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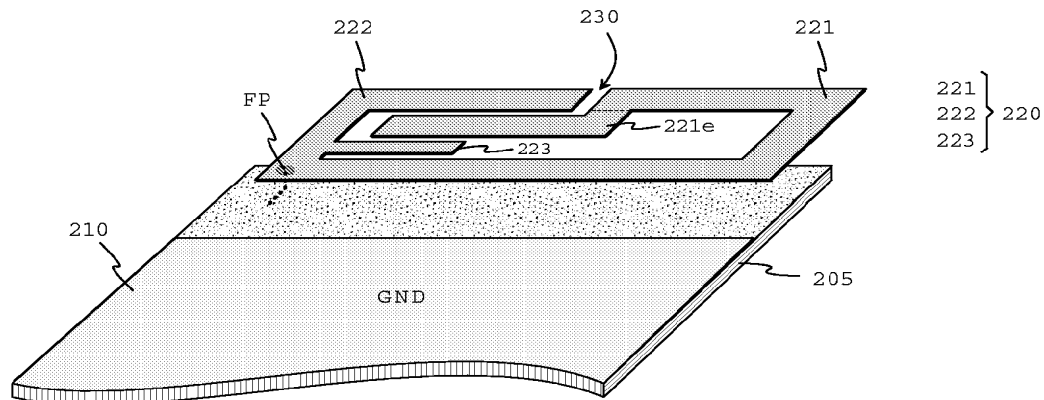
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(54) Title: INTERNAL ANTENNA



(57) Abstract: An internal antenna especially aimed at flat radio devices. The antenna comprises a planar radiator (220) with a branch (221) for forming a lower operating band for the antenna and a second branch (222) for forming an upper operating band. The branches typically form a frame-like pattern. There remains a slot (230) between the branches, opening to the outer edge of the radiator approximately in the middle of the edge running in the direction of the end of the circuit board (205) and being outside the circuit board as seen from above. The omnidirectional radiation of the antenna on its upper operating band improves as compared to the corresponding, known antennas, and its efficiency improves, because the average antenna gain increases.



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Internal antenna

The invention relates to an internal antenna of a radio device. The antenna is aimed especially at small and flat radio devices with several operating bands.

5 An ideal antenna in portable radio devices would be one that transmits and receives equally in all directions. In practice, there is substantial variation in the efficiency of transmitting and receiving depending on the direction. In mobile stations, this drawback is reduced by the fact that the propagation of the radio transmitting signal is of multipath type caused by the environment, whereby the same transmitting signal arrives at the antenna from many directions, and in most cases at least
10 one of the partial transmitting signals arrives in an advantageous direction with regard to receiving. Correspondingly, the part of the transmitting signal of the mobile station, which momentarily takes off to an advantageous direction, propagates to the base station antenna. Therefore, the transfer of speech and text messages generally succeeds without problems. The situation is different when the mobile
15 station is used for Internet connections having a relatively high speed, because the probability of bit errors is then higher. If the antenna had an omni-directional pattern, the reliability of the transfer would improve substantially. An omni-directional pattern would also be advantageous when the transmitting signal comes mainly from one direction only, like in GPS (Global Positioning System) receiving.

20 Of the antenna types, a whip antenna outside the cover of the radio device has a high quality in the above mentioned respect. In theory, its directional pattern has a circular shape in the plane perpendicular to the axis of the whip. However, external antennas are vulnerable to damage, and with the additional parts required by them they increase the manufacturing costs significantly. Therefore, most models of
25 mobile stations have turned to internal antennas.

But when the size of mobile stations has decreased, the space available for the internal antenna has also become smaller and smaller. This means that design becomes more demanding. The space available especially in the vertical direction is naturally the smaller the flatter the device is. Structural parts that are flatter than
30 usual are, for example, the parts of such a two-part radio device, which are either on top of each other or one after the other as extensions of each other, depending on the situation of use. In these cases, the antenna generally used is of the monopole type, which does not require as much space in the vertical direction as the planar antenna of the PIFA type (Planar Inverted F-Antenna), which is otherwise
35 used commonly.

Fig. 1 shows an example of a known internal antenna of a device. A part of the circuit board 105 of the radio device is seen in the drawing. The circuit board has sides and perpendicular ends thereof. The radiator 120 of the antenna is of the monopole type. It has the shape of a planar and elongated rectangle. The longitudinal direction of the rectangle is the same as the direction of the end of the circuit board. The radiator is fastened to one end of the circuit board so that it is approximately in the same plane with the circuit board and is for the most part located on the side of the circuit board as seen from above. A continuous ground plane 110, or signal ground GND, is located on the circuit board at a certain distance from the radiator 120. As seen from its feed point FP, the radiator is divided into two branches of different length for forming two separate operating bands. The shorter branch 122 is L-shaped. When starting from the feed point, it has first a short portion in the direction of the sides of the circuit board 105 and then a longer portion in the direction of the end of the circuit board. The longer branch 121 is U-shaped. When starting from the feed point FP, it has a first portion running beside the shorter branch in the direction of the end of the circuit board, then a second portion in the direction of the sides of the circuit board, and finally a third portion in the direction of the end of the circuit board on the other side of the shorter branch. The third portion extends abreast of the feed point FP as seen in the direction of the side of the feed point. The lower one of the operating bands is based on the longer branch of the radiator and the upper one on the shorter branch.

When the antenna is wanted to have at least two bands, the radiator must be shaped in a way that it is provided with (a) slot(s) directed inward from its outline. In the example of Fig. 1, such a slot 130 is near the corner of the radiator 120, between the tail of the longer branch 121 and the corner point of the shorter branch 122. As a drawback, the directional pattern of the antenna has in this case a minimum point at the frequencies of the upper operating band, which minimum point is in the plane of the radiator in its longitudinal direction on the side of the slot. When the antenna is in the upright position so that the ground plane of the radio device remains below it, the minimum point occurs in the directional pattern of the horizontal plane. Naturally, the directional pattern has variation also at the frequencies of the lower operating band, but it is not dealt with in this description.

The object of the invention is to reduce the above-mentioned drawback, which is characteristic of the prior art antennas. The antenna according to the invention is characterized in what is set forth in the independent claim 1. Some preferred embodiments of the invention are set forth in the other claims.

The basic idea of the invention is the following: The internal antenna of a radio device comprises a planar radiator with a branch for forming a lower operating band for the antenna and a second branch for forming an upper operating band. The branches typically form a frame-like pattern. There remains a slot between the
5 branches, opening to the outer edge of the radiator approximately in the middle of the edge running in the direction of the end of the circuit board and being outside the circuit board as seen from above.

The invention has the advantage that the omnidirectional radiation of the internal antenna in its upper operating band improves in the horizontal plane when the ra-
10 diator is in the upright position so that the ground plane of the radio device remains below it. This is due to the location of the slot between the branches of the radiator as described above. Radiation is then emitted more equally in both directions in the direction of the edge at issue. In addition, the invention has the advantage that the efficiency of the internal antenna improves, because the average an-
15 tenna gain increases.

In the following, the invention will be described in detail. Reference will be made to the accompanying drawings, in which

- Fig. 1 shows an example of a prior art internal antenna of a radio device,
Fig. 2 shows an example of an internal antenna of a radio device according
20 to the invention,
Fig. 3 shows an example of the effect of the invention on the directional characteristics of the antenna,
Fig. 4 shows another example of the effect of the invention on the directional characteristics of the antenna,
25 Fig. 5 shows another example of an internal antenna of a radio device according to the invention,
Fig. 6 shows a third example of an internal antenna of a radio device according to the invention,
Fig. 7 shows a fourth example of an internal antenna of a radio device ac-
30 cording to the invention,
Fig. 8 shows a fifth example of an internal antenna of a radio device according to the invention, and

Fig. 9 shows an example of the location of the radiator in the antenna according to the invention.

Figure 1 was described in connection with the description of the prior art.

Fig. 2 displays an example of an antenna according to the invention, internal to a radio device. A part of the circuit board 205 of the radio device and the monopole-type radiator 220 of the antenna are seen in the drawing. As in Fig. 1, it is plane-like and elongated rectangle by outline, the longitudinal direction of which is the same as the direction of the end of the circuit board. The radiator is attached to the end of the circuit board so that it is approximately in the same plane with the circuit board and for the most part located outside the circuit board as viewed from above. There is a continuous ground plane 210, or signal ground GND, on the circuit board at a certain distance from the radiator 220. Again, like in Fig. 1, the radiator is divided into two branches of different length, as viewed from its feed point FP, for forming two separate operating bands. The feed point is in one of the two corners of the radiator, which are on top of the circuit board. The shaping of the branches differs from that shown in Fig. 1. When starting from the feed point, the second, shorter branch 222 has first a portion directed outward from the end of the circuit board 205, forming one end of the radiator, and then a second portion running in the direction of the end of the circuit board, which forms about half of the outer long side of the radiator. When starting from the feed point, the first, longer branch 221 has a first portion running in the direction of the end of the circuit board, forming the long side of the radiator closer to the circuit board, and then a second portion perpendicular to the former, which forms the second end of the radiator. After this, the first branch has a third portion running in the direction of the end of the circuit board, which forms a part of the outer, long side of the radiator. The third portion extends to a point near the free end of the second branch 222 so that a relatively narrow slot 230 remains between them. In this example, the first branch 221 further makes a bend to the inner area of the radiator, and continues beside the second portion of the second branch towards the end of the radiator on the side of the feed point, forming the end portion 221e of the first branch. The slot 230 continues between the end portion and the second portion of the second branch 222. The coupling over the slot increases the electric length of both branches, in which case the width of the slot and the length of the end portion 221e can be used as parameters for setting the operating bands of the antenna in place. For the same purpose, the radiator has a tuning strip 223 starting near the

feed point FP and extending between the first portion and the end portion of the first branch.

According to what is described above, the slot 230 opens to the edge of the radiator approximately in the middle of the outer side running in the direction of the end
5 of the circuit board. As a result of this, the shape of the near field of the antenna at the frequencies of the upper operating band becomes such that the structure radiates relatively equally in both directions in the longitudinal direction of the radiator. This belongs to the horizontal plane when the radio device and its antenna are in an upright position so that the ground plane on the circuit board of the device is
10 below the antenna.

Figs. 3 and 4 show an example of the effect of the invention on the directional characteristics of the antenna in the upper operating band. The curves display the horizontal directional pattern, i.e. the antenna gain, as a function of the directional angle when the device is in the upright position as described above. Curve 31 in
15 Fig. 3 and curve 41 in Fig. 4 concern a prior art antenna according to Fig.1, and curve 32 in Fig. 3 and curve 42 in Fig. 4 concern an antenna according to the invention shown in Fig. 2. The antennas are designed so that their upper operating band covers the frequency range 1850–1990 MHz used by GSM1900 (Global System for Mobile telecommunications). The directional patterns of Fig. 3 have been
20 measured at the lower boundary frequency of this range, and the directional patterns of Fig. 4 at the upper boundary frequency of this range.

It is seen from Fig. 3 that the gain of the known antenna on the lower boundary of the operating band is about –11 dB in the most adverse direction. The corresponding gain of an antenna according to the invention is approximately –6½ dB, i.e.
25 approximately 4½ dB higher. In addition, the gain is at least 1 dB higher in an area of approximately 180 degrees. It is seen from Fig. 4 that the gain of the known antenna on the upper boundary of the operating band is about -27 dB in the most adverse direction, which is zero gain in practice. The corresponding gain of an antenna according to the invention is approximately –11½ dB, i.e. approximately 15
30 dB higher. In addition, a gain at least 3 dB higher is achieved in an area of approximately 150 degrees, and a gain at least 1 dB higher is achieved in all directions of the horizontal plane. The deep minimum points in the directional patterns of the known antennas are entirely avoided when the antenna according to the invention is used.

Fig. 5 presents another example of an antenna according to the invention, internal to a radio device. Only the radiator 520 is shown in the drawing. Its structure is slightly simpler than in Fig. 2. The first 521 and the second 522 branch of the radiator now form a mere rectangular frame, in which a slot 530 remains between the ends of the branches. The portions of the branches, which are on the long side of the radiator where the slot 530 is, are equally long in this example, and so the slot is located just in the middle of that side. The width d of the slot is not a critical parameter with regard to omnidirectional radiation; it can be in the range of 0.5–5 mm, for example. In this example, the feed point FP of the radiator, from which the branches 521, 522 start, is in a small projection of the radiator, which extends from the frame to the circuit board of the radio device.

More generally, in the antennas according to the invention, the slot may start in the central area of the edge running in the direction of the end of the circuit board on either side of the mid-point. In this description and the claims, the “central area” means an area at a distance of $(0.3–0.7)s$ from the end of the edge, where s is the length of the edge.

Fig. 6 shows a third example of an antenna according to the invention, internal to the radio device. The radiator 620 and the end of a circuit board 605 are seen in the drawing. When starting from the feed point FP, the second branch 622 of the radiator has a first portion directed outward from the end of the circuit board, forming one end of the radiator, and then a second portion in the direction of the end of the circuit board, which forms a little over half of the outer long side of the radiator in this example. When starting from the feed point FP, the first branch 621 of the radiator has a first portion running in the direction of the first portion of the second branch and shorter than it, a second portion running in the direction of the second portion of the second branch and extending to its end, then a third portion directed toward the circuit board 605, a fourth portion directed away from the feed point in the direction of the end of the circuit board, a fifth portion directed outward from the end of the circuit board and forming the second end of the radiator, and a sixth portion running again in the direction of the end of the circuit board and ending near the point where the second portion of the first branch changes to the third portion. A relatively narrow slot 630, opening in the central area of the radiator, remains between the second portion of the first branch and the second portion of the second branch. In this example, the slot opens to the outer edge in the direction of the end of the circuit board, because the sixth portion of the first branch is

directed towards the end of its second portion and not towards the end of the second portion of the second branch.

Fig. 7 shows a fourth example of an antenna according to the invention, internal to the radio device. It shows the main radiator 720 of the antenna, which is similar in principle as the radiator 220 in Fig. 2, but without the tuning strip 223. The frame formed by the main radiator is also strongly rounded at the corners, except for the corner of the feed point FP. In addition, the antenna now includes a radiating parasitic element 740, which is located under the radiator and is connected at one point to the signal ground GND of the radio device. The shape of the parasitic element follows the branches of the main radiator, but it does not extend near the slot 730 of the main radiator so as not to interfere with the operation according to the invention.

Fig. 8 presents a fifth example of an antenna according to the invention, internal to the radio device. Part of the circuit board 805 of a radio device and the radiator 820 of the antenna are seen in the figure. The radiator forms a rectangular frame, where the longitudinal direction in this case is the same as the longitudinal direction of the circuit board, or the direction of the sides. As seen from above, the second, or outer end of the radiator frame and a small part of the longer sides are outside the circuit board at its end. Therefore, the radiator in this example is mostly on top of the circuit board and the ground plane 810 on it, naturally separated from the ground plane. In this case, too, as seen from the feed point FP, the radiator 820 is divided into two branches of different length for forming two separate operating bands. The feed point is on one of the longer sides of the radiator, and the slot 830 between the ends of the branches in the middle of the outer end of the radiator. The second, shorter branch 822 of the radiator is then formed of the part reaching from the feed point FP of the longer side of the radiator to the outer end and a half of the outer end. Correspondingly, the first, longer branch 821 is formed of a portion reaching from the feed point of the longer side of the radiator to the opposite end, the opposite end, the opposite longer side and the other half of the outer end.

Fig. 9 shows an example of the location of the radiator in the antenna according to the invention. Part of the circuit board 905 of a radio device and the radiator 920 of the antenna are seen from the side in the drawing. The radiator of this example is elevated from the circuit board, like the radiator in Fig. 8. In this case, the radiator is mostly outside the circuit board, as seen from above, but a significant part of it is also on top of the ground plane 910 on the circuit board. The radiator is connected

from its feed point FP to the antenna port on the circuit board by a feed conductor 925. The slot 930 between the branches of the radiator is on its outer side as seen from the circuit board. Naturally, the radiator needs a dielectric support structure, which is not shown in the drawing.

- 5 The qualifiers “from above”, “on top of” and “below” in the claims refer to the position of the radio device, in which the circuit board of the radio device and the radiator of the antenna are horizontal in a way that the feed point of the radiator is on the side of the upper surface of the circuit board. Naturally, the antenna can be in any position when used.
- 10 An internal antenna according to the invention has been described above. Its implementation may differ from that described in its details. For example, the slot in the radiator conductor of the antenna can be shaped in a way that it functions as a significant auxiliary radiator on the upper operating band. A short-circuit conductor may also be connected to the radiator for matching it. For example, in the structure
- 15 shown by Fig. 2, such a conductor may extend from the edge of the radiator on the circuit board to the ground plane. The invention does not limit the manufacturing method of the antenna. For example, the radiator(s) may be made of relatively rigid strips of metal sheet, or of the conductor coating of the circuit board. The inventive idea can be applied in different ways within the scope defined by the independent claim 1.
- 20

Claims

1. An internal antenna of a radio device, the radio device having a circuit board (205; 605; 805) provided with a ground plane (210; 610; 810), and which antenna comprises a planar monopole radiator (220; 520; 620; 720; 820), which is divided,
5 as seen from a feed point of the antenna, into a first branch (221; 521; 621; 821) to form a lower operating band for the antenna, and a second branch (222; 522; 622; 822) to form an upper operating band for the antenna, between which branches there remains a slot (230; 530; 630; 730; 830) opening to an outer edge of the radiator, characterized in that said outer edge is the edge of the radiator running
10 substantially in the direction of an end of the circuit board and outside the circuit board as seen from above, and said slot (230; 530; 630; 730; 830) opens to the outer edge in its central area to improve the omnidirectional radiation of the antenna on its upper operating band.
2. An antenna according to Claim 1, characterized in that said radiator (220) is
15 located substantially in the same geometrical plane as the circuit board (205) of the radio device.
3. An antenna according to Claim 1, characterized in that said radiator (820; 920) is elevated from the circuit board (805; 905) of the radio device, partly on top of the ground plane (810; 910).
- 20 4. An antenna according to Claim 3, characterized in that said radiator (820) is for the most part located on top of the ground plane (810).
5. An antenna according to Claim 1, characterized in that it further comprises a radiating parasitic element (740), which is located below said radiator (720) and is connected at one point thereof to the ground plane of the radio device, or the signal ground (GND).
25
6. An antenna according to Claim 1, characterized in that the first branch (221) has an end portion (221e), which is located in a central area of the radiator beside the free end of the second branch (222) to set said operating bands at the desired places in the frequency scale.
- 30 7. An antenna according to Claim 1, characterized in that said radiator (220; 820) is a strip of metal sheet.

8. An antenna according to Claim 1, characterized in that said slot (230; 830) opens to the outer edge of the radiator (220; 820) substantially perpendicularly to the end of the circuit board (205; 805).
9. An antenna according to Claim 1, characterized in that said slot (630) opens
5 to the outer edge of the radiator (620) in the direction of the end of the circuit board (605).

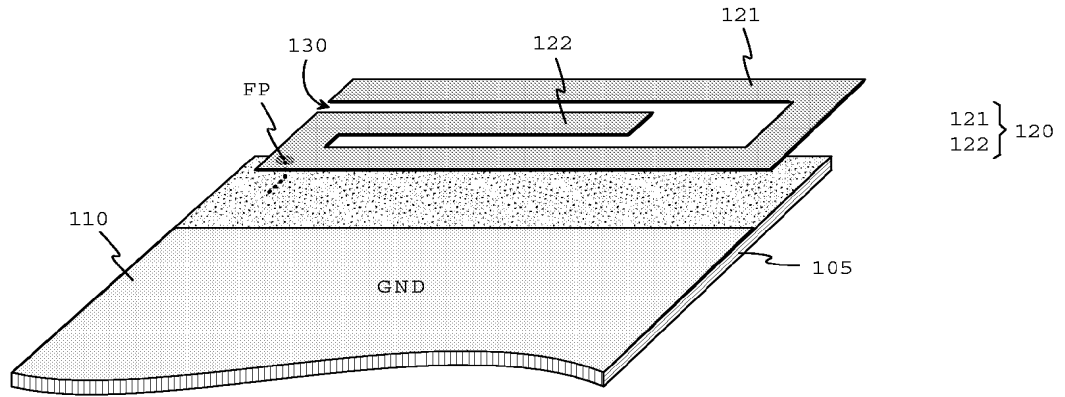


Fig. 1 PRIOR ART

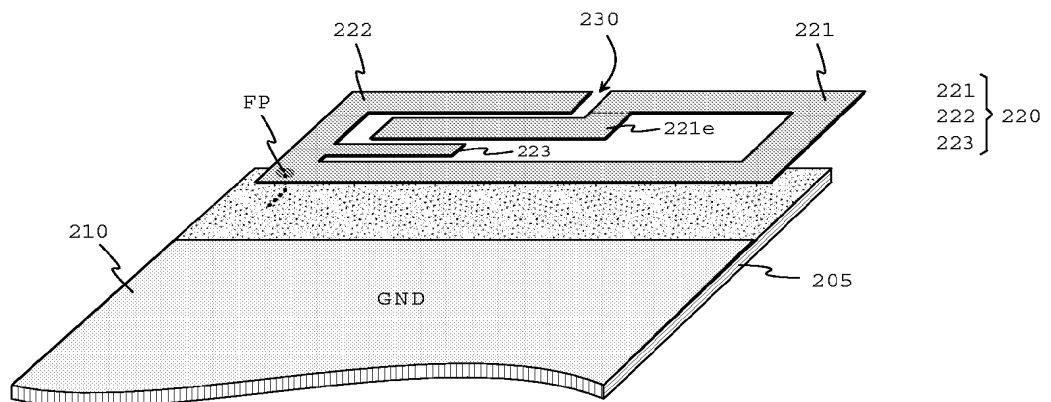


Fig. 2

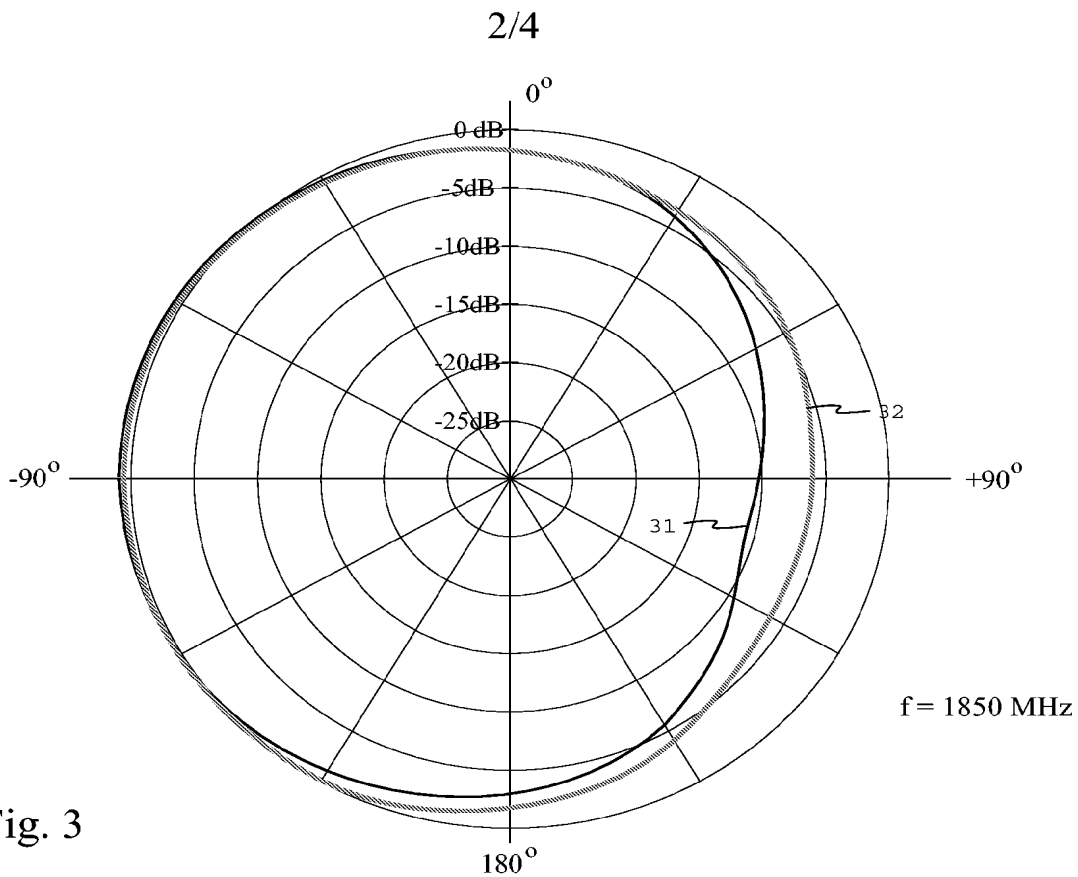


Fig. 3

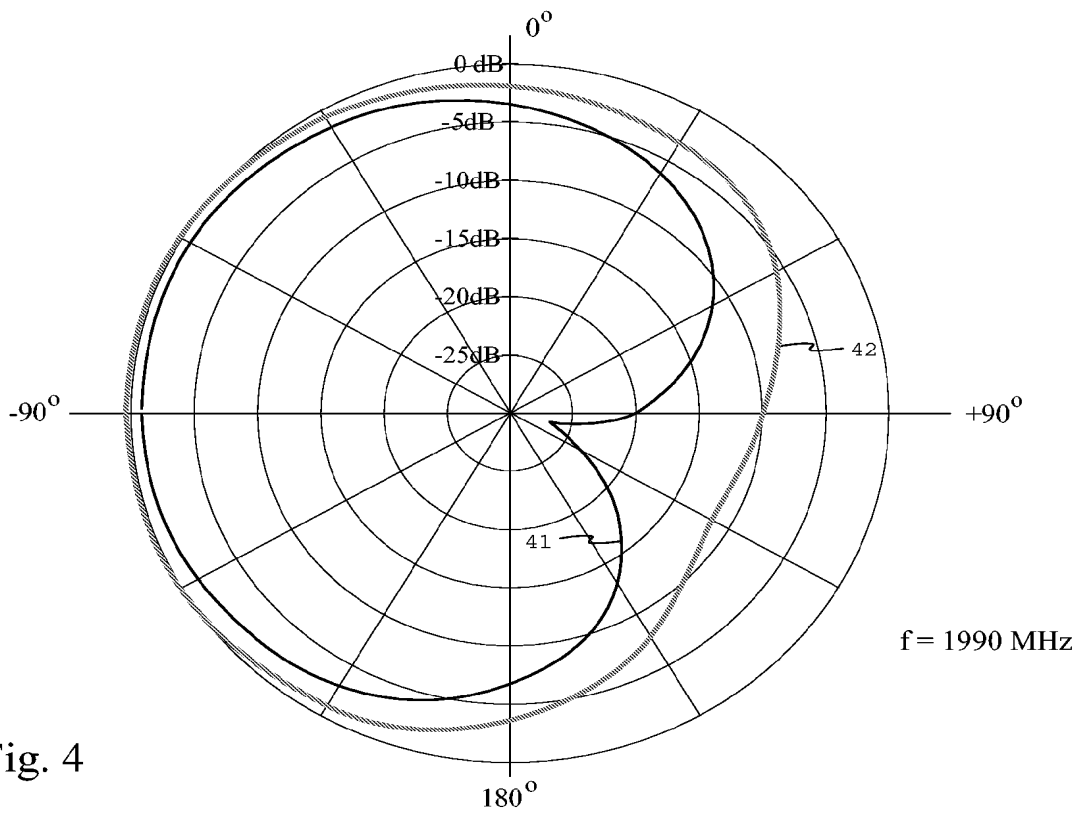


Fig. 4

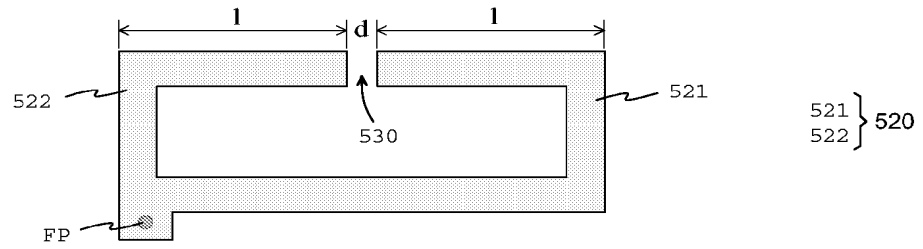


Fig. 5

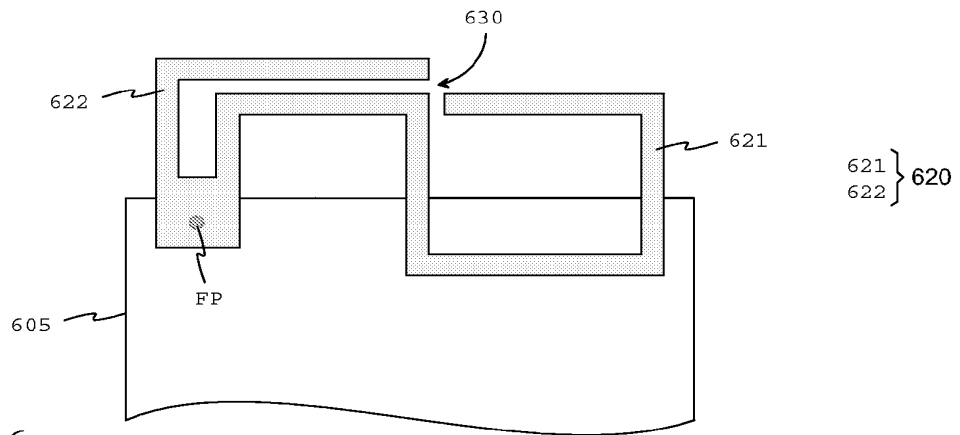


Fig. 6

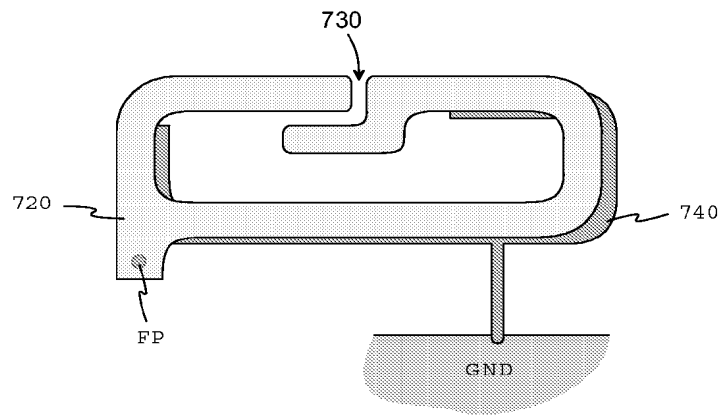


Fig. 7

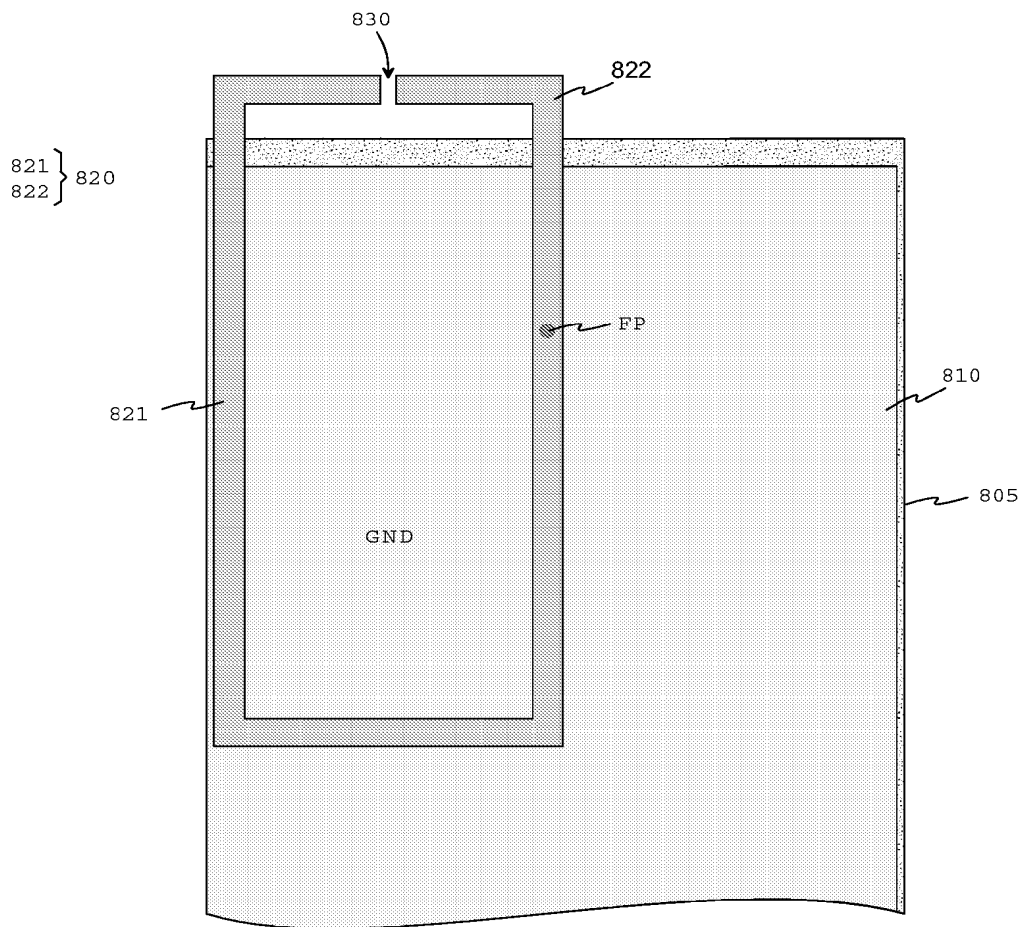


Fig. 8

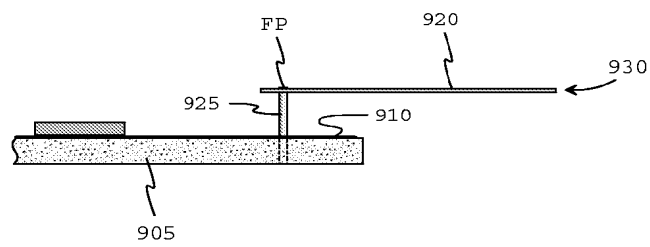


Fig. 9

INTERNATIONAL SEARCH REPORT

International application No.

PCT/FI2006/050407

A. CLASSIFICATION OF SUBJECT MATTER 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 8: H01Q Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched FI, SE, NO, DK Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-internal, WPI, XPI3E, XPIEE		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2004/0090366 A1 (WONG KIN-LU et al.) 13 May 2004 (13.05.2004), abstract; Fig. 1	1-9
A	US 2004/0178957 A1 (CHANG KUANG-YUAN et al.) 16 September 2004 (16.09.2004), the whole document; especially the abstract; Figs 1-9	1-9
A	US 2004/0090378 A1 (DAI HSIN KUO et al.) 13 May 2004 (13.05.2004), abstract; Fig. 1	1-9
A	US 6 097 345 A (WALTON ERIC K) 01 August 2000 (01.08.2000), abstract; Figs 2, 3, 4	1-9
A	WONG, K. et al.: "A Low-Profile Planar Monopole Antenna for Multiband Operation of Mobile Handsets". IEEE Transactions on Antennas and Propagation, January 2003. Vol. 51, no 1, pages 121-125	1-9
P, A	JING, X. et al.: "Compact Planar Monopole Antenna for Multi-Band Mobile Phones". Microwave Conference Proceedings, 4.-7.12.2005. APMC 2005, Asia-Pacific Conference Proceedings, Vol. 5, the whole document	1-9
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.		
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Date of the actual completion of the international search 29 November 2006 (29.11.2006)		Date of mailing of the international search report 12 January 2007 (12.01.2007)
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International application No.

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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 SEARCH REPORT
Information on patent family members

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US 6 097 345 A	01/08/2000	None	

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H01Q 5/00 (2006.01)

H01Q 9/04 (2006.01)