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(54) ANTENNA UNIT

(57) An antenna unit (1) includes: an antenna coil (2) for effecting at least one of reception and transmission of an electromagnetic signal; a bobbin (3) on which the antenna coil (2) is wound; a core (4) to be retained in the bobbin (3); and a sensor electrode coil (5) to be wound on the bobbin (3) to detect a predetermined state change based on a change in capacitance. The bobbin (3) includes: an antenna coil winding part (3a) on which the antenna coil (2) is wound; and an electrode coil winding part (3b) which protrudes from the antenna coil winding part (3a) in one direction and on which the sensor electrode coil (5) can be wound.

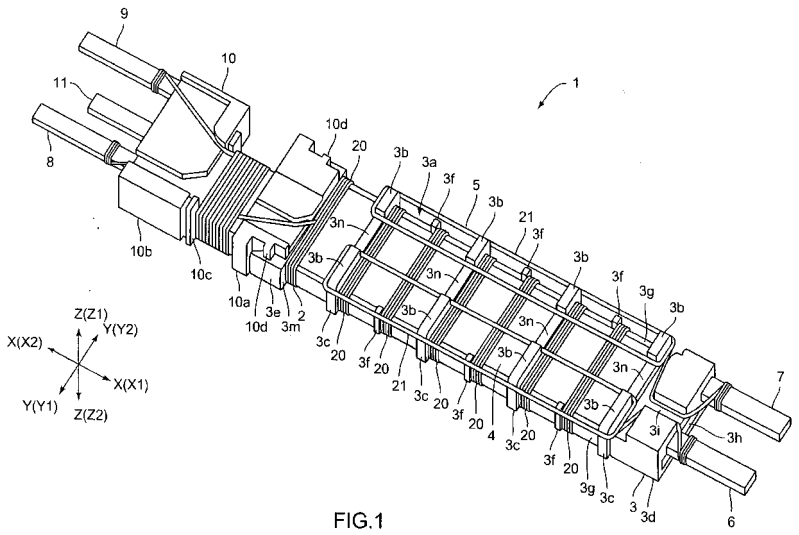

FIG.1

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Description

Technical Field

[0001] The present invention relates to an antenna unit that receives and/or transmits an electromagnetic signal.

Related Art

[0002] An electronic key system which locks or unlocks car doors in response to a portable device carried by a user has been widely used in automobiles. As such an electronic key system, there is known an electronic key system with an antenna unit which is located inside a door handle for communication with a portable device (so-called "keyless entry system") (see Patent Document 1 and Patent Document 2, for example). The antenna units described in Patent Documents 1 and 2 each include a sensor electrode which detects the contact of the hand of a user with the door handle based on a change in capacitance.

[0003] According to the electronic key systems described in Patent Documents 1 and 2, in order to unlock a locked door, first, a predetermined signal is exchanged between the portable device and the antenna unit, and the sensor electrode becomes a detecting state when the registered code from the portable device is verified. When the user's hand touches the inner side (i.e., vehicle side) of the door handle in that state, the capacitance between the sensor electrode and the ground (earth) changes. When the change in the capacitance is detected, a door unlocking/locking unit is driven to unlock the door.

[0004] The antenna unit described in Patent Document 1 includes an antenna coil for transmission and reception of signals, and a core which is configured to have a plurality of thin core sheets laminated and has the antenna coil wound thereon. In the antenna unit described in Patent Document 1, one of the plurality of core sheets serves as a sensor electrode to be connected to a capacitance detector.

[0005] The antenna unit described in Patent Document 2 includes a first coil constituting a first antenna, a core on which the first coil is wound, a bobbin disposed outside the core, and a second coil wound on the bobbin. In the antenna unit described in Patent Document 2, the core is formed in a thin elongated rectangular-parallelepiped shape, the first coil is arranged on the outer periphery side of the core with its winding direction being a lateral direction of the core, and the second coil is arranged on the outer periphery side of the core with its winding direction being a longitudinal direction of the core. In the antenna unit described in Patent Document 2, the second coil wound on the bobbin serves as a sensor electrode to be connected to a sensor detecting section.

[0006]

Patent Document 1: Japanese Patent Application Laid-open No. 2006-96104
Patent Document 2: Japanese Patent Application Laid-open No. 2003-166369

Disclosure of the Invention

Problems to be solved by the Invention

[0007] In the antenna unit described in Patent Document 1, one of the core sheets constituting the core is the sensor electrode, and hence an eddy current is generated in the sensor electrode at the time when the antenna coil is energized for signal transmission and reception. The eddy-current loss caused by the eddy current may affect the transmission and reception of an adequate signal from the antenna unit. On the other hand, in the antenna unit described in Patent Document 2, the second coil is the sensor electrode, whereby an eddy current is not generated, thus making it possible to overcome the above-mentioned problem.

[0008] At the time when a user unlocks a door to enter a vehicle, the user generally touches the inner side of the door handle. To prevent a malfunction, therefore, it is preferable that the door should not be unlocked when the user touches the outer side of the door handle (opposite side to the vehicle), and should be unlocked only when the user touches the inner side of the door handle. However, the second coil constituting the electrode sensor is arranged on the outer periphery side of the core with its winding direction being the longitudinal direction of the core in the antenna unit described in Patent Document 2, which is likely to cause a malfunction of unlocking the door even when the user erroneously touches the outer side of the door handle with no intention of unlocking the door.

[0009] Accordingly, it is an object of the present invention to provide an antenna unit with a structure which can enable transmission and reception of an adequate signal and prevent a malfunction of a predetermined operational target.

Means for solving the Problems

[0010] In order to solve the above-mentioned problems, an antenna unit according to the present invention includes: an antenna coil for effecting at least one of reception and transmission of an electromagnetic signal; a bobbin on which the antenna coil is wound; a core to be retained in the bobbin; and a sensor electrode coil to be wound on the bobbin to detect a predetermined state change based on a change in capacitance, the bobbin including: an antenna coil winding part on which the antenna coil is wound; and an electrode coil winding part which protrudes from the antenna coil winding part in one direction and on which the sensor electrode coil can be wound.

[0011] The antenna unit according to the present invention includes the sensor electrode coil which detects

a predetermined state change based on a change in capacitance. That is, the antenna unit according to the present invention uses the sensor electrode coil to detect a predetermined state change. Therefore, even when the sensor electrode coil is wound on the bobbin on which the antenna coil is to be wound, it is unlikely to cause the problem that the eddy-current loss affects the transmission and reception of an adequate signal from the antenna unit, thus ensuring the transmission and reception of the adequate signal.

[0012] Further, in the antenna unit according to the present invention, the bobbin includes the electrode coil winding part which protrudes from the antenna coil winding part in one direction and on which the sensor electrode coil can be wound. That is, in the antenna unit according to the present invention, the sensor electrode coil can be arranged so as to be wound on the bobbin in one direction thereof. Therefore, when the part having the sensor electrode coil wound thereon is arranged in the detection direction to detect a predetermined state change, it is possible to detect a state change in this one direction only. In other words, even if a state change occurs in another direction, it is possible not to detect the state change. It is therefore possible to prevent the operation of a predetermined operational target when a state change occurs in another direction. This results in prevention of the malfunction of the predetermined operational target.

[0013] In the present invention, it is preferable that the bobbin should include a plurality of winding projections at which a plurality of the electrode coil winding parts are formed. With this configuration, an electrode coil winding part on which the sensor electrode coil is to be wound can be arbitrarily selected from the plurality of electrode coil winding parts, and the sensor electrode coil can be wound at an arbitrary position. This can permit the range of detection by the sensor electrode coil to be easily changed.

[0014] In the present invention, it is preferable that the antenna coil should have one end always grounded. This configuration can allow the antenna coil wound on the antenna coil winding part and grounded to prevent a change in capacitance at the sensor electrode coil even when some situation to change the capacitance at the sensor electrode coil occurs on the opposite side to the part on which the sensor electrode coil is wound.

Effects of the Invention

[0015] As apparent from the above, the antenna unit according to the present invention can ensure the transmission and reception of an adequate signal and prevent the malfunction of the predetermined operational target.

Brief Description of Drawings

[0016]

[FIG. 1] A perspective view illustrating an antenna unit according to an embodiment of the present invention from one direction;

[FIG. 2] A perspective view illustrating the antenna unit illustrated in FIG 1 from another direction;

[FIG. 3] A perspective view illustrating a bobbin illustrated in FIG 1;

[FIG. 4] A diagram for describing a schematic configuration of an electronic key system using the antenna unit illustrated in FIG 1;

[FIG. 5] A diagram illustrating a part of a circuit configuration of the electronic key system using the antenna unit illustrated in FIG 1;

[FIG. 6] A diagram for describing an effect of the antenna unit illustrated in FIG. 1;

[FIG. 7] A circuit diagram illustrating an antenna drive section according to another embodiment of the present invention;

[FIG. 8] A diagram for describing an outline of an electrode coil winding pattern in a verification test for sensor sensitivity;

[FIGS. 9] Perspective views illustrating specific examples of the electrode coil winding pattern illustrated in FIG. 8 with (A) illustrating a specific example of the winding pattern for each of winding patterns No. 1 and No. 2 illustrated in FIG. 8, and (B) illustrating a specific example of the winding pattern for each of winding patterns No. 3 and No. 4 illustrated in FIG. 8;

[FIG. 10] A conceptual diagram for describing a method of conducting the verification test for sensor sensitivity;

[FIGS. 11] Diagrams for describing a layout direction of a copper plate in the verification test for sensor sensitivity; and

[FIGS. 12] Graphs illustrating results of the verification test for sensor sensitivity with (A) illustrating results when one end of an antenna coil is grounded, and (B) illustrating results when one end of the antenna coil is not grounded.

Description of the Symbols

[0017]

1	antenna unit
2	antenna coil
3	bobbin
3a	antenna coil winding part
3b	electrode coil winding part
3c	winding projection
4	core

5 electrode coil (sensor electrode coil)

Best Mode for carrying out the Invention

[0018] Embodiments of the present invention are described below referring to the accompanying drawings.

(Configuration of Antenna Unit)

[0019] FIG. 1 is a perspective view illustrating an antenna unit 1 according to an embodiment of the present invention from one direction. FIG. 2 is a perspective view illustrating the antenna unit 1 illustrated in FIG 1 from another direction. FIG 3 is a perspective view illustrating a bobbin 3 illustrated in FIG 1.

[0020] As is described later, the antenna unit 1 according to the present invention is an antenna unit to be used in an electronic key system for, for example, an automobile. As illustrated in FIGS. 1 and 2, the antenna unit 1 includes an antenna coil 2 for effecting reception and/or transmission of an electromagnetic signal, the bobbin 3 on which the antenna coil 2 is wound, a core 4 to be retained in the bobbin 3, and a sensor electrode coil 5 (hereinafter, referred to as "electrode coil 5") to be wound on the bobbin 3 to detect a predetermined state change based on a change in capacitance. The antenna unit 1 also includes two terminals 6 and 7 to which both end portions of the electrode coil 5 are respectively fixed, two terminals 8 and 9 to which both end portions of the antenna coil 2 are respectively fixed, a fixed base 10 to which the terminals 8 and 9 are fixed, and a terminal 11 fixed to the fixed base 10.

[0021] It is assumed in the following description that an oblique direction sloping lower rightward in FIG. 1 is an X direction, an oblique direction sloping upper rightward and perpendicular to the X direction is a Y direction, and an up-down direction in FIG 1 perpendicular to the X direction and the Y direction is a Z direction. It is also assumed that a lower-rightward oblique direction in FIG. 1 is an X1 direction, a direction opposite thereto is an X2 direction, a lower-leftward oblique direction in FIG. 1 is a Y1 direction, a direction opposite thereto is a Y2 direction, an up direction in FIG. 1 is a Z1 direction, and a down direction in FIG. 1 is a Z2 direction. Further, a plane which is formed by the Y direction and the Z direction is a YZ plane, and a plane which is formed by the Z direction and the X direction is a ZX plane.

[0022] The antenna coil 2 has an insulation film coated on the top surface of a conductive wire material. According to the embodiment, one antenna coil 2 is wound on an antenna coil winding part 3a (to be described later) formed at the bobbin 3, and is wound on a coil winding part 10c (to be described later) formed at the fixed base 10. According to the present invention, for example, the leading end side (end portion on the winding start side) of the antenna coil 2 is fixed to the terminal 8, and the trailing end side (end portion on the winding termination side) of the antenna coil 2 is fixed to the terminal 9.

[0023] The fixed base 10 is formed by a non-magnetic and insulative member (e.g., resin member or the like). The fixed base 10 includes an approximately rectangular-parallelepiped base-side mounting part 10a to be mounted to a base mounting part 3e (to be described later) formed at the X2-directional end portion of the bobbin 3, an approximately rectangular-parallelepiped terminal fixed part 10b to which the terminals 8, 9, and 11 are fixed, and an approximately rectangular-parallelepiped coil winding part 10c arranged between the base-side mounting part 10a and the terminal fixed part 10b. As illustrated in FIG. 1 or the like, the base-side mounting part 10a is arranged at the X1-directional end, and the terminal fixed part 10b is arranged at the X2-directional end. The fixed base 10 may be formed integrally with the bobbin 3.

[0024] The base-side mounting part 10a has engagement projections 10d formed thereat which engage with engagement recesses 3k formed in the base mounting part 3e to be described later. The terminals 8, 9, and 11 are fixed to the terminal fixed part 10b in such a way as to protrude from the X2-directional end of the fixed base 10 toward the X2 direction.

[0025] The core 4 is formed of a magnetic material, such as Mn-Zn ferrite or Ni-Zn ferrite. The core 4 is formed in a flat and thin rectangular parallelepiped shape. The core 4 is disposed between two flat plate parts 3g which form the antenna coil winding part 3a to be described later.

[0026] The electrode coil 5, like the antenna coil 2, has an insulation film coated on the top surface of a conductive wire material. According to the embodiment, one electrode coil 5 is wound around electrode coil winding parts 3b (to be described later) formed at the bobbin 3. According to the embodiment, the leading end side (end portion on the winding start side) of the electrode coil 5 is fixed to the terminal 6, and the trailing end side (end portion on the winding termination side) of the electrode coil 5 is fixed to the terminal 7.

[0027] The bobbin 3, like the fixed base 10, is formed by a non-magnetic and insulative member (e.g., resin member or the like) into a hollow approximately rectangular parallelepiped shape as a whole. As illustrated in FIG 3 or the like, the bobbin 3 includes the antenna coil winding part 3a on which the antenna coil 2 is wound, winding projections 3c each having the electrode coil winding part 3b on which the electrode coil 5 can be wound, a terminal fixing part 3d to which the terminals 6 and 7 are fixed, the base mounting part 3e to which the fixed base 10 is attached, and positioning projections 3f for positioning the winding position of the antenna coil 2 in the X direction.

[0028] The bobbin 3 according to the embodiment has the terminal fixing part 3d, the antenna coil winding part 3a, and the base mounting part 3e arranged adjacently to one another in the X2 direction from the X1 direction in the named order. The winding projection 3c and the positioning projection 3f are formed in such a way as to

protrude from the antenna coil winding part 3a in a predetermined direction. As is described later, the winding projection 3c and the base mounting part 3e serve, together with the positioning projections 3f, to position the winding position of the antenna coil 2 in the X direction.

[0029] The bobbin 3 according to the embodiment has the plurality of winding projections 3c. Specifically, the bobbin 3 has four winding projections 3c formed at predetermined intervals in the X direction. Further, the bobbin 3 according to the embodiment has the plurality of positioning projections 3f. Specifically, the bobbin 3 has a total of six positioning projections 3f formed at the two flat plate parts 3g (to be described later) which form the antenna coil winding part 3a, and between the four winding projections 3c.

[0030] The antenna coil winding part 3a is formed by the two thin elongated flat plate parts 3g parallel to the ZX plane as illustrated in FIG 3. Specifically, the antenna coil winding part 3a is formed by the two flat plate part 3g coupled together via the terminal fixing part 3d and the winding projections 3c. The flat plate parts 3g are respectively arranged on both Y-directional end sides of the bobbin 3.

[0031] The terminal fixing part 3d is formed in an approximately rectangular parallelepiped shape. A layout hole 3h where the X1-directional end portion of the core 4 is disposed is formed in the terminal fixing part 3d in such a way as to penetrate the terminal fixing part 3d in the X direction, and a lead-out/lead-in groove 3i for the electrode coil 5 is formed in the Z1-directional end face of the terminal fixing part 3d. Fixing holes 3j to which the terminals 6 and 7 are fixed are formed in the X1-directional end face of the terminal fixing part 3d, and the terminals 6 and 7 are fixed to the terminal fixing part 3d in such a way as to protrude from the X1-directional end of the bobbin 3 toward the X1 direction.

[0032] The base mounting part 3e is formed in a block shape and is arranged at the X2-directional end portions of the two flat plate parts 3g. The engagement recess 3k which engage with the engagement projections 10d of the fixed base 10 are formed in the base mounting part 3e. An X1-directional end face 3m of the base mounting part 3e which is parallel to the YZ plane serves, together with the positioning projections 3f, to position the winding position of the antenna coil 2 in the X direction as mentioned above.

[0033] The winding projections 3c are formed in such a way that the flat portions parallel to the YZ plane protrude from the flat plate parts 3g outward in the Y direction and outward in the Z direction. Specifically, the winding projections 3c are formed in such a way as to slightly protrude from the two flat plate parts 3g outward in the Y direction and in the Z2 direction, respectively, in order to position the winding position of the antenna coil 2 in the X direction, and are formed in such a way as to significantly protrude from the flat plate parts 3g in the Z1 direction and couple the two flat plate parts 3g together for the winding of the electrode coil 5. As illustrated in FIG 2, the winding projection 3c located at the outermost position in the X1 direction has portions slightly protruding in the Z2 direction of the winding projection 3c, which are connected so as to couple the two flat plate parts 3g. That is, the shape of the winding projection 3c located at the outermost position in the X1 direction as viewed from the X direction is an approximately rectangular parallelepiped shape, while the shape of the other winding projections 3c as viewed from the X direction is an approximately groove-like shape open in the Z2 direction.

[0034] As illustrated in FIG 3, a groove part 3n is formed in a portion of the winding projection 3c, which protrudes in the Z1 direction, in a predetermined Y-directional range, and both sides of the groove part 3n are the electrode coil winding parts 3b on which the electrode coil 5 can be wound. That is, in the embodiment, two electrode coil winding parts 3b to be arranged with a predetermined interval provided in the Y direction therebetween are formed at the winding projection 3c. Note that the X1-directional end faces of the winding projections 3c serve to position the winding position of the antenna coil 2 in the X direction.

[0035] The positioning projections 3f are formed in such a way that the flat plate portions parallel to the YZ plane protrude from the two flat plate parts 3g outward in the Y direction and outward in the Z direction. Specifically, the positioning projections 3f are formed in such a way as to slightly protrude from the two flat plate parts 3g outward in the Y direction and outward in the Z direction in order to position the winding position of the antenna coil 2 in the X direction.

[0036] As illustrated in FIGS. 1 and 2, the antenna coil 2 is sequentially wound around the antenna coil winding part 3a while being positioned in the X direction by the X1-directional end faces of the positioning projections 3f, the X1-directional end faces of the winding projections 3c, and X1-directional end face 3m of the base mounting part 3e. That is, according to the embodiment, antenna coil parts 20 are formed at seven locations by the antenna coil 2 wound around the lateral periphery of the bobbin 3 (periphery formed by the Y direction and the Z direction).

[0037] As illustrated in FIG 1, the electrode coil 5 is wound in such a way as to abut on the X1-directional end face of the electrode coil winding part 3b located at the outermost position in the X1 direction, and the X2-directional end face of the electrode coil winding part 3b located at the outermost position in the X2 direction, and abut on the Y-directional both ends of the electrode coil winding part 3b. Specifically, for example, the electrode coil 5 is wound on the electrode coil winding parts 3b arranged on the Y1-directional side, and then wound on the electrode coil winding parts 3b arranged on the Y2-directional side, with electrode coil parts 21 being formed at two positions on the Z1-directional side of the bobbin 3. In this way, the electrode coil 5 is wound on the electrode coil winding parts 3b protruding in the Z1 direction and is arranged on the Z1-directional side of the bobbin 3.

(Schematic Configuration and Schematic Operation of Electronic Key System)

[0038] FIG. 4 is a diagram for describing the schematic configuration of an electronic key system which uses the antenna unit 1 illustrated in FIG. 1. FIG. 5 is a diagram illustrating a part of the circuit configuration of the electronic key system using the antenna unit 1 illustrated in FIG 1.

[0039] The antenna unit 1 with the foregoing configuration is used in, for example, an electronic key system for an automobile (so-called keyless entry system). This electronic key system includes an on-vehicle device to be mounted on a vehicle, and a portable device which is carried around by a user who drives or so the automobile. As illustrated in FIG 5, the on-vehicle device includes, for example, an antenna drive section 26 which energizes the antenna coil 2 to drive the antenna unit 1, a drive control section 27 which controls the antenna drive section 26, and a detecting section 28 which is connected to the electrode coil 5 to detect a change in capacitance between the electrode coil 5 and the ground (earth) or the like.

[0040] In the on-vehicle device, as illustrated in FIG 4, the antenna unit 1 is disposed inside a handle of a door 30 of the automobile (door handle) 31. Specifically, the antenna unit 1 is disposed inside the door handle 31 with the face of the Z1-directional side (i.e., side where the electrode coil 5 is arranged) of the antenna unit 1 facing toward the door 30 side (i.e., facing the depth side of the sheet of FIG 4). The detecting section 28 is disposed inside the door handle 31 in such a way as to adjoin the antenna unit 1. Further, the antenna drive section 26 and the drive control section 27 are disposed in the main part of the automobile (not shown).

[0041] As illustrated in FIG 5, the antenna drive section 26 includes, for example, an n-channel field effect transistor (FET) 32 and a p-channel FET 33 connected in series. As illustrated in FIG. 5, the gates of the n-channel FET 32 and the p-channel FET 33 are connected to the drive control section 27. The drains of the n-channel FET 32 and the p-channel FET 33 are connected via a capacitor 34 to the terminal 8 to which the end portion of the antenna coil 2 is fixed. Further, the source of the n-channel FET 32 is connected to a battery (not shown) to be installed in the vehicle for energizing the antenna coil 2, while the source of the p-channel FET 33 is grounded.

[0042] According to the embodiment, one end of the antenna coil 2 is always grounded. For example, the terminal 9 to which the end portion of the antenna coil 2 is fixed is grounded through a predetermined wiring line.

[0043] The detecting section 28 is connected through predetermined wiring lines to the terminals 6 and 7 to which both end portions of the electrode coil 5 are respectively connected. This detecting section 28 detects a change in capacitance between the electrode coil 5 and the ground, which occurs when the user's hand touches, for example, the inner side (depth side of the sheet of FIG. 4) of the door handle 31. The detecting section 28 then outputs a detection signal representing a change in capacitance to the drive control section 27.

[0044] The electronic key system having the foregoing configuration operates as follows. First, when the user touches the inner side of the door handle 31 to unlock the locked door 30 and enter the automobile, the capacitance between the electrode coil 5 and the ground changes. Based on the change in capacitance, the detecting section 28 outputs a detection signal representing a change in capacitance to the drive control section 27.

[0045] Based on the input detection signal representing the change in capacitance, the drive control section 27 drives the antenna drive section 26 to energize the antenna coil 2. When the antenna coil 2 is energized, the antenna unit 1 radio-transmits a predetermined detection signal to the portable device (not shown). The portable device which has received the signal transmitted from the antenna coil 2 transmits an unlock signal for the door 30 toward a predetermined door unlocking/locking control section (not shown) installed in the on-vehicle device. Then, the door unlocking/locking control section drives an urllocking/locking device (not shown) for the door 30 to unlock the door 30 based on the unlock signal.

[0046] The electronic key system may operate in the same way as the electronic key system described in the Patent Document 1 or the Patent Document 2. That is, the electronic key system may operate as follows. When the locked door 30 is unlocked, first, the drive control section 27 drives the antenna drive section 26 to set the antenna coil 2 in an energized state for transmission and reception of a predetermined signal between the portable device and the antenna unit 1. When a registered code of the portable device which is stored in the on-vehicle device is verified through the transmission and reception of the signal, the detecting section 28 is ready to be able to detect a change in capacitance between the electrode coil 5 and the ground. When the user's hand touches the inner side of the door handle 31 in this state to change the capacitance between the electrode coil 5 and the ground, the unlocking/locking device for the door 30 is driven, whereby the door is unlocked.

(Main Effect of the Embodiment)

[0047] As described above, the antenna unit 1 according to the embodiment includes the electrode coil 5 for detecting a predetermined state change, such as touching of the user's hand with the inner side of the door handle 31, based on a change in capacitance. That is, the antenna unit 1 according to the embodiment detects the predetermined state change by using the electrode coil 5. Therefore, even if the electrode coil 5 is wound on the bobbin 3 on which the antenna coil 2 is wound, it is unlikely to raise a problem such that the eddy-current loss affects the transmission and reception of an adequate signal from the antenna unit 1. As a result, according to the embodiment, the transmission and reception

of the adequate signal from the antenna unit 1 can be ensured.

[0048] According to the embodiment, the electrode coil winding parts 3b around which the electrode coil 5 can be wound are formed in such a way as to protrude from the antenna coil winding part 3a in the Z1 direction. That is, according to the embodiment, the electrode coil 5 is wound and arranged around the Z1-direction side of the bobbin 3. According to the embodiment, one end of the antenna coil 2 is always grounded. Therefore, for example, in a case where the antenna unit 1 is used in an electronic key system for an automobile which has the configuration as illustrated in FIGS. 4 and 5, when the user touches the door handle 31 from the inner side thereof, the capacitance between the electrode coil 5 and the ground changes, whereas when the user touches the door handle 31 from the outer side (near side of the sheet of FIG 4) thereof, the capacitance between the electrode coil 5 and the ground does not change because one end of the antenna coil 2 is grounded.

[0049] As described above, even when some situation to change the capacitance between the electrode coil 5 and the ground occurs on the Z2-directional side opposite to the Z1-directional side on which the electrode coil 5 is wound, a change in capacitance between the electrode coil 5 and the ground can be prevented by the antenna coil 2 wound on the antenna coil winding part 3a and grounded. Therefore, a predetermined operational target, such as the door 30, can be operated based only on a state change on the Zl-directional side where the electrode coil 5 is wound and arranged. This makes it possible to prevent the malfunction of the unlocking/locking operation or the like of the door 30. For example, the antenna unit 1 can be configured in such a way that the door 30 is not unlocked unless the door handle 31 is held firmly even if the user erroneously touches the outer side of the door handle 31.

[0050] According to the embodiment, the bobbin 3 has four winding projections 3c formed at predetermined intervals in the X direction. Each winding projection 3c has two electrode coil winding parts 3b formed at a predetermined interval in the Y direction. That is, the bobbin 3 has a total of eight electrode coil winding parts 3b. It is therefore possible to arbitrarily select, from the eight electrode coil winding parts 3b, the electrode coil winding parts 3b on which the electrode coil 5 is to be wound, and wind and arrange the electrode coil 5 at arbitrary positions. That is, in addition to the arrangement of the electrode coil 5 illustrated in FIG 1, for example, two winding projections 3c arranged inward in the X direction are used, and the electrode coil 5 is wound and arranged on the electrode coil winding parts 3b formed at those winding projections 3c as illustrated in FIG 6. Various arrangements of the electrode coil 5 other than the one illustrated in FIG 6 are also possible. This makes it possible to easily change the range of detection by the electrode coil 5.

[0051] According to the embodiment, the sensor electrode which detects a predetermined state change is formed by the electrode coil 5, and hence the inductance value of the sensor electrode can be easily and arbitrarily set by the number of turns (turn number) of the electrode coil 5 to be wound on the electrode coil winding parts 3b. Particularly, the bobbin 3 includes eight electrode coil winding parts 3b according to the embodiment, and hence each of the inductance value of the electrode coil part 21 formed by the electrode coil 5 wound on one electrode coil winding part 3b and the inductance value of the electrode coil part 21 formed by the electrode coil 5 wound on another electrode coil winding part 3b can be easily and arbitrarily set.

(Relation between Winding Pattern of Electrode Coil and Sensor Sensitivity)

[0052] FIG. 8 is a diagram for describing the outline of the winding pattern of the electrode coil 5 in a verification test for sensor sensitivity. FIGS. 9 are perspective views illustrating specific examples of the winding pattern of the electrode coil 5 illustrated in FIG 8 with (A) illustrating a specific example of each of the winding patterns No. 1 and No. 2 illustrated in FIG. 8, and (B) illustrating a specific example of each of the winding patterns No. 3 and No. 4 illustrated in FIG. 8. FIG. 10 is a conceptual diagram for describing a method of conducting the verification test for sensor sensitivity. FIGS. 11 are diagrams for describing the layout direction of a copper plate 40 in the verification test for sensor sensitivity. FIGS. 12 are graphs illustrating the results of the verification test for sensor sensitivity with (A) illustrating the results when one end of the antenna coil 2 is grounded, and (B) illustrating the results when one end of the antenna coil 2 is not grounded.

[0053] According to the embodiment, the sensor electrode is configured with the winding of the electrode coil 5 as described above. Further, the sensor for detecting a predetermined state change includes the sensor electrode and the detecting section 28. The relation between the winding pattern of the electrode coil 5 and the sensitivity of the sensor (sensor sensitivity) is described below referring to the results of the test.

[0054] While the antenna unit 1 illustrated in FIGS. 8, 9, and 11 slightly differs from the antenna unit 1 illustrated in FIGS. 1 to 3, the former antenna unit 1 has substantially the same configuration and the same functions as the latter antenna unit 1 illustrated in FIGS. 1 to 3. Same reference numerals are given to the components in FIGS. 8, 9, and 11, which have the same functions as the corresponding components of the antenna unit 1 illustrated in FIGS. 1 to 3.

[0055] First, test conditions for the verification test for sensor sensitivity are described below. In the verification test, as illustrated in FIG 8, the antenna units 1 having the sensor electrodes formed by the electrode coil 5 wound in four winding patterns No. 1 to No. 4 were used. That is, the antenna unit 1 having the sensor electrode (No. 1, No. 2) formed by the electrode coil 5 wound so

as to surround the entire periphery of the face of the Z1-directional side, which is a reaction surface, and the antenna unit 1 having the sensor electrode (No. 3, No. 4) formed by the electrode coil 5 wound on the reaction surface separately on both sides (both Y-directional sides) were used in the verification test.

[0056] Specifically, used in the verification test were the antenna unit 1 having the sensor electrode formed by the electrode coil 5 wound in the winding pattern No. 1 in which one electrode coil 5 is wound in one turn in FIG. 9(A), the antenna unit 1 having the sensor electrode formed by the electrode coil 5 wound in the winding pattern No. 2 in which one electrode coil 5 is wound in four turns in FIG 9(A), the antenna unit 1 having the sensor electrode formed by the electrode coil 5 wound in the winding pattern No. 3 in which one electrode coil 5 is wound in one turn in FIG 9(B), and the antenna unit 1 having the sensor electrode formed by the electrode coil 5 wound in the winding pattern No. 4 in which one electrode coil 5 is wound in four turns in FIG 9(B).

[0057] As a comparative example, an antenna unit having the sensor electrode formed by a sheet core 55 made of a thin magnetic member instead of the electrode coil 5, as illustrated in a pattern No. 5 of FIG 8, was used in the verification test, too.

[0058] The antenna unit 1 having the sensor electrode formed by the electrode coil 5 wound in each of the winding patterns No. 1 to No. 4 illustrated in FIG 8 or the antenna unit 1 having the sensor electrode formed by the sheet core 55 illustrated in the pattern No. 5 was secured at a position apart from a metal plate (steel plate equivalent to the sheet metal of the door 30) 41 by 30 mm as illustrated in FIG 10. With the copper plate 40 used as a detection target being caused to gradually approach the antenna unit 1, the distance (detection distance) between the antenna unit 1 and the copper plate 40 when the copper plate 40 was detected by the sensor formed by the electrode coil 5 or the like was measured.

[0059] As illustrated in FIG 11, the antenna unit 1 used in the test had a longitudinal (X direction in FIG. 1) width of 55 mm and a lateral (Y direction in FIG 1) width of 16 mm. The copper plate 40 used in the test was formed in a rectangular shape and had a lateral width of 25 mm as illustrated in FIG 11. In the verification test, the antenna coil 2 and the end portion side of the electrode coil 5 (or sheet core 55) are connected to a substrate 42 for the test.

[0060] In the verification test, the detection distance was measured as the copper plate 40 was caused to gradually approach the antenna unit 1 in two patterns, namely, a pattern (pattern A) in which the copper plate 40 was caused to gradually approach the antenna unit 1 with the longitudinal direction of the copper plate 40 being perpendicular to the longitudinal direction of the antenna unit 1 and a part of the sensor electrode and the copper plate 40 overlying each other, as illustrated in FIG 11 (A), and a pattern (pattern B) in which the copper plate 40 was caused to gradually approach the antenna unit 1 with the longitudinal direction of the copper plate 40 being matched with the longitudinal direction of the antenna unit 1 and the entire sensor electrode and the copper plate 40 overlying each other, as illustrated in FIG 11(B).

[0061] Further, the detection distance was measured in the verification test with one end of the antenna coil 2 being grounded (for example, state illustrated in FIG 5) and with one end of the antenna coil 2 being ungrounded (state in which a capacitor is arranged between the terminal 9 and the ground in FIG 5).

[0062] The results show that, as illustrated in FIG. 12 (A), with one end of the antenna coil 2 being grounded, the detection distance of the antenna unit 1 having the sensor electrode formed by the electrode coil 5 wound in the pattern No. 4 is the longest and this antenna unit 1 has the best sensor sensitivity. The results also show that, as illustrated in FIG. 12(B), even with one end of the antenna coil 2 being ungrounded, the detection distance of the antenna unit 1 having the sensor electrode formed by the electrode coil 5 wound in the pattern No. 4 is the longest and this antenna unit 1 has the best sensor sensitivity. In other words, it is found that when the sensor electrode is formed by the electrode coil 5 wound on the reaction surface separately on both sides thereof in a plurality of turns, the sensor sensitivity of the antenna unit 1 becomes the best. Note that "A" and "B" of FIG. 12 respectively indicate the detection distances when the copper plate 40 is caused to approach the antenna unit 1 in the pattern A and the pattern B.

[0063] The detection distance in the patterns No. 1 to No. 4 did not change regardless of whether one end of the antenna coil 2 was grounded or not. That is, it is found that with the sensor electrode formed by the electrode coil 5, the grounding state of the antenna coil 2 hardly affects the sensor sensitivity of the antenna unit 1. In the case of the pattern No. 5 using the sheet core 55, by way of contrast, the detection distance changed between the case where one end of the antenna coil 2 was grounded and the case where one end of the antenna coil 2 was not grounded. That is, it is found that with the sensor electrode formed by the sheet core 55, the grounding state of the antenna coil 2 affects the sensor sensitivity of the antenna unit. It can be said from the above that in the case of the sensor electrode formed by the electrode coil 5, as compared with the case of the sensor electrode formed by the sheet core 55, the sensor sensitivity of the antenna unit 1 is not easily affected by the state of the antenna coil 2 and is stable.

[0064] The reason why the detection distance provided by the antenna unit 1 having the sensor electrode formed by the electrode coil 5 wound in the pattern No. 4 becomes longer than the detection distance provided by the antenna unit 1 having the sensor electrode formed by the sheet core 55 seems to come from the suppression of the influence of the floating capacitance component between the sheet core 55 and the antenna coil 2 which is produced with the use of the sheet core 55.

[0065] In the verification test, one electrode coil 5 is

wound on the reaction surface separately on both sides thereof in the patterns No. 3 and No. 4, but two electrode coils 5 may be wound on the reaction surface on one side and the other side thereof, respectively. That is, a 2-channel sensor electrode may be formed by two electrode coils 5. Alternatively, the leading end side and the trailing end side of the electrode coil 5 may be twined and fixed to the same terminal 6 (or terminal 7). In other words, the leading end and the trailing end of the electrode coil 5 may be short-circuited. Further, the number of turns of the electrode coil 5 in the pattern No. 2, No. 4 should not necessarily be four (four turns). For example, the number of turns of the electrode coil 5 in the pattern No. 2, No. 4 may be two or three, or five or more.

(Another Embodiment)

[0066] In the foregoing embodiment, the bobbin 3 has four winding projections 3c formed at predetermined intervals in the X direction. For example, the bobbin 3 may have two or three winding projections 3c, or five or more winding projections 3c instead. Further, a single wide winding projection 3c in the X direction may be formed, and the electrode coil 5 is wound on the single winding projection 3c. In the foregoing embodiment, each winding projection 3c has two electrode coil winding parts 3b formed at a predetermined interval therebetween in the Y direction. Alternatively, for example, each winding projection 3c may have three or more electrode coil winding parts 3b formed at predetermined intervals in the Y direction, or may have a single electrode coil winding part 3b.

[0067] In the electronic key system according to the foregoing embodiment, the antenna coil 2 is energized using the antenna drive section 26 which has the n-channel FET 32 and the p-channel FET 33 connected in series. Alternatively, for example, the antenna coil 2 may be energized using an antenna drive section 36 which is a so-called full bridge circuit which uses two n-channel FETs 32 and two p-channel FETs 33 as illustrated in FIG 7 in place of the antenna drive section 26. In the antenna drive section 36, the gates of the n-channel FETs 32 and the p-channel FETs 33 are connected to the drive control section 27, while the drains of the n-channel FETs 32 and the p-channel FETs 33 are connected to the end portions of the antenna coil 2. The sources of the n-channel FETs 32 are connected to the battery (not shown) of the on-vehicle device, with the sources of the p-channel FETs 33 being grounded.

[0068] In the case of using the antenna drive section 36, when at least one of the two p-channel FETs 33 is turned on with the antenna coil 2 being grounded, a predetermined operational target, such as the door 30, can be operated based only on a state change on the Z1-directional side where the electrode coil 5 is wound as per the above-mentioned embodiment. If both of the two p-channel FETs 33 are turned off with the antenna coil 2 being ungrounded, on the other hand, a predetermined operational target can be operated based on a state change on the Z1-directional side where the electrode coil 5 is wound and a state change on the Z2-directional side where the electrode coil 5 is not wound.

[0069] In the foregoing embodiment, the electrode coil 5 has one end side fixed to the terminal 6, and the other end side fixed to the terminal 7. Alternatively, for example, resin terminals (projections) may be formed at the bobbin 3, and the electrode coil 5 may have one end side fixed to this resin terminals, and the other end side fixed to the terminal 11. In this case, the terminals 6, 7 can be omitted, thus simplifying the configuration of the antenna unit 1. Further, the detecting section 28 may be arranged on the terminal 11 side. Note that a plurality of the resin terminals are formed in such a way that, for example, the resin terminals protrude from the two flat plate parts 3g of the bobbin 3 outward in the Y direction.

[0070] The foregoing descriptions of the embodiments have been given of an example of using the antenna unit 1 in, for example, an electronic key system for an automobile, but the antenna unit 1 may be used in an electronic key system for a house other than for an automobile. For example, the approach of a user from the front side of the door of a house may be detected by the electrode coil 5, whereby the opening/closing of the door may be carried out using the antenna unit 1. In addition, the antenna unit 1 may be used in a system other than an electronic key system.

Claims

1. An antenna unit comprising:

an antenna coil for effecting at least one of reception and transmission of an electromagnetic signal;
a bobbin on which the antenna coil is wound;
a core to be retained in the bobbin; and
a sensor electrode coil to be wound on the bobbin to detect a predetermined state change based on a change in capacitance,
the bobbin including:

an antenna coil winding part on which the antenna coil is wound; and
an electrode coil winding part which protrudes from the antenna coil winding part in one direction and on which the sensor electrode coil can be wound.

2. An antenna unit according to Claim 1, wherein the bobbin includes a plurality of winding projections at which a plurality of the electrode coil winding parts are formed.

3. An antenna unit according to Claim 1 or 2, wherein the antenna coil has one end always grounded.

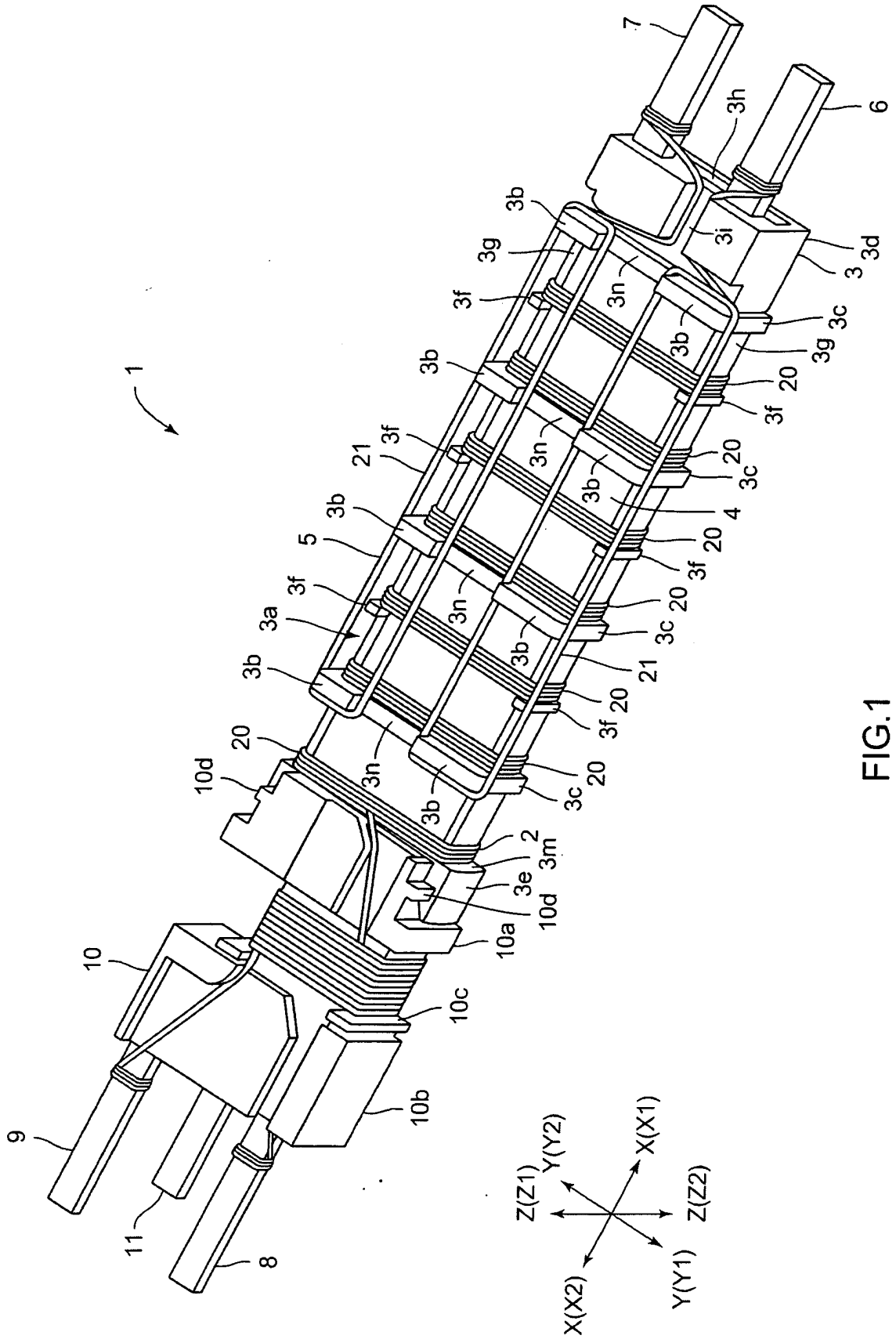

1
2
3
3a
3b
3c
3d
3e
3f
3g
3h
3i
3m
3n
4
5
6
7
8
9
10
10a
10b
10c
10d
11
20
21
Z(Z1)
Y(Y2)
X(X1)
Z(Z2)
X(X2)
Y(Y1)

FIG.1

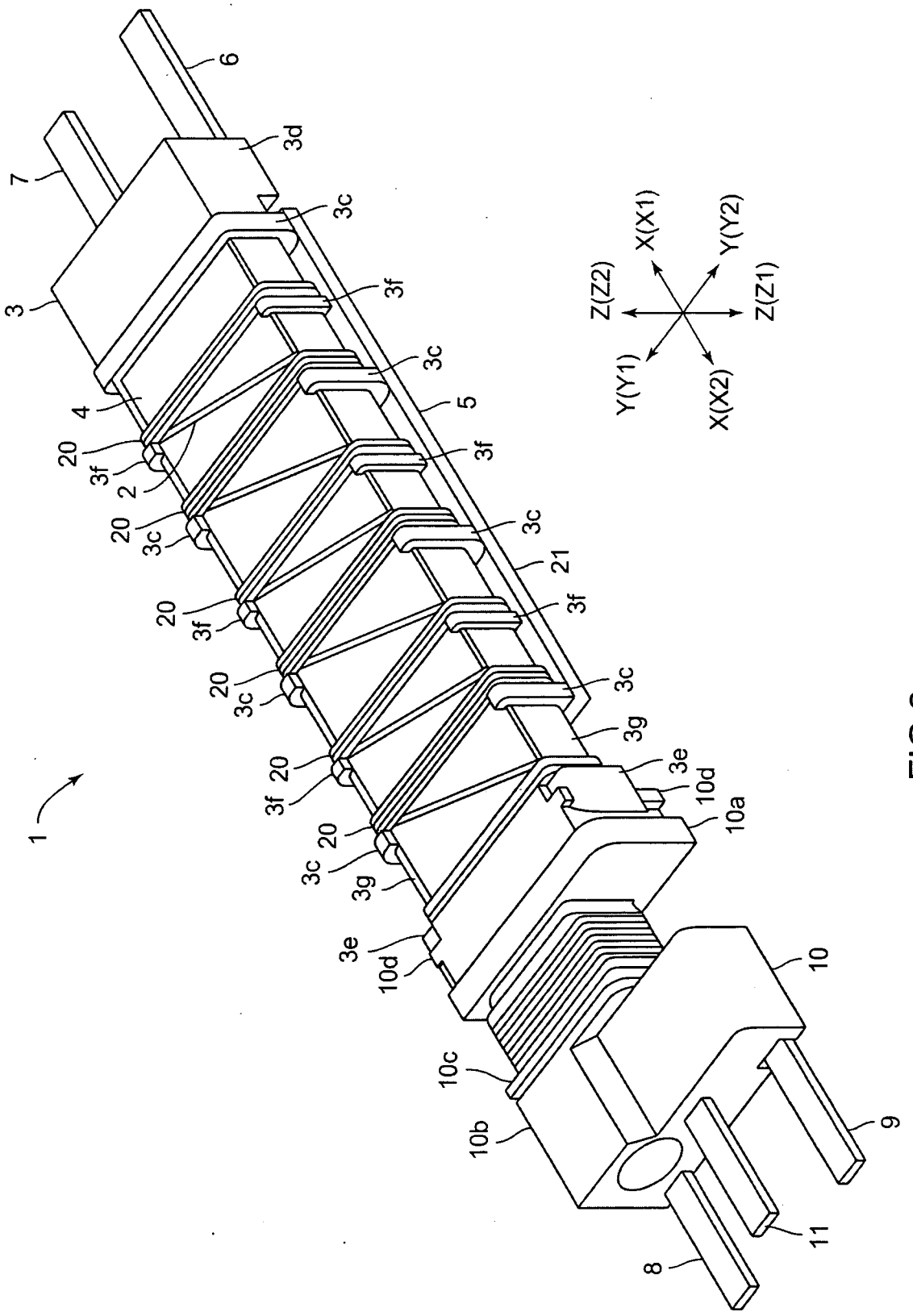

1
2
3
4
5
6
7
8
9
10
10a
10b
10c
10d
11
20
21
3c
3d
3e
3f
3g
X(X1)
X(X2)
Y(Y1)
Y(Y2)
Z(Z1)
Z(Z2)

FIG.2

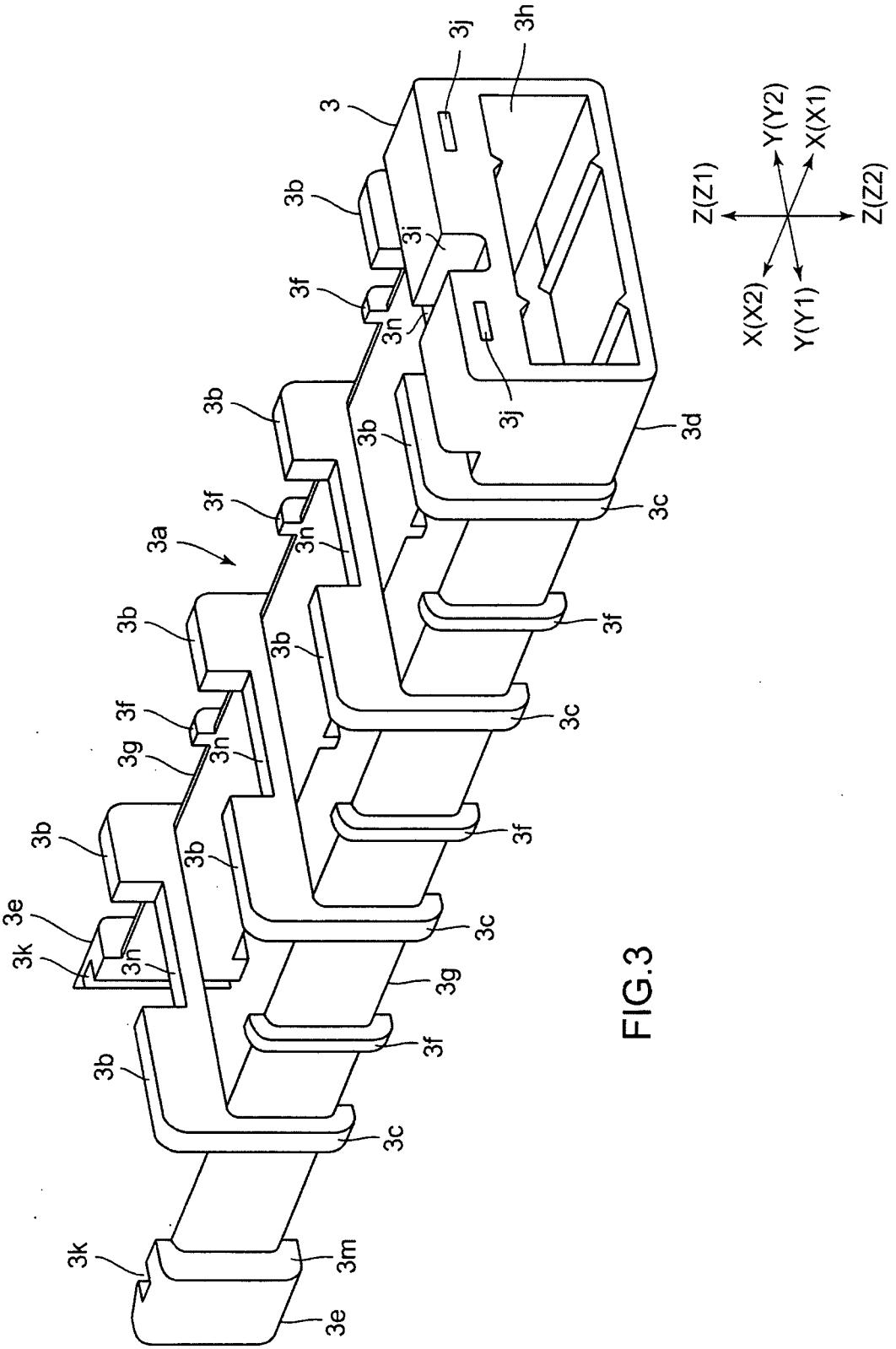


FIG.3

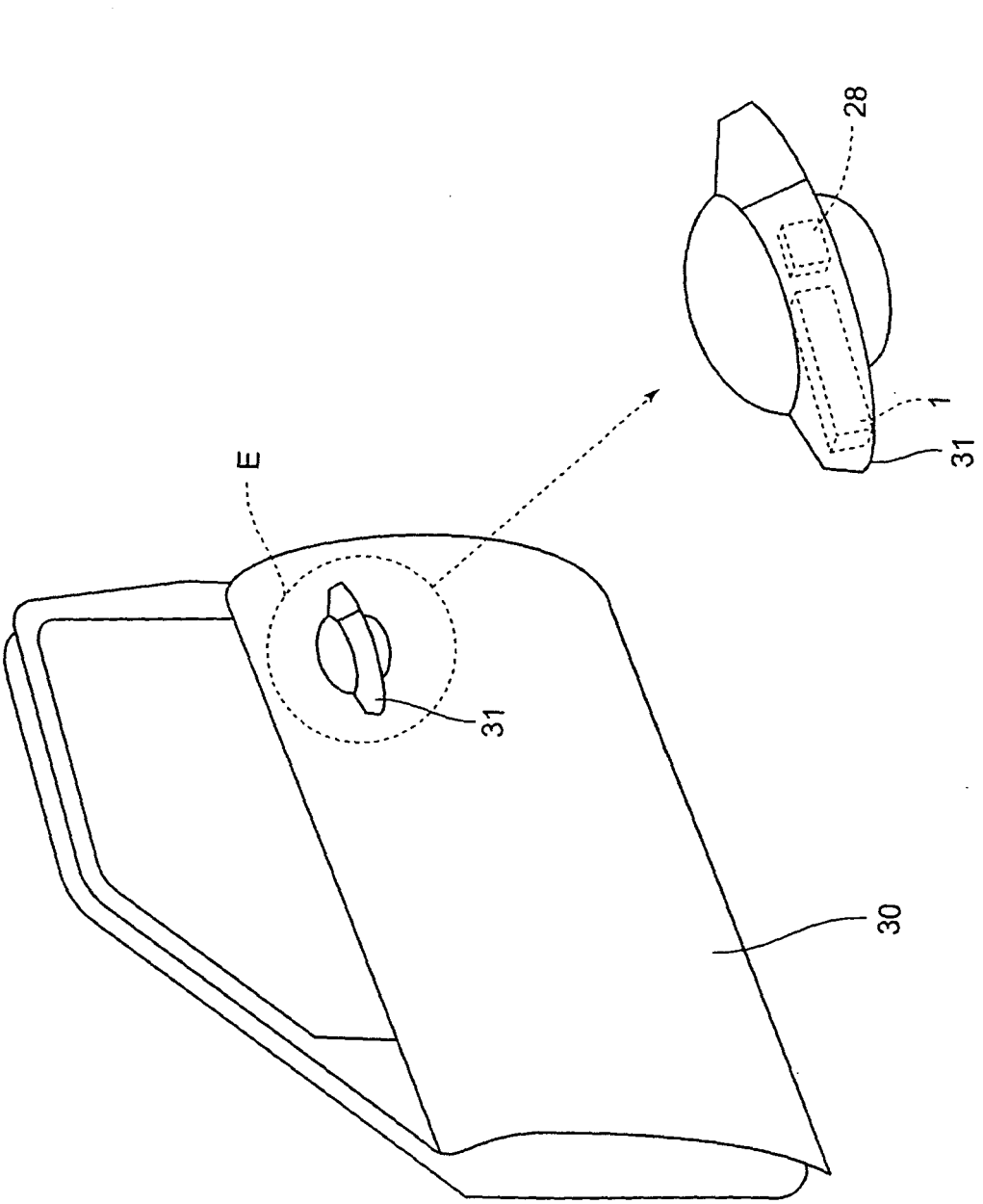


FIG.4

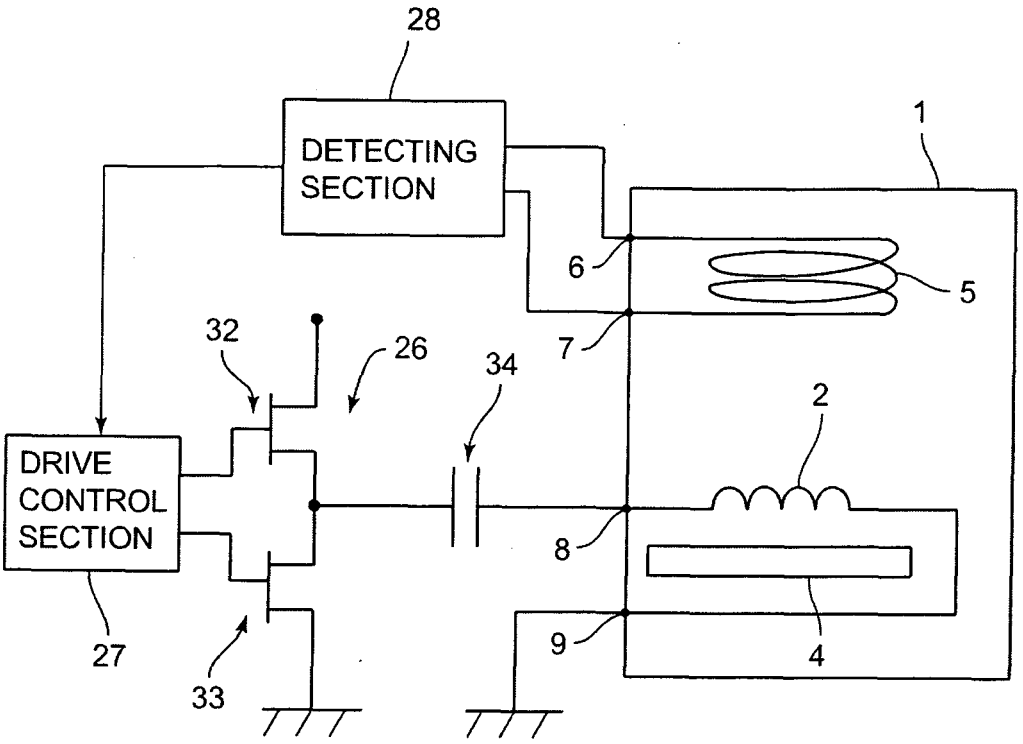

28
DETECTING SECTION
1
6
5
7
32
26
34
2
DRIVE CONTROL SECTION
8
27
33
9
4

FIG.5

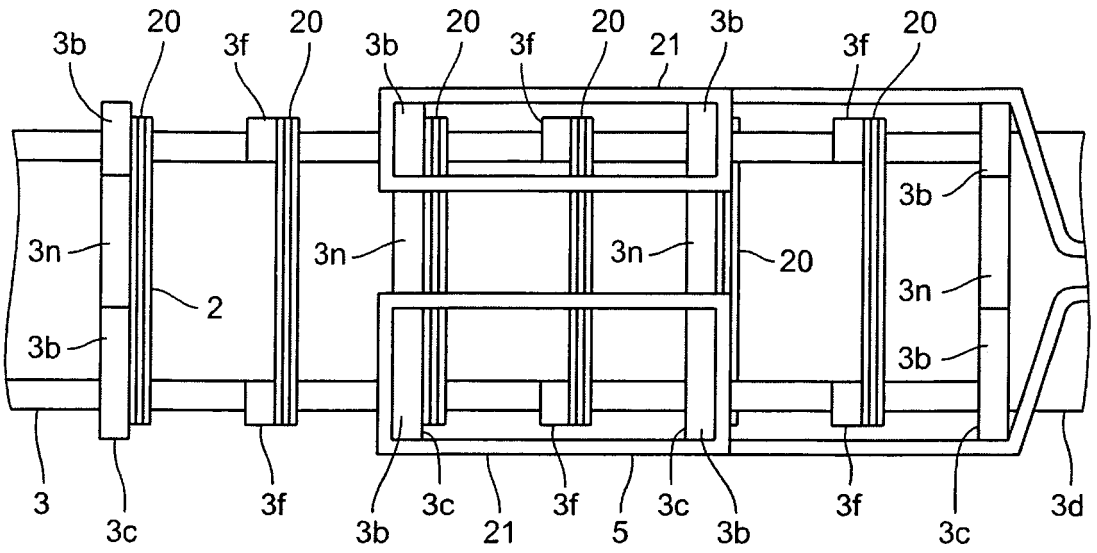

3b
20
3f
20
3b
20
3f
20
21
3b
3f
20
3b
3n
3n
3n
20
2
3n
3b
3b
3
3c
3f
3b
3c
21
3f
5
3c
3b
3f
3c
3d

FIG.6

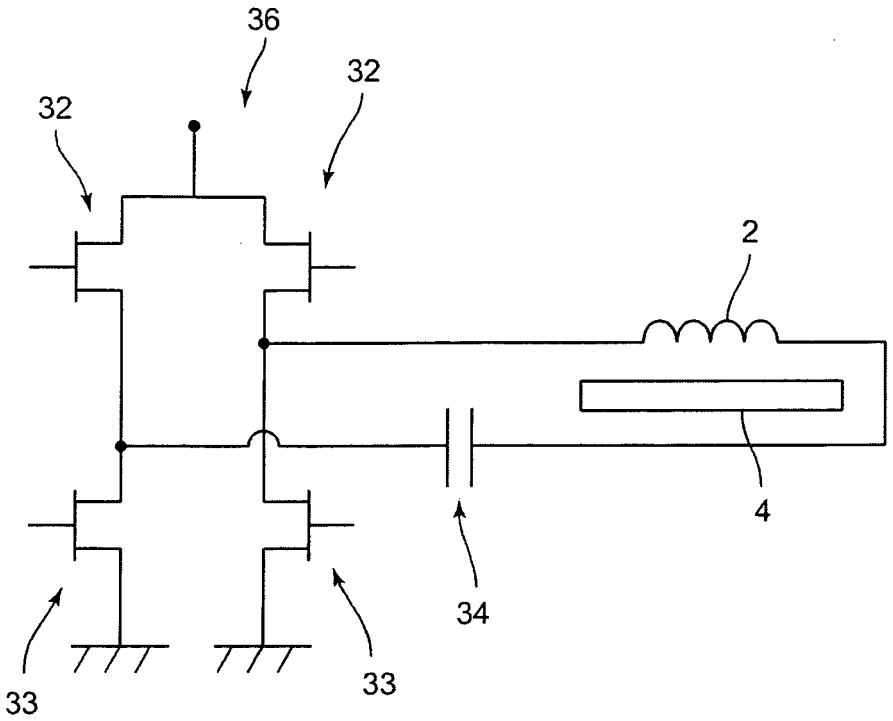


FIG.7

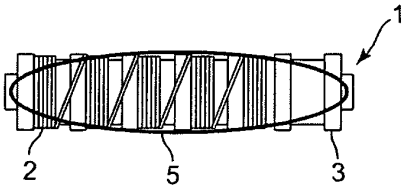
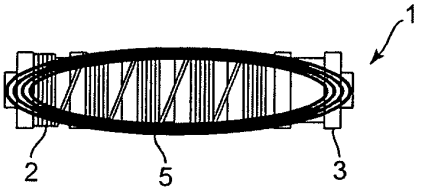
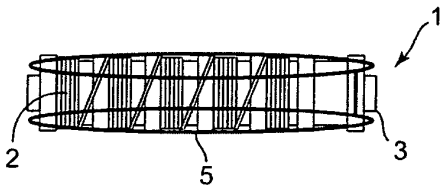
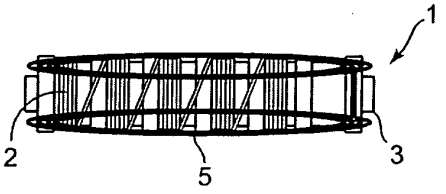
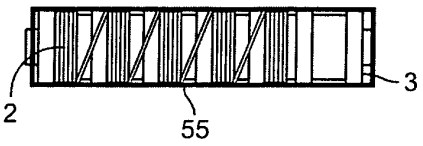
No.	WINDING IMAGE	WINDING STATE
1		ELECTRODE COIL IS WOUND SO AS TO SURROUND ENTIRE REACTION SURFACE. NUMBER OF TURNS IS ONE.
2		ELECTRODE COIL IS WOUND SO AS TO SURROUND ENTIRE REACTION SURFACE. NUMBER OF TURNS IS FOUR.
3		ELECTRODE COIL IS WOUND ON REACTION SURFACE SEPARATELY ON BOTH SIDES THEREOF. NUMBER OF TURNS IS ONE.
4		ELECTRODE COIL IS WOUND ON REACTION SURFACE SEPARATELY ON BOTH SIDES THEREOF. NUMBER OF TURNS IS FOUR.
5 (COMPARATIVE EXAMPLE)		INSTEAD OF ELECTRODE COIL, SHEET CORE IS USED FOR SENSOR ELECTRODE AS COMPARATIVE EXAMPLE.

FIG.8

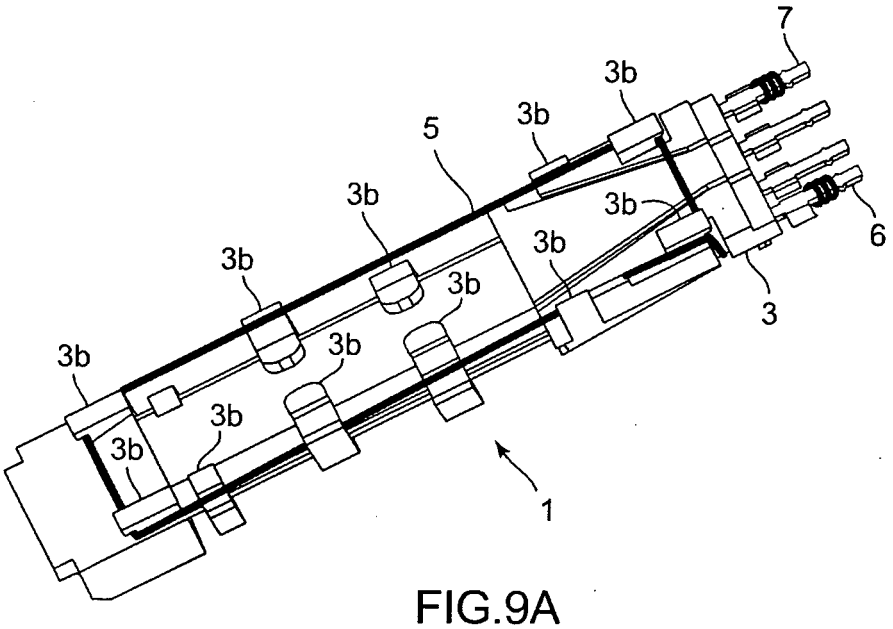

7
3b
3b
5
3b
3b
3b
6
3b
3b
3b
3
3b
3b
3b
3b
1

FIG.9A

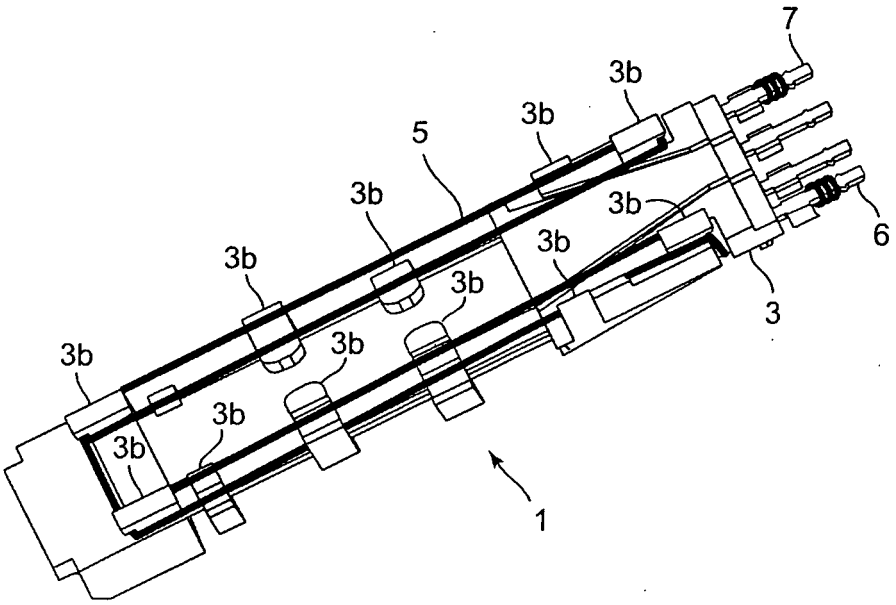

7
3b
3b
5
3b
3b
3b
6
3b
3b
3b
3
3b
3b
3b
3b
1

FIG.9B

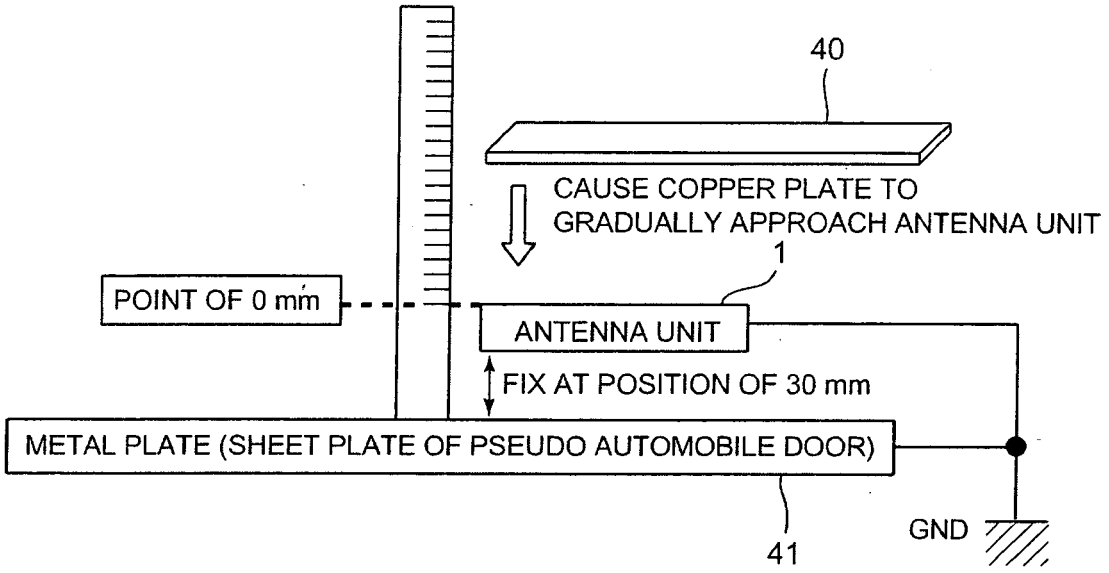

40
CAUSE COPPER PLATE TO
GRADUALLY APPROACH ANTENNA UNIT
1
POINT OF 0 mm
ANTENNA UNIT
FIX AT POSITION OF 30 mm
METAL PLATE (SHEET PLATE OF PSEUDO AUTOMOBILE DOOR)
41
GND

FIG.10

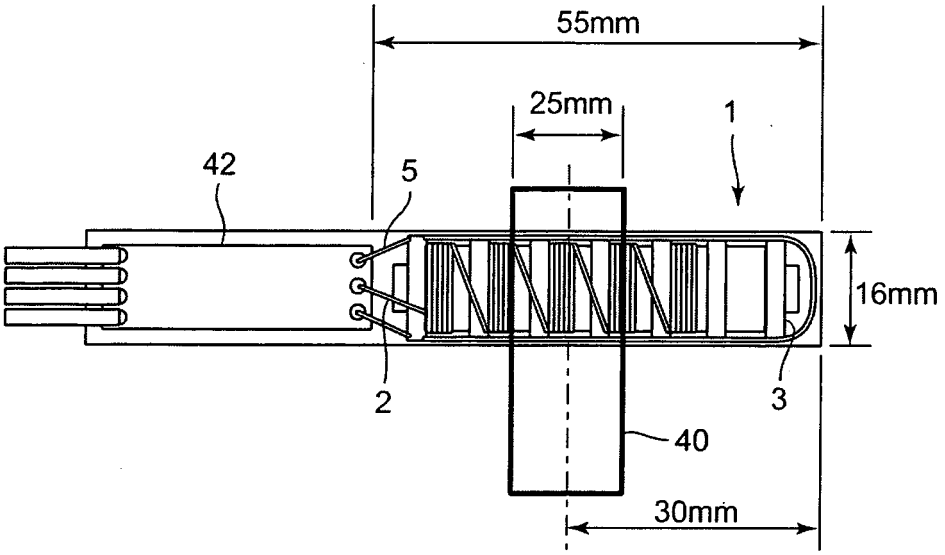


FIG.11A

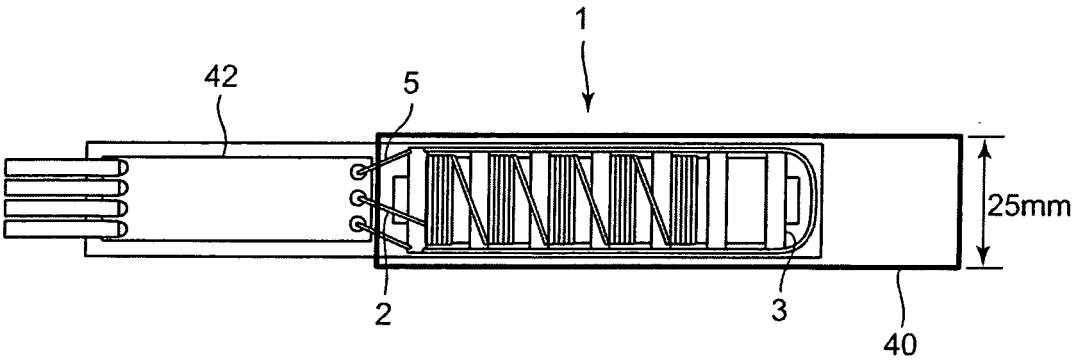


FIG.11B

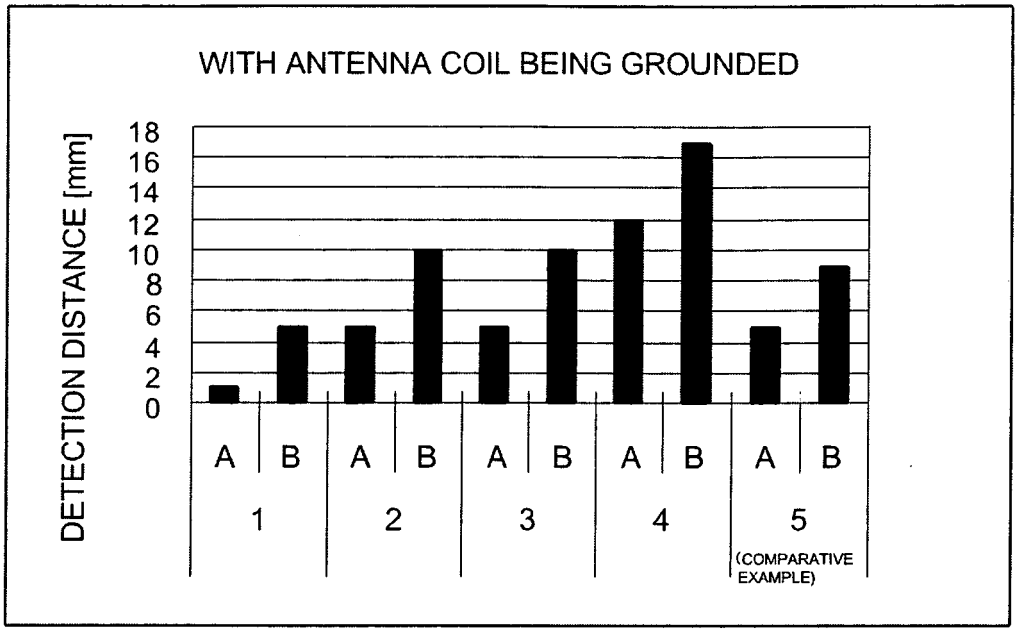


FIG.12A

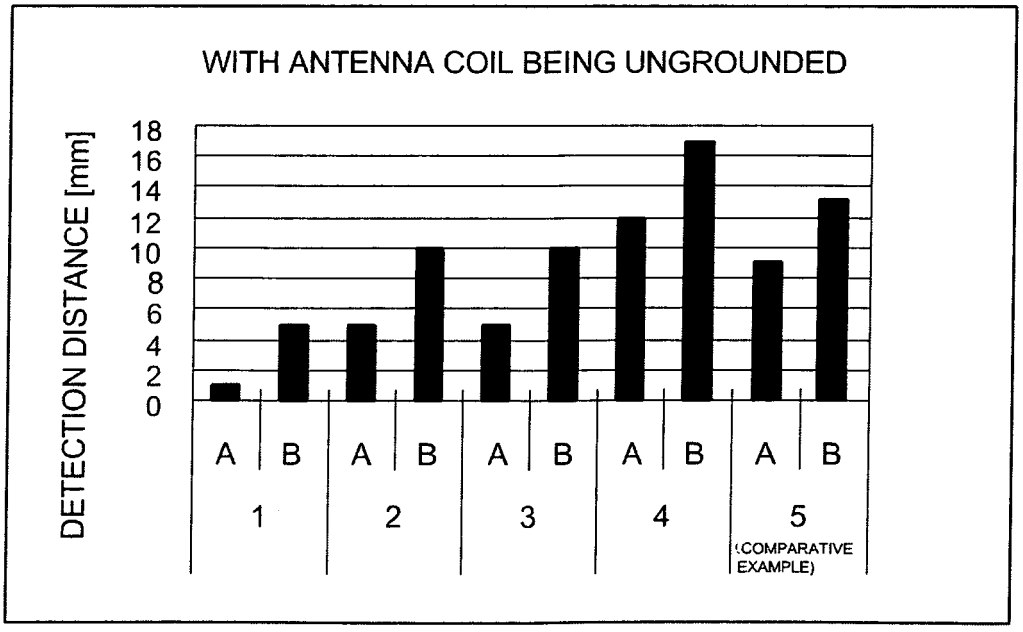


FIG.12B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2007/071372

A. CLASSIFICATION OF SUBJECT MATTER
H01Q7/08(2006.01)i, *H01F5/02*(2006.01)i, *H01F27/32*(2006.01)i, *H01Q11/08*(2006.01)i, *E05B49/00*(2006.01)n

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01Q7/08, H01F5/02, H01F27/32, H01Q11/08, E05B49/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2007
Kokai Jitsuyo Shinan Koho 1971-2007 Toroku Jitsuyo Shinan Koho 1994-2007

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2003-92509 A (Sumida Corporation Kabushiki Kaisha), 28 March, 2003 (28.03.03), Full text; all drawings & JP 2004-32754 A & JP 2004-159348 A & US 2006/152427 A1 & EP 1489683 A1 & WO 2003/75403 A1 & JP 2003-171189 A	1-3
Y	JP 2004-147098 A (Aisin Seiki Co., Ltd.), 20 May, 2004 (20.05.04), Full text; all drawings (Family: none)	1-3
Y	JP 2000-286630 A (Toshiba Corp.), 13 October, 2000 (13.10.00), Full text; all drawings (Family: none)	1-3

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 November, 2007 (21.11.07)	04 December, 2007 (04.12.07)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (April 2007)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2007/071372

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2003-166369 A (Aisin Seiki Co., Ltd.), 13 June, 2003 (13.06.03), Full text; all drawings (Family: none)	1-3
A	JP 2001-297918 A (Mitsubishi Electric Corp.), 26 October, 2001 (26.10.01), Full text; all drawings (Family: none)	1-3
A	JP 1-121877 U (Tohoku Kinzoku Kogyo Ltd.), 18 August, 1989 (18.08.89), Full text; all drawings (Family: none)	1-3

Form PCT/ISA/210 (continuation of second sheet) (April 2007)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2006096104 A **[0006]**
- JP 2003166369 A **[0006]**