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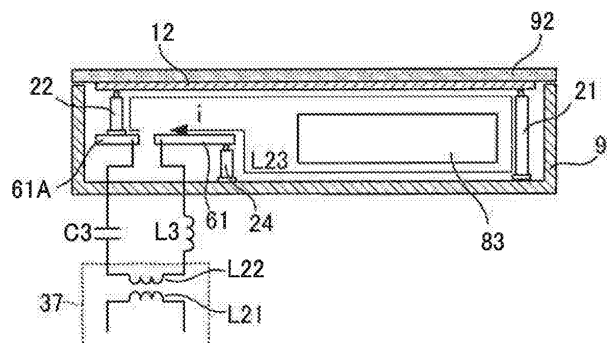
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(54) Title of the Invention: **Antenna device, electricity supply element, and communication terminal device**  
Abstract Title: **Loop antenna device with inductively coupled integrated circuit element**

(57) A loop antenna device comprising a feed circuit or integrated circuit (RFIC 60, fig 1) connected to a first coil L21 and a second coil L22 magnetically coupled to the first coil and a conductor member 12 wherein the conductor member and the second coil constitute a loop. The loop may also include capacitors C3 and inductor L3. Such an arrangement may allow current *i* to flow through the following circular path: second coil L22, capacitor C3, mounting portion 61A, connector 22, conductor surface 12, connector 21, casing part 91, connector 24, circuit board 61 (which includes a ground connector) and inductor L3. Thus, this path defines an opening that may act as a radiation portion that allows inductive coupling between the antenna and an RFID reader. The connectors 21, 22 and 24 may be spring connectors. The antenna may be an HF or UHF band antenna and employed in Near Field Communication (NFC).

FIG. 15 (A)



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FIG. 1

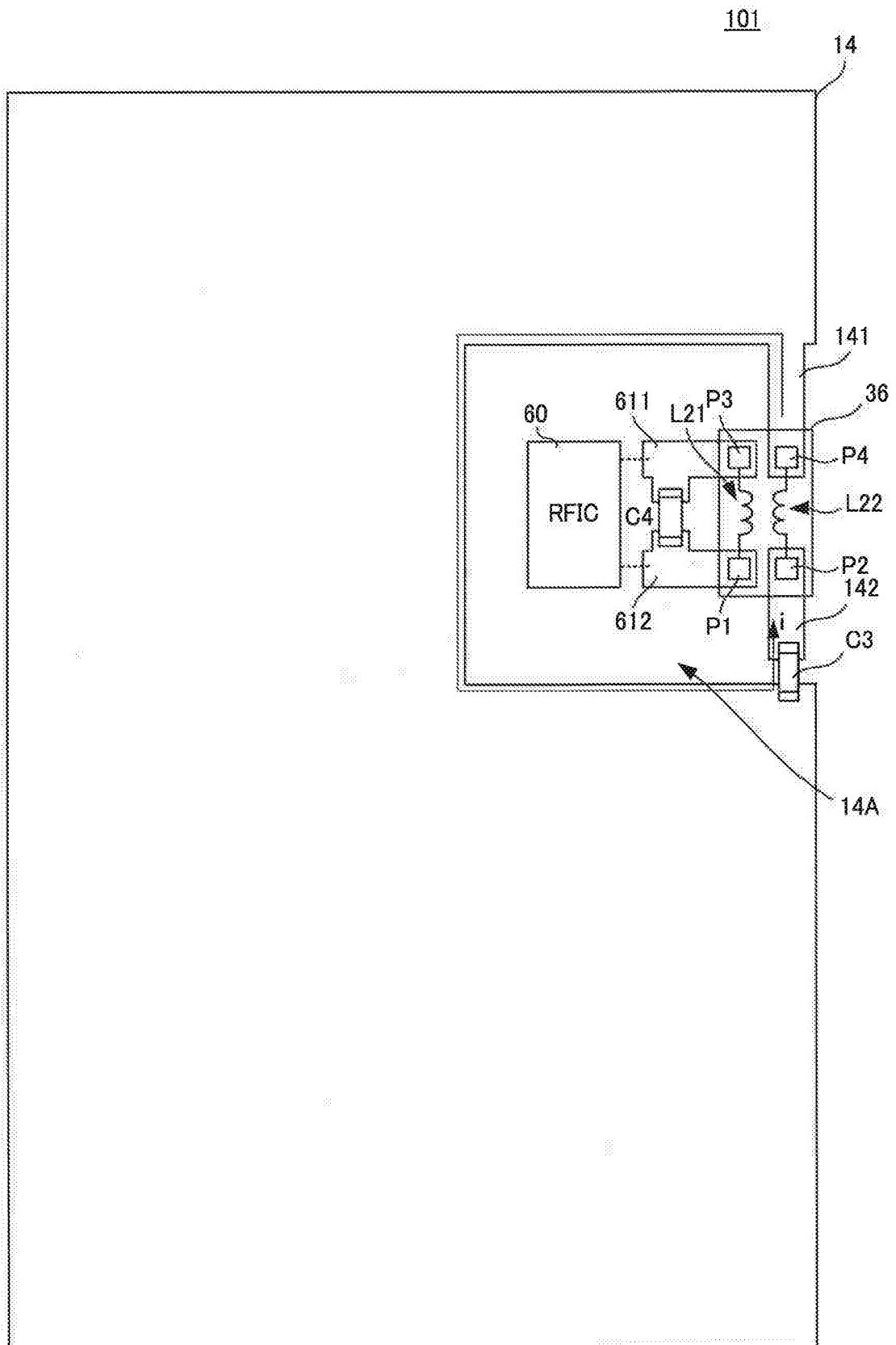


FIG. 2

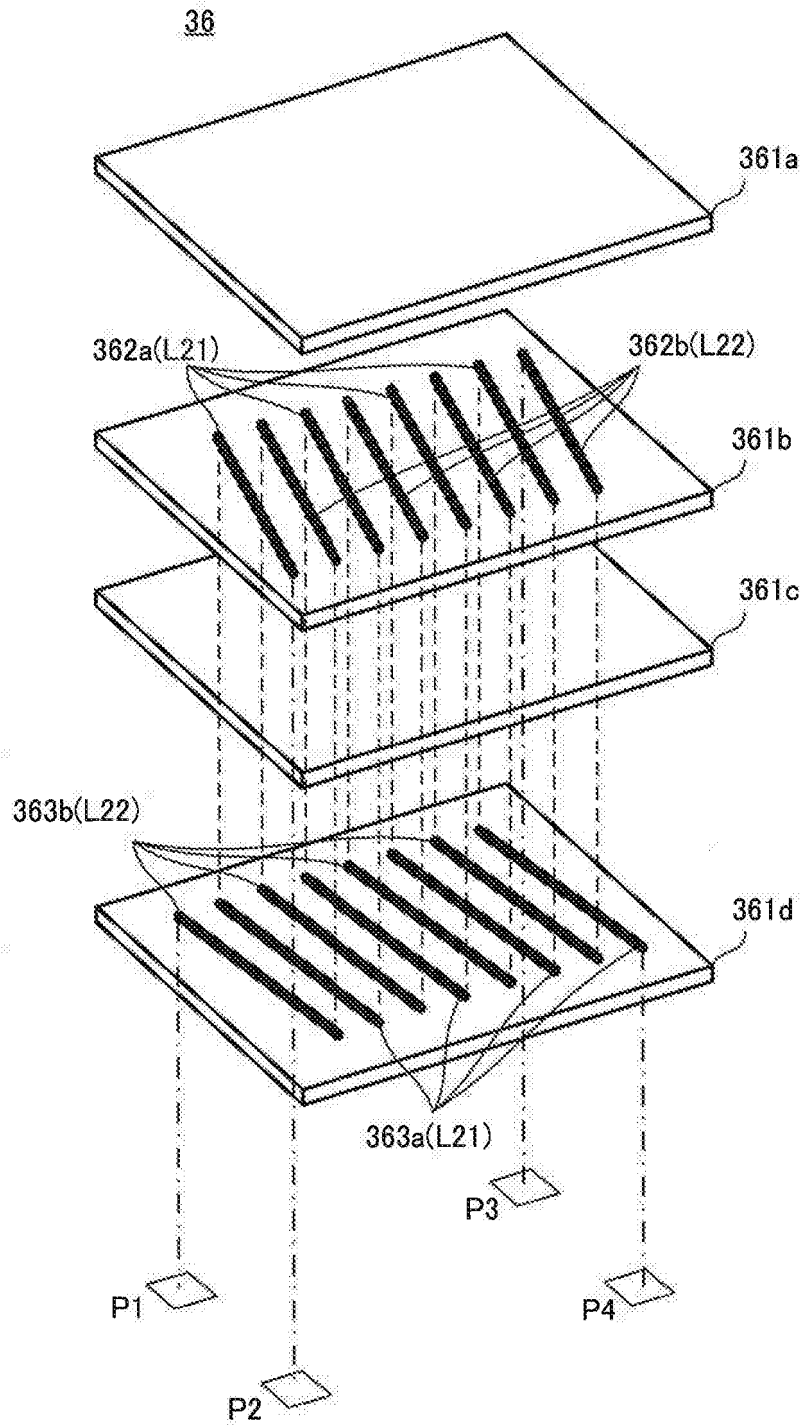


FIG. 3

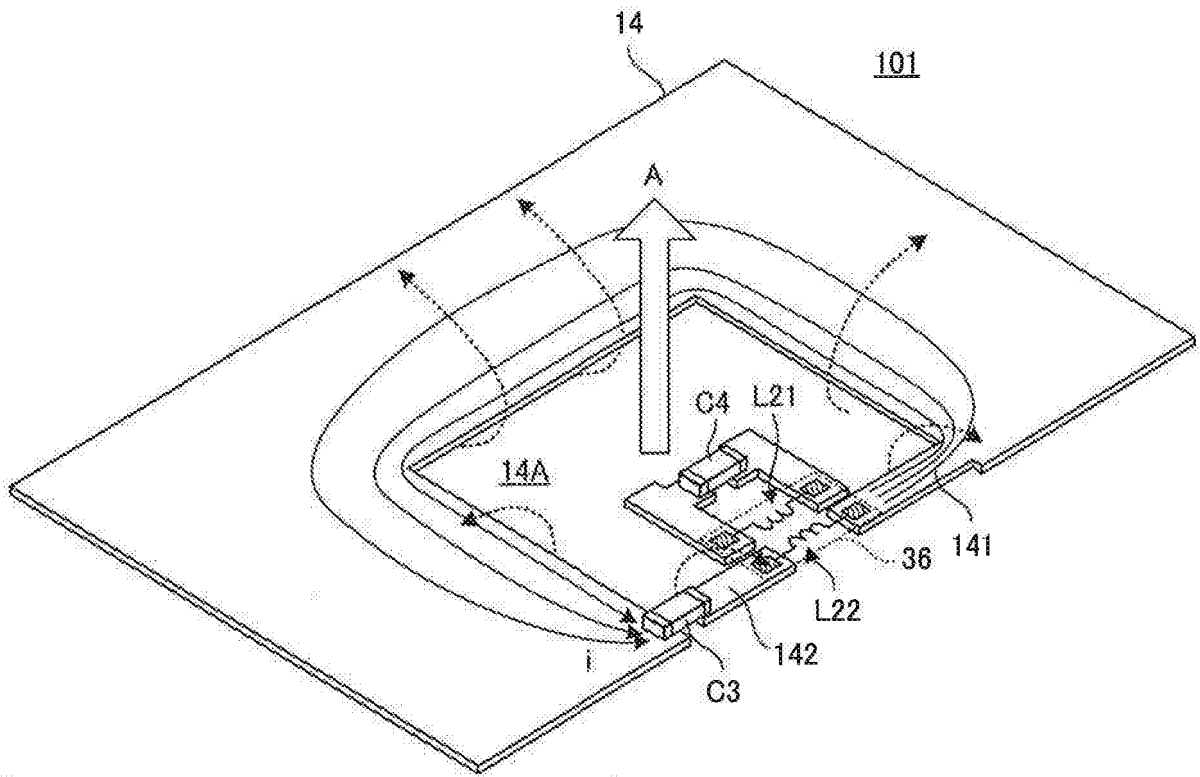


FIG. 4

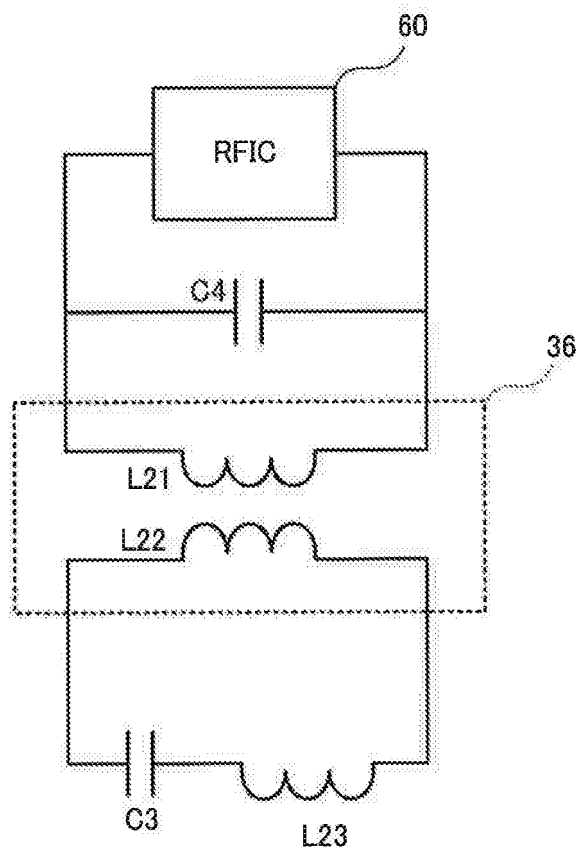


FIG. 5

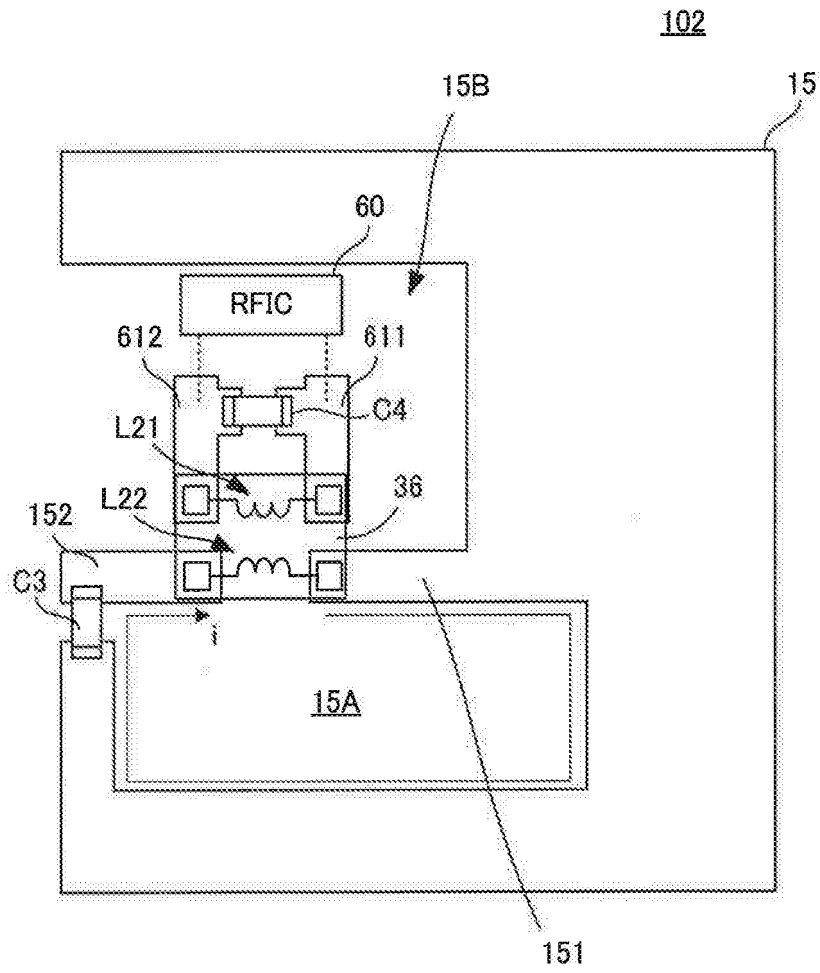


FIG. 6

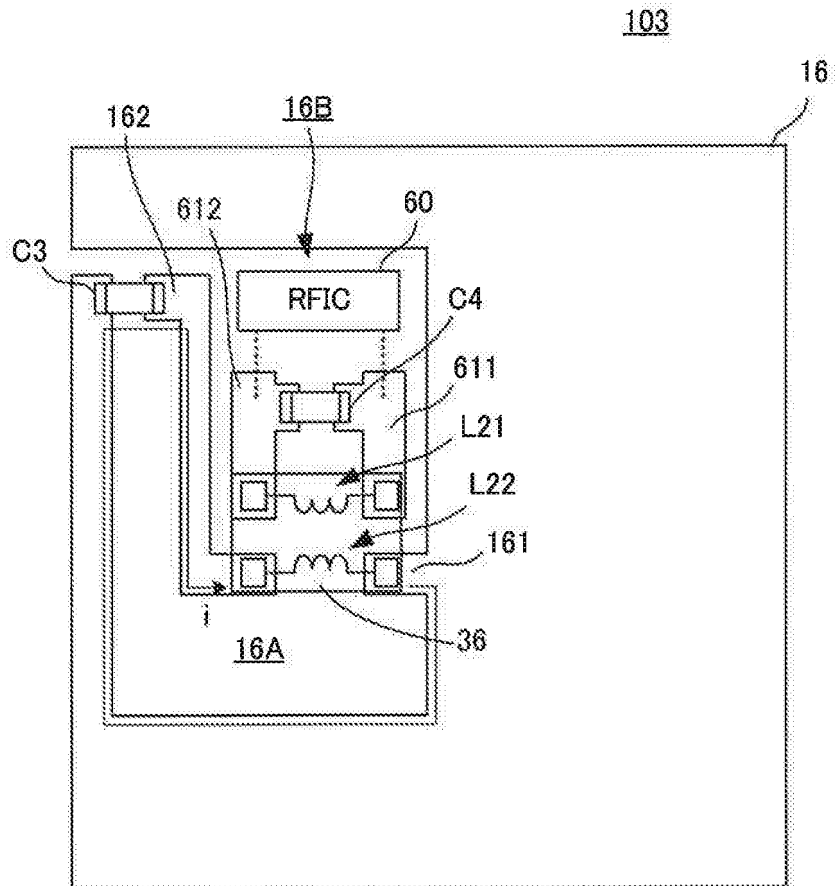


FIG. 7

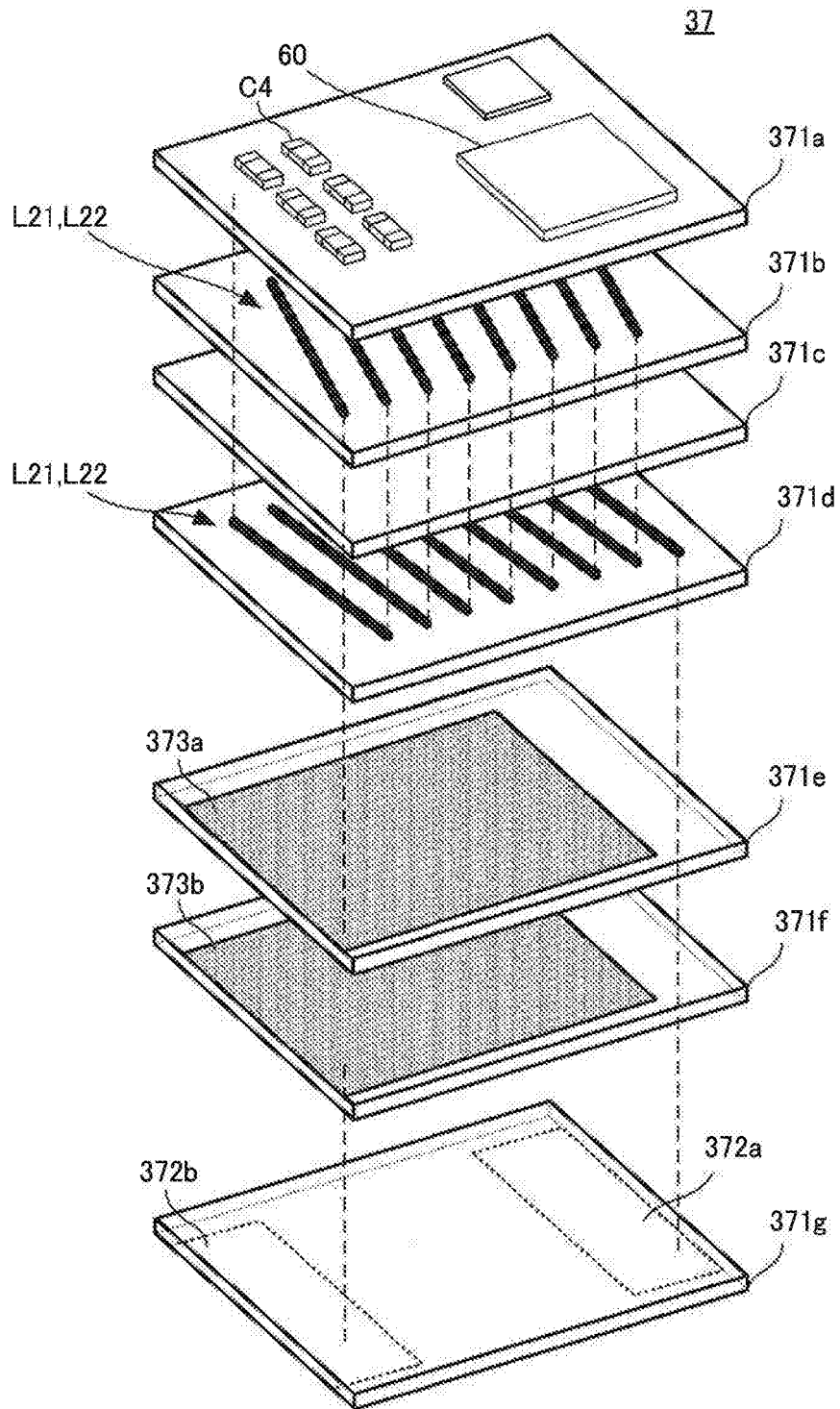


FIG. 8

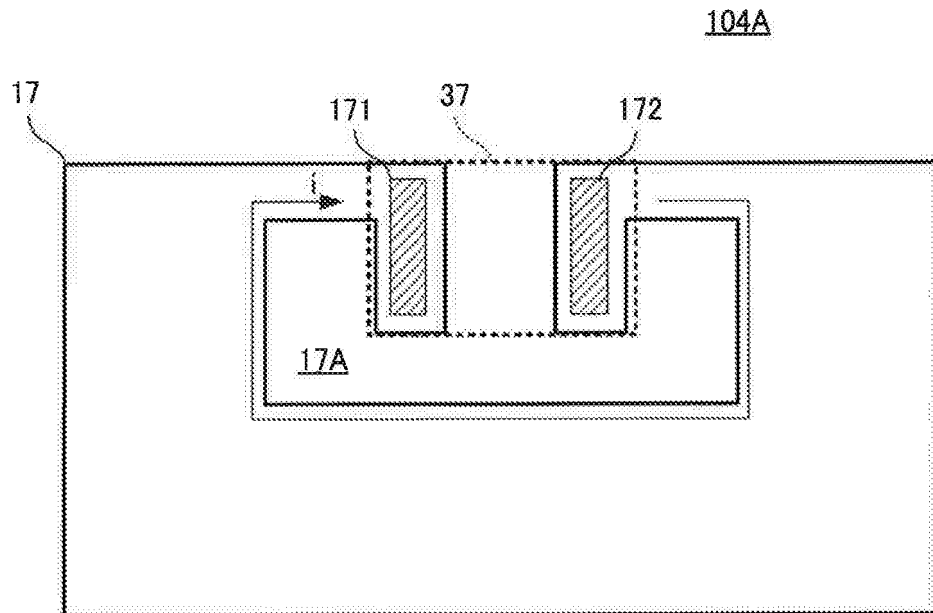


FIG. 9

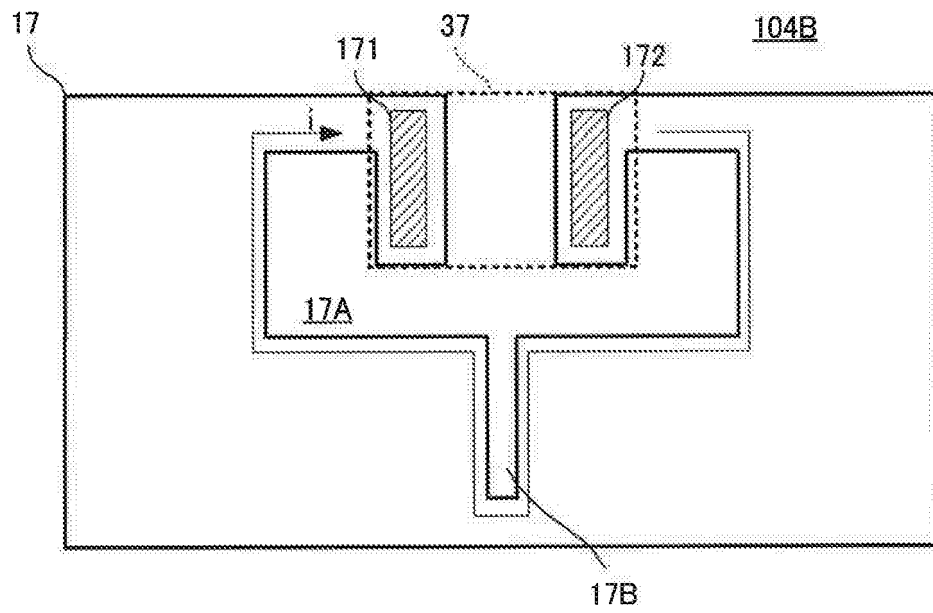




FIG. 10

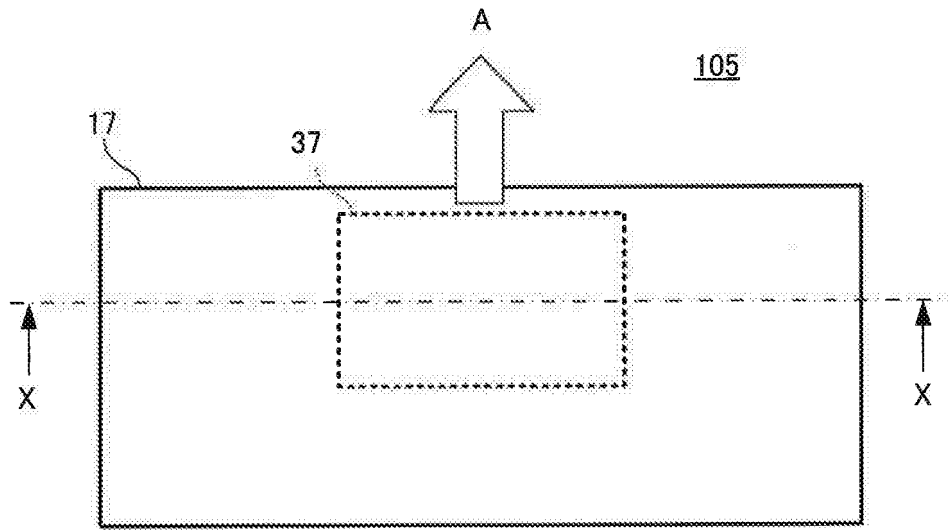


FIG. 11

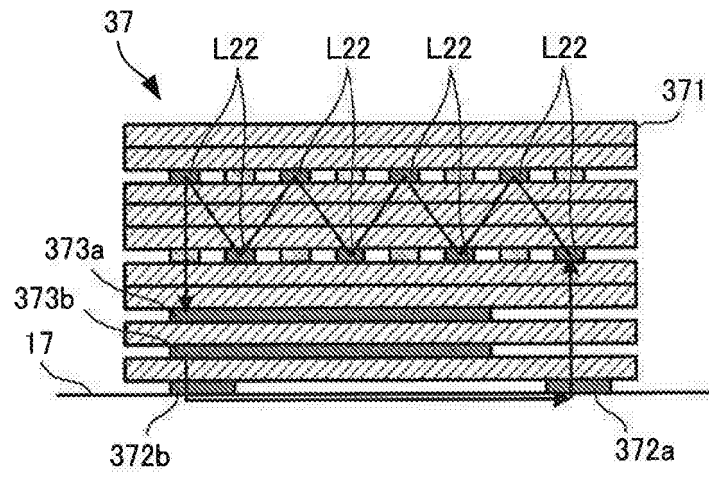


FIG. 12

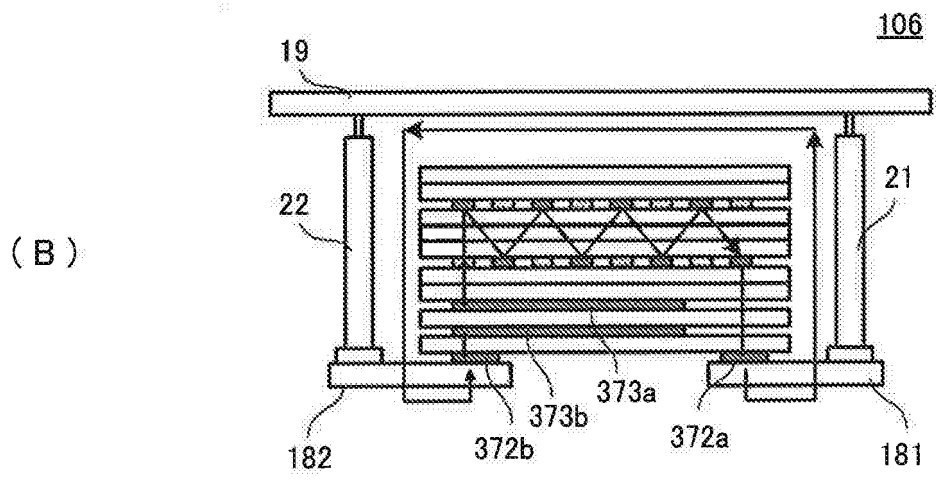
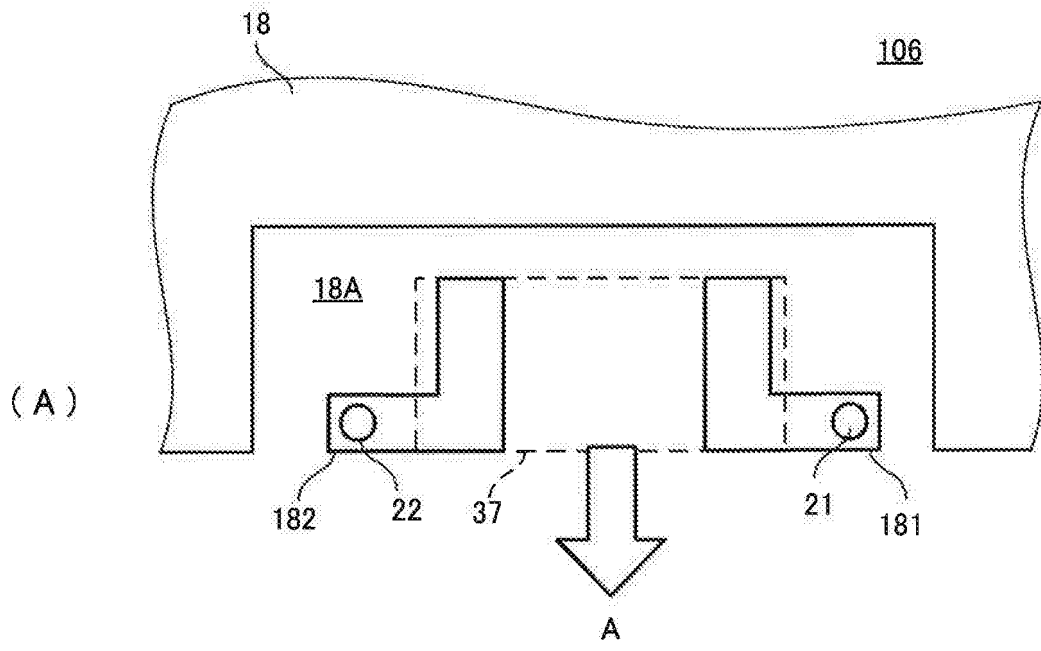


FIG. 13

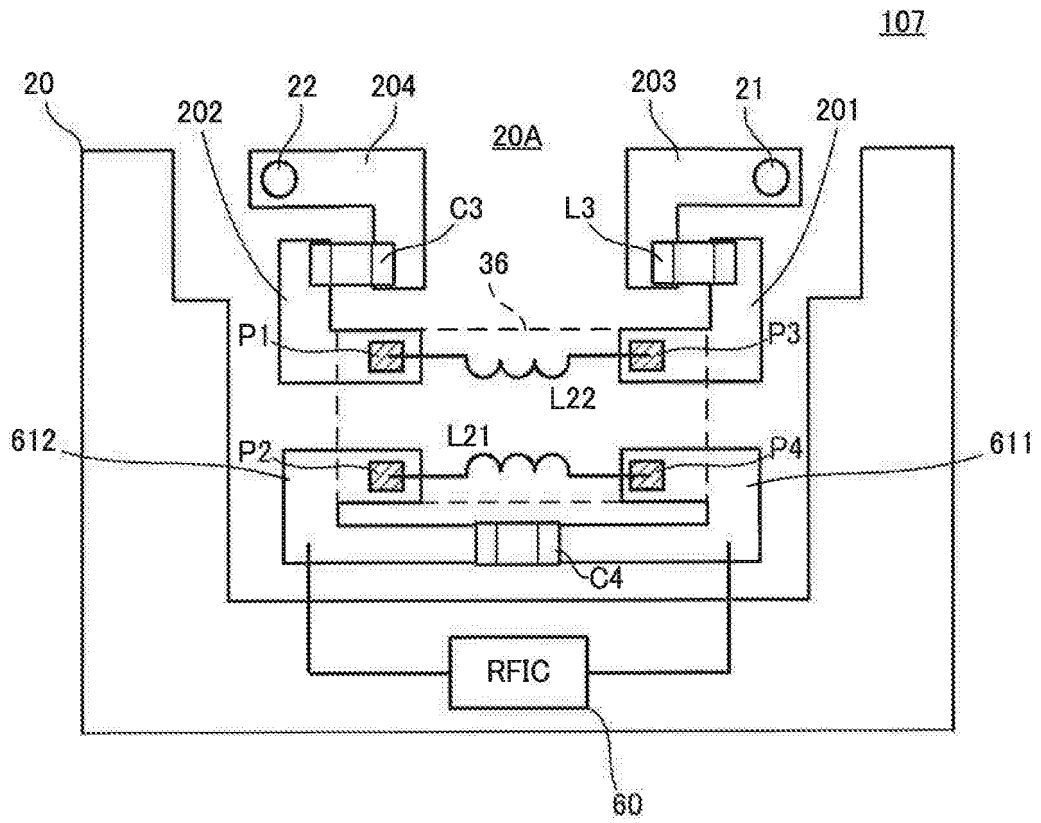


FIG. 14

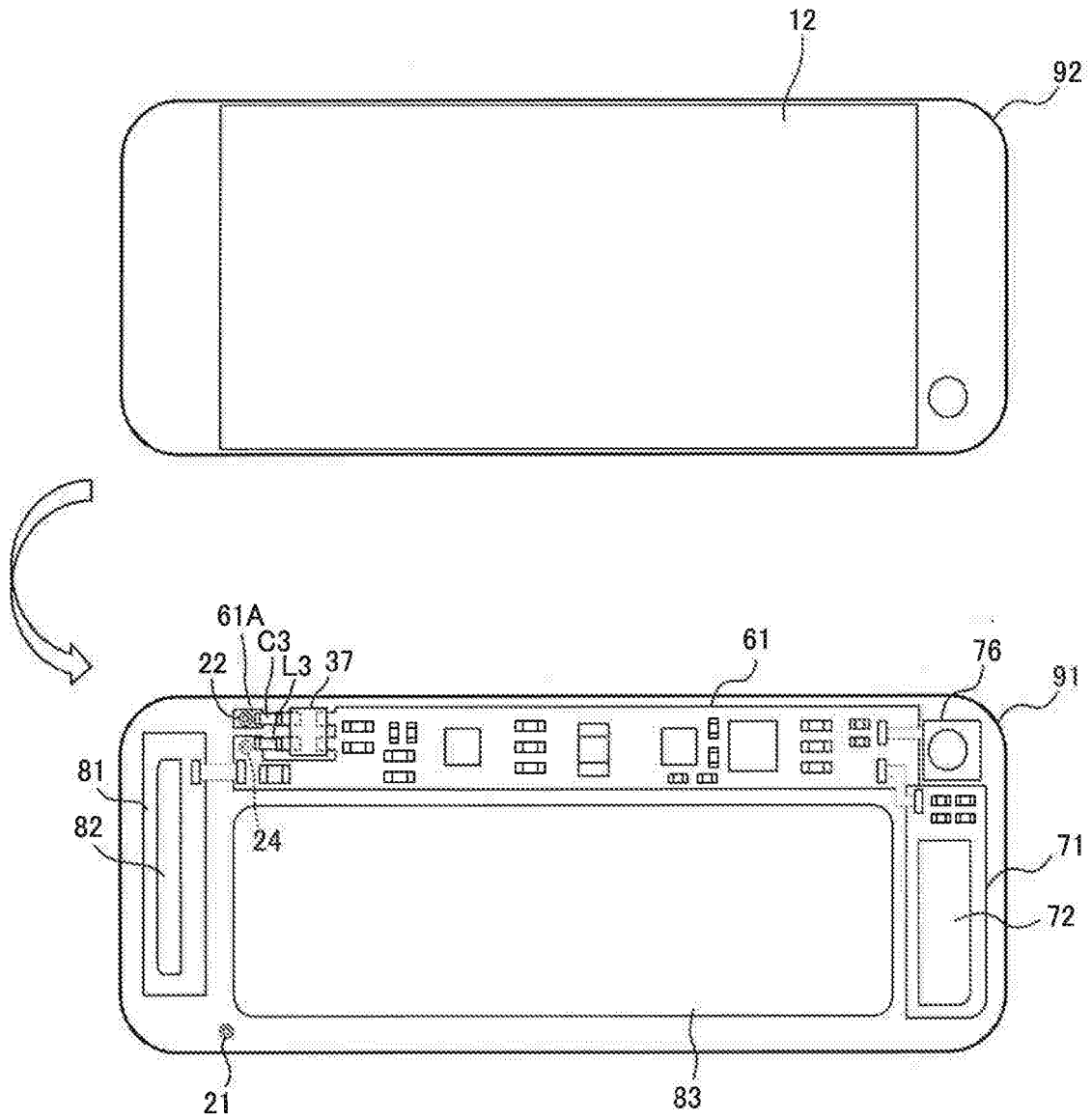


FIG. 15

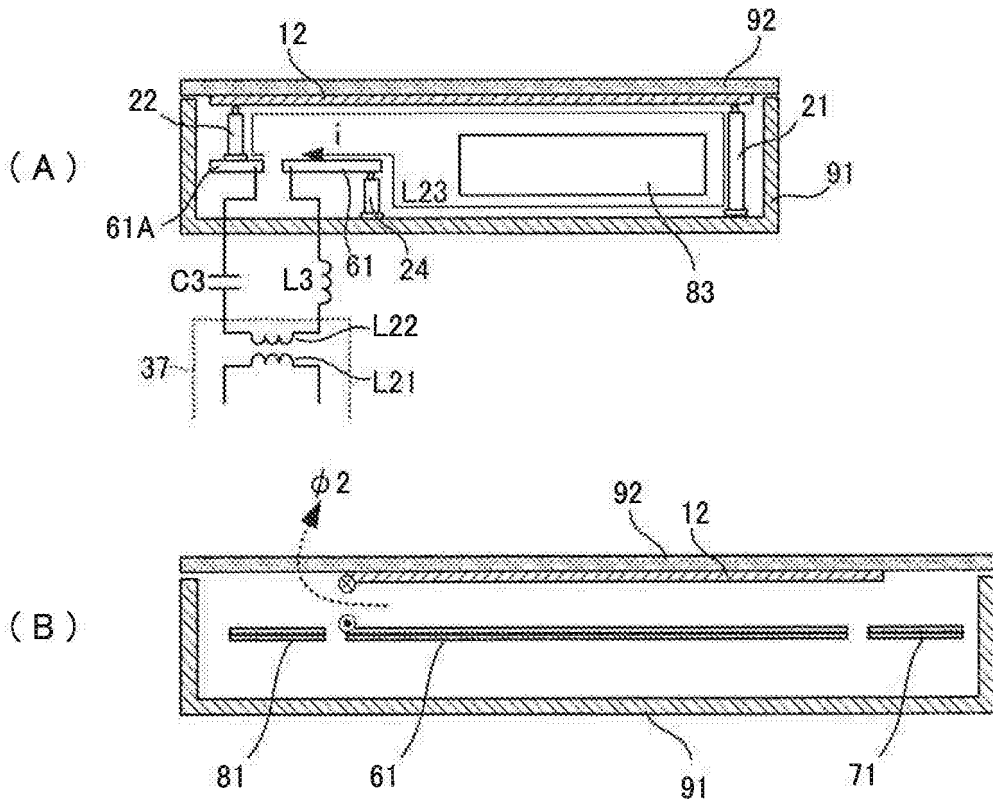


FIG. 16

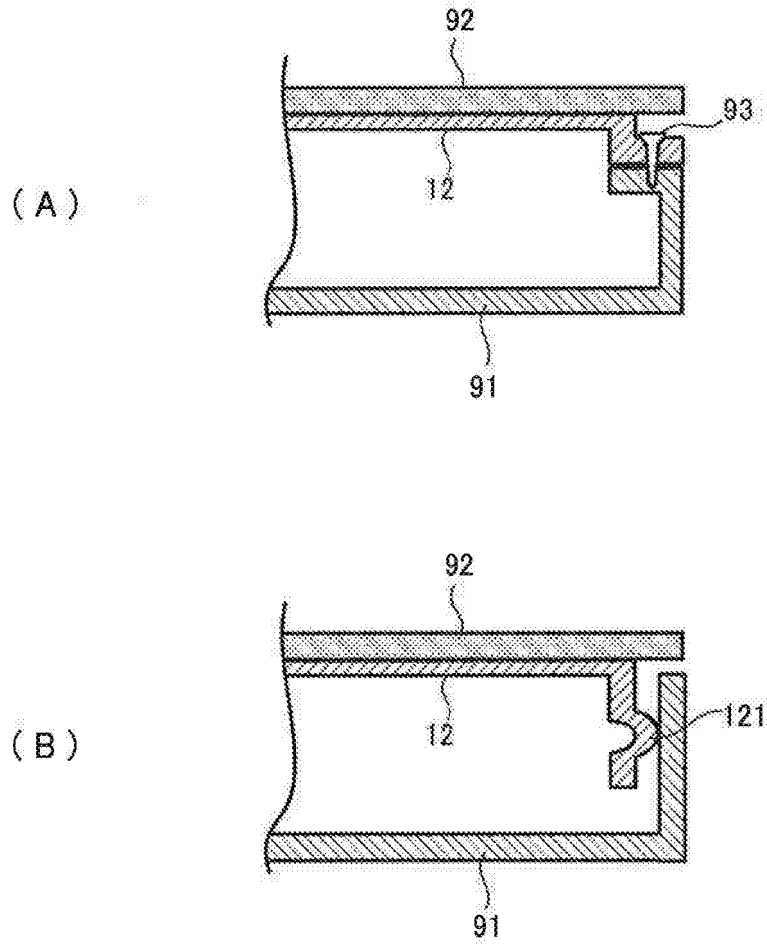
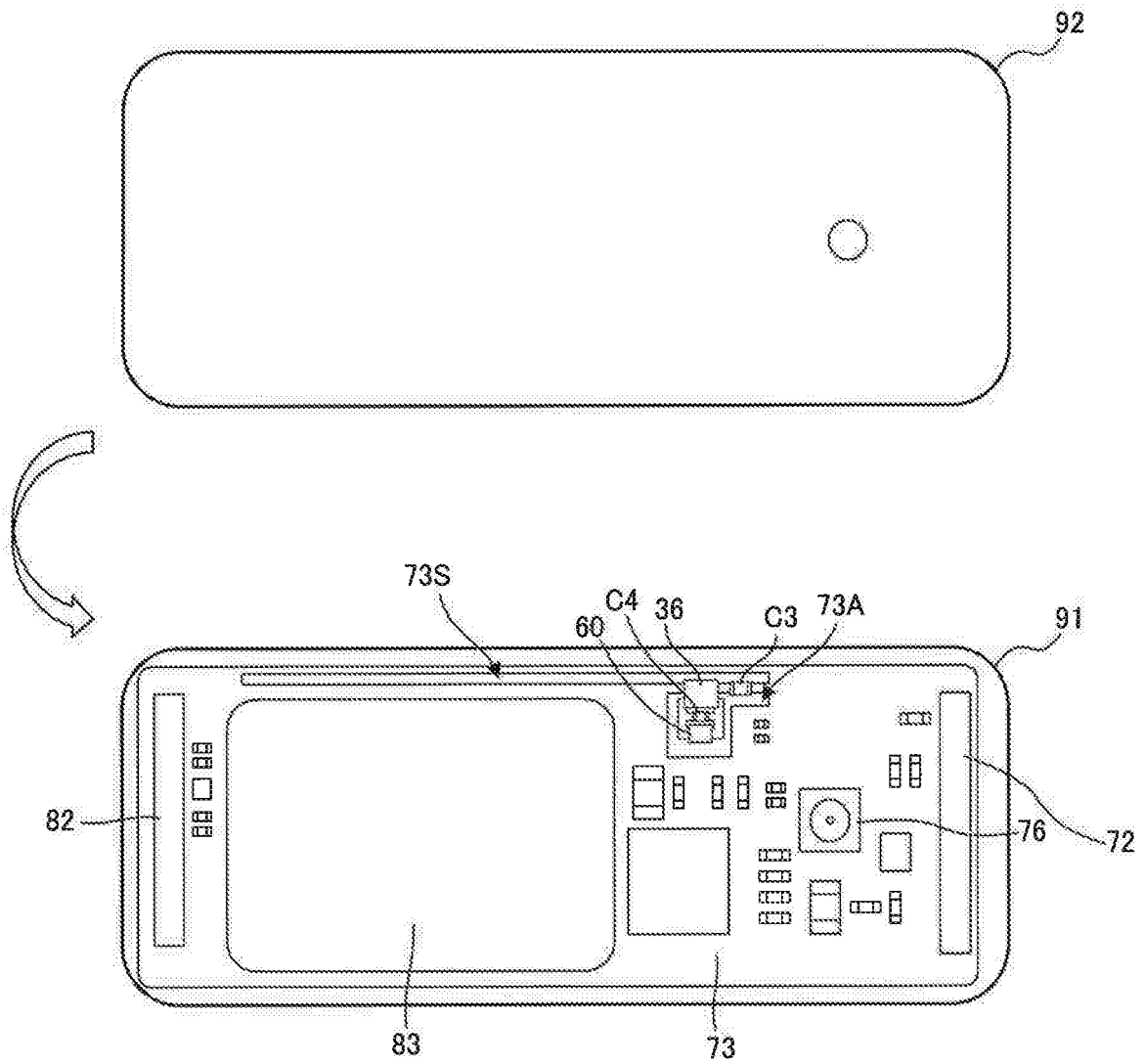


FIG. 17



ANTENNA DEVICE, FEED ELEMENT,  
AND COMMUNICATION TERMINAL DEVICE

Technical Field

The present invention relates to an antenna device, a feed element, and a  
5 communication terminal device, which are used in communication systems of HF- and  
UHF-bands.

Background Art

In 13.56 MHz-band RFID installed in a cellular phone terminal and employed for,  
10 e.g., NFC (Near Field Communication), an RFID IC chip and a matching element are  
generally mounted on a printed wiring board in many cases, and an antenna is affixed to  
the inner side of a terminal casing. Furthermore, the RFID IC chip and the antenna are  
electrically connected (DC-connected) through a spring pin, for example. However, such a  
connection method has the problem that a contact failure may occur due to friction in a  
15 contact portion or a positional deviation caused in assembly.

In view of the above-mentioned problem, a reader/writer is disclosed which has a  
structure including an antenna substrate on which a loop antenna is disposed, and a  
control substrate on which a transmitting and receiving circuit is disposed (see Japanese  
Patent No. 4325621). In the structure disclosed in Japanese Patent No. 4325621, a coil  
20 disposed on the control substrate and the loop antenna are magnetically coupled to each  
other to establish electrical connection of the loop antenna with the transmitting and  
receiving circuit. As a result, a physical contact portion is not present, and the occurrence  
of a contact failure can be avoided.

In the structure disclosed in Japanese Patent No. 4325621, however, because of  
25 utilizing the magnetic coupling, a coupling degree changes due to a variation in the  
mounted position of the coil, and the distance between a surrounding component and the  
coil varies due to a variation in the mounted position of the coil, whereby a value of stray  
capacitance generated between the surrounding component and the coil is changed. This



raises the problem that antenna characteristics vary.

We have appreciated that it would be desirable to provide an antenna device, a feed element, and a communication terminal device including the formers, which can reduce a variation in the coupling degree, and which can suppress, e.g., the problem of interference with surrounding components.

#### SUMMARY OF THE INVENTION

(1) The present invention provides an antenna device comprising a conductor member and a feed element that feeds a high-frequency signal to the conductor member,

wherein the feed element comprises a first coil connected to a feed circuit, a second coil magnetically coupled to the first coil, and two terminal electrodes that connect the second coil to the conductor member, the first coil, the second coil, and the two terminal electrodes being integrally provided with an insulating stacked body.

(2) Preferably, the feed element includes a capacitor connected between at least one of the two terminal electrodes and at least one of terminals of the second coil.

(3) In above (1), preferably, the conductor member is a conductor film provided with a substrate, the substrate including a terminal to which at least one of the two terminal electrodes of the feed element is connected, and a capacitor connected between the relevant one terminal and the conductor member.

(4) Preferably, the conductor member, the capacitor, the first coil constitute a resonance circuit.

(5) Preferably, a capacitance of the capacitor and an inductance of the first coil are determined such that a resonance frequency of the resonance circuit is a communication frequency or close to the communication frequency.

(6) Preferably, an inductance of the second coil is smaller than an inductance component of the conductor member, the inductance component being determined when looking from the two terminal electrodes.

(7) Preferably, the conductor member includes a slit or an opening that spans from an

edge to an inner side of the conductor member, and the two terminal electrodes are arranged at positions on both sides across the slit or the opening.

(8) Preferably, the feed element has a stacked structure including a plurality of stacked insulator layers with which conductors forming the first coil and the second coil are provided.

(9) Preferably, the feed element includes a plurality of insulator layers with which conductors forming the first coil and the second coil are provided, and a plurality of insulator layers with which conductors forming the capacitor are provided.

(10) Preferably, the conductor film is a ground electrode or a shield electrode of a circuit formed on the substrate.

(11) Preferably, the feed circuit includes an RFIC, and the RFIC is mounted on the insulating stacked body.

(12) The present invention provides a feed element used to constitute an antenna device in cooperation with a conductor member,

wherein the feed element comprises an insulating stacked body, a first coil connected to a feed circuit, a second coil magnetically coupled to the first coil, and two terminal electrodes that connect the second coil to the conductor member, the first coil, the second coil, and the two terminal electrodes being integrally provided with the insulating stacked body.

(13) The present invention provides a communication terminal device comprising an antenna device and a feed circuit connected to the antenna device,

the antenna device comprising:

a conductor member and a feed element that feeds a high-frequency signal to the conductor member,

wherein the feed element comprises a first coil connected to the feed circuit, a second coil magnetically coupled to the first coil, and two terminal electrodes that connect the second coil to the conductor member, the first coil, the second coil, and the two terminal electrodes being integrally provided with an insulating stacked body.

According to the present invention, since the first coil and the second coil are magnetically coupled to each other with the feed element in the form of the insulating stacked body, an influence caused by magnetic coupling to the outside of the feed element can be suppressed in comparison with the case of developing magnetic coupling between different members. Furthermore, since the magnetic coupling is developed by using one insulating stacked body, a coupling degree is not changed depending on a variation in mounting of the feed element, and a variation in antenna characteristics attributable to change of the coupling degree can be suppressed.

#### BRIEF DESCRIPTION OF DRAWINGS

Fig. 1 is a plan view of an antenna device 101 according to a first embodiment.

Fig. 2 is an exploded perspective view of a feed element 36 according to the first embodiment.

Fig. 3 is an illustration to explain radiation of a magnetic field in the antenna device 101 according to the first embodiment.

Fig. 4 is an equivalent circuit diagram of the antenna device 101, including a feed circuit as well.

Fig. 5 is a plan view of an antenna device 102 according to a second embodiment.

Fig. 6 is a plan view of an antenna device 103 according to a third embodiment.

Fig. 7 is an exploded perspective view of a feed element 37 according to a fourth embodiment.

Fig. 8 is a plan view of an antenna device 104A incorporating the feed element 37 illustrated in Fig. 7.

Fig. 9 is a plan view of an antenna device 104B different from the antenna device illustrated in Fig. 8.

Fig. 10 is a plan view of an antenna device 105 according to a fifth embodiment.

Fig. 11 is a sectional view taken along a line X-X in Fig. 10.

Fig. 12(A) is a top plan view of an antenna device 106 according to a sixth

embodiment, and Fig. 12(B) is a sectional view.

Fig. 13 is a plan view of an antenna device 107 according to a seventh embodiment.

Fig. 14 is a plan view illustrating the structure inside a casing of a communication terminal device according to an eighth embodiment.

Fig. 15(A) is a sectional view, taken in a direction along a shorter side, of the communication terminal device illustrated in Fig. 14, and Fig. 15(B) is a sectional view, taken in a direction along a longer side, of the communication terminal device.

Figs. 16(A) and 16(B) illustrate examples of a structure joining an upper casing and a lower casing to each other.

Fig. 17 is a plan view illustrating the structure inside a casing of a communication terminal device according to a ninth embodiment.

#### DESCRIPTION OF EMBODIMENTS

Embodiments for carrying out the present invention will be described below in connection with several practical examples by referring to the drawings. Through the drawings, the same constituent elements are denoted by the same reference signs. It is as a matter of course that the following embodiments are merely illustrative, and that partial replacement or combination of individual configurations described in the different embodiments may be practiced as required.

Antenna devices according to the several embodiments described below are each an antenna device for transmitting and receiving a high-frequency signal in a HF-band (e.g., 13.56 MHz band), which is incorporated in a communication terminal represented by a smartphone and a tablet terminal.

#### 25 First Embodiment

Fig. 1 is a plan view of an antenna device 101 according to a first embodiment. Fig. 2 is an exploded perspective view of a feed element 36 according to the first embodiment. Fig. 3 is an illustration to explain radiation of a magnetic field in the antenna device 101

according to the first embodiment. In Figs. 1 and 3, the feed element 36 is illustrated in an external shape, and a first coil L21 and a second coil L22 both incorporated in the feed element 36 are denoted by circuit symbols.

The antenna device 101 includes a conductor surface 14 serving as a conductor member. A rectangular opening 14A is formed in the conductor surface 14. The conductor surface 14 is, e.g., a ground conductor pattern formed on a circuit board, and the opening 14A corresponds to, e.g., a non-conductor portion of the circuit board in which the ground conductor pattern is not formed. Furthermore, the opening 14A is not a closed opening, and it has an open edge portion that is formed to be communicated with the outside of the conductor surface 14. A first mounting portion 141 and a second mounting portion 142, which are used to mount the feed element 36, are formed in the open edge portion.

The first mounting portion 141 is directly connected to the conductor surface 14. The first mounting portion 141 may be integral with the conductor surface 14, or may be a member that is separate from the conductor surface 14 and that is connected to the conductor surface 14 by, e.g., a connecting component, such as a wire or a chip inductor. The second mounting portion 142 is isolated from both the conductor surface 14 and the first mounting portion 141, and is connected to the conductor surface 14 through a capacitor C3.

The feed element 36 includes, though described in detail later, the first coil L21 and the second coil L22 that are mainly coupled to each other through a magnetic field. A first end of the second coil L22 is connected to the first mounting portion 141, and a second end of the second coil L22 is connected to the second mounting portion 142. With such an arrangement, the open edge portion of the opening 14A is closed by the capacitor C3, the second coil L22, and so on, such that a peripheral edge of the opening 14A constitutes a loop. An inductance component of the loop, the capacitor C3, and the second coil L22 form a resonance circuit.

Alternatively, the first mounting portion 141 may be connected to the conductor surface 14 through a capacitor. A resonance frequency of the resonance circuit formed as

mentioned above can be adjusted with the provision of such a capacitor.

As illustrated in Fig. 2, the feed element 36 is a component in the form of an insulating stacked body, and has a stacked structure in which a plurality of insulator layers 361a, 361b, 361c and 361d are stacked one above another. In more detail, the insulator layers 361a and 361d are nonmagnetic layers formed of nonmagnetic ferrite sheets, for example, and the insulator layers 361b and 361c are magnetic layers formed of magnetic ferrite sheets, for example. The feed element 36 includes the first coil L21 and the second coil L22 that are magnetically coupled to each other. Coil conductor patterns 362a and 362b forming the first coil L21 are formed on the magnetic layer 361b, and coil conductor patterns 363a and 363b forming the second coil L22 are formed on the insulator layer 361d. The coil conductor patterns 362a and 362b and the coil conductor patterns 363a and 363b are formed such that coil winding axes thereof are each oriented perpendicular to the direction in which the insulator layers are stacked.

More specifically, the coil conductor patterns 362a and 362b each having a linear shape are alternately formed on the magnetic layer 361b, and the coil conductor patterns 363a and 363b each having a linear shape are alternately formed on the insulator layer 361d. Moreover, via conductors interconnecting the coil conductor patterns 362a and 362b and the coil conductor patterns 363a and 363b, respectively, are formed in the magnetic layers 361b and 361c. With the arrangement described above, the first coil L21 and the second coil L22 are formed such that respective coil openings are matched with each other.

Terminal electrodes P1, P2, P3 and P4 are formed on a lower surface of the insulator layer 361d. The terminal electrode P1 is connected to one end of outermost one of the coil conductor patterns 363b through the via conductor. The terminal electrode P2 is connected to one end of outermost one of the coil conductor patterns 362a through the via conductor. The terminal electrode P3 is connected to one end of outermost one of the coil conductor patterns 362b through the via conductor. The terminal electrode P4 is connected to one end of outermost one of the coil conductor patterns 363a through the via conductor.

Although Fig. 2 illustrates an example including two magnetic layers, a larger number of magnetic layers may be stacked. For example, the magnetic layer 361c may be stacked in plural number.

As seen from Fig. 1, feed-circuit side mounting portions 611 and 612 are disposed in the opening 14A and are connected to a first end and a second end of the first coil L21, respectively. A capacitor C4 is connected between the feed-circuit side mounting portions 611 and 612. Moreover, an RFIC 60 is connected to the feed-circuit side mounting portions 611 and 612. The RFIC 60 forms a feed circuit. The RFIC 60 is constituted as a semiconductor chip component.

The first coil L21 and the second coil L22 of the feed element 36 are magnetically coupled to each other. Because the feed circuit is connected to the first coil L21, a current  $i$  flows along the loop around the opening 14A, as illustrated in Figs. 1 and 3, through the magnetic coupling between the two coils L21 and L22. With the current  $i$  flowing around the opening 14A, the opening 14A acts as a radiation portion, as illustrated in Fig. 3. Accordingly, the antenna device 101 has directivity in a direction denoted by an arrow A in Fig. 3.

Fig. 4 is an equivalent circuit diagram of the antenna device 101, including the feed circuit as well. A resonance circuit on the feed-circuit side is constituted by the first coil L21 and the capacitor C4. An inductor L23 in Fig. 4 represents the inductance of the opening 14A that defines the loop, and a resonance circuit on the radiation-element side is constituted by the inductor L23 together with the second coil L22 and the capacitor C3. By setting each of resonance frequencies of the two resonance circuits to be matched with a frequency band of a communication frequency (i.e., a carrier frequency), a degree of coupling between the resonance circuit on the feed-circuit side and the resonance circuit on the radiation-element side can be increased, and radiation efficiency can be increased.

Given that the inductance of the second coil L22 is denoted by  $L_{22}$  and the inductance of the inductor L23 is denoted by  $L_{23}$ , the above-described equivalent circuit is preferably designed so as to satisfy  $L_{22} < L_{23}$ . By satisfying such a condition, an amount

of magnetic field radiated from the opening 14A, which acts as the radiation portion, can be increased. Furthermore, by forming the coupling portion inside a magnetic body constituting the feed element 36, a variation in the coupling degree can be reduced. Moreover, by integrally forming the coupling portion and the feed element 36 inside the magnetic body, a higher coupling degree can be obtained, and the size of the feed element 36 can be reduced. In the case of employing a magnetic body that exhibits a larger material loss in a high-frequency range of UHF-band, a large influence is generated upon a UHF-band antenna in which antenna characteristics are obtained with a casing current, like a main antenna. However, such an influence can be reduced when the size of the magnetic body can be reduced as in this embodiment. In addition, a ferrite member or the like to suppress undesired radiation of the magnetic field to the outside from the feed element 36 is no longer required, and flexibility in layout of the feed element 36 is increased with no need of considering the positional relation with respect to another high-frequency antenna (cellular antenna) or the first connecting portion 21 described in the first embodiment, etc.

The following advantageous effects can be obtained by employing the feed element 36 having the transformer-coupled structure described above in the first embodiment.

- (1) Since the first coil L21 is formed on the magnetic layer made of ferrite, for example, the first coil L21 is less affected by the surroundings. In other words, since undesired coupling to an external circuit is less apt to occur, the undesired radiation of the magnetic field is suppressed and the interference from the external circuit is also suppressed.
- (2) Since the resonance circuits are constituted on both the primary and secondary sides of the transformer and two resonance frequencies are generated, a wider frequency band can be realized.
- (3) Since the primary and secondary sides of the transformer are isolated from each other, high ESD resistance is obtained.

### Second Embodiment



Fig. 5 is a plan view of an antenna device 102 according to a second embodiment. In the antenna device 102, two openings 15A and 15B, each being not closed and having an open edge portion, are formed in a conductor surface 15. Between the openings 15A and 15B, there are formed a first mounting portion 151 to which the first end of the second coil L22 of the feed element 36 is connected, and a second mounting portion 152 to which the second end of the second coil L22 is connected. The first mounting portion 151 is connected to the conductor surface 15 directly or indirectly (through, e.g., a capacitor). The first mounting portion 151 may be integral with the conductor surface 15, or may be a member that is separate from the conductor surface 15 and that is connected to the conductor surface 15.

The second mounting portion 152 is formed in a state isolated from both the first mounting portion 151 and the conductor surface 15. The capacitor C3 is connected between the second mounting portion 152 and the conductor surface 15. Furthermore, the second coil L22 is connected between the second mounting portion 152 and the first mounting portion 151. Thus, a peripheral edge of the opening 15A constitutes a loop because two open edge portions of the opening 15A are closed by the capacitor C3 and the second coil L22. An inductance component of the loop, the capacitor C3, and the second coil L22 constitute a resonance circuit.

The feed-circuit side mounting portions 611 and 612 are disposed in the opening 15B, and the capacitor C4 is connected to the feed-circuit side mounting portions 611 and 612. The first end and the second end of the first coil L21 of the feed element 36 are connected to the feed-circuit side mounting portions 611 and 612, respectively. While the feed circuit is formed in the opening 14A, which acts as the radiation portion, in the antenna device 101 illustrated in Fig. 1, the feed circuit is formed in the opening 15A, which is different from the opening 15A acting as the radiation portion, in the antenna device 102 of this embodiment, the radiation efficiency can be increased.

### Third Embodiment

Fig. 6 is a plan view of an antenna device 103 according to a third embodiment. In the antenna device 103, two openings 16A and 16B are formed in a conductor surface 16 as in the case illustrated in Fig. 5. Between the openings 16A and 16B, there are formed a first mounting portion 161 to which the first end of the second coil L22 of the feed element 5 36 is connected, and a second mounting portion 162 to which the second end of the second coil L22 is connected. The first mounting portion 161 is directly or indirectly connected to the conductor surface 16. The capacitor C3 is connected between the second mounting portion 162 and the conductor surface 16.

Furthermore, in this embodiment, the opening 16A is formed to extend from a portion of a rectangular shape in one direction and to have an L-shape. Such a shape 10 contributes to providing not only the advantageous effects of the above-described antenna device 102 illustrated in Fig. 5, but also the advantageous effect of enlarging a radiation range of the magnetic field because the magnetic field is radiated from the extended portion as well.

#### Fourth Embodiment

While, in the first to third embodiments, the capacitor C3 in the form of a discrete component is mounted on the conductor surface to constitute the resonance circuit, a feed element incorporates a capacitor in a fourth embodiment.

Fig. 7 is an exploded perspective view of a feed element 37 according to the fourth 20 embodiment. The feed element 37 has a stacked structure including a plurality of insulator layers 371a to 371g. In more detail, the insulator layers 371b and 371c are magnetic layers, and the other insulator layers are nonmagnetic layers. As in the case described above with reference to Fig. 2, respective conductor patterns forming the first coil L21 and 25 the second coil L22 are formed on the insulator layer 371b and 371d, which are positioned midway in the direction of stacking of the insulator layers. Various elements constituting the feed-circuit side matching circuit, including the RFIC 60 and the capacitor C4, are mounted on the insulator layer 371a that is an uppermost layer in the direction of the

stacking. The first end and the second end of the first coil L21 are connected to the matching circuit.

A flat-plate conductor pattern 373a is formed on the insulator layer 371e and a flat-plate conductor pattern 373b is formed on the insulator layer 371f, the insulator layers 371e and 371f being positioned successively under the insulator layer on which the first coil L21 and the second coil L22 are formed. The flat-plate conductor patterns 373a and 373b constitute a capacitor. Furthermore, terminal conductor patterns 372a and 372b serving as external terminals are formed on the lowermost insulator layer 371g. The first end of the second coil L22 is connected to the flat-plate conductor pattern 373a through a via conductor, for example, and the flat-plate conductor pattern 373b is connected to the terminal conductor pattern 372b. In addition, the second end of the second coil L22 is connected to the terminal conductor pattern 372a.

Fig. 8 is a plan view of an antenna device 104A incorporating the feed element 37 illustrated in Fig. 7. The antenna device 104A includes a conductor surface 17. An opening 17A, having a partly opened edge portion, is formed in the conductor surface 17. On both sides of the open edge portion, there are disposed, on the conductor surface 17, a first mounting portion 171 to which the terminal conductor pattern 372a of the feed element 37 is connected, and a second mounting portion 172 to which the terminal conductor pattern 372b of the feed element 37 is connected.

The feed element 37 incorporates a capacitor. By mounting the feed element 37 on the conductor surface 17, therefore, a resonance circuit is constituted by the capacitor in the feed element 37 and inductances of both the second coil L22 and the opening 17A. In other words, a capacitor in the form of a discrete component to constitute the resonance circuit is not required to be disposed on the conductor surface 17. Moreover, since the RFIC 60, the capacitor C4, etc. are formed integrally with the feed element 37, an installation space for the matching circuit is also not required. It is hence possible to realize reduction in the number of components and saving of a space that is necessary as a mounting region.

Fig. 9 is a plan view of an antenna device 104B different from the antenna device illustrated in Fig. 8. In the antenna device 104B, a slit 17B communicating with the opening 17A is further formed in the conductor surface 17. By forming the slit 17B, the magnetic field can be radiated from the slit 17B as well, and a peak position of the radiation of the magnetic field can be shifted to a direction in which the slit 17B extends (namely, a directivity center of the radiation of the magnetic field can be inclined to the direction in which the slit 17B extends). A position of the slit 17B is not limited to the position illustrated in Fig. 9, and the slit 17B may be formed to extend in a direction in which directivity is to be widened. The number of slits to be formed can be changed as appropriate.

#### Fifth Embodiment

Fig. 10 is a plan view of an antenna device 105 according to a fifth embodiment. Fig. 11 is a sectional view taken along a line X-X in Fig. 10. In the antenna device 105 of this embodiment, no openings are formed in the conductor surface 17, and the feed element 37 is mounted on the conductor surface 17 at any desired position. In this embodiment, when looking at a section of the feed element 37, as denoted by a bold-line arrow in Fig. 11, an opening is defined by a path passing the terminal conductor pattern 372b, the capacitor formed by the terminal conductor patterns 373a and 373b, the second coil L22, the terminal conductor pattern 372a, and the conductor surface 17. That opening acts as the radiation portion. Stated in another way, in the configuration of this embodiment, an opening (loop) denoted by the arrow in Fig. 11 is formed by the second coil of the feed element 37 and the conductor surface when looking from a direction facing a longitudinal lateral surface of the feed element 37 (i.e., when looking at the feed element 37 in a direction perpendicular to the direction of the stacking), and that opening acts as the radiation portion. Thus, a radiation means can be obtained just by mounting the feed element onto the conductor surface. With the arrangement described above, the antenna device 105 has directivity in the direction of an arrow A in Fig. 10.

### Sixth Embodiment

In a sixth embodiment, the feed element 37 illustrated in Fig. 7 is employed, and an opening acting as the radiation portion is formed by two conductor surfaces. Fig. 12(A) is a top plan view of an antenna device 106 according to the sixth embodiment, and Fig. 12(B) is a sectional view.

The antenna device 106 includes a conductor surface 18 in which an opening 18A is formed. A first mounting portion 181 and a second mounting portion 182, both isolated from the conductor surface 18, are formed in the opening 18A of the conductor surface 18. The terminal conductor pattern 372a of the feed element 37 is connected to the first mounting portion 181, and the terminal conductor pattern 372b of the feed element 37 is connected to the second mounting portion 182.

The antenna device 106 further includes a conductor surface 19 arranged opposite to the conductor surface 18. The conductor surface 19 is, for example, a part of a metallic casing. The conductor surface 19 is connected to the first mounting portion 181 and the second mounting portion 182 through a first connecting portion 21 and a second connecting portion 22, respectively. The first connecting portion 21 and the second connecting portion 22 are each, for example, a spring connector.

When looking at a section of the feed element 37 having the above-described configuration, as denoted by arrows in Fig. 12(B), an opening is defined by a path passing the terminal conductor pattern 372b, the capacitor formed by the flat-plate conductor patterns 373a and 373b, the second coil L22, the terminal conductor pattern 372a, the first connecting portion 21, the conductor surface 19, and the second connecting portion 22. That opening acts as the radiation portion. With the arrangement described above, the antenna device 106 has directivity in the direction of an arrow A in Fig. 12(A).

### Seventh Embodiment

Fig. 13 is a plan view of an antenna device 107 according to a seventh embodiment. The feed element 36 illustrated in Fig. 2 is employed in this embodiment. In

the antenna device 107, an opening 20A is formed in a conductor surface 20. A first mounting portion 201 and a second mounting portion 202 are formed in the opening 20A. The first mounting portion 201 is connected to a terminal electrode P3 to which the first end of the second coil L22 of the feed element 36 is connected, and the second mounting portion 202 is connected to a terminal electrode P1 to which the second end of the second coil L22 of the feed element 36 is connected.

Furthermore, a third mounting portion 203 and a fourth mounting portion 204 are formed in the opening 20A in an isolated state. A first connecting portion 21 connected to a not-illustrated conductor surface (corresponding to the conductor surface 19 in Fig. 12) is mounted to the third mounting portion 203, and a second connecting portion 22 connected to the not-illustrated conductor surface (corresponding to the conductor surface 19 in Fig. 12) is mounted to the fourth mounting portion 204. An inductor L3 is connected between the first mounting portion 201 and third mounting portion 203. A capacitor C3 is connected between the second mounting portion 202 and fourth mounting portion 204.

Moreover, feed-circuit side mounting portions 611 and 612 to which a terminal electrode P4 connected to the first end of the first coil L21 and a terminal electrode P2 connected to the second end of the first coil L21 are connected, respectively, are disposed in the opening 20A. The RFIC 60 is connected to the feed-circuit side mounting portions 611 and 612.

Thus, even when the feed element 36 does not incorporate the capacitor, the opening acting as the radiation portion can be formed, as in the case of Fig. 12, by mounting the capacitor C3, which is a discrete component, in a region outside the feed element 36. With the capacitor C3 mounted to the region outside the feed element 36, the resonance frequency can be adjusted. Furthermore, since an inductance component of the resonance circuit is determined depending on the inductance of the inductor L3, the inductor L3 having a proper inductance can be employed, as required, depending on the size and the shape of the conductor surface to which the first connecting portion 21 and the second connecting portion 22 are connected. It is to be noted that a capacitor may be

installed instead of the inductor L3.

While, in the embodiments described above, the first coil L21 and the second coil L22 are formed such that a coil winding axis of each coil is oriented perpendicular to the direction in which the insulator layers are stacked, the arrangement of the coils of the feed element is not limited to such an example. As another example, the first coil L21 and the second coil L22 may be formed such that the winding axis of each coil is matched with the direction in which the insulator layers are stacked. As still another example, the first coil L21 and the second coil L22 may be formed such that the second coil L22 is positioned inside a coil aperture of the first coil L21. Furthermore, while Fig. 2, etc. illustrate an example in which the first coil L21 and the second coil L22 are alternately wound, the second coil L22 may be wound outside the first coil L21 in sandwiching relation to the first coil L21. Moreover, in the case of the first coil L21 and the second coil L22 having the same winding axis and the same coil aperture, the coils may be formed by successively arranging some plural turns of the first coil L21, some plural turns of the second coil L22, other plural turns of the first coil L21, and other plural turns of the second coil L22 side by side.

#### Eighth Embodiment

Fig. 14 is a plan view illustrating the structure inside a casing of a communication terminal device according to an eighth embodiment. Fig. 15(A) is a sectional view, taken in a direction along a shorter side, of the communication terminal device illustrated in Fig. 14, and Fig. 15(B) is a sectional view, taken in a direction along a longer side, of the communication terminal device. In Figs. 15(A) and 15(B), an upper casing is illustrated as being positioned to face downwards.

Circuit boards 61, 71 and 81, a camera module 76, a battery pack 83, etc. are contained inside an upper casing 91. The RFIC 60 (not illustrated) including the communication circuit, the feed element 36, etc. are mounted on the circuit board 61. A UHF-band antenna 72, etc. are mounted on the circuit board 71. A UHF-band antenna 82,

etc. are mounted on the circuit board 81. The circuit boards 61, 71 and 81 are connected to each other via cables.

A ground conductor formed on the circuit board 61 acts as a conductor surface. A cutout is partly formed in the ground conductor on the circuit board 61, and a mounting portion to mount a feed element 37, etc. are disposed in the cutout. The feed element 37 is the same as that described above with reference to Fig. 7. A mounting portion 61A provided with a second connecting portion 22 is also disposed in the cutout. The mounting portion 61A is connected to the ground conductor on the circuit board 61 through a capacitor C3, a second coil L22 of the feed element 37, and an inductor L3.

The upper casing 91 is a metallic casing. The ground conductor of the circuit board 61 is connected to the upper casing 91 through a fourth connecting portion 24.

A lower casing 92 is made of resin, but a conductor surface 12 made of a metal film is formed on an inner surface of the lower casing 92. The second connecting portion 22 provided on the mounting portion 61A is connected to the conductor surface 12.

Furthermore, the upper casing 91 and the metal film of the conductor surface 12 are electrically connected to each other through a first connecting portion 21.

With the arrangement described above, as denoted by an arrow in Fig. 15(A), a current  $i$  flows along a path of the second coil L22 of the feed element → the capacitor C3 → the mounting portion 61A → the second connecting portion 22 → the conductor surface 12 → the first connecting portion 21 → the upper casing 91 → the fourth connecting portion 24 → the ground conductor formed on the circuit board 61 → the inductor L3 → the second coil L22 in the order named. The above-mentioned path of the current  $i$  defines an opening that acts as the radiation portion. As seen from Fig. 15(B), magnetic flux  $\phi_2$  passes through the opening.

An additional element, e.g., a capacitor or an inductor, may be mounted as appropriate midway the path, which defines the opening acting as the radiation portion, in order that an actual resonance frequency is matched with the desired resonance frequency.

An arrangement to electrically connect the upper casing 91 and the conductor



surface 12 formed on the lower casing 92 is not limited to the above-described connection using the second connecting portion 22. Figs. 16(A) and 16(B) illustrate examples of a structure joining the upper casing and the lower casing to each other. In Figs. 16(A) and 16(B), the upper casing 91 is a metallic casing. As illustrated in Fig. 16(A), the metal film serving as the conductor surface 12 may be partly bent and fixed to the upper casing 91 by a screw 93. With such a configuration, the conductor surface 12 and the upper casing 91 are electrically connected to each other. Alternatively, as illustrated in Fig. 16(B), the metal film serving as the conductor surface 12 may be partly shaped into the form of a fitting portion 121, and the fitting portion 121 may be fixedly press-fitted to the casing 91. With such a configuration, the conductor surface 12 and the upper casing 91 are electrically connected to each other.

While, in the eighth embodiment, the opening acting as the radiation portion is formed to face in a direction toward a shorter side of the communication terminal device, the opening may be formed to face in a direction toward a longer side of the communication terminal device, or in a direction of a diagonal line of the casing.

#### Ninth Embodiment

Fig. 17 is a plan view illustrating the structure inside a casing of a communication terminal device according to a ninth embodiment. In this embodiment, the metal film serving as the conductor surface 12 is not formed on the lower casing 92.

A battery pack 83 and a circuit board 73 are disposed on the upper casing 91. UHF-band antennas 72 and 82, a camera module 76, and so on are mounted on the circuit board 73. A slit 73S is formed in a portion of the circuit board 73 where a ground pattern is not formed. Moreover, an opening 73A is formed near the slit 73S. As in the case described above with reference to Fig. 6, feed-circuit side mounting portions 611 and 612 are disposed in the opening 73A, and the RFIC 60, the capacitor C4, etc. are mounted on the feed-circuit side mounting portions 611 and 612. The capacitor C3 is disposed between the slit 73S and the opening 73A. In addition, as described above with reference to Fig. 13,

for example, other feed-circuit side mounting portions are disposed between the slit 73S and the opening 73A, and the feed element 36 is mounted on those mounting portions.

With the configuration described above, a current flows along the periphery of the slit 73S, and the slit 73S acts as the radiation portion. Thus, when the circuit board 73 has a certain extent of vacant space as in the above-described case, effective space utilization can be realized by forming a slit in the vacant space in such a manner that the slit acts as the radiation portion.

It is to be noted that the above-described embodiments are merely illustrative, and that the present invention is not limited to those embodiments. One of the conductor films in the present invention is not limited to a ground conductor formed on the circuit board or a battery pack. Furthermore, one of the conductor surfaces is not limited to a metal portion of the casing. For example, a shield case, a shield plate, an LCD panel, or the like may be utilized as a first conductor surface or a second conductor surface.

#### 1.5 Reference Signs List

i ... current

C3, C4 ... capacitors

L21 ... first coil

L22 ... second coil

2.0 L23, L3 ... inductors

P1, P2, P3, P4 ... terminal electrodes

12 ... conductor surface

14 to 20 ... conductor surfaces

14A, 18A, 20A ... openings

2.5 15A, 15B ... openings

16A, 16B ... openings

17A, 17B ... slits

21 ... first connecting portion

- 22 ... second connecting portion
- 24 ... fourth connecting portion
- 36, 37 ... feed elements
- 60 ... RFIC
- 5 61, 71, 81 ... circuit boards
- 61A ... mounting portion
- 71, 81 ... circuit boards
- 72, 82 ... UHF-band antennas
- 73 ... circuit board
- 10 73A ... opening
- 73S ... slit
- 76 ... camera module
- 83 ... battery pack
- 91 ... upper casing
- 1.5 92 ... lower casing
- 101 to 107 ... antenna devices
- 121 ... fitting portion
- 141, 151, 161, 171, 181, 201 ... first mounting portions
- 142, 152, 162, 172, 182, 202 ... second mounting portions
- 20 203 ... third mounting portion
- 204 ... fourth mounting portion
- 361a, 361b, 361c, 361d ... insulator layers
- 361a, 361d ... nonmagnetic layers
- 361b, 361c ... magnetic layers
- 25 362a, 362b ... coil conductor patterns
- 363a, 363b ... coil conductor patterns
- 371a to 371g ... insulator layers
- 371a, 371d to 371g ... nonmagnetic layers

371b, 371c ... magnetic layers

372a, 372b ... terminal conductor patterns

373a, 373b ... flat-plate conductor patterns

611, 612 ... feed-circuit side mounting portions

## CLAIMS

1. An antenna device comprising:

a feed circuit;

a first coil (L21) connected to the feed circuit;

5 a second coil (L22) coupled magnetically to the first coil; and

a casing (91, 92) inside which the feed circuit is housed, the casing including a conductor member (12), the conductor member being connected to the second coil, the conductor member and the second coil constituting a loop by said connection of the conductor member to the second coil.

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2. The antenna device according to claim 1, wherein the conductor member (12) is formed as at least a part of an opening that functions as a radiation portion.

3. The antenna device according to claim 1 or 2, further comprising:

15 a capacitor (C3) connected between the second coil (L22) and the conductor member (12).

4. The antenna device according to any of claims 1, 2, and 3, further comprising:

20 an inductor (L3) connected between the second coil (L22) and the conductor member (12).

5. The antenna device according to any of claims 1 to 4, wherein the second coil (L22) and the conductor member (12) are connected via a connecting portion (21).

25 6. The antenna device according to claim 5, wherein the connecting portion (21, 22, 24) is a spring connector.

7. The antenna device according to any of claims 1 to 6, wherein the loop is an HF-band antenna.

8. The antenna device according to claim 1, further comprising:

5 a ground conductor connected between the second coil (L22) and the conductor member (12).

9. A communication terminal apparatus, comprising:

an antenna device;

10 a feed circuit; and

a casing (91, 92),

wherein the antenna device includes

a first coil (L21) connected to the feed circuit, and

a second coil (L22) coupled magnetically to the first coil, and

15 wherein the feed circuit is housed inside the casing (91, 92), the casing includes a conductor member (12), the conductor member is connected to the second coil, and the conductor member and the second coil constitute a loop by said connection of the conductor member to the second coil.



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**Claims searched:** 1-9

**Date of search:** 16 November 2016

**Patents Act 1977: Search Report under Section 17**

**Documents considered to be relevant:**

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1-9	US 2006/012482 A1 (ZALUD) [see abstract, description and figs 2-4]
X	1-9	US 6378774 B1 (EMORI) [see abstract, description and figs 2, 3A&B and 16A&B]
X	1-9	EP0977145 A2 (TOSHIBA) [see abstract, description and figs 13A-D, 14 and 15]
X	1-9	CA 2279176 A1 (AMATECH) [see abstract, description and figs 1-4]
X,A	1-9	WO 2012/019768 A1 (STMICRO) [see reference to background art, paras [0010-15] and fig 5]
X,A	1-9	US 6774865 B1 B1 (SERRA) [see fig 3 and reference to "classical" smart card, col. 3, lines 19-20 and col. 4, lines 10-32 ]
X	1-9	US 2009/079574 A1 (OROKU) [see abstract, description and figs 8, 9B and 12]
X	1-9	EP 1037755 A1 (GOODYEAR) [abstract, description and fig 4]
X	1-9	JP2001266100 A (DAINIPPON) [abstract, description and figs 1-6]
A	1	GB2216726 A (KOKUSAI): relevant with reference to common general knowledge [see abstract, description and figs 5a&b]
A	1	US 2011/227798 A1 (HSU): relevant with reference to common general knowledge [see abstract, description and figs 1-2]



A	1	US3736591 A (RENNEL): relevant with reference to common general knowledge [see abstract, description and figs 2-4 ]
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**Field of Search:**

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC<sup>X</sup> :

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Worldwide search of patent documents classified in the following areas of the IPC

G06K; H01Q
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The following online and other databases have been used in the preparation of this search report

WPI, EPODOC, TXTE
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**International Classification:**

Subclass	Subgroup	Valid From
H01Q	0001/22	01/01/2006
G06K	0019/07	01/01/2006
G06K	0019/077	01/01/2006