(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
25 September 2008 (25.09.2008)

PCT

(10) International Publication Number
WO 2008/115117 A1

(51) International Patent Classification:
*H01Q 1/24* (2006.01) *H04B 1/18* (2006.01)

(21) International Application Number:
PCT/SE2008/000197

(22) International Filing Date: 14 March 2008 (14.03.2008)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
07445011.5 22 March 2007 (22.03.2007) EP

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

**Published:**
— *with international search report*

(54) **Title:** ANTENNA DEVICE AND PORTABLE RADIO COMMUNICATION DEVICE COMPRISING SUCH ANTENNA DEVICE

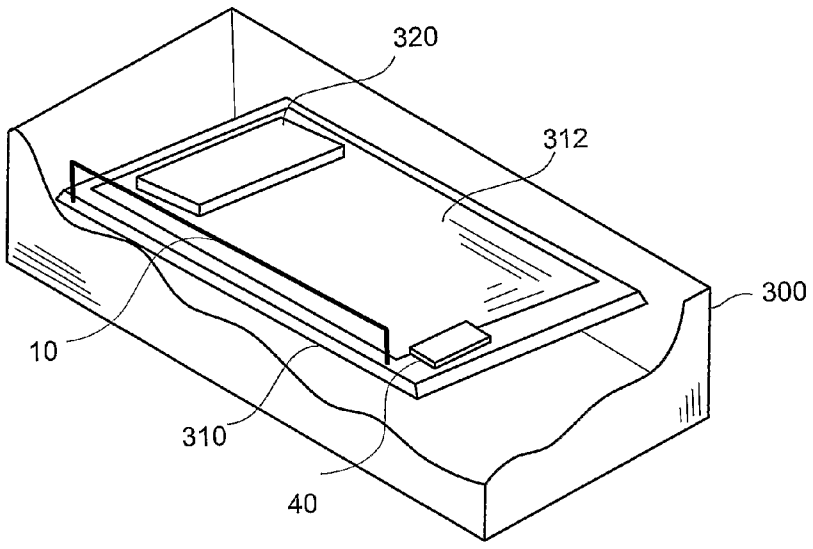


Fig. 6

(57) **Abstract:** An antenna device for a portable radio communication device, preferably for the FM frequency range, comprises a radiating element (10), and an amplifier stage. By providing the radiating element as a half-loop radiating element, the noise figure is essentially flat across the entire operating frequency range, giving adequate signal to noise ratio despite gain variances.

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# ANTENNA DEVICE AND PORTABLE RADIO COMMUNICATION DEVICE COMPRISING SUCH ANTENNA DEVICE

## FIELD OF INVENTION

The present invention relates generally to antenna devices and more particularly to an antenna device for use in a radio communication device, such as a mobile phone, which is adapted for radio signals having a relatively low frequency, such as radio signals in the FM band.

## BACKGROUND

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.

However, the application of internal antennas in a mobile phone puts some constraints on the configuration of the antenna element. In particular, in a portable radio communication device the space for an internal antenna arrangement is limited. These constraints may make it difficult to find a configuration of the antenna that provides for a wide operating band. 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.

One specific application operating in a relatively low frequency band is the FM radio application. The FM band is defined as frequencies between 88-108 MHz in Europe or between 76-110 MHz in the USA. 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.

Instead, a conventional FM antenna for portable radio communication devices is 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.

Another problem is that in case a second antenna, such as a GSM antenna, is provided in the same communication device as the FM antenna, this second antenna interferes with the operation of the FM antenna.

## SUMMARY OF THE INVENTION

An object of the present invention is to provide an internal antenna device for use in a portable radio communication device, which operates with sufficient performance throughout a frequency band having a relatively low frequency, such as the FM radio band.

The invention is based on the realization that an active internal antenna can be configured as a half-loop antenna.

According to the present invention there is provided an antenna device for a portable radio communication device adapted for receiving radio signals in at least a first operating frequency band, said antenna device comprising a first radiating element comprising a feeding portion, a ground plane, and an amplifier stage directly connected to the feeding portion of the first radiating element and connectable to a receiver device for radio signals, wherein the first radiating element is part of a loop comprising part of the ground plane. The antenna device is characterized in that the feeding portion of the first radiating element, the ground plane and the amplifier stage are provided on a common printed circuit board and the amplifier stage is co-located with the feeding portion of the first radiating element on the board.

A portable radio communication device comprising such an antenna device is also provided.

The antenna device according to the invention provides operation with sufficient performance throughout a frequency band having a relatively low frequency, such as the FM radio band. By using a half-loop antenna, it has been found that the noise figure is essentially flat across the entire operating frequency range, giving adequate signal to noise ratio despite gain variances.

In a preferred embodiment, the feeding portion of the first radiating element is provided at or close to one end of the printed circuit board and the end of the first radiating element opposite to the feeding portion is grounded at or close to the other end of the printed circuit board. In this way the area of the printed circuit board is used to a maximum.

A capacitor is preferably provided, which has a first end directly connected to the first radiating element in proximity of the feeding portion and a second end connected to the ground plane. This capacitor, which preferably has a value of 10-40 pF, increases source resistance seen by the transistor of the amplifier, thus matching noise and increasing stability. Also, since the first radiating element is essentially grounded at or close to the ends of the printed circuit board where the E field of a primary antenna device, such as a GSM antenna, is large, cross-talk from this primary antenna is minimized.

Further preferred embodiments are defined in the dependent claims.

## BRIEF DESCRIPTION OF DRAWINGS

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

FIG. 1 is a schematic diagram showing an antenna device according to the invention connected to an FM receiver circuit;

FIG. 2 is a diagram showing in more detail a first embodiment of an antenna device according to the invention;

FIG. 3 is a diagram showing in more detail a second embodiment of an antenna device according to the invention;

FIG. 4 is a schematic view of a first radiating element configuration of an antenna device according to the invention;

FIG. 5 is a schematic view of a multi-turn first radiating element configuration of an antenna device according to the invention;

FIG. 6 is a perspective partially cut-away view of an antenna device according to the invention mounted in a portable radio communication device; and

FIG. 7 is a perspective partially cut-away view of an alternative antenna device according to the invention mounted in a portable radio communication device.

## DETAILED DESCRIPTION OF THE INVENTION

In the following, a detailed description of preferred embodiments of an antenna device and a portable radio communication device according to the invention will be given.

In the following description and claims, the term radiating element is used. It is to be understood that this term is intended to cover electrically conductive elements arranged for receiving and/or transmitting radio signals.

First with reference to FIG. 1, the general configuration of an antenna device 1 according to the invention is shown. It comprises a first radiating element 10 in the form of a non-resonant piece of electrically conductive material. The first radiating element is part of a half loop antenna, as will be described in detail below. By half loop antenna is meant that the first radiating element is part of a loop, wherein the loop comprises part of the ground plane. Thus, the non-resonant piece of electrically conductive material essentially forms a half loop and the loop is completed by the ground plane.

The first radiating element has a feeding portion 11 directly connected to a shunt capacitor 20 arranged to resonate with the first radiating element, directly connected to an amplifier input and optionally connected to an ESD protection circuit. The resonant frequency response acts as a band pass filter for signals in the operating frequency band. In the case of operation in the FM band, the pass band is between 88-108 MHz in Europe or between 76-110 MHz in the USA.

The function of the resonant frequency response further acts as ESD protection circuit, effectively blocking the major part of ESD pulse spectrum. The filter also eliminates or at least reduces interference from electro magnetic interference (EMI) signals and possibly signals from other antennas provided in the same radio communication device, such as cellular GSM antennas operating at frequencies well above the FM antenna.

An amplifier stage 30 is arranged after the shunt capacitor 20 for amplifying signals received by the first radiating element 10.

Signals received and amplified by the antenna device 1 are supplied to an FM receiver circuit 40, which could be a conventional circuit manufactured by Philips Semiconductors and sold under the name HVQFN40. The FM receiver circuit comprises an RF input 41, which is connected to the amplifier 30.

It is preferred that the shunt capacitor 20 and amplifier stage 30 are provided relatively close to the first radiating element 10 in order to minimize parasitic effects and interference from external sources. They are therefore provided in proximity of the feeding portion of the first radiating element 10.

An implementation of the general idea expressed in FIG. 1 will now be described with reference to FIG. 2.

The amplifier stage 30 comprises a field effect transistor (FET) 31 with the gate connected to the shunt capacitor 20, the source connected directly to ground and the drain connectable to the input 41 of the FM receiver circuit 40. There is also a load resistor 32 connected between the drain of the transistor 31 and the feed voltage Vdd.

In order for the antenna device 1 to operate, the transistor preferably has a minimum noise figure below 1 dB and a gain above 15 dB in the operating frequency band. Also, it is preferred that the transistor has a noise resistance Rn of less than 10 Ohms in order to

achieve highest possible signal reception quality for arbitrary antenna configurations. A further preferred characteristic of the transistor is that the input capacitance is low, preferably less than 3 pF, in order to obtain high input impedance.

It is appreciated that the described antenna device is an active device. The described configuration is preferably so that the first radiating element is co-designed directly with the amplifier stage.

An alternative implementation of the inventive idea in the form of a second embodiment will now be described with reference to FIG. 3. Like the above described first embodiment, this antenna device comprises a first radiating element 10 having a feeding portion 11, a shunt capacitance, and amplifier stage 30. However, in this second embodiment the shunt capacitance is adjustable, i.e., implemented as a so-called varactor 120, providing a controllable antenna device. Furthermore, the amplifier stage is a so-called cascode amplifier 130. This cascode amplifier comprises a field effect transistor 131 with the gate connected to the first radiating element and shunt capacitance, the source connected directly to ground and the drain connected to the source of a second field effect transistor 133. The gate of the second transistor 133 is connected to ground via a capacitor 134. The drain of the second transistor 133 is connectable to the input 41 of the FM receiver circuit 40. There is also a load resistor 132 connected between the drain of the second transistor 133 and the feed voltage Vdd.

In this second embodiment, an FM transmitter circuit 140 is connected to the first radiating element via a switch 141. This switch is necessary if the input impedance $Z_{Tx}$ of the transmitter circuit is much lower, such as ten times lower than the input impedance $Z_{Rx}$ of the amplifier 130 in front of the receiver circuit 40. However, this switch 141 can be omitted if the input impedance $Z_{Tx}$ of the transmitter circuit is in the same order as the input impedance $Z_{Rx}$ of the amplifier 130.

By providing a transmitter circuit connected to the first radiating element 10, this radiating element can be shared and thus function for both transmission and reception. The transmitter circuit should preferably be connected to the first radiating element approximately at feeding portion 11.

General layouts of the first radiating element of an antenna device according to the invention will now be described with reference to FIGs. 4 and 5. A printed circuit board (PCB) 310 is suitably arranged in a portable radio communication device (not shown in these figures). A ground plane 312 is provided on the PCB. A signal load, corresponding to the above described amplifiers 30, 130, is provided on this PCB, which is preferably a multi-layer PCB. The first radiating element 10, which is preferably elongated and may be a wire-shaped electrical conductor, is directly connected to the amplifier at the feeding portion 11, preferably at or close to one end of the PCB. The amplifier and the feeding portion are therefore co-located at this end. The feeding portion of the first radiating element, the ground plane and

the amplifier stage are thus provided on a common PCB. The conductor runs essentially parallel to and at a distance h from the PCB 310 for most of its length. The end or the conductor 10 opposite the end connected to the signal source is connected to the ground plane 312 provided on the PCB 310 at or close to the other, opposite end of the PCB. This means that the first radiating element, which forms a half loop, takes advantage of as much space as possible since the loop area is important for the antennas performance.

A capacitor 20 is provided between the first radiating element and ground relatively close to the feeding portion 11, i.e. it is provided in proximity of the feeding portion 11. The capacitor 20 has a first end directly connected to the first radiating element in proximity of the feeding portion 11 and a second end connected to ground. This capacitor, which preferably has a value of 10-40 pF, increases the source resistance seen by the transistor of the amplifier, thus matching noise and increasing stability.

In an alternative embodiment, the conductor 10 is provided in more than one turn, in the example shown in FIG. 5 in two turns. The conductor of the first half loop is lead through a hole 314 in the PCB and to the lower side thereof. On the lower side, the conductor runs along the PCB, preferably in the form of a micro strip line 10a, from one end of the PCB to the other. The conductor is there lead through a second hole 316 in the PCB to the upper side thereof, along the PCB at a distance thereof, and is finally grounded at the second end of the PCB. In this way, the radiation

resistance, being proportional to the number of loop turns squared, is increased, improving the performance of the antenna.

A ferrite inside the loop, schematically referenced 14 can be used with both the embodiment of Fig. 4 and the one of Fig. 5 in order to improve the performance of the antenna device.

A first preferred position of the antenna device according to the invention as described above with reference to FIGs. 1-3 will now be described with reference to FIG. 6, wherein the general outlines of the casing of a portable radio communication device 300, such as a mobile phone, is depicted. The casing is shown partially cut away so as to not obscure the position of the antenna device, which could be any of the devices described with reference to FIGS 1-3.

The PCB 310 is provided in the casing, having the circuits (not shown) conventionally found in a mobile phone. On the PCB there is also mounted the FM receiver circuit 40. In the upper portion of the casing there is provided a second antenna radiating element 320 for receiving and transmitting RF signals for a cellular mobile phone system, such as a GSM system. This second radiating element 320 is provided on the same side of the board as the feeding portion of the first radiating antenna element.

A battery package (not shown) is also provided towards the back of the casing 300.

The first radiating element 10 is preferably placed so that it is connected to the FM circuit at the end of the PCB opposite to the end where the second radiating element 320 is provided. The first radiating element then runs along a long side of the PCB until it reaches the other end of the PCB, where it is grounded to the ground plane 312 provided on the PCB 310.

In order to make the antenna device less sensitive to orientation, the first radiating element 10 can be provided so that it also runs along a short side of the PCB, see Fig. 6, before it is grounded to the ground plane 312 provided on the PCB.

Preferred embodiments of an antenna device according to the invention have been described. However, the person skilled in the art realizes that these can be varied within the scope of the appended claims without departing from the inventive idea.

It is realized that the shape and size of the antenna device according to the invention can be varied within the scope defined by the appended claims. Thus, the exact antenna configurations can be varied so as to correspond to the shape of the radio communication device, desired performance etc.

The above-described embodiments of an antenna device according to the invention have been described as antenna devices adapted for reception of radio signals in the FM frequency band. However, other applications are also possible, such as use for digital video broad-casting (DVB) signals in the frequency range of about 400-800 MHz.

Although an antenna device for a portable radio communication device has been described with reference to its use in a mobile phone, it will be appreciated that the inventive idea is also applicable to other portable radio communication devices, also devices that are portable but primarily intended for stationary use. Examples thereof could be small clocks, such as travel alarm clocks, TV receivers, or game consoles. Yet a possible application of the antenna device according to the invention is in personal digital assistants (PDAs), MP3 and CD players, FM radio receivers, and laptop computers. A further application is in cars. Thus, the term portable radio communication device should be construed in a broad sense.

The embodiments described above with reference to FIGs. 6 and 7 include a GSM antenna. It will be appreciated that this could be substituted for a different antenna as long as its operating frequency is well above that of the lower frequency band, such as the FM band. A second antenna can also be omitted.

A FET has been described as the preferred transistor type. It will be realized that other types of transistors, such as hetero-junction bipolar transistors (HBT), can be used as well.

It will be appreciated that the Tx part can be implemented also in the first embodiment shown in Fig. 2. It is likewise appreciated that the capacitor 20 of the first embodiment can be replaced by a varactor.

CLAIMS

1. An antenna device for a portable radio communication device adapted for receiving radio signals in at least a first operating frequency band, said antenna device comprising

- a first radiating element (10) comprising a feeding portion (11; 111),
- a ground plane (312), and
- an amplifier stage (30) directly connected to the feeding portion of the first radiating element and connectable to a receiver device for radio signals,
- wherein the first radiating element is part of a loop comprising part of the ground plane.

**characterized in that**

- the feeding portion of the first radiating element, the ground plane and the amplifier stage are provided on a common printed circuit board (310) and the amplifier stage is co-located with the feeding portion of the first radiating element on said board.

2. The antenna device according to claim 1, wherein the feeding portion (11) of the first radiating element is provided at or close to one end of the ground plane and the end of the first radiating element opposite to the feeding portion is grounded at or close to the other end of the ground plane.

3. The antenna device according to claim 1 or 2, comprising a capacitor (20; 120) having a first end directly connected to the first radiating element in proximity of the feeding portion (11) and a second end connected to the ground plane (312).

4. The antenna device according to claim 3, wherein the capacitor (20; 120) has a value of 10-40 pF.

5. The antenna device according to claim 3 or 4, wherein the capacitor (120) has an adjustable capacitance value.

6. The antenna device according to any previous claim, wherein the first radiating element (10) is elongated and runs along a long side of the printed circuit board.

7. The antenna device according to claim 6, wherein the first radiating element (10) additionally runs along a short side of the printed circuit board (310).

8. The antenna device according to any previous claim, wherein the first radiating element (10) comprises a plurality of turns.

9. The antenna device according to claim 8, wherein part of the radiating element (10) is partly provided as a micro strip line (10a).

10. The antenna device according to any previous claim, wherein the first radiating element is co-designed directly with the amplifier stage.

11. The antenna device according to any previous claim, comprising a ferrite (14) inside the half-loop of the first radiating element.

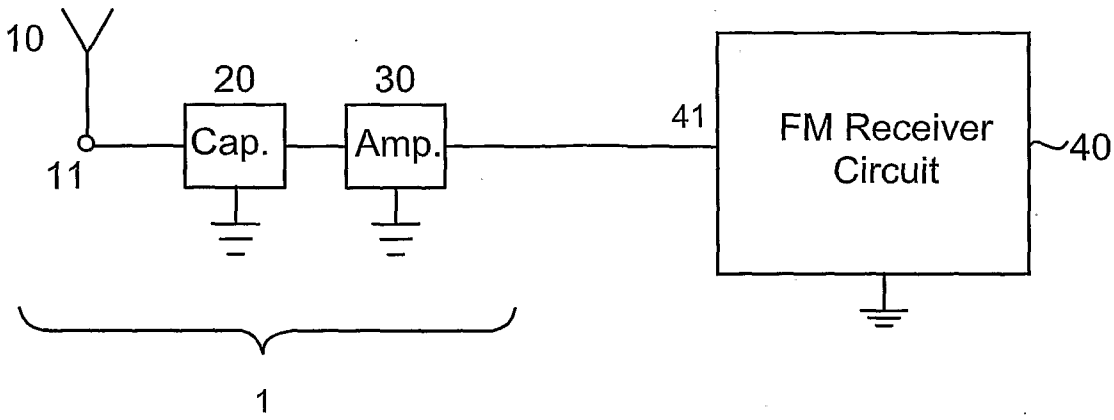
12. The antenna device according to any previous claim, wherein the first radiating element (10) is connectable to a transmitter circuit (40).

13. The antenna device according to any previous claim, wherein the first operating frequency band is the FM band.

14. The antenna device according to any previous claim, further comprising a second radiating element (320) adapted to operate in at least a second operating frequency band.

15. The antenna device according to claim 14, wherein the second radiating antenna element is provided on the same side of said board as the feeding portion of the first radiating antenna element, where the feeding portion (11) of the first radiating element is provided at or close to one end of the board and the second radiating element is provided at or close to an opposite other end of the board.

16. A portable radio communication device (300) comprising an antenna device according to any of claims 1 - 15.


10
20
30
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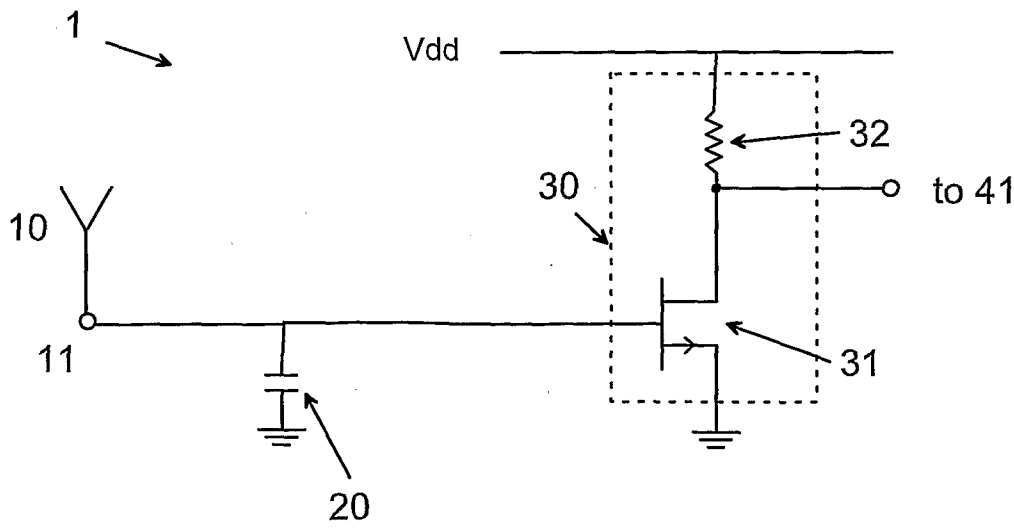
Cap.
Amp.
FM Receiver
Circuit
40
11
1

Fig. 1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to 41
10
11
31
20

Fig. 2

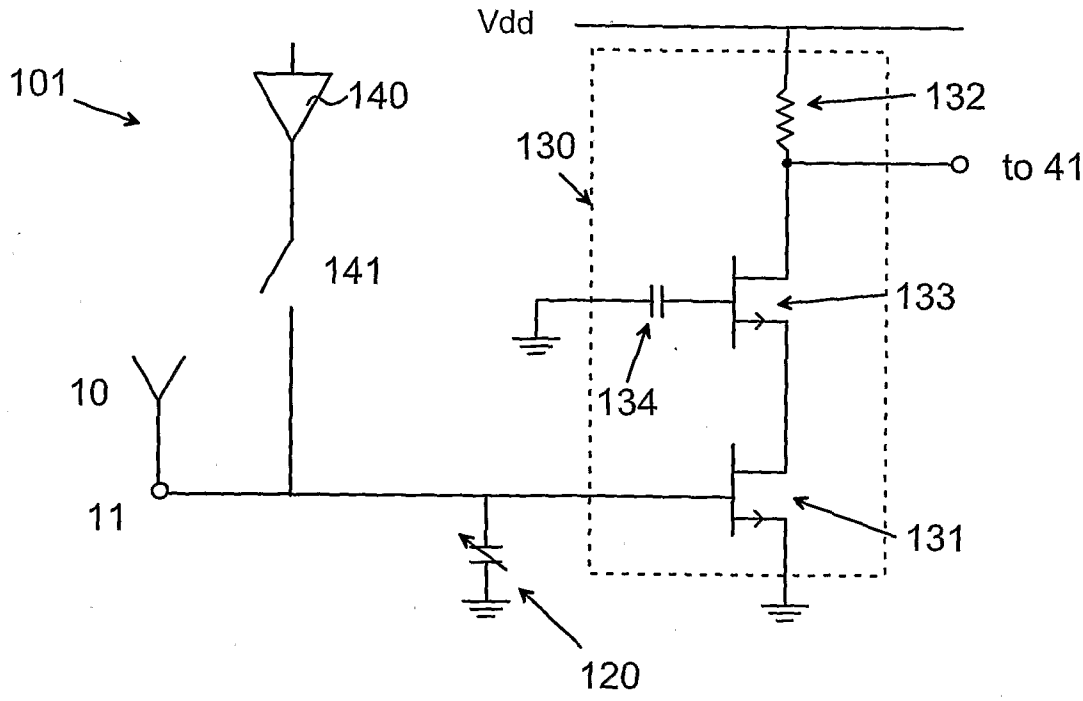


Fig. 3

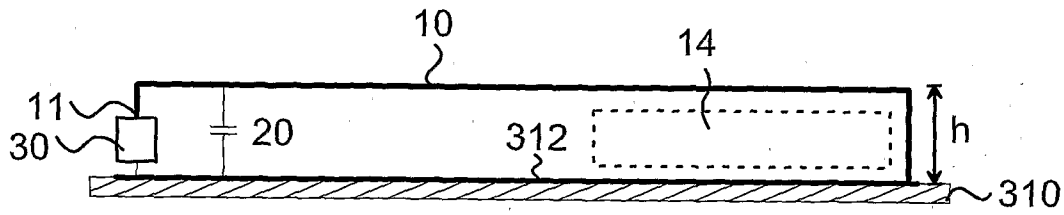


Fig. 4

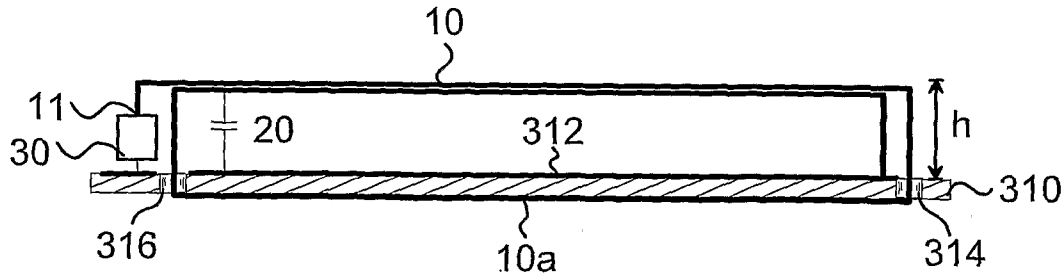


Fig. 5

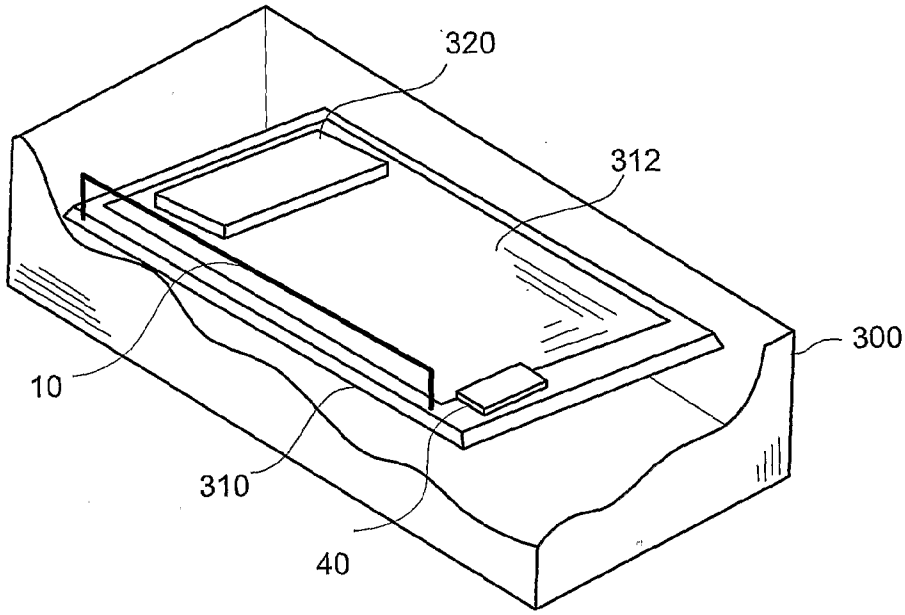


Fig. 6

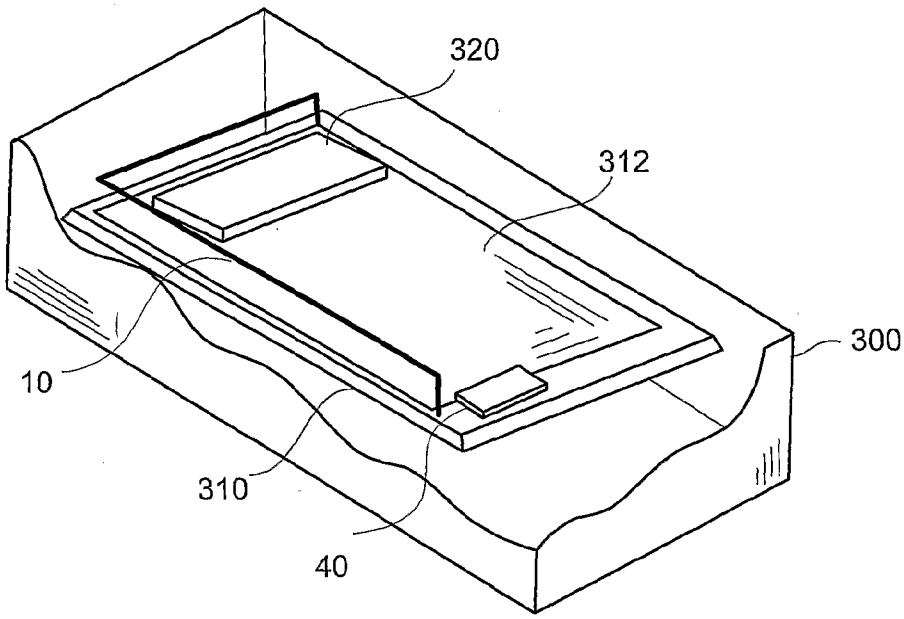


Fig. 7

# INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2008/000197

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: H01Q, H04B

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

SE,DK,FI,NO classes as above

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

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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| Date of the actual completion of the international search | Date of mailing of the international search report |
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| 16 June 2008 | 17 -06- 2008 |
| Name and mailing address of the ISA/<br>Swedish Patent Office<br>Box 5055, S-102 42 STOCKHOLM<br>Facsimile No. +46 8 666 02 86 | Authorized officer<br>Rune Bengtsson /LR<br>Telephone No. +46 8 782 25 00 |

INTERNATIONAL SEARCH REPORT

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
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**International patent classification (IPC)**
***H01Q 1/24*** (2006.01)
***H04B 1/18*** (2006.01)

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Cited literature, if any, will be enclosed in paper form.

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