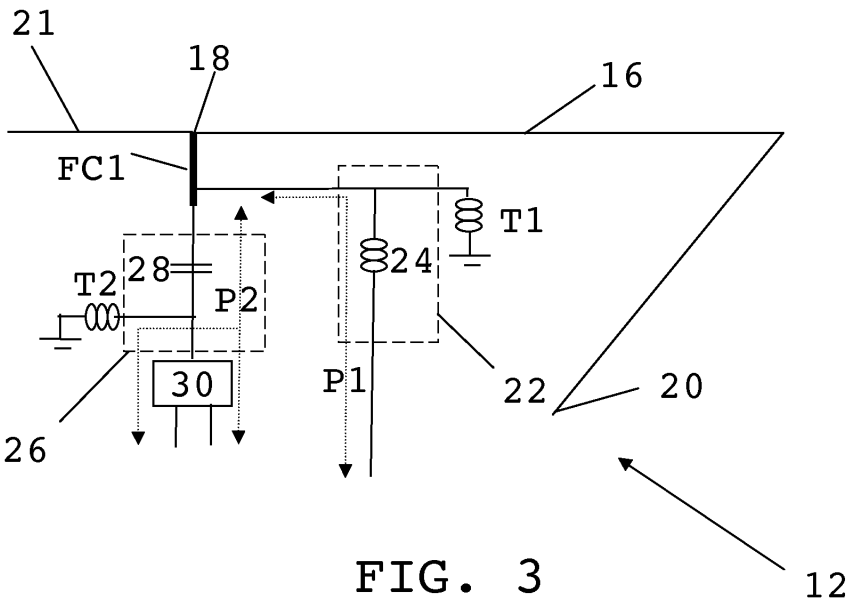

FIG. 3

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Description

FIELD OF INVENTION

[0001] The present invention relates generally to antenna devices and more particularly to an antenna device for a portable radio communication device operable in at least a first lower and a second higher frequency band. The invention also relates to a portable radio communication device comprising such an antenna device.

BACKGROUND

[0002] Internal antennas have been used for some time in portable radio communication devices. There are a number of advantages connected with using internal antennas, of which can be mentioned that they are small and light, making them suitable for applications wherein size and weight are of importance, such as in mobile phones.

[0003] However, the use of internal antennas in a mobile phone puts some constraints on the configuration of the radiating elements of the antenna. In particular, in a portable radio communication device the space for an internal antenna is limited. These constraints may make it difficult to find a configuration of the antenna that enables the desired use. This is especially true for antennas intended for use with radio signals of relatively low frequencies as the desired physical length of such antennas are large compared to antennas operating with relatively high frequencies.

[0004] One specific application operating in a relatively low frequency band is the FM radio application. The FM operating band is defined as frequencies between 88-108 MHz in most of the world and frequencies between 76-90 MHz in Japan. Prior art conventional antenna configurations, such as loop antennas or monopole antennas, fitted within the casing of a portable radio communication device will result in unsatisfactory operation in that the antenna either has too bad performance over a sufficiently wide frequency band or sufficient performance over a too narrow frequency band.

[0005] Instead, a conventional FM antenna for portable radio communication devices is usually provided in the headset wire connected to the communication device. This configuration with a relatively long wire permits an antenna length that is sufficient also for low frequency applications. However, if no external antenna is permitted this solution is obviously not feasible.

[0006] Further, a portable radio communication device is today many times provided with frequency operational coverage for other frequency bands than FM, such as GSM900, GSM1800, Bluetooth, WLAN, WCDMA and GPS. A portable radio communication device has limited space and it is thus desirable to, if possible, add multiple functionality to an antenna.

[0007] The antenna is then to resonate in more than one frequency band. This is hard to accomplish in a small portable radio communication device.

[0008] This is made even more difficult since many portable radio communication devices show varying losses for different frequency bands in various areas of the portable radio communication device. A mobile phone may for instance be provided with a component area including a circuit board with components, a battery area, with a battery and with a basic communication antenna section, which includes antennas for basic communication for instance for GSM antennas.

[0009] These various sections all influence any further antennas in different ways, which makes it hard to provide an antenna device that operates well for such further antennas in a portable radio communication device of the above described type.

[0010] US 6204819, US 2006/097918 and US 2004/041734 all disclose antennas being operable in different bands.

[0011] However these use switching arrangements for obtaining multiband operation. It would in view of this be of interest to provide an antenna device providing multiband functionality which does not require switches.

SUMMARY OF THE INVENTION

[0012] An object of the present invention is to provide a small-sized antenna device that provides improved multiband functionality.

[0013] Another object is to provide an antenna device that can provide simultaneous multiband functionality.

[0014] The invention is based on the realization that improved multiband functionality can be obtained in an antenna device by providing a first elongated radiating element for operation in a first lower frequency band and having a first and a second opposite end and a second elongated radiating element joined to the first end of the first radiating element. The second element stretches away from the first radiating element and is dimensioned for resonating in the second frequency band. In this way the first end of the first radiating element defines a first junction. The antenna device further includes a first feeding connection leading to the first junction, a first connection path between the first feeding connection and a first frequency band signal handling unit, a first tuning element connected to the first connection path and being arranged to tune the first radiating element for resonance in the first frequency band, a first signal passing and blocking arrangement arranged to allow signals in the first frequency band to pass through the first connection path and to block signals in the second frequency band from passing through the first connection path, a second connection path provided between the first junction and a second frequency band signal handling unit and a second signal passing and blocking arrangement arranged to allow signals in the second frequency band to pass through the second connection path and to block signals in the first frequency band from passing through the second connection path. According to a first aspect of the present invention there is provided an antenna device as defined in claim 1.

[0015] According to a second aspect of the present invention there is provided portable radio communication device as defined in claim 20.

[0016] Further preferred embodiments are defined in the dependent claims.

[0017] The invention has a number of advantages. The radiating elements of the antenna device that provides multiband operation are very small. Multiband operation is furthermore obtained simultaneously. There is no switching between operations in different bands. This has the advantage of providing a more rapid signal processing as well as energy savings. The radiating elements of the antenna device are also simple to produce. These advantages are obtained while considering environmental limitations imposed by the portable radio communication device in which the antenna device is to be placed.

BRIEF DESCRIPTION OF DRAWINGS

[0018] The invention is now described, by way of example, with reference to the accompanying drawings, in which:

Fig. 1 is a front view of a portable radio communication device comprising an antenna device according to the invention;

Fig. 2 schematically shows a view from above of the interior of the portable radio communication device;

Fig. 3 schematically shows a perspective view of an antenna device according to a first embodiment of the present invention;

Fig. 4 schematically shows perspective view of the antenna device in the first embodiment being provided above a circuit board with frequency band signal handling units;

Fig. 5 schematically shows a perspective view of an antenna device according to a second embodiment of the present invention connected to frequency band signal handling units and being provided above a reference plane;

Fig. 6 schematically shows a perspective view of an antenna device according to a third embodiment of the present invention connected to frequency band signal handling units and being provided above a reference plane; and

Fig. 7 schematically shows a perspective view of an antenna device according to a fourth embodiment of the present invention connected to frequency band signal handling units and being provided above a reference plane.

DETAILED DESCRIPTION OF THE INVENTION

[0019] In the following, a detailed description of preferred embodiments of an antenna device according to the invention will be given. In the description, for purposes of explanation and not limitation, specific details are set forth, such as particular hardware, applications, techniques etc. in order to provide a thorough understanding of the present invention. However, it will be apparent to one skilled in the art that the present invention may be utilized in other embodiments that depart from these specific details. In other instances, detailed descriptions of well-known methods, apparatuses, and circuits are omitted so as not to obscure the description of the present invention with unnecessary details.

[0020] Fig. 1 shows a front view of the exterior or casing of a portable radio communication device 2, in the form of a mobile phone. A mobile phone is just an example of one type of portable radio communication device. Other examples are lap top computers, palm top computers, electronic organizers and electronic gaming machines.

[0021] These types of portable radio communication devices are often small in size. It is furthermore often desirable that the antenna device is completely provided in the interior of the portable radio communication device, i.e. inside the casing of it. Consequently the space provided for radiating elements in antenna devices is limited. This means that in order to use the allocated space as efficiently as possible it may be necessary to use the same antenna for handling signals of different types, i.e. signals that are modulated differently from each other and also occupy significantly different frequency bands. This is hard to do, especially when considering the normal layout of the interior of a portable radio communication device.

[0022] Fig. 2 schematically shows a view from above of the interior of the portable radio communication device 2 from fig. 1. There is here a circuit board section 4, a battery section 6 and a basic communication antenna section. These sections are provided side by side laterally in relation to each other. The circuit board section 4 provides a component area, where components such as radio circuits or frequency band signal handling units, i.e. units arranged to modulate and demodulate signals on radio waves can be placed. These may be arranged to only transmit, only receive or to both transmit and receive radio signals. These may be FM signal handling units, Bluetooth signal handling units, GPS signal handling units as well as cellular radio signal handling units such as WCDMA RX (diversity) signal handling units. The basic communication antenna section includes antennas for basic communication like various types of cellular communication and may thus for instance be GSM antennas. Here the basic communication antenna section 8 is connected with the circuit board 4 via a flex film 10 holding conductors being placed over the battery 6. There are here also the radiating elements of an antenna device of the invention. These radiating elements are then connected to such frequency band signal handling units as well as to a ground plane. This ground plane is normally provided as a part of the circuit board. The radiating elements can be seen as forming an antenna 11. The radiating elements of the antenna 11 shown in fig. 2 are here the radiating elements provided according to a first embodiment of the invention. As can be seen part of the antenna 11 stretches over the battery section 6 and part over the circuit board section 4.

[0023] The problem with the various sections mentioned above is that for antennas operating at high frequencies, such as Bluetooth, WCDMA_Rx, and GPS, the battery section 6 provides high losses, while the circuit board section 4 provides low losses. However for antennas operating at low frequencies the battery section has a limited influence on the performance. In addition the circuit board section 4 may have a high level of electromagnetic interference at low frequencies but not at high frequencies.

[0024] The present invention is directed towards providing a multiband antenna device operating in at least a first lower and a second higher frequency band that considers such limitations imposed by an environment, such as the environment in a portable radio communication device with various sections. These bands may with advantage be separated from each other by more than 1 GHz.

[0025] This is furthermore done using a small sized antenna device and therefore the space it occupies is limited.

[0026] The first lower frequency band may with advantage be an FM frequency band (76 - 108 MHz) and the second a Bluetooth frequency band (2400 - 2482 MHz). However, the second frequency band may also be a GPS band (1575 MHz) or a WCDM RX (diversity) band (2110 - 2170 MHz).

[0027] An antenna device according to a first embodiment of the present invention will now be described with reference being made to fig. 3 which schematically shows a perspective view of the antenna device on its own and to fig. 4, which schematically shows the antenna device above the circuit board 4 and on which frequency band signal handling units are provided. The circuit board also includes a ground plane (not shown). From the drawings it is evident that the antenna device 12 according to the present invention is provided in the interior of the portable radio communication device. It is also clear that some of it is provided adjacent the circuit board and thus adjacent also the ground plane. However a major part of it is not placed above the circuit board, but instead stretches laterally away from the circuit board. This major part is furthermore placed adjacent the battery section, as can also be gathered from fig. 2.

[0028] The antenna device 12 includes a first elongated radiating antenna element 16 provided in a plane parallel with and distanced from or spaced above a circuit board 4 provided with a ground plane (not shown). The ground plane here typically is provided as one layer in the circuit board and occupies as much as possible of the area of the circuit board 4. The circuit board may here have four orthogonal sides. There is here also a battery 6 adjacent the circuit board 4.

[0029] The first radiating element has a first end 18 as well as a second opposite end 20. The first radiating element 16 may typically have the first end 18 provided at or close to a first corner of the circuit board where a first and a second circuit board side meet. The first radiating element then stretches along the first side of the board 4 in the direction towards this first corner and then continues past this first corner in the same direction away from the circuit board and thus continues along a first side of the battery 6, which first side of the battery has the same orientation as the first side of the circuit board 4. This part of the first radiating element is here straight. At a first corner of the battery 6, where the first battery side meets a second battery side at ninety degrees, the first radiating element 16 makes a ninety degree turn and runs to the second end 20. This part of the first radiating element is thus straight and follows the second battery side. The first radiating element 16 thus also runs in parallel with the second circuit board side, however at a distance from it. Thereafter the second end 20 of the first element is provided at a second battery corner where the second battery side joins a third battery side at ninety degrees. The first radiating element thus extends away from the ground plane. The circuit board 4 has a corresponding second corner where the second circuit board side meets a third circuit board side at ninety degrees.

[0030] The second end 20 of the first radiating element 20 is in this embodiment electrically floating, i.e. it does not have a direct electrical connection to any other elements. On the other hand, the first end 18 of the first radiating element 16 is joined to a second elongated radiating element 21, which second radiating element 21 is stretching away from the first radiating element. Here it stretches along the first side of the circuit board 4 in the opposite direction of the first radiating element 16. The second radiating element is thus wholly aligned with the circuit board 4. The second radiating element is furthermore also provided in a plane parallel with and distanced from or spaced above the ground plane.

[0031] All radiating elements that have appeared and will appear in this description, including the first and the second radiating elements 16 and 21, may be provided as wires or conductors and can also be provided on a carrier such as a flex film.

[0032] The first end 18 of the first radiating element 16 is here also denoted a first junction because it forms a junction between the first and the second radiating elements 16 and 21. The first junction here has a first feeding connection FC1 leading to other elements of the antenna device. This feeding connection is typically provided as a conductor which can lead from the plane of the circuit board 4 to the plane in which the two radiating elements are provided.

[0033] The antenna device 12 according to the present invention is provided with a first connection path P1 (shown as a dotted bidirectional arrow) that stretches between the first radiating element 16 and a first frequency band signal handling unit 34. In the figures this path P1 is shown as stretching from the first feeding connection FC1 to the first frequency band signal handling unit 34. In this first path P1 there is here provided a first signal passing and blocking arrangement 22 (indicated with a dashed box).

[0034] The antenna device 12 according to the present invention is also provided with a second connection path P2 (shown as a dotted branched bidirectional arrow) that stretches between the first junction 18 and a second frequency band signal handling unit 32. In this first embodiment the second path P2 also stretches between the second radiating element 21 and a further frequency band signal handling unit 36. In order to enable simultaneous connection of these frequency band signal handling units 32 and 36, the second connection path P2 includes a first branch connecting the first junction 18 with the second frequency band signal handling unit 32 and a second branch connecting the first junction 18 with the further frequency band signal handling unit 36. In order to provide the two branches of the second path P2, this second path includes a signal combining unit 30, here in the form of a diplexer, that allows the antenna device to simultaneously handle signals in the second and the further frequency bands via the first feeding connection FC1. In this second path P2 there is provided a second signal passing and blocking arrangement 26 (also indicated with a dashed box). This is at one end connected to the first feeding connector FC1 and at another end to the diplexer 30, which diplexer 30 is then connected to the second and the further frequency band signal handling units 32 and 36.

[0035] The further frequency band is in this embodiment a GPS frequency band and therefore the further frequency band signal handling unit 36 is a GPS signal handling unit. The second frequency band is as mentioned above the Bluetooth frequency band in this embodiment, why the second frequency band signal handling unit 32 is a Bluetooth signal handling unit. The first frequency band signal handling unit 34 is an FM signal handling unit.

[0036] The first signal passing and blocking arrangement 22 is here arranged to allow signals in the first frequency band to always pass through the first connection path P1 and to always block signals in the second frequency band and in this embodiment also in the further frequency band from passing through the first connection path, while the second signal passing and blocking arrangement 26 is arranged to always allow signals in the second frequency band and in this embodiment also in the further frequency band to pass through the second connection path P2 and to always block signals in the first frequency band from passing through the second connection path.

[0037] In this and the other embodiments described later the first signal passing and blocking arrangement 22 includes a first filter 24 connected between the first radiating element 16 and the first frequency band signal handling unit 34 and set to let signals in the first frequency band to pass and to stop signals in the second frequency band from passing. As the first frequency band is lower than the second frequency band and here also lower than the further frequency band this first filter may be a low pass filter. In the embodiments described here this first filter 24 is provided in the form of an inductor connected between the first radiating element 16 and the first frequency band signal handling unit 34, which inductor in these embodiments has, only as an example, a value of 56 nH. It should be realized that a low pass filter may be realized in other ways.

[0038] It should also be realized that the first filter is not limited to a low pass filter but may also be a band pass filter with the pass band set to cover the first frequency band.

[0039] In a similar manner the second signal passing and blocking arrangement 26 includes a second filter 28 connected between the first junction 18 and the diplexer 30 and set to let signals in the second frequency band to pass and to stop signals in the first frequency band from passing. As the second frequency band and here also the further frequency band is higher than the first frequency band this second filter may be a high pass filter. In the embodiments described here this second filter is provided in the form of a capacitor 28 connected between the first junction 18 and the second frequency band signal handling unit 32, which capacitor in these embodiments has, only as an example, a value of 1 pF. It should be realized that a high pass filter may be realized in other ways. It should also be realized that the second filter is not limited to a high pass filter but may also be a band pass filter with the pass band set to cover the second frequency band and any other frequency bands of signals that are to pass the second connection path.

[0040] The length of the first radiating element 16 is according to the invention smaller than the quarter of a wavelength at which fundamental resonance occurs in the first frequency band. Therefore a first tuning element T1 is connected to the first radiating element 16 and in this embodiment also to the first connection path. This first tuning element T1 is arranged to tune the first radiating element 16 for resonance and then with advantage fundamental resonance in the first frequency band.

[0041] The length of the second radiating element 21 may here be a quarter of a wavelength at which fundamental resonance occurs in the second or the further frequency band, while the other frequency band can be covered through matching of the second radiating element to a harmonics or fundamental frequency resonance in that band.

[0042] Because the second end 20 of the radiating element is electrically floating, the first radiating element is a monopole element and more particularly acting as an ILA (Inverted L Antenna) antenna. This means that this first radiating element 16 is capacitive in nature in the first frequency band. This also means that the first tuning element T1 can be provided as an inductive element connected between the radiating element 16 and ground. In the present example it has a value of 470 nH. The first tuning element T1 is here furthermore also connected to the first connection path P1 and then to the connection point between the first filter 24 and the first radiating element 16. This also means that in this embodiment the first tuning element T1 assists in blocking signals in the second frequency band from reaching ground.

[0043] As was mentioned earlier, the second filter 28 in the second signal passing and blocking arrangement 26 blocks signals in the first frequency band and allows signals in the second and the further frequency band to pass.

[0044] In relation to this filter it is possible to provide a second tuning element T2, connected between the second connection path P2 and ground, where the connection to the second path P2 may be made between the second filter 28 and the diplexer 30. This second tuning element T2 may be used to tune the second radiating element to the second and/or the further frequency band. As an example it may have a value of 5 nH.

[0045] Also the second radiating element here functions as an ILA antenna.

[0046] In this first embodiment of the present invention both the first and the second paths P1 and P2 are connected to the first feeding connection FC1 and thus both are connected to the first junction 18. This means that the first tuning element T1 tunes the first radiating element for resonance in the first frequency band, preferably fundamental resonance which in this example is the FM band. For the second frequency band, the second filter 28 together with the second tuning element T2 tunes the second radiating element 21 to the second and the further frequency bands. This tuning may, as was mentioned earlier be to fundamental for one and harmonic for the other. In this way simultaneous operation of all the bands is enabled with an antenna device having a small sized group of radiating elements.

[0047] Fig. 5 shows a perspective view of an antenna device according to a second embodiment of the present invention being provided above a reference plane. This reference plane represents a combination of the circuit board and battery shown in fig. 4.

[0048] In this second embodiment many of the elements are the same as in the first embodiment, and therefore only the differences will be described in detail. The first radiating element 16 here starts out from the first end 18 in the same way as in the first embodiment through a straight section stretching past a first corner of the circuit board (not shown) and then making a ninety degree turn in order to run in parallel with a side of the circuit board as in the first embodiment. However in this second embodiment it then makes another ninety degree turn and stretches straight back towards the second corner of the circuit board, passes by the second corner and then ends at a second feeding connection FC2. The second feeding connection FC2 is with advantage aligned with the first feeding connection FC1 in that it is provided opposite of the first feeding connection FC1 in relation to the first and third circuit board sides. The second end 20 of the first radiating element 16 is here connected to this second feeding connection FC2. At the first junction 18 the only thing that differs is the second connection path. In the second connection path there is no diplexer, instead the second filter 28 is directly connected to the second frequency band signal handling unit 32. There is no further frequency band signal handling unit and no second tuning element.

[0049] To the second end 20 of the first antenna element there is joined a third elongated radiating element 38. This stretches away from the first radiating element and here inwards towards the circuit board. To the second end 20 there is furthermore joined an additional radiating element 40 that also stretches away from the first radiating element. This element may stretch in parallel with the third element. Because of this the second end of the first radiating element defines a second junction. The third radiating element is here provided in a plane parallel with and distanced from or spaced above the ground plane as is the further radiating element. They may furthermore be provided in the same plane as may the first and the second radiating elements.

[0050] The third radiating element is dimensioned for radiating in a third frequency band that is higher than the first frequency band and the additional radiating element is dimensioned to be radiating in an additional frequency band, which is also higher than the first frequency band. In this embodiment the third frequency band is a GPS frequency band, while the additional frequency band is a WCDMA_Rx frequency band.

[0051] A third connection path P3 (shown as a dotted branched bidirectional arrow) is provided in relation to the second feeding connection FC2. This third path P3 is provided in the same way as the second connection path in the first embodiment.

[0052] This means that the third connection path P3 stretches between the third radiating element 38 and a third frequency band signal handling unit 48 as well as between the additional radiating element 40 and an additional frequency band signal handling unit 48. In order to enable simultaneous connection of these frequency band signal handling units 46 and 48, the third connection path includes a first branch connecting the second junction 20 with the third frequency band signal handling unit 46 and a second branch connecting the second junction 20 with the additional frequency band signal handling unit 48. In order to provide the two branches, also the third path P3 includes a signal combining unit 44, here in the form of a diplexer that allows the antenna device to simultaneously handle signals in the third and the additional frequency bands via the second feeding connection FC2. In this third path P3 there is provided a third signal passing and blocking arrangement. This is at one end connected to the second feeding connector FC2 and at another end to the diplexer 40.

[0053] The third signal passing and blocking arrangement is configured to always allow signals in the third frequency band and in this embodiment also in the additional frequency band to pass through the third connection path and to always block signals in the first frequency band from passing through the third connection path P3.

[0054] The third signal passing and blocking arrangement includes a third filter 42 connected between the second junction 20 and the diplexer 44. As the third and additional frequency bands are higher than the first frequency band this third filter may be a high pass filter. In the embodiments described here this third filter is provided in the form of a capacitor 42 connected between the radiating elements 38 and 40 and the diplexer 44, which capacitor in these embodiments has, only as an example, a value of 1 pF. It should be realized that a high pass filter may be realized in other ways. It should also be realized that the third filter is not limited to a high pass filter but may also be a band pass filter with the pass band set to cover the third frequency band and any other frequency bands of signals that are to pass the second connection path.

[0055] Because of this filter 42, the second end of the first radiating element is still electrically floating. Therefore the first radiating element is still acting as an ILA antenna.

[0056] Also the second, third and additional radiating elements here function as ILA antennas that each resonate and preferably with fundamental resonance.

[0057] It should here be realized that the additional radiating element can as an alternative be omitted and the third radiating element be made to operate for both the third and the additional frequency bands. In a similar manner it is possible that the second radiating element in the first embodiment can be joined also to a further radiating element set to operate in the further frequency band. Alternatively the second radiating element in the first embodiment may be only operating in the second frequency band, which would remove the need for a diplexer and a connection to the further frequency band signal handling unit. In relation to the second embodiment it should also be mentioned that the second connection path could be branched and lead to the second and possibly a further radiating element, while the third connection path could be unbranched and only connect the third frequency band signal handling unit with the third radiating element. It is also possible with both the third and the second paths being branched.

[0058] Fig. 6 shows a perspective view of an antenna device according to a third embodiment of the present invention being provided above a reference plane.

[0059] This third embodiment looks quite similar to the second embodiment. However here there is no second feeding connection. Instead there is a grounding connection GC, which connects the second junction 20 with ground via an inductor 50, which has an exemplifying value of 10 nH. The third path P3 is connected to the grounding connector, however without any third filter. Here the inductor 50 acts as a matching element for the third and additional radiating elements but as a short-circuit to ground for the first frequency band. Since the first radiating element is grounded for the first frequency band, there is no need for the third filter.

[0060] The only difference at the first junction compared with the second embodiment is the first connection path and the first tuning element.

[0061] In this embodiment the second, third and additional radiating elements are acting as ILA antennas as before. However, the second end of the first radiating element is effectively grounded. The grounding connection GC provides ground for the first radiating element. It also provides feed for the third and additional radiating element. Therefore the first radiating element 16 acts as a half loop antenna, which can be seen as half a magnetic dipole antenna. This means that in the first frequency band the first radiating element 16 is inductive in nature. This also means that the first tuning element T1' can be provided as a capacitance connected to ground instead of an inductor connected to ground. The first tuning element T1' is here as an example a capacitance of 30 pF. However, the first tuning element T1' when provided in this way will also provide a path to ground for operations in the second frequency band.

[0062] In order to avoid this a further filter 49 is provided between the first tuning element T1' and the first radiating element 16. In this embodiment the first tuning element T1' and the first filter 24 share the same connection to the first radiating element 16. This also means that the further filter may be considered as a part of the first signal passing and blocking arrangement. Because of this the further filter 49 is provided in the first path P1 and here between the first radiating element 16 and the first filter 24. The first tuning element T1' is then connected between ground and the junction between the first filter 24 and the further filter 49. The further filter may here be a low pass filter in the form of an inductor having an exemplifying value of 20 nH.

[0063] In operation resonance is obtained similarly to what has been described in relation to the second embodiment.

[0064] Fig. 7 shows a perspective view of an antenna device according to a fourth embodiment of the present invention being provided above a reference plane.

[0065] This embodiment has the same radiating elements as in the third embodiment. The second and third connection paths are provided in the same way as in the third embodiment. Also the first connection path is in many ways similar to the connection path of the third embodiment. The only difference between these two paths is that the further filter is omitted. This is done since it is no longer needed.

[0066] The major difference is the feeding connections. In this fourth embodiment the first connection path is joined with the first junction 18 via the first feeding connection FC1 and the third connection path is joined to the second junction 20 via the second feeding connection FC2 like in the second embodiment. However, the second connection path is here joined with the first junction 18 via a further feeding connection FC3 and the second junction 20 connected to ground via a grounding connection GC. Each end of the first radiating element is thus provided with two connections, where three of these are feeding connections and one is a grounding connection.

[0067] As in the third embodiment the first radiating element is here a half-loop element. However here the second, third and additional radiating elements are IFA (Inverted F Antenna) elements. This means that the first feeding connection FC1 is a ground connection for the second radiating element, while the grounding connection GC acts as a grounding connection for both the first radiating element as well as the third and additional radiating elements. The reason for the first feeding connection FC1 acting as a ground connection is that the first tuning element T1' acts as a short-circuit to ground in the second frequency band for the second radiating element.

[0068] The fourth embodiment can also be varied in the same way as the previous embodiments regarding which feeding connections are to be branched and which are to receive further or additional radiating elements. It is actually possible that both ends of the first radiating element provides additional functionality for two different frequency bands with one or two radiating elements.

[0069] Another possible variation concerns the use of IFA and ILA. The first radiating element can be combined with either ILA or IFA elements at one or both ends. This means that it is also possible with the radiating elements connected to one end of the first radiating element to act as IFA, while the other radiating elements connected to the other end of the first radiating element act as ILA.

[0070] The feeding and grounding connections may typically be provided as conductors which can lead from the plane of the circuit board to the plane in which the radiating elements are provided.

[0071] From this it is also evident that the connection paths may be provided on the circuit board

[0072] There has here been described a number of different embodiments of the present invention that all provide an antenna device for operation in two three four or even five bands. This operation is furthermore obtained simultaneously. There is no switching between operation in different bands. This has the advantage of providing a more rapid signal processing, since there is no switching between bands. This also saves energy that would be used for operating switches. The antenna device is also easy to produce.

[0073] The radiating elements and feeding and grounding connections can also be seen as providing an antenna. This antenna is small in size while being adapted in shape to the environmental limitations imposed by a portable radio communication device.

[0074] It should here be realized that it is possible to make several modifications to the present invention. The second tuning element can be provided in all of the second paths. The different bands used may furthermore be varied. The second frequency band may thus be any frequency band in the group of WCMA_Rx, GPS or Bluetooth. This is also the case for the third, further and additional frequency bands. Also the first band may be a different band than FM, such as for instance a DVBH television band.

[0075] The dimensioning of the circuit board section and battery section that was described earlier can of course also be varied. The circuit board and battery may have any shape this is desired for adapting to the design of the portable radio communication device. This is also true for the radiating elements. They need not be provided along the sides of the sections, but may be provided above the sections. The placing of the first radiating element is not critical. However space is saved if it is provided closer to the battery section than the circuit board section. However it is advantageous if the other radiating elements are as much as possible spaced from the battery section. The different parts of the radiating elements were earlier being described as being straight or the whole elements as being straight. This is not necessary. They may have any desirable shape, such as curved or meandering.

[0076] The signal handling units were here described as separate units. It should be realized that two or more of them may be combined into the same physical entity, such as in the same component. These signal handling units were here also described as excluded from the antenna device. It should be realized that they may as an alternative also be included in the antenna device. Preferred embodiments of an antenna device according to the invention have been described. However, it will be appreciated that these can be varied within the scope of the appended claims. Therefore the present invention is only to be limited by the following claims.

Claims

1. An antenna device (12) for a portable radio communication device (2) operable in at least a first lower frequency band and a second higher frequency band, the antenna device comprising:

   - a first elongated radiating element (16) provided for operation in the first frequency band and having a first and a second opposite end;
   - a second elongated radiating element (21) joined to said first end of the first radiating element, said first end of the first radiating element thereby defining a first junction (18), said second element stretching away from the first radiating element and dimensioned for resonating in the

second frequency band,
- a first feeding connection (FC1) leading to the first junction;
- a first connection path (P1) provided between the first feeding connection and a first frequency band signal handling unit (34);
- a first tuning element (T1; T1') connected to said first connection path and being arranged to tune the first radiating element (16) for resonance in the first frequency band;
- a first signal passing and blocking arrangement (22) arranged to allow signals in the first frequency band to pass through the first connection path and to block signals in the second frequency band from passing through the first connection path;
- a second connection path (P2) provided between the first junction and a second frequency band signal handling unit (32); and
- a second signal passing and blocking arrangement (26) arranged to allow signals in the second frequency band to pass through the second connection path and to block signals in the first frequency band from passing through the second connection path.

2. The antenna device according to claim 1, further comprising a second tuning element (T2) connected to said second connection path and being arranged to tune the second radiating element for resonance in the second frequency band.

3. The antenna device according to claim 1 or 2, wherein the second connection path is connected to the first feeding connection.

4. The antenna device according to claim 1 or 2, wherein the second connection path is connected to a further feeding connection (FC3) leading to the first junction.

5. The antenna device according to any previous claim, wherein the second connection path includes a first branch connecting the first junction (18) with the second frequency band signal handling unit (32) and a second branch connecting the first junction (18) with a further frequency band signal handling unit (38) that operates at frequencies in a further frequency band that is higher than the first frequency band.

6. The antenna device according to claim 5, wherein the second connection path (P2) includes a signal combining unit (30) for allowing the antenna device to simultaneously handle signals in the second and the further frequency bands.

7. The antenna device according to claim 5 or 6, wherein the second radiating element is dimensioned to provide operation also in said further frequency band.

The antenna device according to claim 9, wherein the second radiating element is dimensioned for fundamental resonance in the second or the further frequency band and for harmonics resonance in the other frequency band.

8. The antenna device according to claim 5 or 6, further comprising a further elongated radiating element joined to said first end of the first radiating element at the first junction and being designed for operating in the further frequency band.

9. The antenna device according to any previous claim, further including a third elongated radiating element (38) joined to said second end (20) of the first radiating element, said second end of the first radiating element thereby defining a second junction (20), said third element stretching away from the first radiating element and being dimensioned for resonating in a third frequency band that is higher than the first frequency band and a third connection path (P3) provided between the second junction (18) and a third frequency band signal handling unit (46).

10. The antenna device according to claim 9, wherein the third connection path includes a third signal passing and blocking arrangement (42) arranged to allow signals in the third frequency band to pass through the third connection path and to block signals in the first frequency band from passing through the third connection path.

11. The antenna device according to claim 9 or 10, wherein the third connection path includes a first branch connecting the second junction (20) with the third frequency band signal handling unit (46) and a second branch connecting the second junction (20) with an additional frequency band signal handling unit (48) operating at frequencies in an additional frequency band that is higher than the first frequency band.

12. The antenna device (10) according to claim 11, wherein the third connection path (P3) includes a signal combining unit (44) for allowing the antenna device to simultaneously handle signals in the third and the additional frequency bands.

13. The antenna device according to claim 11 or 12, wherein the third radiating element (38) is dimensioned to provide operation also in the additional frequency band.

14. The antenna device according to claim 11 or 12, further comprising an additional elongated radiating element (40) joined to said second end of the first radiating element at the second junction and stretching away from the first radiating element.

15. The antenna device according to any of claims 9 - 14, wherein the third connection path (P3) is connected to a second feeding connection (FC2) leading to the second junction (20).

16. The antenna device according to any of claims 9 - 14, wherein the third connection path (P3) is connected to a grounding connector (GC) grounding the second end of the first radiating element.

17. The antenna device according to claim 16, further comprising a matching element (50) between the grounding connection and ground.

18. The antenna device according to any of claims 1 - 15, wherein the second end (20) of the first radiating element is electrically floating in the first frequency band and the first tuning element (T1) is realized as an inductive tuning element.

19. The antenna device according to any of claims 1 - 17, further comprising a grounding connection (GC), where the second end (20) of the first radiating element is connected to this grounding connection and the first tuning element (T1') is realized as a capacitive tuning element.

20. A portable radio communication device (10) comprising a first frequency band signal handling unit (34), a second frequency band signal handling unit (32), a ground plane and an antenna device (12) operable in at least a first lower frequency band and a second higher frequency band, said antenna device comprising:

- a first elongated radiating element (16) provided for operation in the first frequency band and having a first and a second opposite end;
- a second elongated radiating element (21) joined to said first end of the first radiating element, said first end of the first radiating element thereby defining a first junction (18), said second element stretching away from the first radiating element and dimensioned for resonating in the second frequency band,
- a first feeding connection (FC1) leading to the first junction;
- a first connection path (P1) provided between the first feeding connection and a first frequency band signal handling unit (34);
- a first tuning element (T1; T1') connected to said first connection path and being arranged to tune the first radiating element (16) for resonance in the first frequency band;
- a first signal passing and blocking arrangement (22) arranged to allow signals in the first frequency band to pass through the first connection path and to block signals in the second frequency band from passing through the first connection path;
- a second connection path (P2) provided between the first junction and a second frequency band signal handling unit (32); and
- a second signal passing and blocking arrangement (26) arranged to allow signals in the second frequency band to pass through the second connection path and to block signals in the first frequency band from passing through the second connection path.

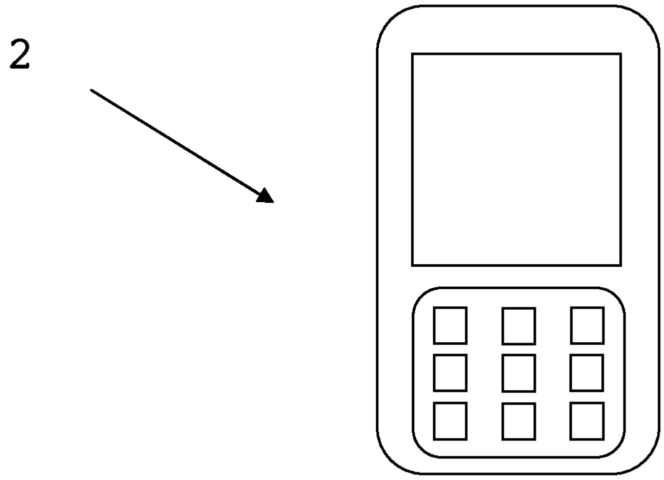


FIG. 1

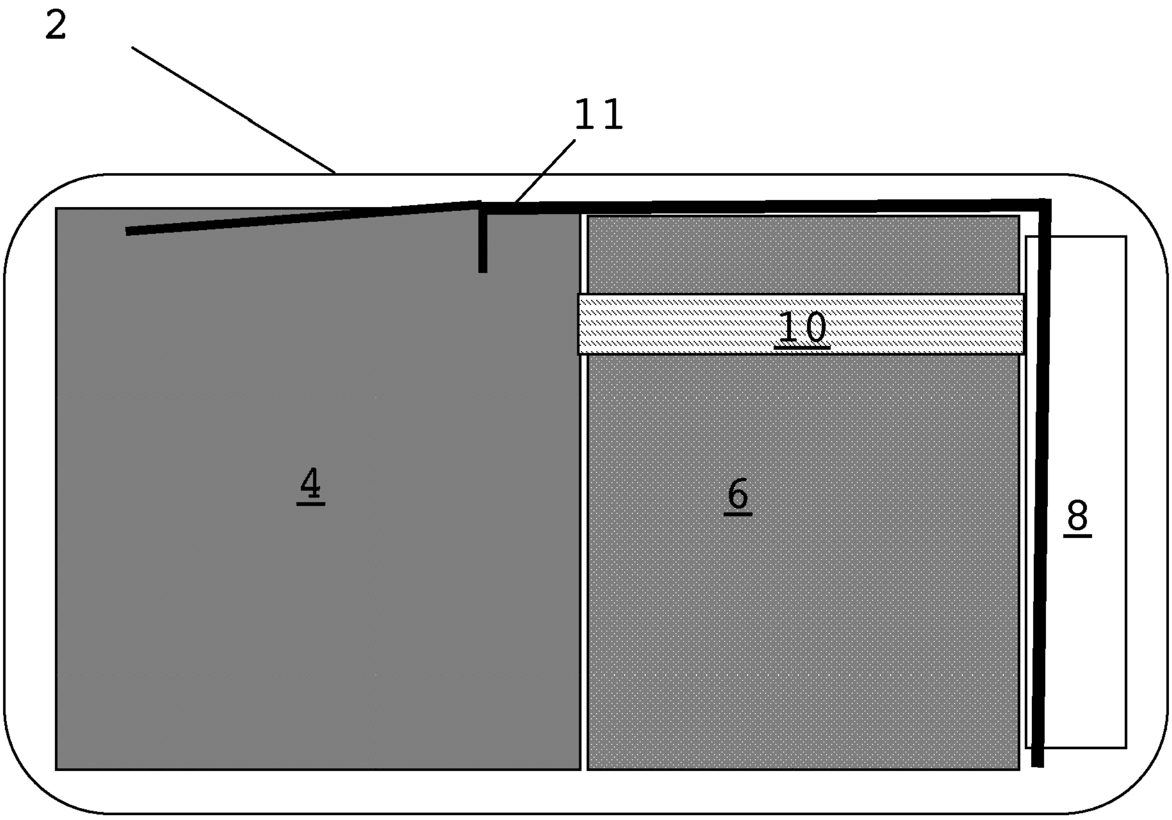
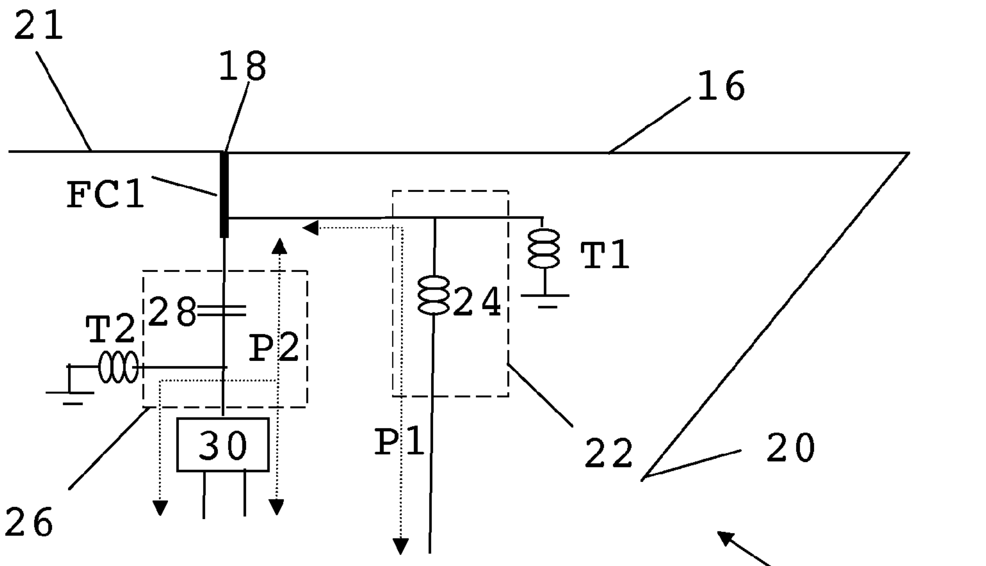


FIG. 2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18
16
FC1
T1
28
24
T2
P2
30
P1
22
20
26
12

FIG. 3

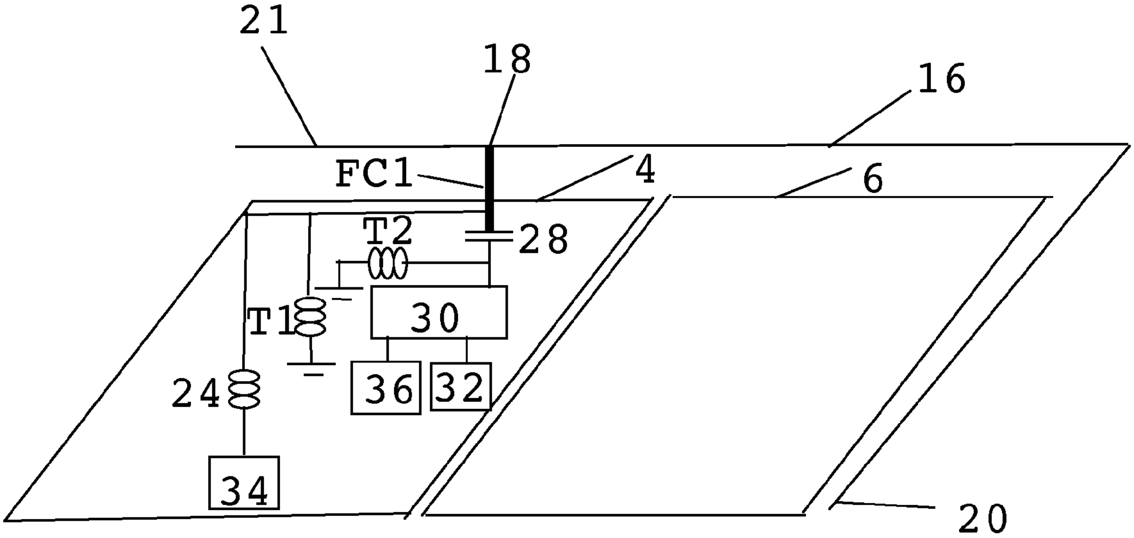
21
18
16
FC1
4
6
T2
28
30
T1
24
36
32
34
20

FIG. 4

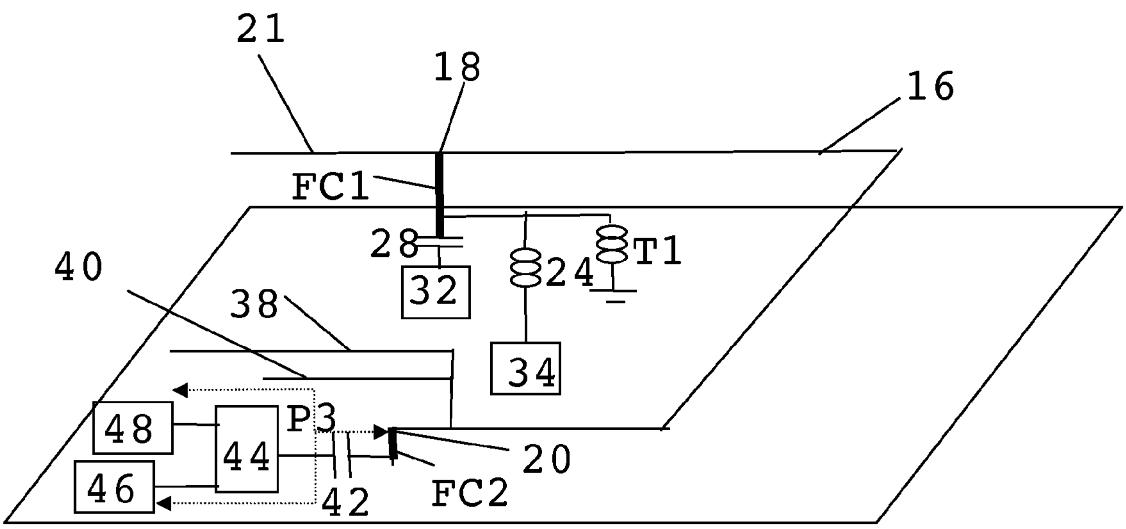
21
18
16
FC1
28
T1
24
40
32
38
34
48
P3
20
44
46
42
FC2

FIG. 5

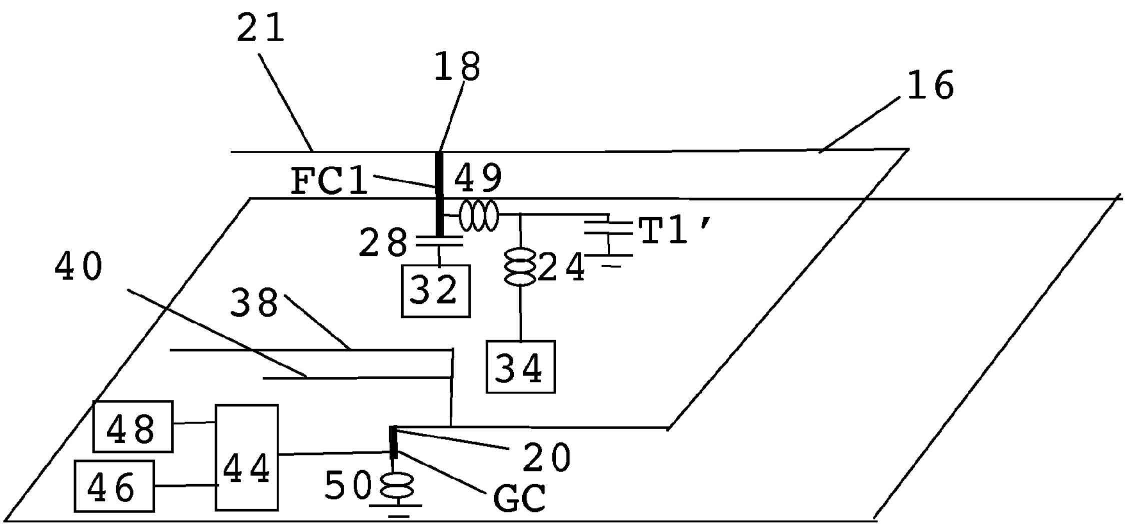
21
18
16
FC1
49
28
T1'
24
40
32
38
34
48
20
44
46
50
GC

FIG. 6

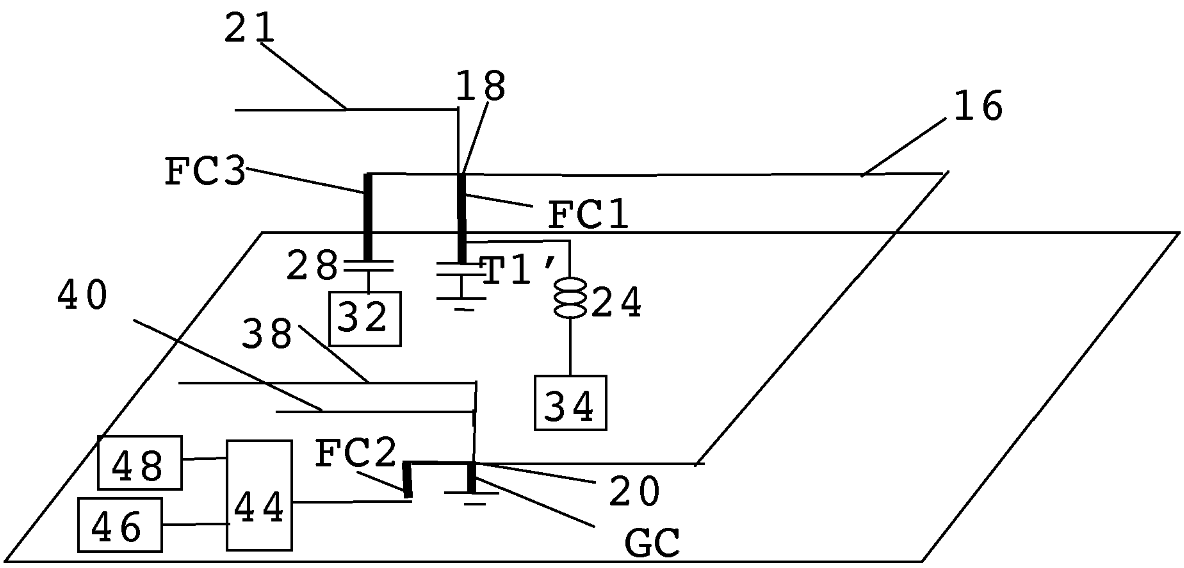

FIG. 7

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EUROPEAN SEARCH REPORT

Application Number
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Place of search	Date of completion of the search	Examiner
The Hague	27 October 2009	Fredj, Aziz

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