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(54) Antenna device

(57) An antenna device (51a; 51b; 51c; 51d) designed to increase the volume that it occupies in a mobile communication apparatus as well as to achieve a large gain and a wide frequency band width without occupying a large area on a main circuit board (53a; 53b) and without changing the overall size of the mobile communication apparatus. The antenna device (51a; 51b; 51c; 51d) is also designed so that its impedance can be set or finely adjusted in a simple manner. The antenna device has a current supply element (52) and a radiating element (56a; 56b), and is mounted on a main circuit board (53a; 53b), with the current supply element (52) placed on a major surface of the main circuit board (53a; 53b), and with the radiating element (56a; 56b) accommodated in a gap formed between the main circuit board (53a; 53b) and an outer case (55). One major surface of the radiating element (56a; 56b) is opposed to the current supply element (52) and is maintained in contact with the same.

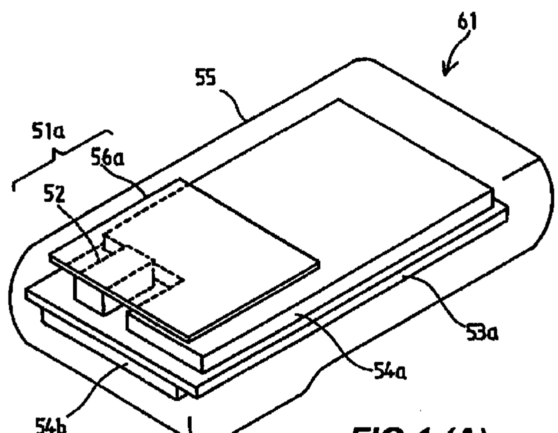

FIG.1 (A)

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Description

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to an antenna device for use in a mobile communication apparatus such as a portable telephone.

Description of the Related Art

Generally, there is a demand for antenna devices improved in gain, reflection loss and in other characteristics. There is also a demand for smaller antenna devices for use in mobile communication apparatuses.

For example, as a conventional antenna device, an inverted F type antenna is described in "Small Antennas" written by K. Fujimoto, A. Henderson, K. Hirasawa and J.R. James (Research Studies Press Ltd., England). Fig. 9 shows this inverted F type antenna. The inverted F type antenna shown in Fig. 9 has a rectangular metallic plate 72 which functions as a radiating portion. A grounding terminal 73 is formed on one side of the metallic plate 72 by being bent so as to be perpendicular to the metallic plate 72. A current supply terminal 74 is also formed on another side of the metallic plate 72 by bending a portion of the metallic plate 72.

The inverted F type antenna is constructed as described above and can be mounted on a printed circuit board by inserting its grounding and current supply terminals into through holes formed in the printed circuit board.

In the inverted F type antenna 71, however, it is difficult to reduce the size of the metallic plate 72 because the gain is not sufficiently large.

To solve this problem, the applicant of the present invention has proposed a circuit board surface mount type antenna (hereinafter referred to as "surface mount type antenna") in Japanese Patent Application No. 81652/1994, not published yet, which is related to commonly assigned U.S. Serial No. 08/230,857 filed April 21, 1994, allowed September 19, 1995. Fig. 10 shows this surface mount type antenna, and Figs. 11 to 14 show an example of the surface mount type antenna in which an antenna switch circuit is mounted as an antenna circuit.

Referring to Fig. 10, a member 1 is a dielectric substrate in the form of a rectangular prism made of a ceramic or resin, and a pair of grounding electrodes 2 are formed on opposite side surfaces of the dielectric substrate 1 corresponding to the longer sides of the two major surfaces of the dielectric substrate 1 while connection electrodes 3a, 3b, and 3c are formed on the other opposite side surfaces corresponding to the shorter sides. A member 4 is a metallic chassis made of, for example, copper or a copper alloy and having, as viewed in a cross section, the shape of a rectangle open at one side. The metallic chassis 4 has a rectangular flat radiating portion 5, and two fixing portions 6 and 7 bent downwardly and perpendicularly from shorter-side opposite ends of the radiating portion 5. A current supply terminal 8 and a grounding terminal 9 are formed integrally on the extreme end of the fixing portion 6. The fixing portion 6 is reduced in length relative to the fixing portion 7 to form the current supply terminal 8 and the grounding terminal 9. The overall length of the fixing portion 6, including the length of the current supply terminal 8 and the grounding terminal 9, is set so as to be larger than the thickness of the dielectric substrate 1.

The dielectric substrate 1 is inserted into the metallic chassis 4 with the shorter-side side surfaces of the dielectric substrate 1 brought into contact with inner surfaces of the fixing portions 6 and 7 of the metallic chassis 4. At this time, a vacant space 10 is formed between the radiating portion 5 of the metallic chassis 4 and the obverse surface of the dielectric substrate 1 due to the difference between the values of the thickness of the dielectric substrate 1 and the length of the fixing portion 6 including the current supply terminal 8 and the grounding terminal 9 and the fixing portion 7. The connection terminal 3a of the dielectric substrate 1 is soldered to the fixing portion 7 of the metallic chassis 4. Also, the connection terminals 3b and 3c of the dielectric substrate 1 are respectively soldered to the current supply terminal 8 and the grounding terminal 9 of the metallic chassis 4. Thus, a surface mount type antenna 13 is constructed.

A main circuit board 15 has, on its obverse surface, a micro-strip line 16 for supplying an antenna current, connected to an antenna circuit, e.g., an antenna switch circuit (not shown), and grounding electrodes 17a insulated from the micro-strip line 16. Also, a grounding electrode 17b is formed generally over the entire reverse surface of the main circuit board 15.

The surface mount type antenna 13 is placed on the obverse surface of the main circuit board 15, the current supply terminal 8 and the micro-strip line 16 are soldered to each other, and the pair of grounding electrodes 2 and the grounding electrode 9 are soldered to the grounding electrodes 17a on the obverse surface of the main circuit board 15. The surface mount type antenna 13 is thus mounted on the main circuit board 15 in a surface mount manner. Electric waves are transmitted or received through the radiating portion 5 of the metallic chassis 4.

Referring then to Figs. 11 and 12, a member 21 is a multilayer dielectric substrate in the form of a rectangular prism made of a ceramic or a resin. A transmission input portion TX, a receiving output portion RX, control input portions VC1 and VC2 of an antenna switch circuit and a plurality of grounding electrodes 22 are formed as external electrodes on opposite side surfaces of the dielectric substrate 21 corresponding to the longer sides of the two major surfaces of the dielectric substrate 21 while connection electrodes 23a, 23b, and 23c are formed on the other opposite side surfaces corresponding to the shorter sides. As circuits elements, a strip line 24a and capacitors 24b are formed in the dielectric substrate 21 while diodes 24c and printed resistors 24d are mounted on the obverse surface of the dielectric substrate 21, thus forming an antenna switch circuit 24. An antenna output portion 24e of the antenna switch circuit 24 in the dielectric substrate 21 is connected to the connection electrode 23b on the side surface, and the circuit elements are connected to each other by internal electrodes or via holes.

A member 26 is a metallic chassis made of, for example, copper or a copper alloy and having, as viewed in a cross section, the shape of a rectangle open at one side. The metallic chassis 26 has a rectangular flat radiating portion 27, and two fixing portions 28 and 29 bent downwardly and perpendicularly from shorter-side opposite ends of the radiating portion 27. A current supply terminal 30 and a grounding terminal 31 are formed integrally on the extreme end of the fixing portion 28. The fixing portion 28 is reduced in length relative to the fixing portion 29 to form the current supply terminal 30 and the grounding terminal 31. The overall length of the fixing portion 29, including the length of the current supply terminal 30 and the grounding terminal 31, is set so as to be larger than the thickness of the dielectric substrate 21.

The dielectric substrate 21 is inserted into the metallic chassis 26 with the shorter-side side surfaces of the dielectric substrate 21 brought into contact with inner surfaces of the fixing portions 28 and 29 of the metallic chassis 26. At this time, a vacant space 32 is formed between the radiating portion 27 of the metallic chassis 26 and the obverse surface of the dielectric substrate 21 due to the difference between the values of the thickness of the dielectric substrate 21 and the length of the fixing portion 28 including the current supply terminal 30 and the grounding terminal 31 and the fixing portion 29. The connection terminal 23a of the dielectric substrate 21 is soldered to the fixing portion 29 of the metallic chassis 26. Also, the connection terminals 23b and 23c of the dielectric substrate 21 are respectively soldered to the current supply terminal 30 and the grounding terminal 31 of the metallic chassis 26. Thus, a surface mount type antenna 35 is constructed.

Connection electrodes 37, 38, 39, and 40 and grounding electrodes 41a insulated from the connection electrodes 37 to 40 are formed on the obverse surface of a main circuit board 36. A grounding electrode 41b are formed on the entire reverse surface of the main circuit board 36.

The surface mount type antenna 35 is placed on the obverse surface of the main circuit board 36, and the transmission input portion TX, the receiving output portion RX and the control input portions VC1 and VC2 are respectively soldered to the connection electrodes 37 to 40 while the grounding electrodes 22 and the grounding terminal 31 are soldered to the grounding electrodes 41a. The surface mount type antenna 35 is thus mounted on the main circuit board 36 in a surface mount manner. Electric waves are transmitted or received through the radiating portion 27 of the metallic chassis 26.

Fig. 13 shows a well-known circuit as an example of the antenna switch circuit 24, and Fig. 14 is a block diagram of the antenna 35. An antenna circuit such as a low-pass filter or a band-pass filter may be mounted as well as the antenna circuit 24 shown in Fig. 13.

With respect to the antennas constructed as described above, it has been empirically recognized that the gain, the frequency band width and the volume occupied by the antenna have the following relationship:

$$(\text{Gain}) \times (\text{Frequency Band Width}) = (\text{Constant}) \times (\text{Volume occupied by Antenna})$$

and that reducing the antenna size is contrary to increasing the gain and increasing the frequency band width. Accordingly, the surface mount type antennas 13 and 35, occupying a small volume, are necessarily inferior than large antennas in gain and band characteristics. If the size of the surface mount type antennas 13 and 35 is increased, the antenna occupies a large area on the main circuit board such that the overall size of the mobile communication apparatus using the antenna is disadvantageously large.

There is also a need to design the antenna so that the impedance of the antenna matches with that of an internal circuit of the mobile communication apparatus in order to reduce reflection loss. The impedance of the inverted F type antenna 71, however, is determined by the position of the current supply terminal 4, the distance between the grounding terminal 3 and the current supply terminal 4 and other factors. Therefore, it is necessary to change the shape of the inverted F type antenna 71 in order to set or finely adjust the impedance of the antenna. Also in the case of the surface mount type antennas 13 and 35, the impedance is determined by the position of the current supply terminal 30, the distance between the grounding terminal 31 and the current supply terminal 30 and other factors. Accordingly, it is necessary to change the shape of the surface mount type antennas 13 and 35 for the purpose of setting or finely adjusting the impedance.

SUMMARY OF THE INVENTION

In view of these problems, an object of the present invention is to provide an antenna device designed to increase the volume that it occupies in a mobile communication apparatus as well as to achieve a large gain and a wide frequency band width without occupying a large area on a main circuit board and without changing the overall size of the mobile communication apparatus.

Another object of the present invention is to provide an antenna device the impedance of which can be set or finely adjusted more easily.

To achieve these object, according to one aspect of the present invention, there is provided an antenna device comprising a current supply element provided on a main circuit board, and a radiating element provided in a gap between the main circuit board and an outer case in which the main circuit board is accommodated, wherein one of two major surfaces of the radiating element faces the current supply element.

According to another aspect of the invention, the current supply element and the radiating element are in contact with each other.

According to yet another aspect of the invention, the current supply element and the radiating element are spaced apart from each other by such a distance as to be electromagnetically connected to each other.

According to still another aspect of the invention, a surface mount type antenna is used as the current supply element.

According to a further aspect of the invention, at least one edge of the radiating element is bent toward the main circuit board having a grounding electrode so as to be brought close to the grounding electrode.

According to still a further aspect of the invention, a part or the whole of the current supply element is inserted into a hole provided in the main circuit board.

According to still a further aspect of the invention, the radiating element is made of an electroconductive material.

According to still a further aspect of the invention, the radiating element is provided on a major surface of the main circuit board having the grounding electrode opposite from the surface of the main circuit board facing a human body.

In the above-described antenna device, only the current supply element is placed on the main circuit board while the radiating element is apart from the main circuit board, so that the area on the main circuit board occupied by the antenna device is limited.

Also, the radiating element is placed in the gap between the main circuit board and the outer case for accommodating the main circuit board, i.e., the space not used in the conventional arrangement. Therefore, the area of the radiating element can be largely increased without changing the overall size of the mobile communication apparatus. Accordingly, it is possible to increase the gain and the frequency band width of the antenna device.

Further, it is possible to easily change the resonance frequency and the impedance characteristic of the antenna device to reduce the reflection loss by selecting the position of the radiating element opposed to the current supply element. Accordingly, it is not necessary to change the shapes of the current supply element and the radiating element in order to set or finely adjust the impedance.

BRIEF DESCRIPTION OF THE DRAWINGS

Figs. 1(A)	through 1(C) are a perspective view, a front view and a side view, respectively, of an antenna device in accordance with a first embodiment of the present invention seen through a case;
Fig. 2	is a perspective view of an example of a current supply element in the antenna device of the first embodiment;
Fig. 3(A)	is a block diagram showing connections in an example of the antenna device of the first embodiment using a current supply element;
Fig. 3(B)	is a block diagram showing connections in another example of the antenna device of the first embodiment using a surface mount type antenna;
Figs. 4(A) and 4(B)	are a front view and a side view, respectively, of an antenna device in accordance with a second embodiment of the present invention seen through a case;
Fig. 5(A)	is a block diagram showing connections in an example the antenna device of the second embodiment using a current supply element;
Fig. 5(B)	is a block diagram showing connections in another example of the antenna device of the second embodiment using a surface mount type antenna;
Fig. 6(A)	is a side view of an example of an antenna device in accordance with a third embodiment of the present invention seen through a case, wherein a current supply element and a radiating element are in contact with each other;

Fig. 6(B)	is a side view of another example of an antenna device in accordance with the third embodiment of the present invention seen through a case, wherein a current supply element and a radiating element are spaced apart from each other by such as distance as to be electromagnetically connected to each other;
Figs. 7(A) through 7(C)	are a perspective view, a front view and a side view, respectively, of an antenna device in accordance with a fourth embodiment of the present invention seen through a case;
Figs. 8(A) and 8(B)	are a front view and a side view, respectively, of another example of the antenna device in accordance with the fourth embodiment seen through a case;
Fig. 9	is a perspective view of a conventional inverted F type antenna;
Fig. 10	is a perspective view of a surface mount type antenna;
Fig. 11	is a perspective view of a surface mount type antenna incorporating an antenna switch circuit;
Fig. 12	is a cross-sectional view of Fig. 11;
Fig. 13	is a circuit diagram of an antenna switch circuit; and
Fig. 14	is a block diagram of the antenna shown in Fig. 11.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the present invention will be described below with reference to the accompanying drawings.

Figs. 1(A) to 1(C) and 2 show an antenna device 51a and a current supply element 52 in accordance with a first embodiment of the present invention. The antenna device 51a is incorporated in a portable telephone 61. Figs. 1(A), 1(B), and 1(C) are a perspective view, a front view and a side view, respectively, of the antenna device seen through a case, and Fig. 2 is a perspective view of the current supply element 52.

Referring to Figs. 1(A) to 1(C) and 2, the antenna device 51a has the current supply element 52 and a radiating element 56a, and is mounted on a main circuit board 53a with the current supply element 52 placed on a major surface of the main circuit board 53a. The current supply element 52 is connected to a micro-strip line 66 which is formed on the main circuit board 53a to supply an antenna current. The radiating element 56a is accommodated in a vacant space formed between the main circuit board 53a and an outer case 55 in which the main circuit board 53a is accommodated. The current supply element 52 is grounded to a grounding electrode 67a formed on the main circuit board 53a while the radiating element 56a is grounded to the outer case 55. One major surface of the radiating element 56a is opposed to and maintained in contact with the current supply element 52. To protect the main circuit board 53a, shield covers 54a and 54b are attached to the two surfaces of the main circuit board 53a over the entire areas thereof excepting the area where the current supply element 52 is placed.

The current supply element 52 is made of, for example, copper or a copper alloy and has, as viewed in a cross section, the shape of a rectangle open at one side. The current supply element 52 has a rectangular flat opposed portion 52a opposed to the major surface of the radiating element 56a in parallel with the same, and two leg portions 52b and 52c bent downwardly and perpendicularly from shorter-side opposite ends of the opposed portion 52a. A current supply terminal 52d and a grounding terminal 52e are formed integrally on the extreme end of the leg portion 52b.

The micro-strip line 66 and grounding electrodes 67a formed on the obverse surface of the main circuit board 53a are insulated from each other. A grounding electrode 67b is formed generally over the entire reverse surface of the main circuit board 53a.

To mount the current supply element 52 in a surface mount manner, the current supply element 52 is placed on the obverse surface of the main circuit board 53a, the current supply terminal 52d and the micro-strip line 66 are soldered to each other, and the grounding terminal 52e is soldered to the grounding electrode 67a on the obverse surface of the main circuit board 53a.

The shape of the current supply element 52 is not limited to that shown in Fig. 2, and the current supply element 52 may have any other shape as long as at least one current supply terminal 52d and at least one grounding terminal 52e are provided and a transmitted electric wave output can be supplied to the radiating element 56a electrically or electromagnetically. For example, the current supply element 52 may be formed of a metallic block. The positional relationship between the current supply terminal 52d and the grounding terminal 52e is not limited to that shown in Fig. 2. For example, the current supply terminal 52d and the grounding terminal 52e may be respectively formed on different leg portions of the current supply element 52. Further, for the purpose of reducing the resonance frequency of the antenna device 51a, a dielectric may be inserted in the current supply element 52 to provide the current supply element 52 with an electrostatic capacity.

In this antenna device 51a, the current supply element 52 and the radiating element 56a in contact with each other are electrically connected as shown in Fig. 3(A), and a transmitted electric wave output from the current supply element 52 is radiated through the radiating element 56a. In Fig. 3(A), C1 represents a stray capacity of the radiating element 56a.

In the thus-constructed antenna device 51a, only the current supply element 52 of the antenna 51a is placed on the main circuit board 53a while the radiating element 56a is apart from the main circuit board, so that the area occupied by the antenna device 51 on the main circuit board 53a is limited. Also, the radiating element 56a is placed in the gap between the main circuit board 53a and the outer case 55 for accommodating the main circuit board 53a, i.e., the space not used in the conventional arrangement. Accordingly, the area of the radiating element 56a can be largely increased without changing the overall size of the portable telephone 61, thus making it possible to increase the gain and the frequency band width of the antenna device.

The position of the radiating element 56a opposed to the current supply element 52 can be selected to change the resonance frequency and the impedance characteristic of the antenna 51a, whereby the reflection loss can be reduced. Accordingly, it is not necessary to change the shapes of the current supply element 52 and the radiating element 56a in order to set or finely adjust the impedance, and impedance setting or fine adjustment can be performed easily in comparison with the conventional art. It is possible to reduce the Joule loss by forming the radiating element 56a of an electroconductive material such as copper or a copper alloy. The gain of the antenna can be improved thereby. Further, the radiating element 56a is provided on the major surface of the main circuit board 53a having the grounding electrodes 67a and 67b opposite from the surface facing the human body of a user to attenuate the output transmitted in the direction of the human body by a shielding effect of the grounding electrodes 67a and 67b, thereby reducing the influence of the transmission output on the human body.

Each of the surface mount type antennas 13 and 35 constructed as shown in Figs. 10 to 13 may be used in place of the current supply element 52. The surface mount type antenna 13 or 35 and the radiating element 56a are electrically connected to each other as shown in Fig. 3(B), and a transmitted electric wave output from the surface mount type antenna is radiated from the radiating element 56a.

In such an arrangement, the above-described effect of the present invention can also be achieved by the operation of the radiating element 56a while the same antenna unit as the surface mount type antenna is used.

Figs. 4(A) and 4(B) show an antenna device 51b in accordance with a second embodiment of the present invention. The antenna device 51b is incorporated in a portable telephone 62. Figs. 4(A) and 4(B) are front and side views of the antenna device seen through a case. The components identical or corresponding to those shown in Fig. 1 are indicated by the same reference characters and the description for them will not be repeated.

Referring to Figs. 4(A) and 4(B), the antenna device 51b is constructed in such a manner that the antenna device 51a and the current supply element 52 of the first embodiment are mounted while being spaced apart from each other by such a distance as to be electromagnetically connected to each other.

In this arrangement, the current supply element 52 and the radiating element 56a are electromagnetically connected by a magnetic field and a stray capacity in the space formed between the current supply element 52 and the radiating element 56a, as shown in Fig. 5(A), and a transmitted electric wave output from the current supply element 52 is radiated by the radiating element 56a. C2 represents the stray capacity of the radiating element 56a. In this arrangement, the current supply portion 52 and the radiating element 56a are not electrically connected since they do not contact each other, but they are electromagnetically connected to each other. Therefore, the same effect as that of the above-described antenna device 51a of the first embodiment can also be obtained.

Also in the second embodiment, each of the surface mount type antennas shown in Figs. 10 to 13 can be used as the current supply element 52. In such a case, the surface mount type antenna 13 or 35 and the radiating element 56a are electromagnetically connected to each other by a magnetic field and a stray capacity in the space between the surface mount type antenna 13 or 35 and the radiating element 56a, as shown in Fig. 5(B), and a transmitted electric wave output from the surface mount type antenna can therefore be radiated from the radiating element 56a.

Fig. 6(A) shows a side view of an antenna device 51c in accordance with a third embodiment of the present invention seen through a case. The antenna device 51c is incorporated in a portable telephone 63. The components identical or corresponding to those shown in Fig. 1 are indicated by the same reference characters and the description for them will not be repeated.

As shown in Fig. 6(A), in the antenna device 51c, a radiating element 56b is provided by bending one edge 56z of the radiating element 56a of the first embodiment toward a main circuit board 53a having a grounding electrode (not shown) so that the edge 56z is brought close to the grounding electrode.

In the thus-constructed antenna device 51c, the edge 56z of the radiating element 56b is brought close to the grounding electrode 67a so that the distance between the radiating element 56b and ground is small. In this manner, the stray capacity of the radiating element 56b can be increased. Consequently, the resonance frequency of the antenna device 51c can be lowered.

Also, another antenna device 51c may be constructed in such a manner that, a shown in Fig. 6(B), a radiating element 56b is formed by bending one edge 56z of the radiating element 56a of the second embodiment toward the main circuit board 53a so that the edge 56z is brought close to the main circuit board 53a, thereby obtaining the same effect as the above-described arrangements.

The antenna device 51c can function with substantially the same effect as those described above as long as the bent edge 56g is provided as at least a part of the edges of the radiating element 56b.

Figs. 7(A), 7(B), and 7(C) show an antenna device 51d in accordance with a fourth embodiment of the present invention. The antenna device 51d is incorporated in a portable telephone 64. Figs. 7(A), 7(B) and 7(C) are a perspective view, a front view and a side view, respectively of the antenna device seen through a case. The components identical or corresponding to those shown in Fig. 1 are indicated by the same reference characters and the description for them will not be repeated.

In the antenna device 51d, as shown in Figs. 7(A) to 7(C), a main circuit board 53b is provided by forming a hole 57 in the main circuit board 53a of the first embodiment, and a part of the current supply element 52 is inserted into the hole 57.

In the thus-constructed antenna device 51d, a part of the current supply element 52 is inserted into the hole 57 formed in the main circuit board 53b to reduce the height of the current supply element 52 projecting from the main circuit board 53b. The height of the portion of the antenna device 51d projecting from the main circuit board 53b is correspondingly reduced. Thus, it is possible to further reduce the thickness of the portable telephone 64.

The arrangement may also be such that, as shown in Figs. 8(A) and 8(B), a main circuit board 53b is provided by forming a hole 57 in the main circuit board 53a of the second embodiment, and a part of the current supply element 52 is inserted into the hole 57, thereby achieving the same effect as in the above-described arrangement. Also, another antenna device 51d may be constructed by bending an edge of the radiating element 56a so as to form a radiating element 56b, as in the case of the antenna device 51c of the third embodiment shown in Figs. 6(A) and 6(B).

To further reduce the overall thickness of the portable telephone, the current supply element 52 may be mounted so that its portion projects on the reverse side of the main circuit board 53b through the hole 57.

In the antenna device of the present invention, as described above, only the current supply element of the antenna device is placed on the main circuit board while the radiating element is apart from the main circuit board, so that the area on the main circuit board occupied by the antenna device is limited and the desired flexibility of circuit layout can be maintained.

The radiating element is placed in the gap between the main circuit board and the outer case for accommodating the main circuit board, i.e., the space not used in the conventional arrangement. Therefore, the area of the radiating element can be largely increased relative to that of the radiating element of the surface mount type antenna without changing the overall size of the portable telephone. Consequently, it is possible to increase the gain and the frequency band width of the antenna device.

It is possible to easily change the resonance frequency and the impedance characteristic of the antenna device to reduce the reflection loss by selecting the position of the radiating element opposed to the current supply element. Accordingly, it is not necessary to change the shapes of the current supply element and the radiating element in order to set or finely adjust the impedance, and impedance setting or fine adjustment can be performed more easily.

In the case where the antenna is constructed by maintaining the current supply element and the radiating element in contact with each other, the current supply element and the radiating element are electrically connected to enable the transmitted electric wave output from the current supply element to be radiated from the radiating element.

In the case where the antenna is constructed by maintaining the current supply element and the radiating element at such a distance from each other that they are electromagnetically connected to each other, the transmitted electric wave output from the current supply element can also be radiated from the radiating element since the current supply element and the radiating element are electromagnetically connected to each other.

A surface mount type antenna may also be used in place of the current supply element to obtain the above-described effect.

The arrangement may also be such that an edge of the radiating portion is bent toward the main circuit board having a grounding electrode so as to be brought close to the grounding electrode, whereby the distance between the radiating element and ground is reduced and the stray capacity of the radiating element is increased. As a result, the resonance frequency of the antenna device can be lowered.

A part or the whole of the current supply element may be inserted into a hole formed in the main circuit board to reduce the height of the part of the current supply element projecting from the main circuit board. Correspondingly, the height of the portion of the antenna device projecting from the main circuit board is reduced, thereby reducing the overall thickness of the mobile communication apparatus.

The radiating element is made of an electroconductive material to reduce the Joule loss of the radiating element, thereby increasing the gain of the antenna device.

Further, the radiating element is provided on the major surface of the main circuit board with the grounding electrode opposite from the surface facing the human body of a user, so that the transmission output in the direction of the human body attenuates by the shielding effect of the grounding electrode. The influence of the transmission output on the human body is reduced thereby.

Claims

1. An antenna device (51a; 51b; 51c; 51d) comprising:
a current supply element (52) provided on a main circuit board (53a; 53b); and
a radiating element (56a; 56b) provided in a gap between said main circuit board (53a; 53b) and an outer case (55) in which said main circuit board (53a; 53b) is accommodated,
wherein one of two major surfaces of said radiating element (56a; 56b) is faced to said current supply element (52).

2. An antenna device (51a; 51c; 51d) according to Claim 1, wherein said current supply element (52) and said radiating element (56a; 56b) are in contact with each other.

3. An antenna device (51b; 51c; 51d) according to Claim 1, wherein said current supply element (52) and said radiating element (56a; 56b) are spaced apart from each other by such a distance as to be electromagnetically connected to each other.

4. An antenna device (51a; 51b; 51c) according to one of Claims 1 to 3, wherein a surface mount type antenna is used as said current supply element (52).

5. An antenna device (51c) according to one of Claims 1 to 4, wherein at least one edge of said radiating element (56b) is bent toward said main circuit board (53a) having a grounding electrode (67a) so as to be brought close to the grounding electrode (67a).

6. An antenna device (51d) according to one of Claims 1 to 3, wherein a part or the whole of said current supply element (52) is inserted into a hole (57) provided in said main circuit board (53b).

7. An antenna device according to one of Claims 1 to 6, wherein said radiating element (56a; 56b) is made of an electroconductive material.

8. An antenna device (51a; 51b; 51c; 51d) according to one of Claims 1 to 7, wherein said radiating element (56a; 56b) is provided on a major surface of said main circuit board (53a; 53b) having the grounding electrode (67a; 67b) opposite from the surface of said main circuit board facing a human body.

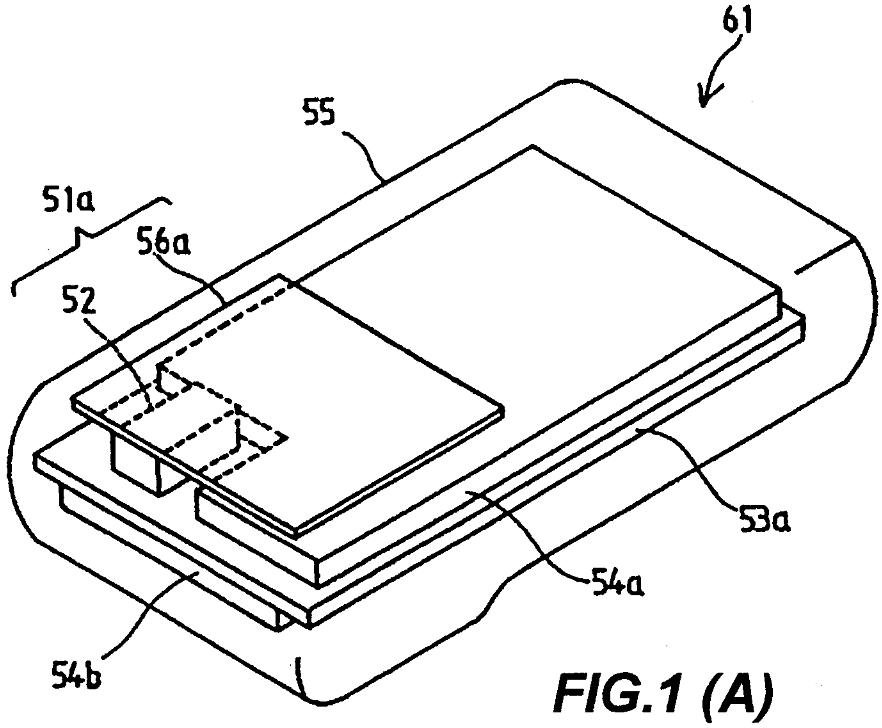

FIG.1 (A)

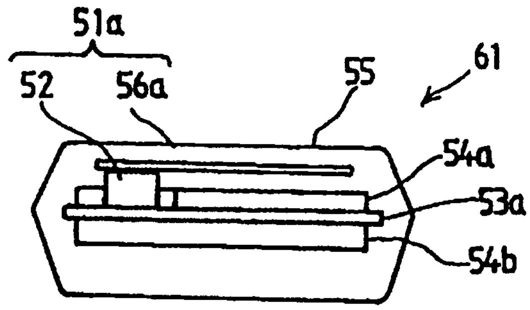

FIG.1 (B)

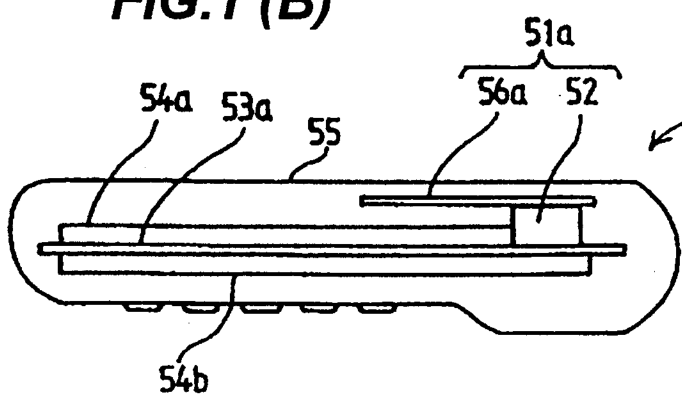

FIG.1 (C)

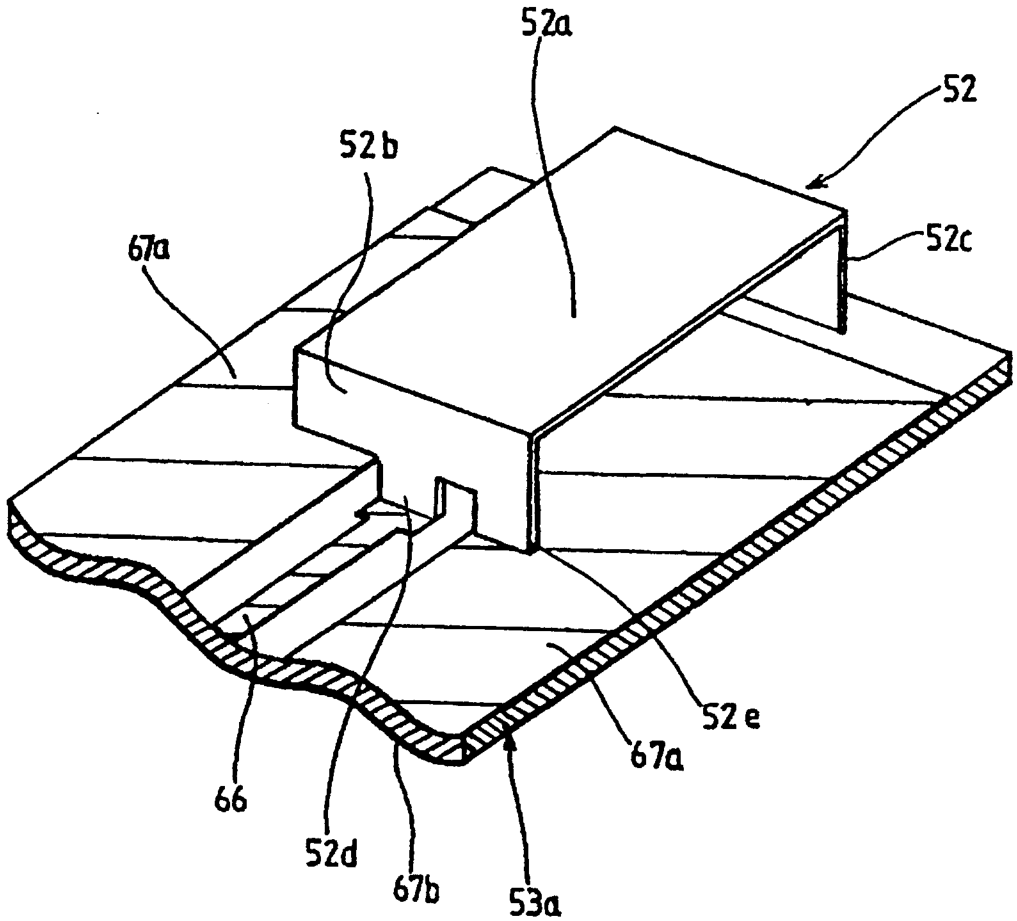

FIG.2

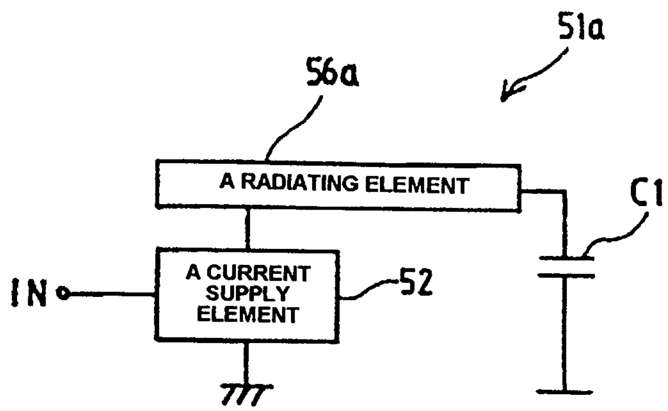
51a
56a
A RADIATING ELEMENT
C1
A CURRENT SUPPLY ELEMENT
52
IN

FIG.3(A)

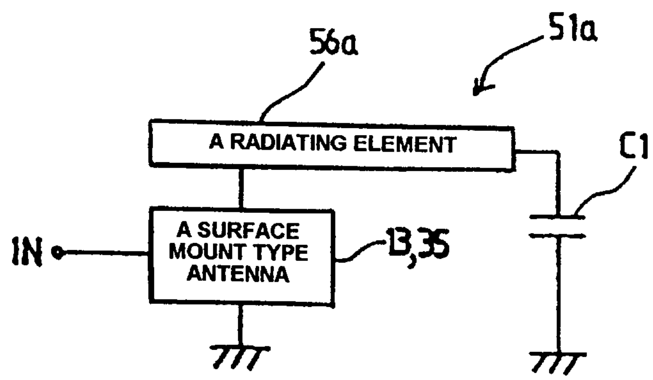
51a
56a
A RADIATING ELEMENT
C1
A SURFACE MOUNT TYPE ANTENNA
13,35
IN

FIG.3(B)

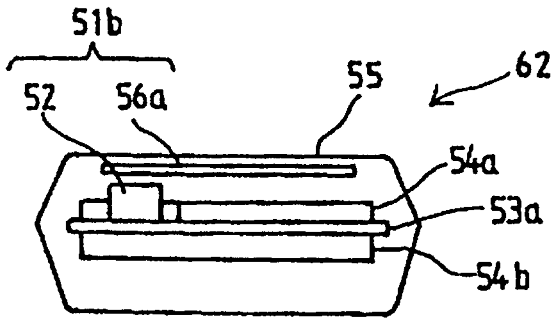

FIG.4(A)

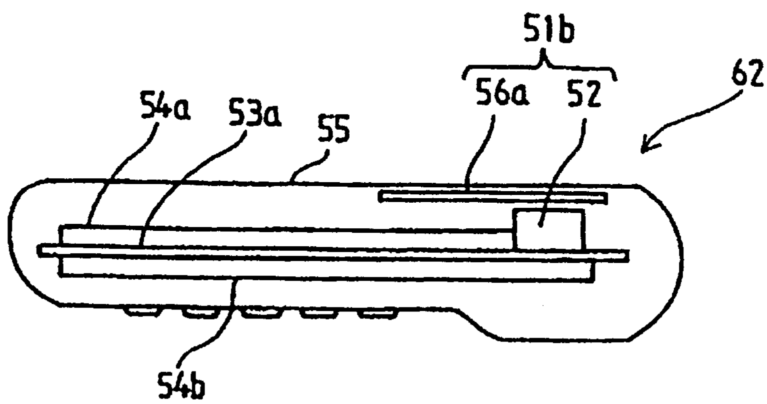

FIG.4(B)

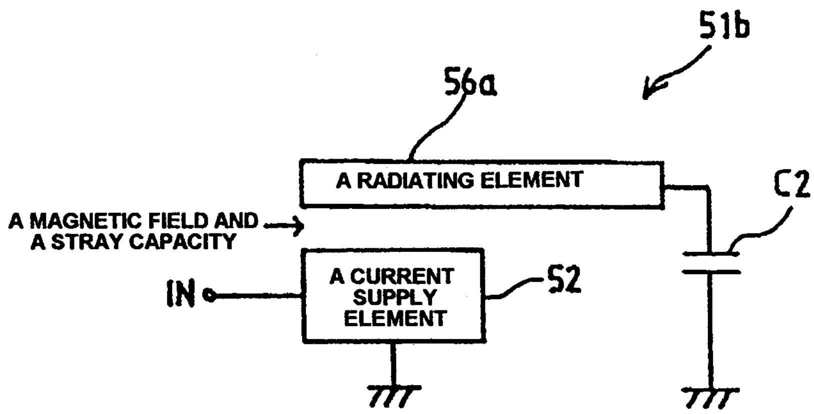
51b
56a
A RADIATING ELEMENT
C2
A MAGNETIC FIELD AND
A STRAY CAPACITY
IN
A CURRENT
SUPPLY
ELEMENT
52

FIG.5(A)

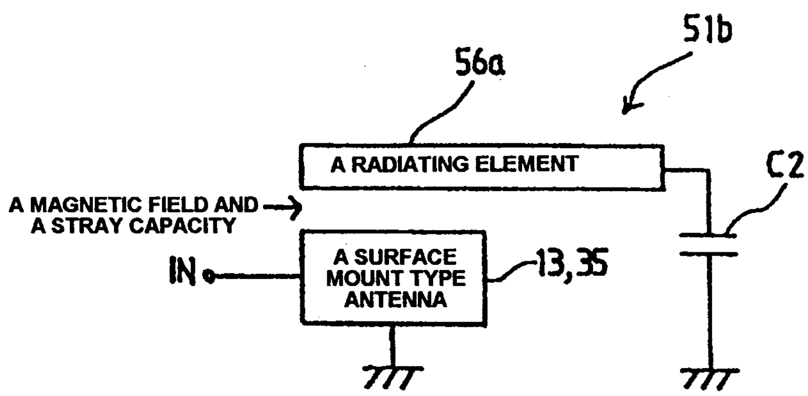
51b
56a
A RADIATING ELEMENT
C2
A MAGNETIC FIELD AND
A STRAY CAPACITY
IN
A SURFACE
MOUNT TYPE
ANTENNA
13,35

FIG.5(B)

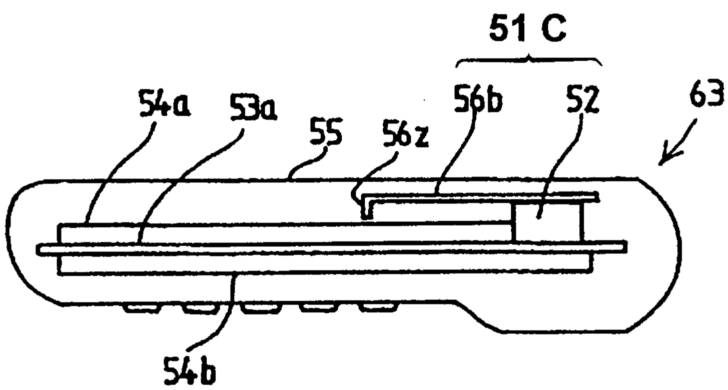

FIG.6(A)

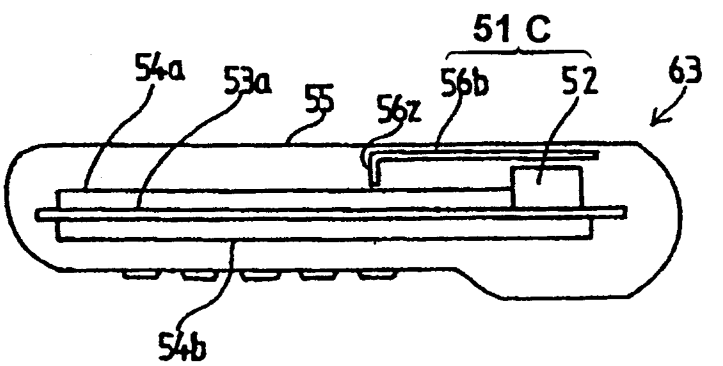

FIG.6(B)

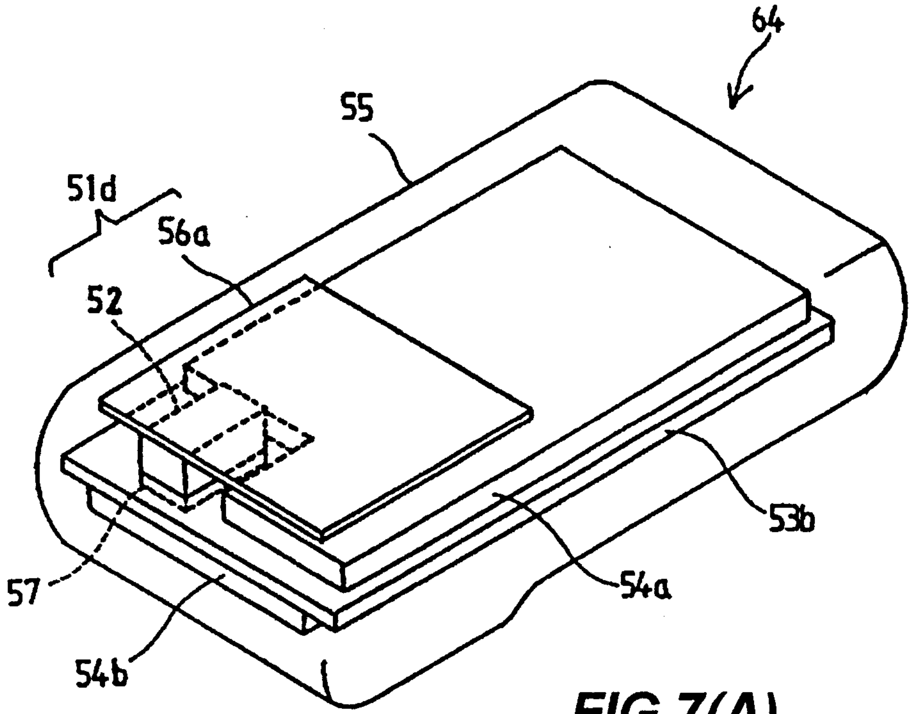

FIG.7(A)

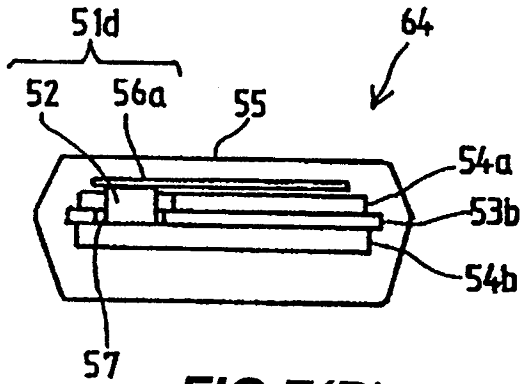

FIG.7(B)

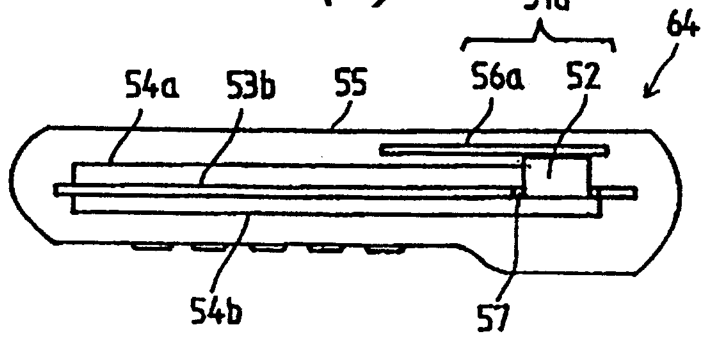

FIG.7(C)

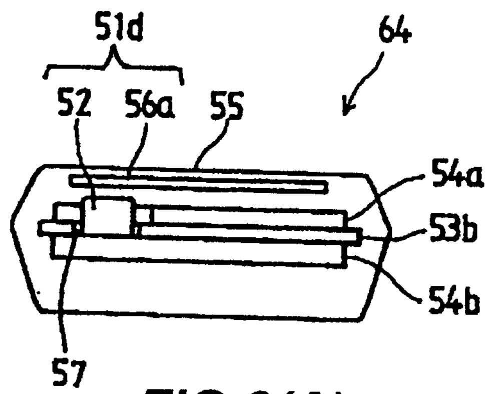

FIG.8(A)

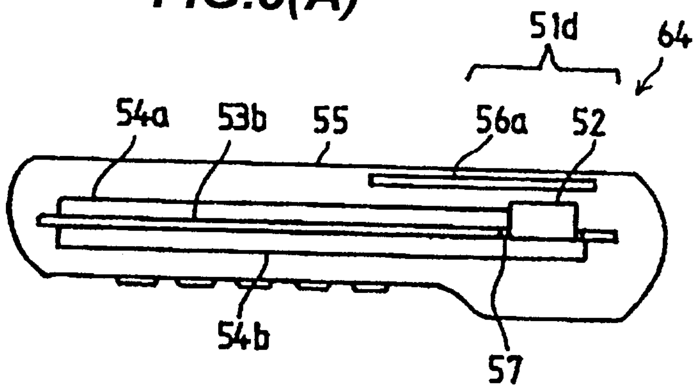

FIG.8(B)

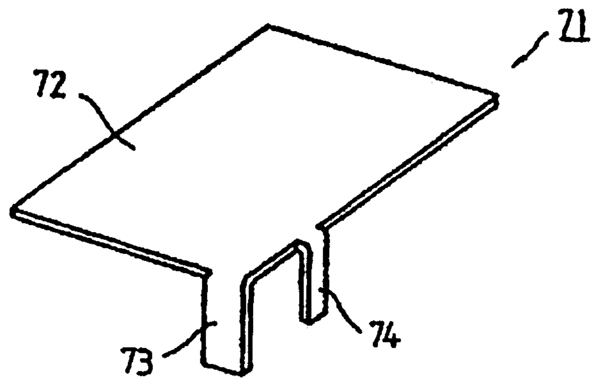

FIG.9

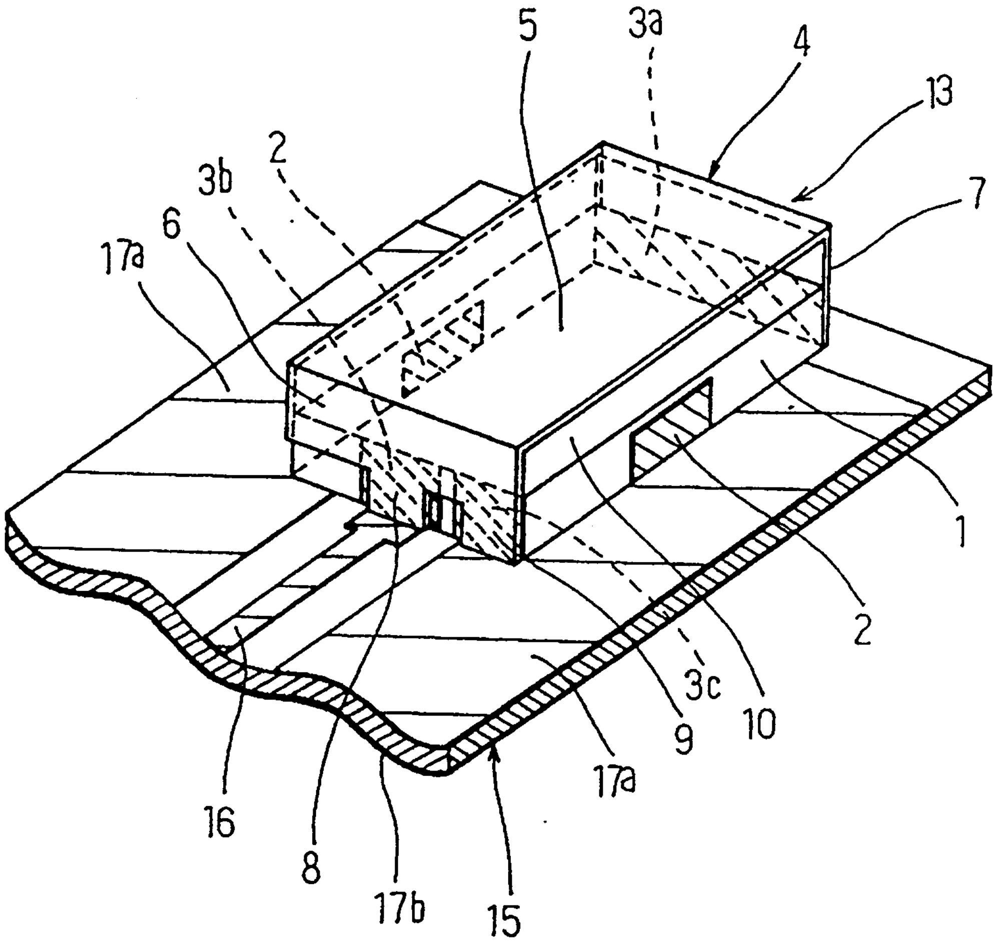

FIG. 10

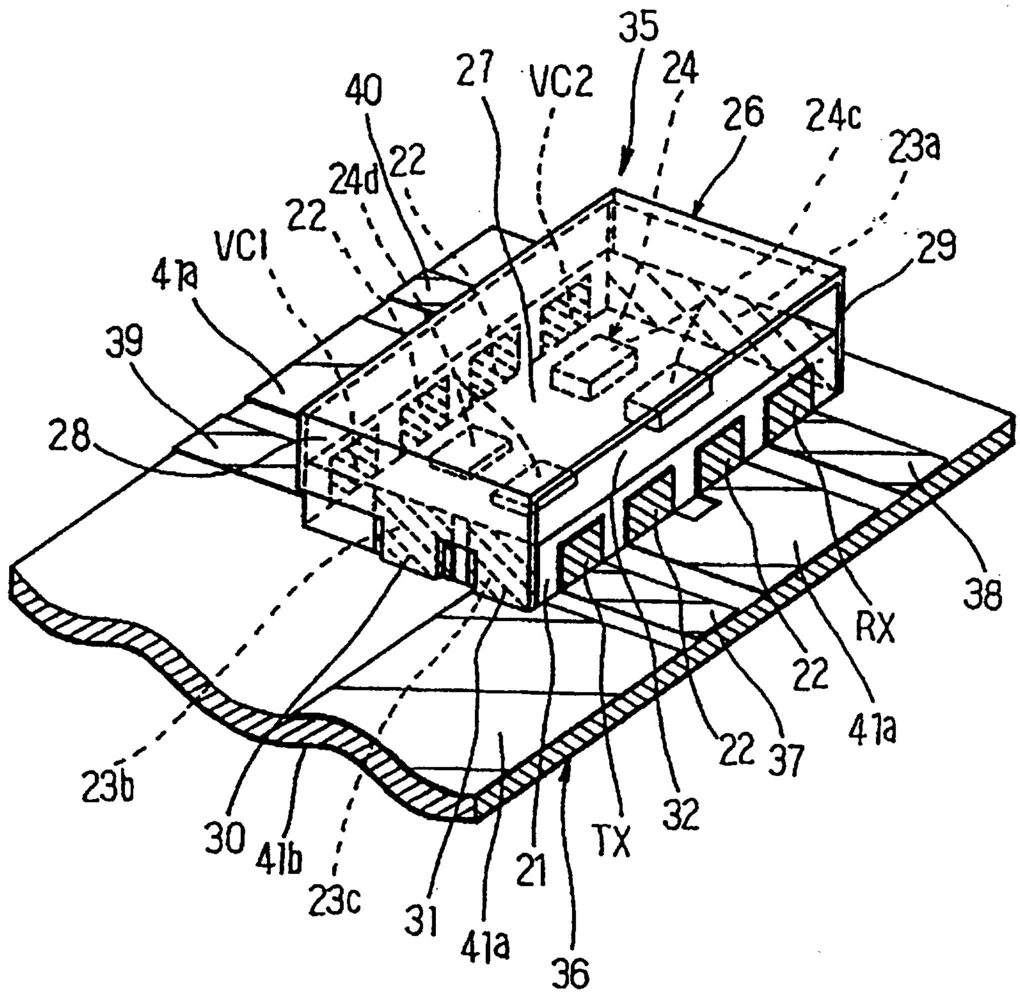
35
27
VC2
24
40
26
24c
23a
24d
22
22
VC1
29
41a
39
28
38
RX
22
41a
22
37
23b
32
TX
30
41b
21
23c
31
41a
36

FIG.11

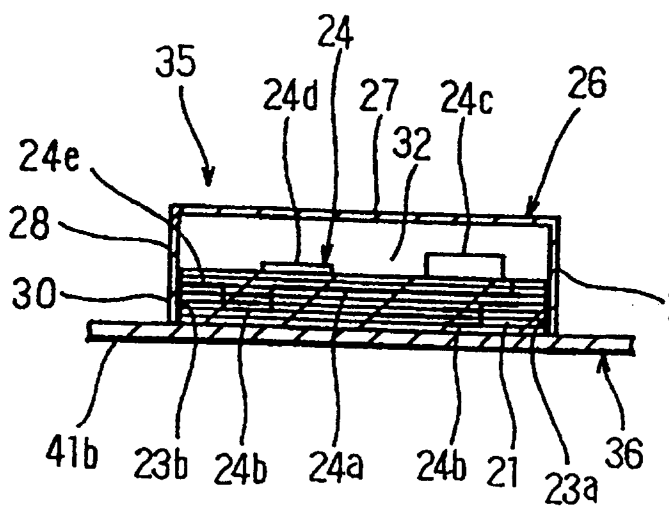
24
35
24d
27
24c
26
24e
32
28
30
29
41b
23b
24b
24a
24b
21
23a
36

FIG.12

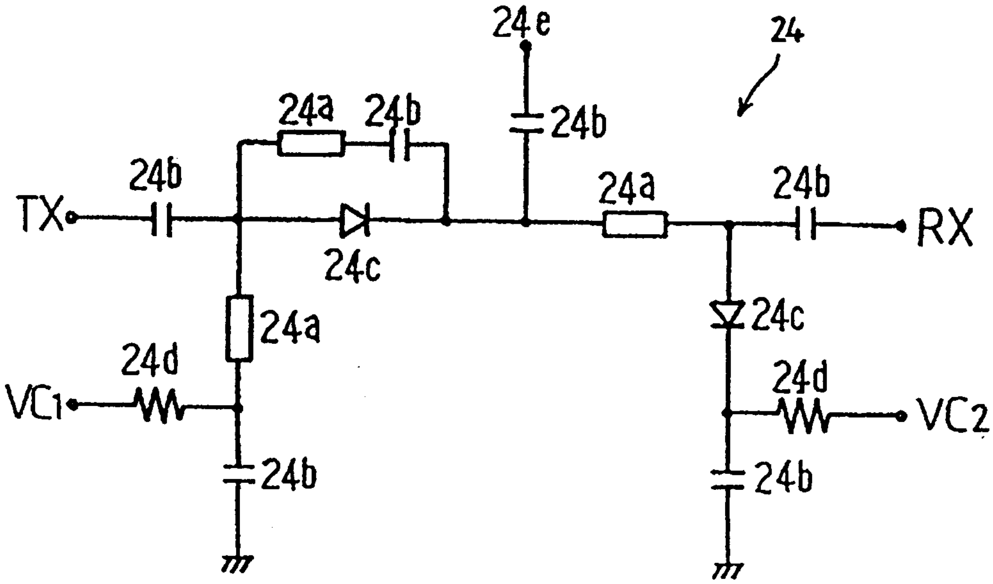
24e
24
24a
24b
24b
24b
24a
24b
TX
RX
24c
24c
24a
24d
24d
VC1
VC2
24b
24b

FIG.13

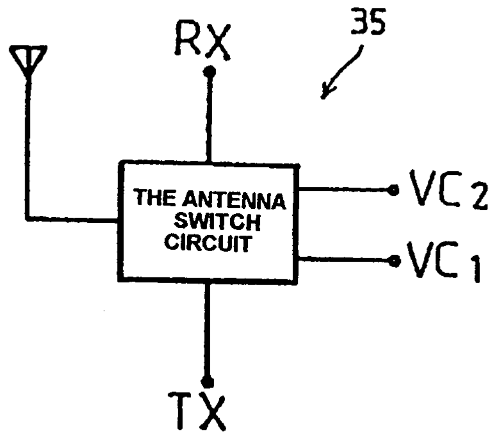
RX
35
THE ANTENNA SWITCH CIRCUIT
VC 2
VC 1
TX

FIG.14

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 95 11 5886

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
Y	EP-A-0 526 643 (MITSUBISHI) * abstract; figures 1-6,9 *	1-3,7	H01Q9/04 H01Q1/24
Y	EP-A-0 246 026 (UNIDEN) * claims 1-7; figures 4,5 *	1-3,7	
A	EP-A-0 400 872 (HARADA) * claims 1-18; figures 1,3A,4A *	1-8	
A	US-A-4 724 443 (NYSEN) * claims 1-7; figures 1-7 *	1	
P,A	EP-A-0 621 653 (MURATA) * abstract; figures 1-40C *	1	

TECHNICAL FIELDS SEARCHED (Int.Cl.6)

H01Q

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	24 January 1996	Angrabeit, F

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
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P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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