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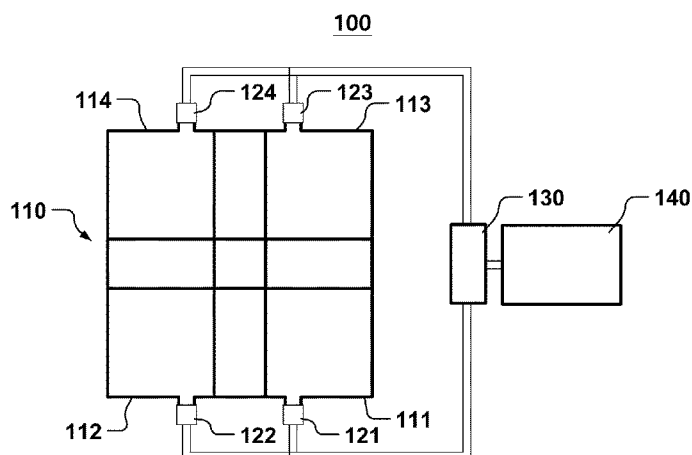
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(54) Title: WIRELESS POWER TRANSFER SYSTEM INCLUDING PRIMARY COIL UNIT HAVING A PLURALITY OF INDEPENDENTLY CONTROLLABLE COILS AND PICKUP COIL UNIT HAVING A PLURALITY OF COILS



(57) Abstract: Disclosed are a primary coil unit of a new type having four coils which are independently controllable and a pickup coil unit having four coils which are independently controllable. There are a proposed power transfer system and a proposed power pickup system which can satisfy standard compatibility and improve the efficiency of wireless power transmission by a power transfer device and a power pickup device. The power transfer device is compatible with various types of conventional power pickup systems and capable of expanding compatibility with a new power pickup system to be developed in future by changing the power transfer magnetic flux pattern. The power pickup device is compatible with various types of conventional power transfer systems and capable of expanding compatibility with a power transfer system to be developed in future. It has been confirmed that if the power transfer device and the power pickup device are combined to construct a single wireless power transfer system, the effects are superimposed so that the system is more robust against a deviation.

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Description

Title of Invention: WIRELESS POWER TRANSFER SYSTEM INCLUDING PRIMARY COIL UNIT HAVING A PLURALITY OF INDEPENDENTLY CONTROLLABLE COILS AND PICKUP COIL UNIT HAVING A PLURALITY OF COILS

Technical Field

- [1] The present invention relates to a primary coil unit having a plurality of coils, a power transfer device for wireless power transmission using the same and a power pickup device, and more particularly, relates to a primary coil unit having four coils which are electrically separated from each other and independently controllable and a power transfer device which is capable of forming various types of power transfer magnetic flux patterns for wireless power transmission using the same. In addition, the present invention relates to a pickup coil unit having four coils which are electrically separated from each other and independently controllable, and a power pickup device which is capable of effectively receiving magnetic fields of various patterns generated from a power transfer device. Furthermore, the present invention relates to a wireless power charging system which is capable of more effectively performing power transfer by using the power transfer device and the power pickup device to change the form of a magnetic field through mode switching when a positional deviation occurs.

Background Art

- [2] In a wireless power transfer scheme based on a power pickup system including a circular coil and a power transfer system according to the related art, it is difficult to perform a remote charge because the efficiency of the wireless power transmission is greatly reduced when a deviation occurs between the power transfer system and the power pickup system. In addition, the power transfer system and the power pickup system of a wireless power transfer system according to the related art tend to have little or no compatibility with other types of power transfer systems and power pickup systems. Thus, when a different type of a power pickup system is to wirelessly receive power from a power transfer system to be charged, the capacity and efficiency of the charge fall short of those required in the standard.
- [3] In recent years, as one scheme for solving such a problem, there has been a proposed power transfer system which is capable of performing remote charging using two primary coils which is current-controllable independently and has more than a certain degree of compatibility within the existing standard space. However, it has been known that the power transfer system has somewhat lower compatibility than a power

transfer system having a conventional circular coil at the correct position and deviation of the wireless power transfer standard. As the types of the primary coil and the pickup coil are proposed, there are the DD type in which two primary coils are arranged side by side, the DDQ type in which one circular coil is additionally overlapped with two primary coils arranged side by side, and the BP type in which coils are arranged but partially overlapped with each other. A power pickup device including a power transfer device having such primary coils and a power pickup device having pickup coils have been described in "Adeel Zaheer et al., Investigation of Multiple Decoupled Coil Primary Pad Topologies in Lumped IPT Systems for Interoperable Electric Vehicle Charging, IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 30, NO. 4, APRIL 2015". A power pickup device corresponding to the power transfer device proposed in the literature includes two pickup coils (DD type) arranged side by side.

- [4] Accordingly, there is a need to provide a power transfer system capable of satisfying the capacity and efficiency required by the standard, and capable of performing remote charging, which is not provided by a conventional power transfer system having a circular coil. For example, there is a need to provide a power transfer system capable of performing efficient wireless power transmission corresponding to a newly proposed power pickup system such as the DD type pickup coil.
- [5] In addition, there is a need to provide a power pickup device capable of satisfying the capacity and efficiency required by the standard and capable of effectively receiving power wirelessly even when there is a large deviation in the magnetic field formed by a conventional power transfer device having a circular coil.

Disclosure of Invention

Technical Problem

- [6] It is an object of the present invention to provide a power transfer system and a power pickup system that can satisfy standard compatibility and at the same time improve the efficiency of wireless power transmission even when a large deviation exists, and a wireless power transfer system with integrated power transfer and power reception.
- [7] In detail, it is one object of the present invention to provide a power transfer system which is capable of being compatible with various types of conventional power pickup systems and capable of expanding compatibility with different magnetic fields or new power pickup systems to be developed in future by changing the power transfer magnetic flux pattern. In addition, it is another object of the present invention to provide a power pickup system which is capable of being compatible with various types of conventional power transfer systems and capable of expanding compatibility

with different magnetic fields or new power transfer systems to be developed in future by changing the state of connecting pickup coils or controlling the phase of a current flowing through the pickup coil.

Solution to Problem

- [8] To achieve the objects, in accordance with one aspect of the present invention, there is a provided method of controlling a wireless power transfer device including four primary coils each of which partially overlaps other adjacent primary coils and is electrically independent from other primary coils, the method comprising: (a) supplying power to the four primary coils such that each of the four primary coils generates a magnetic field having a same intensity in a same direction; (b) sensing a state change of each primary coil when a magnetic field formed by the wireless power transfer device is changed by an adjacent wireless power pickup device; (c) determining a position of the adjacent wireless power pickup device based on information including the state change of each primary coil sensed in the step (b); (d) deciding an operation mode of each primary coil based on the position of the adjacent wireless power pickup device determined in the step (c); and (e) controlling an operation of each primary coil based on the operation mode of each primary coil decided in the step (d).
- [9] In accordance with another aspect of the present invention, there is provided a wireless power transfer device comprising:
- [10] at least four primary coils each of which partially overlaps other adjacent primary coils and is electrically independent from other primary coils;
- [11] a power pickup device position determining unit configured to output information including a position of an adjacent wireless power pickup device when information including a change of a current generated from each of the at least four primary coils is provided as inputs;
- [12] a control unit configured to individually control operations of the at least four primary coils by performing: (a) supplying power to at least four primary coils such that at least four primary coils generate magnetic fields having a same intensity in a same direction; (b) sensing a state change of each of the at least four primary coils when a magnetic field formed by the wireless power transfer device is changed by the adjacent wireless power pickup device; (c) determining the position of the adjacent wireless power pickup device based on information including the state change of each of at least four primary coils sensed in the step (b); (d) deciding an operation mode of each of at least four primary coils based on the position of the adjacent wireless power pickup device decided in the step (c); and (e) controlling an operation of each of at least four primary coils based on the operation mode of each of at least four primary coils determined in the step (d).

- [13] In accordance with still another aspect of the present invention, there is a proposed primary coil unit used in a wireless power transfer device, the primary coil unit comprising: four primary coils each of which partially overlaps with other primary coils and has a rectangular shape, wherein the four primary coils are electrically independent from each other, an aspect ratio of each primary coil is in a range of 1.0 to 1.1, and a ratio of overlapping one side of each primary coil with another adjacent primary coil is in a range of 0.47 to 0.58.
- [14] In accordance with still another aspect of the present invention, there is provided a proposed method of controlling a wireless power pickup device including four pickup coils each of which partially overlaps other adjacent pickup coils and is electrically independent from other pickup coils, the method comprising: (a) sensing states of each pickup coils; (b) determining a position of the wireless power pickup device based on information including changes in the states of each pickup coils sensed in the step (a); (c) deciding an operation mode of each pickup coil based on information including the position of the wireless power pickup device determined in the step (b); and (d) controlling an operation of each pickup coil based on the operation mode of each pickup coil decided in the step (c).
- [15] In accordance with still another aspect of the present invention, there is a proposed wireless power pickup device comprising: at least four pickup coils each of which partially overlaps other adjacent pickup coils and is electrically independent from other pickup coils; a power pickup device position determining unit configured to output information including a position of the wireless power pickup device when information including a change of a current generated from each pickup coil is provided as an input; a control unit configured to individually control an operation of each pickup coil by performing: (a) sensing a state of each pickup coils; (b) determining a position of the wireless power pickup device based on information including the changes in the state of each pickup coil sensed in the step (a); (c) deciding an operation mode of each pickup coil based on information including the position of the wireless power pickup device determined in the step (b); and (d) controlling an operation of each pickup coil based on the operation mode of each pickup coil decided in the step (c).
- [16] In accordance with still another aspect of the present invention, there is a proposed pickup coil unit used in a wireless power pickup device comprising: four pickup coils each of which partially overlaps with other pickup coils and has a rectangular shape, wherein the four pickup coils are electrically independent from each other, an aspect ratio of each pickup coil is in a range of 1.0 to 1.25, and a ratio of overlapping one side of each pickup coil with another adjacent pickup coil is in a range of 0.5 to 0.8.

Advantageous Effects of Invention

[17] According to the present invention, there is a proposed power transfer system and a power pickup system capable of satisfying the standard compatibility and improving the efficiency of remote wireless power transmission. In addition, there is a proposed wireless power transfer system in which the power transfer system and the power pickup system are combined to maximize the effect.

[18] In addition, according to the present invention, there is a proposed power transfer system which is capable of being compatible with various types of conventional power pickup systems and capable of expanding compatibility with different magnetic fields or new power pickup systems to be developed in future by changing the power transfer magnetic flux pattern.

[19] In addition, according to the present invention, there is a proposed power pickup system which is capable of being compatible with various types of conventional power transfer systems and capable of expanding compatibility with different magnetic fields or new power transfer systems to be developed in future by changing the state of connecting pickup coils or controlling the phase of a current flowing through the pickup coil.

Brief Description of Drawings

[20] Hereinafter, exemplary embodiments of the present invention for achieving the effects will be described in detail with reference to the accompanying drawings.

[21] FIG. 1 is a diagram showing an induced voltage according to a positional deviation of a standard power pickup device when a power transfer device according to the related art is arranged long in the transverse direction;

[22] FIG. 2 is a diagram showing an induced voltage according to a positional deviation of a standard power pickup device when a power transfer device according to the related art is arranged long in the longitudinal direction;

[23] FIG. 3 is a schematic view of a power transfer device according to an embodiment of the present invention;

[24] FIG. 4 is plan and front views of a primary coil unit of the power transfer device shown in FIG. 3;

[25] FIG. 5 is a schematic view of a resonant capacitor module of the power transfer device shown in FIG. 3;

[26] FIG. 6 is a diagram illustrating an operation mode of the primary coil unit of the power transfer device shown in FIG. 3, where each primary coil of the primary coil unit has a square shape;

[27] FIG. 7 is a diagram showing an operation mode of the primary coil unit of the power transfer device shown in FIG. 3, where each primary coil of the primary coil unit has a rectangular shape;

- [28] FIG. 8 is a diagram showing a change in the induced voltage according to the aspect ratio and degree of overlap of the primary coil unit in the power transfer device shown in FIG. 3;
- [29] FIG. 9 is a diagram of a power pickup device according to an embodiment of the present invention;
- [30] FIG. 10 is a diagram of a pickup coil unit of the power pickup device shown in FIG. 9;
- [31] FIG. 11 is a diagram of one pickup coil of the pickup coil unit shown in FIG. 10;
- [32] FIG. 12 is a diagram illustrating an operation mode of the pickup coil shown in FIG. 10;
- [33] FIG. 13A is a diagram illustrating an operation mode of a pickup coil when a power pickup device according to the present invention is disposed at a position deviated from the center of a standard power transfer device in the y-direction;
- [34] FIG. 13B is a diagram illustrating an operation mode of a pickup coil when a power pickup device according to the present invention is disposed at a position deviated from the center of a standard power transfer device in the x-direction;
- [35] FIG. 13C is a diagram illustrating an operation mode of a pickup coil when a power pickup device according to the present invention is disposed at a position diagonally deviated from the center of a standard power transfer device;
- [36] FIG. 14 is a graph illustrating an voltage induced to a power pickup device when a power pickup device according to the present invention is deviated from the center of the a standard power transfer device;
- [37] FIG. 15 is a flowchart illustrating a method of obtaining a position of a power pickup device by a power transfer device according to present invention;
- [38] FIG. 16 is a flowchart illustrating the detailed steps of step S120 of FIG. 15;
- [39] FIG. 17 is a flowchart illustrating a method of obtaining the position of a power pickup device by the power pickup device according to the present invention;
- [40] FIG. 18 is a graph illustrating a change of an induced voltage according to a positional deviation of a power receiving device when the power transfer device and power pickup device according to the present invention are combined with each other;
- [41] FIG. 19A is a diagram illustrating the change of the operation mode of a power pickup device according to a positional deviation of a power transfer device according to the present invention when the power pickup device according to the present invention is in an all-mode;
- [42] FIG. 19B is a diagram illustrating the change of the operation mode of a power pickup device according to a positional deviation of a power transfer device according to the present invention when the power pickup device according to the present invention is in an all-mode;

- [43] FIG. 19C is a diagram illustrating the change of the operation mode of a power pickup device according to a positional deviation of a power transfer device according to the present invention when an operation mode of the power pickup device according to the present invention is changed;
- [44] FIG. 19D is a diagram illustrating the change of the operation mode of a power pickup device according to a positional deviation of a power transfer device according to the present invention when an operation mode of the power pickup device according to the present invention is changed;
- [45] FIG. 20 is a diagram illustrating a positional deviation between a standard power pickup system and a power pickup system according to the present invention; and
- [46] FIG. 21 is a diagram illustrating an operation of a switch in each mode of a primary coil when a shared-capacitor module shown in FIG. 5 is used.

Best Mode for Carrying out the Invention

- [47] Hereinafter, an embodiment of the present invention will be described in detail with reference to accompanying drawings. In the following description, specific details are merely provided to assist the overall understanding of exemplary embodiments of the present invention. Therefore, it should be apparent to those skilled in the art that various changes and modifications of the embodiments described herein can be made without departing from the scope and spirit of the invention. In a description of the present invention, a detailed description of related known functions and configurations will be omitted when it may make the essence of the present invention unnecessarily obscure. Further, parts irrelevant to the present invention are omitted in the drawings to make the present invention clear and the same reference numerals are designated to the same or similar components throughout the specification.

[48]

[49] Power Transfer Device

[50]

[51] Configuration of Power Transfer Device

[52]

- [53] FIG. 1 illustrates a standard power transfer/pickup system in which a power pickup device 2 moves in the x-direction and y-direction with respect to the center of a power transfer device 1 after the power transfer device 1 is arranged long in a transverse direction, and shows the results of calculating a voltage induced to the power pickup device 2 through a simulation. FIG. 2 illustrates the standard power transfer/pickup system in which the power pickup device 2 moves in the x-direction and y-direction with respect to the center of the power transfer device 1 after the power transfer device 1 is arranged long in a longitudinal direction, and shows the results of calculating a

voltage induced to the power pickup device 2 through a simulation. In FIGS. 1 and 2, a box filled with a red letter means that a counter voltage is generated in the power pickup device 2.

[54] Meanwhile, although the standards for parking areas vary from country to country, the width is specified in the range of 2.0 m to 2.6 m and the length is specified in the range of about 5 m to about 6 m. Generally, in the case of a compact vehicle, the width is about 1.6 m. In the case of a semi-midsized vehicle, the width is about 1.8 m. Thus, when the battery of a vehicle is charged through wireless power transmission, a deviation of about 0.1 m to about 0.5 m may be generated between a power transfer device and a power pickup device.

[55] Accordingly, in a standard power transfer/pickup system, when a deviation occurs between the positions of a power transfer device and a power pickup device, the induced power is greatly reduced even though the deviation is small. When the deviation is large, a counter voltage may be generated.

[56] FIG. 3 schematically shows a primary coil unit 110 having four coils according to an embodiment of the present invention and a power transfer device 100 using the same. The power transfer device 100 includes a primary coil unit 110 having four primary coils 111 to 114, a resonant capacitor module 130, an inverter 140 and four switches 121 to 124 connecting each coil 111 to 114 to the inverter 140 via the resonant capacitor module 130.

[57] One example of the primary coil unit 110 of FIG. 3 is shown in FIG. 4. The same reference numerals are designated to the same components. Reference numeral 15 represents a power transfer core 115. The four primary coils 111 to 114 depicted in FIG. 4, each of which has a substantially rectangular shape, are arranged such that the internal areas formed by each primary coil are partially overlapped with each other. The primary coils have the rectangular shapes of the same size. However, the shape of the primary coil is not necessarily limited to the rectangular shape but may be variously modified corresponding to a required magnetic flux pattern. In addition, in the embodiment depicted in FIG. 4, although the primary coils are overlapped in the same manner, the overlap manner may be variously modified corresponding to a required magnetic flux pattern. The four primary coils of the primary coil unit are stacked on the power transfer core 115 in the sequence of the third primary coil 113, the second primary coil 112, the first primary coil 111 and the fourth primary coil 114. A shape maintaining member (not shown) for maintaining the shape of each primary coil may be provided in the space inside each primary coil. It is obvious that the primary coils may be arranged in other manners.

[58] Each of the primary coils 111 to 114 is connected to the inverter 140 through the medium of the switches 121 to 124. For example, each of the switches 121 to 124 may

be formed to switch the direction of the power supplied to each primary coil 111 to 114 or shut off the power. Thus, high-frequency power having the same phase or an opposite phase may be provided to each primary coil 111 to 114 by the switching operation of each switch or the power supply may be shut off. Each of the primary coils 111 to 114 is connected to the inverter 140 through the medium of the resonant capacitor module 130.

[59] FIG. 5 substantially shows one example of the resonant capacitor module 130 and the electrical connection between each primary coil 111 to 114 and the resonant capacitor module 130. In FIG. 5, the primary coils 111 to 114 and the switches SW1 to SW4 are connected to each other in a manner different from that depicted in FIG. 3. The switches SWA, SWB and SWC in the resonant capacitor module 30 may be electrically controlled. Several operation modes of the power transfer device 100 according to an individual operation of each primary coil 111 to 114 will be described in detail below.

[60]

[61] Operation Mode of Primary Coil

[62]

[63] FIG. 6 shows the direction of the current applied to each primary coil 111 to 114 when the most advantageous induced voltage is generated as the position of the standard power pickup device is changed in the x-direction and the y-direction with respect to the central position of the primary coil unit 110 according to an embodiment of the present invention. In detail, the direction of the current supplied to each primary coil has been controlled such that a section in which the voltage induced to the standard power pickup device is opposite and a dead section in which any induced voltage do not exist are non-existent.

[64] In the table of FIG. 6, a 4-digit number represents the direction of a current applied to each primary coil, and the first to fourth primary coils are denoted in order. That is, for example, "1 1 -1 -1" represents that a clockwise current is applied to the first and second primary coils 111 and 112 and a counterclockwise current is applied to the third and fourth primary coils 113 and 114.

[65] When sorting modes are confirmed through a simulation by type, there are three types of modes: quarter mode, all mode and half mode. In the quarter mode, the direction of the current flowing through one of the four primary coils is different from those of currents flowing through the remaining primary coils, which are the same. In the half mode, the directions of currents flowing through the primary coils adjacent to each other in a transverse or longitudinal direction are the same. In the all mode, the directions of currents flowing through the four primary coils are the same. In each mode, there is a case where the directions of the currents flowing through the coils, which are

electrically symmetric to each other, are opposite to each other. Thus, the primary coil is operated in eight quarter modes, four half modes and two all modes, that is, a total of 14 operation modes.

- [66] In the case where the primary coil has a rectangular shape, the operation mode of the primary coil for generating an induced voltage which is most favorable to the standard power pickup device is changed. For example, FIG. 7 shows the direction of the current supplied to each primary coil such that a section in which the voltage induced to the standard power pickup device is opposite and a dead section in which any electromotive forces do not exist are non-existent. When compared with FIG. 6, it is known that the direction of the current supplied to each primary coil is changed.

[67]

[68] Shape and Arrangement of Primary Coil

[69]

- [70] The primary coils shown in the above-mentioned drawings have a rectangular shape and are partially overlapped with each other. Hereinafter, the variation of a magnetic field generated by the primary coils according to the shape of the primary coils and the overlap areas will be described.

- [71] FIG. 8 shows a table filled with the results of calculating voltage induced to the standard power pickup device through a simulation while changing the aspect ratio and degree of overlap of the primary coil. For comparison, the mass of the conductor included in each primary coil is kept the same even though the aspect ratio is changed. The degree of overlap is changed by moving each coil by the same distance in the x-direction and y-direction toward the center of the primary coil unit 110.

- [72] The simulation results are summarized as follows:

- [73] 1) Although the induced voltage is increased as the degree of overlap is increased when the standard power pickup device is in position to match the center of the power transfer device, the degree of reduction of the induced voltage is increased when the positional deviation of the standard power pickup device is increased.

- [74] 2) Regarding the aspect ratio, even if the aspect ratio is not changed greatly, the voltage induced to the standard power pickup device varies greatly.

- [75] 3) Regarding the shape of the primary coil, it is judged that the primary coil is advantageous in the case of a rectangular shape rather than a square shape. However, the difference between the voltage induced to the standard power pickup device according to the shape of the primary coil is not large. Considering the manufacturing conditions of the primary coil, the primary coil may have a square shape.

- [76] The range of each variable in the embodiments illustrated based on the aspect ratio and the degree of overlap of the primary coil unit 110 confirmed in the simulation is as follows: the aspect ratio is in the range of about 1.0 to about 1.1 and the degree of

overlap is in the range of about 0.25 to about 0.55 based on the inner area of each primary coil.

[77]

[78] **Power Pickup Device**

[79]

[80] **Configuration of Power Pickup Device**

[81]

[82] FIG. 9 is a schematic view showing a pickup coil unit 210 having four coils and a power pickup device 200 using the same according to an embodiment of the present invention. The power pickup device 200 includes a pickup coil 210 having four pickup coils 211 to 214, a rectifier module 230. Each of the pickup coils 211 to 214 is connected to the rectifier module 230 through each switch 221 to 224. The rectifier module 230 provides direct current power to a load resistor or a battery 300.

[83] FIG. 10 shows one example of the primary coil unit 210 depicted in FIG. 9. the same reference numerals are designated to the same components. A power pickup core is not depicted for the purpose of convenient description. Each of the pickup coils 211 to 214 depicted in FIG. 10 has a substantially rectangular shape, and the coils are arranged to allow the inner areas formed by the coils to partially overlap each other. In addition, the coils have rectangular shapes of the same size. The shape of the pickup coil is not limited to the rectangular shape but may be variously modified corresponding to a required magnetic flux pattern. In addition, In addition, although the coils are overlapped with each other in the same manner in the embodiment depicted in FIG. 10, the embodiment may be variously modified in such a manner that the coils are overlapped with each other corresponding to the required magnetic flux pattern.

[84] FIG. 11 shows one 211 of the four pickup coils of the pickup coil unit 210. The pickup coil 211 having a rectangular shape has a concave portion 211a formed by concaving one of two short sides. The concave portion 211a is formed at a position at which the concave portion 211a is overlapped with another pickup coil, so that the height of the pickup coil unit 210 is prevented from rising even if the four pickup coils are overlapped with each other. Since the pickup coil unit 210 is disposed on a lower portion of the vehicle, a lower height is advantageous.

[85] Each of the pickup coils 211 to 214 is connected to the rectifier module 230 through the switches 221 to 224. For example, each switch 221 to 224 is formed to switch the direction of power output from each pickup coil 211 to 214. By the switching operations of the switches, the phases of the powers output from the pickup coils 211 to 214 may be the same or opposite to each other. Unlike the primary coil, the power output from the pickup coil is not cut off.

[86]

[87] Operation Mode of Pickup Coil

[88]

[89] FIG. 12 shows all operable modes of the pickup coil unit 210 according to an embodiment of the present invention. In the quarter mode, the direction of the current induced to one of the four pickup coils is different from the directions of the currents induced to the remaining pickup coils, which are the same. In the half mode, the currents flowing in the same direction are induced to the pickup coils adjacent to each other in the transverse or longitudinal direction. In the all-mode, the currents flowing in the same direction are induced to all the four pickup coils. In each mode depicted, there exist currents electrically symmetrical to each other, that is, flowing through the coils in opposite directions. Thus, as the operation modes of the pickup coil, there are a total of 14 operation modes consisting of eight quarter modes, four half modes and two all-modes.

[90] FIGS. 13A to 13C show the operation modes in which the highest voltage is induced from the standard power transfer device according to the position of the pickup coil according to the present invention and is calculated and confirmed through a simulation. In the drawings, 'Z2min' and 'Z2max' represent the degree that the pickup coil is vertically away from the primary coil, and the numbers in parenthesis represent the distances, in millimeters, from the center of the primary coil to the pickup coil in the x-direction and y-direction.

[91] As shown in FIG. 13A, as the pickup coil according to the present invention goes away from the center of the standard primary coil in the y-direction while maintaining the vertical position of 'Z2min', the operation mode of the pickup coil is changed in the order of the all-mode, the half mode and the quarter mode. This manner is substantially the same as in the vertical position of 'Z2max', but the quarter mode is only shown at position (0,275).

[92] As shown in FIG. 13B, as the pickup coil according to the present invention goes away from the center of the standard primary coil in the x-direction while maintaining the vertical position of 'Z2min', the operation mode of the pickup coil is changed in the order of the all-mode, the quarter mode and the half mode. At the vertical position of 'Z2max', the all-mode is changed to the quarter mode.

[93] As shown in FIG. 13C, as the pickup coil according to the present invention goes away from the center of the standard primary coil in the diagonal direction while maintaining the vertical position of 'Z2min', the operation mode of the pickup coil is changed in the order of the all-mode (+), the half mode and the all-mode (-). At the vertical position of 'Z2max', the operation mode is changed in the order of the all-mode, the quarter mode, the half mode and the quarter mode.

[94] FIG. 14 is a graph showing a simulation result of the voltage induced by the pickup

coil according to the present invention at each position in the x-axis and the y-direction in accordance with the mode of the pickup coil with respect to the standard primary coil. As shown, when the pickup coil is maintained in the all-mode, the dead section, in which the voltage induced to the pickup coil is 0 (zero) is shown. However, when the mode of the pickup coil is suitably changed, it is known that the dead section is not shown.

[95]

[96] Shape and Arrangement of Pickup Coil

[97]

[98] The pickup coils shown in the above-described drawings have a rectangular shape and are partially overlapped with each other. When the degree of overlap of the pickup coil is changed, the induced voltage is increased when the pickup coil is located at the position coinciding with the center of the power transfer device as the degree of overlap increases, but the degree of decrease in the induced voltage is increased when the positional deviation of the power pickup device is increased.

[99] In the illustrated embodiment, the pickup coil has a rectangular shape, but may have a square shape. However, as a result of the simulation, it was found that it is advantageous that the inner area of the pickup coil is overlapped with a certain area. When the aspect ratio of the pickup coil and the degree of overlap are summarized by taking this into consideration, the aspect ratio is in the range of about 1 to about 1.25, and the degree of overlap of the inner area of the pickup coil with respect to the long side of the pickup coil is preferably in the range of about 0.35 to about 0.65.

[100]

[101] Control Method

[102]

[103] Method of Controlling Power Transfer Device

[104]

[105] FIGS. 15 and 16 illustrate a method of controlling a power transfer device having four primary coils according to the present invention.

[106] As shown in FIG. 15, the method of controlling a power transfer device includes: step S100 of supplying power to the four primary coils such that each of the four primary coils generates a magnetic field of the same magnitude in the same direction, step S120 of obtaining a position of an adjacent power pickup device; and step S140 of determining an operation mode of each primary coil based on the position of the adjacent wireless power pickup device. Based on the operation mode of each primary coil determined as described above, the operation of each primary coil is controlled.

[107] In step 120, the position of the adjacent power pickup device is obtained by performing the method depicted in FIG. 16 as follows. The method includes step S122

of receiving information including the type of the power pickup device by communicating with the power pickup device, step S124 of obtaining a change in the state of each primary coil, and step S126 of determining the position of the adjacent wireless power pickup device based on the information including the change in the state of each primary coil obtained. In this case, the change in the state of each primary coil includes at least one of a change in a current flowing through each primary coil, a change in an applied voltage, a change in power, and a change in a magnetic field. In step S126, the position of the power pickup device may be obtained by considering the received information including the type of the power pickup device.

[108] When the power pickup device includes a plurality of pickup coils, information about the change in the state of each pickup coil, such as a voltage, a current, a power, a magnetic field, or the like, generated by the magnetic field formed by the power transfer device may be included in the information including the type of the power pickup device in step S210. Such a change in the state of the pickup coil may occur when the position of the pickup coil is not changed, and may occur as the power pickup device installed in a vehicle approaches from a remote position to the power transfer device. When the state of the pickup coil is changed as a vehicle approaches to the power transfer device, the information about the movement of the vehicle may be further transmitted to the power transfer device.

[109] When the communication with the power pickup device is not performed, the position of the power pickup device may be determined based only on the state change of each primary coil.

[110] In step S126, various schemes may be utilized to obtain the position of the power pickup device based on given information. In the present invention, based on simulation or experiment data, a machine learning technique such as a support vector machine or a neural network algorithm such as CNN or RNN.

[111] When a case of using the neural network algorithm is explained as an example, a power pickup device position determining unit may be formed by performing supervised learning which includes the change of a current generated in each primary coil of the power transfer device by the adjacent power pickup device as an input and the position of the adjacent power pickup device as an output. When the information including the change of a current generated from each primary coil of the power pickup device position determining unit is provided as an input, the power pickup device position determining unit outputs the information including the position of the adjacent wireless power pickup device. The input of the neural network algorithm may include information about the type of the adjacent power pickup device and/or the state of the pickup coil changed by the magnetic field formed by the power transfer device.

[112]

[113] Method of Controlling Power Pickup Device

[114]

[115] FIG. 17 illustrates a method of controlling an operation mode of each pickup coil in the power pickup device according to the present invention.

[116] First, in step S210, the states of the four pickup coils of the power pickup device are sensed. To this end, power is supplied in advance to the power transfer device to form a magnetic field and the state of each pickup coil is changed by the magnetic field. The state of the pickup coil includes at least one of a current, a voltage, a power, and a magnetic field. The state of the pickup coil may be detected in the state where the pickup coil is stopped, or may be obtained continuously while the vehicle in which the pickup coil is installed approaches from a remote position to the power transfer device.

[117] Next, in step S220, the position of the power pickup device is determined based on only the state of each pickup coil sensed in step S210 or considering additional information together. The additional information includes information about the type of the power transfer device or the like.

[118] In step S230, when the position of the power pickup device is obtained, the operation mode of each pickup coil is determined using the information or the additional information together. In this case, the additional information may include information about the operation mode of the power transfer device when the power feeding device is a type capable of switching the operation mode. The reason is that the state of the pickup coil is changed according to the operation mode of the power transfer device.

[119] When the operation mode of each pickup coil is determined, the operation of the each pickup coil is controlled according to the determined operation mode.

[120] In step S210, the power pickup device may include a power pickup device position obtaining unit for obtaining the position of the power pickup device. Like the power transfer device position obtaining unit, the power pickup device position obtaining unit utilizes a machine learning technique or a neural network algorithm.

[121] For example, when the neural network algorithm is utilized, supervised learning including the state of each pickup coil of the power pickup device as an input and the position of the wireless power pickup device as an output is performed. When the information including the state of each pickup coil of the power pickup device is provided by the neural network algorithm as the input, the information including the position of the wireless power pickup device is output.

[122]

[123] Control of Power Transfer device and Power pickup device

[124]

[125] FIG. 18 shows the induced voltage generated in the power pickup device according to the operation mode of each device when the power transfer device and the power

pickup device according to the present invention are used together.

- [126] As shown in FIG. 18, in a state where the power transfer device and the power pickup device are fixed in the all-mode, there is a dead section in which no induced voltage is generated according to the position of the power pickup device. When the power transfer device is fixed in the all-mode and the operation mode of only the power pickup device is switched, there are no dead sections. When the operation mode of the power transfer device is switched, the induced voltage generated in the power pickup device is further increased, and when the operation modes of the power transfer device and the power pickup device are switched, the induced voltage of the power pickup device is somewhat increased.
- [127] FIGS. 19A to 19D show how the case where the operation mode of the power transfer device is switched or not affects the position and the operation mode of the power pickup device.
- [128] Referring to FIGS. 19A and 19B, when the power transfer device is in the all-mode, the power pickup device is operated in the half mode or quarter mode at a position apart by 300 mm or 375 mm in the x-direction or the y-direction. The power pickup device is operated in the quarter mode or all-mode at a position apart in the diagonal direction. To the contrary, referring to FIGS. 19C and 19D, the power pickup device is operated in the all-mode at a position apart by 300 mm in the y-direction and is operated in the half mode or all-mode at a position apart by 375 mm.
- [129] Referring to FIGS. 19A to 19D, it was known that the voltage induced to the power pickup device is increased when the operation mode of the power transfer device is switched.
- [130] FIG. 20 shows the simulation results of the voltage induced to the power pickup device in the coil according to the present invention at each position in the combination of the standard power transfer device and the standard power pickup device and the combination of the power transfer device and the power pickup device according to the present invention. In the case of the device according to the present invention, this figure shows a result of switching both the operation modes of the power transfer device and the power pickup device.
- [131] As shown in the drawings, in the case of using the power transfer device according to the present invention and the power pickup device according to the present invention, as compared with the case of using the power transfer device and the power pickup device according to the standard, the voltage induced to the power pickup device is still high even when a deviation occurs in the position of the power pickup device. Therefore, according to the present invention, it is possible to obtain a wireless power transfer system robust against the positional deviation of the power pickup device.
- [132] FIG. 21 shows how each of the switches is operated to switch the operation mode of

each primary coil of the power transfer device according to the embodiment of the present invention. As shown in the drawing, in order to operate the primary coil in the all-mode, SWA, SW2 and SW4 are closed and the remaining switches are opened. In order to operate the primary coil in the half mode, SWB, SW1 and SW4 are closed and the remaining switches are opened. In order to operate the primary coil in the quarter mode, SWC, SW2, SW3 are closed and the remaining switches are opened.

[133] The resonant capacitor module shown in FIG. 21 is applicable not only to the power transfer device but also to the power pickup device. That is, as shown, the resonant capacitor module and the switch may be provided between each pickup coil and the rectifier module.

[134] It should be noted that the present invention is not limited to the specific forms mentioned in the detailed description of the present invention and includes all modifications and equivalents, and replacements that are within the spirit and range of the present invention, which are defined in the annexed claims.

[135] For example, although it has been described that the phase of the current supplied to the primary coil is changed by 180 degrees by switching of the switch, the present invention is not necessarily limited thereto and the phase of the current may be continuously changed by using a phase shifter. Similarly, although it has been described that the phase of the current output from the pickup coil is changed by 180 degrees by the switch, the phase of the output current may be continuously changed by using the phase shifter.

Claims

- [Claim 1] A method of controlling a wireless power transfer device including four primary coils each of which partially overlaps other adjacent primary coils and is electrically independent from other primary coils, the method comprising:
- (a) supplying power to the four primary coils such that each of the four primary coils generates a magnetic field having a same intensity in a same direction;
 - (b) sensing a state change of each primary coil as a magnetic field formed by the wireless power transfer device is changed by an adjacent wireless power pickup device;
 - (c) determining a position of the adjacent wireless power pickup device based on information including the state change of each primary coil sensed in the step (b);
 - (d) deciding an operation mode of each primary coil based on the position of the adjacent wireless power pickup device determined in the step (c); and
 - (e) controlling an operation of each primary coil based on the operation mode of each primary coil decided in the step (d).
- [Claim 2] The method of claim 1, wherein the wireless power transfer device includes a power pickup device position determining unit using a deep learning algorithm based on simulation or experiment data, and determining of the position of the adjacent wireless power pickup device is performed by the power pickup device position determining unit,
- wherein, in the supervised learning, a change of a current generated in each primary coil of the wireless power transfer device by the adjacent wireless power pickup device is provided as an input and the position of the adjacent wireless power pickup device as a label, and the power pickup device position determining unit outputs information including the position of the adjacent wireless power pickup device when information including the change of the current generated in each primary coil of the wireless power transfer device is provided as inputs.
- [Claim 3] The method of claim 2, wherein information for determining the position of the adjacent wireless power pickup device includes information about a kind of the adjacent wireless power pickup device.
- [Claim 4] The method of claim 3, wherein inputs provided for the supervised

learning of the power pickup device position determining unit include information about the kind of the adjacent wireless power pickup device.

[Claim 5] The method of claim 2, wherein information for determining the position of the adjacent wireless power pickup device in the step (c) includes information about a state of a current of a pickup coil of the adjacent wireless power pickup device induced from the magnetic flux formed by the wireless power transfer device.

[Claim 6] The method of claim 5, wherein inputs provided for the supervised learning of the power pickup device position determining unit comprise information about a state of a current induced to a pickup coil of the adjacent wireless power pickup device.

[Claim 7] A wireless power transfer device comprising:
at least four primary coils each of which partially overlaps other adjacent primary coils and is electrically independent from other primary coils;
a power pickup device position determining unit configured to output information including a position of an adjacent wireless power pickup device when information including a change of a current generated from each of at least four primary coils is provided as inputs;
a control unit configured to individually control operations of at least four primary coils by performing:
(a) supplying power to at least four primary coils such that at least four primary coils generate magnetic fields having a same intensity in a same direction;
(b) sensing a state change of each of at least four primary coils as a magnetic field formed by the wireless power transfer device is changed by the adjacent wireless power pickup device;
(c) determining the position of the adjacent wireless power pickup device based on information including the state change of each of at least four primary coils sensed in the step (b);
(d) deciding an operation mode of each of at least four primary coils based on the position of the adjacent wireless power pickup device decided in the step (c); and
(e) controlling an operation of each of at least four primary coils based on the operation mode of each of at least four primary coils determined in the step (d).

[Claim 8] The wireless power transfer device of claim 7, wherein the power

pickup device position determining unit uses a deep learning algorithm based on simulation or experiment data, during the supervised learning, a change of a current generated in each of at least four primary coils of the wireless power transfer device by the adjacent wireless power pickup device is provided as inputs and the position of the adjacent wireless power pickup device as a label, and the power pickup device position determining unit outputs information including the position of the adjacent wireless power pickup device when information including the change of the current generated in each of at least four primary coils of the wireless power transfer device is provided as inputs.

[Claim 9] The wireless power transfer device of claim 8, further comprising a communication unit configured to communicate with the adjacent wireless power pickup device.

[Claim 10] The wireless power transfer device of claim 9, wherein input provided for the supervised learning of the power pickup device position determining unit includes information about a kind of the adjacent wireless power pickup device.

[Claim 11] The wireless power transfer device of claim 9, wherein the input provided for the supervised learning of the power pickup device position determining unit includes information about a state of a current of a power pickup coil of the adjacent wireless power pickup device induced from the magnetic flux formed by the wireless power transfer device.

[Claim 12] A primary coil unit used in a wireless power transfer device, the primary coil unit comprising:
four primary coils each of which partially overlaps with other primary coils and has a rectangular shape,
wherein the four primary coils are electrically independent from each other,
an aspect ratio of each primary coil is in a range of 1.0 to 1.1, and
a ratio of overlapping one side of each primary coil with another adjacent primary coil is in a range of 0.47 to 0.58.

[Claim 13] A method of controlling a wireless power pickup device including four pickup coils each of which partially overlaps other adjacent pickup coils and is electrically independent from other pickup coils, the method comprising:
(a) sensing states of each pickup coils;

(b) determining a position of the wireless power pickup device based on information including changes in the states of each pickup coils sensed in the step (a);

(c) deciding an operation mode of each pickup coil based on information including the position of the wireless power pickup device determined in the step (b); and

(d) controlling an operation of each pickup coil based on the operation mode of each pickup coil decided in the step (c).

[Claim 14]

The method of claim 13, wherein the wireless power pickup device comprises a power pickup device position determining unit using a deep learning algorithm based on simulation or experiment data, and determining of the position of the wireless power pickup device is performed by the power pickup device position determining unit, wherein, in the supervised learning, the states of each pickup coils of the wireless power pickup device is provided as inputs and the position of the wireless power pickup device is provided as a label, and the power pickup device position determining unit outputs information including the position of the wireless power pickup device when information including the state of each pickup coil of the wireless power pickup device is provided as the input.

[Claim 15]

The method of claim 14, wherein information for determining the position of the wireless power pickup device in the step (b) includes a kind of the wireless power pickup device.

[Claim 16]

The method of claim 15, wherein the input provided for the supervised learning of the power pickup device position determining unit includes the information about the kind of the wireless power pickup device.

[Claim 17]

The method of claim 15, further comprising a step of requesting the wireless power transfer device to switch to a power transfer mode before the step (c),

wherein information about the power transfer mode of the wireless power transfer device is further used to determine the operation mode of each pickup coil in the step (c).

[Claim 18]

A wireless power pickup device comprising:

at least four pickup coils each of which partially overlaps other adjacent pickup coils and is electrically independent from other pickup coils;

a power pickup device position determining unit configured to output information including a position of the wireless power pickup device when information including a change of a current generated from each

pickup coil is provided as an input;
a control unit configured to individually control an operation of each pickup coil by performing:

- (a) sensing a state of each pickup coils;
- (b) determining a position of the wireless power pickup device based on information including the changes in the state of each pickup coil sensed in the step (a);
- (c) deciding an operation mode of each pickup coil based on information including the position of the wireless power pickup device determined in the step (b); and
- (d) controlling an operation of each pickup coil based on the operation mode of each pickup coil decided in the step (c).

[Claim 19]

The wireless power pickup device of claim 18, wherein the power pickup device position determining unit using a deep learning algorithm based on simulation or experiment data, and, during the supervised learning, the state of each pickup coil of the wireless power pickup device is provided as an input and the position of the wireless power pickup device is provided as a label, and wherein the power pickup device position determining unit outputs information including the position of the wireless power pickup device when information including the state of each pickup coil of the wireless power pickup device is provided as the input.

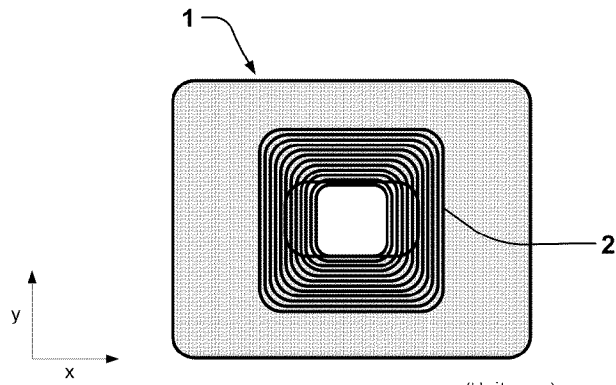
[Claim 20]

The wireless power pickup device of claim 19, further comprising a communication unit configured to communicate with an adjacent wireless power transfer device.

[Claim 21]

A pickup coil unit used in a wireless power pickup device comprising: four pickup coils each of which partially overlaps with other pickup coils and has a rectangular shape, wherein the four pickup coils are electrically independent from each other, an aspect ratio of each pickup coil is in a range of 1.0 to 1.25, and a ratio of overlapping one side of each pickup coil with another adjacent pickup coil is in a range of 0.5 to 0.8.

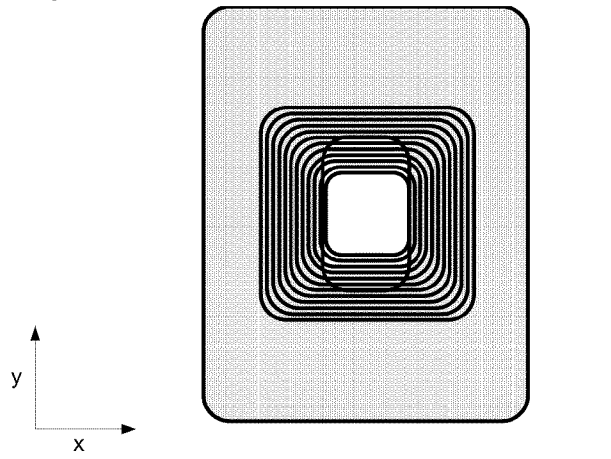
[Fig. 1]



(Unit: mm)

$x \backslash y$	0	100	200	300
0	272	244	144	32
75	228	203	121	20
150	129	116	61	-4
225	28	23	-1.5	-27
300	-23	-25	-30	-35

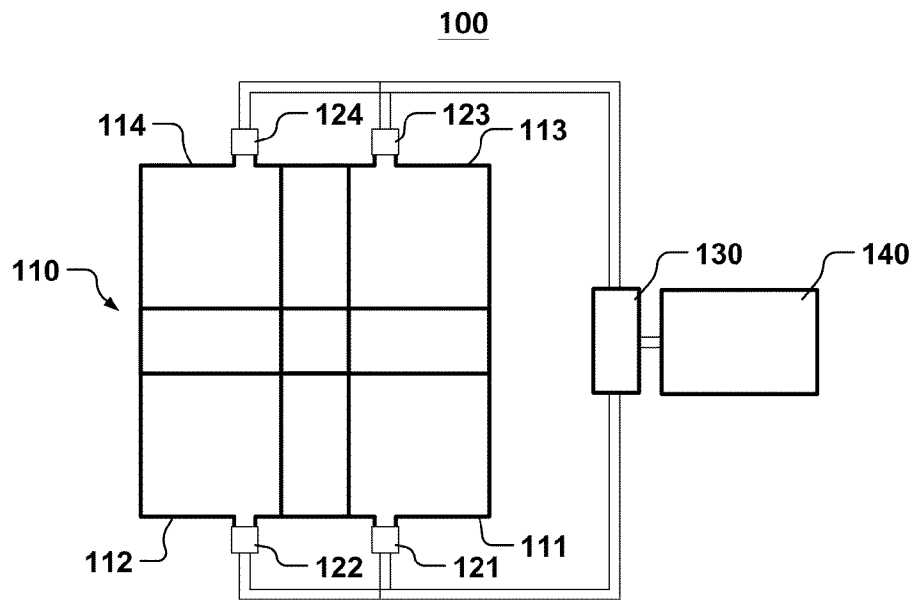
[Fig. 2]



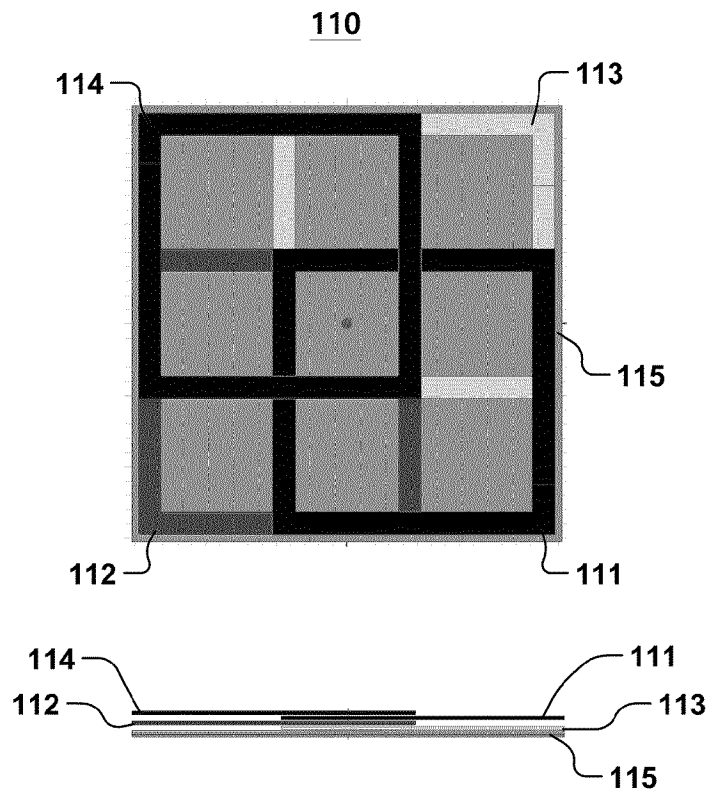
(Unit: mm)

$x \backslash y$	0	100	200	300
0	272	199	60	-23
75	252	188	53	-25
150	201	144	35	-26
225	115	79	9	-29
300	32	14	-18	-35

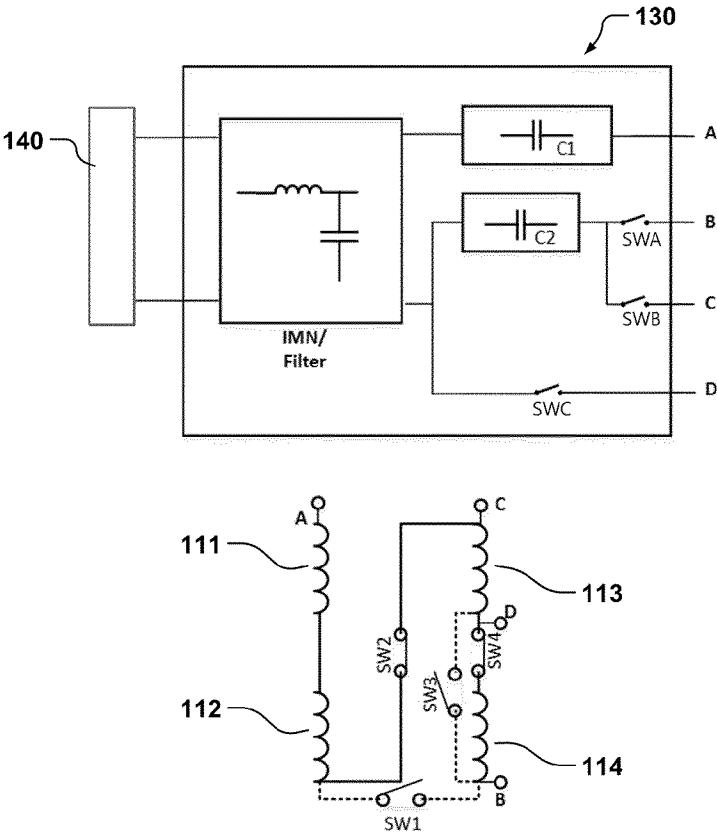
[Fig. 3]



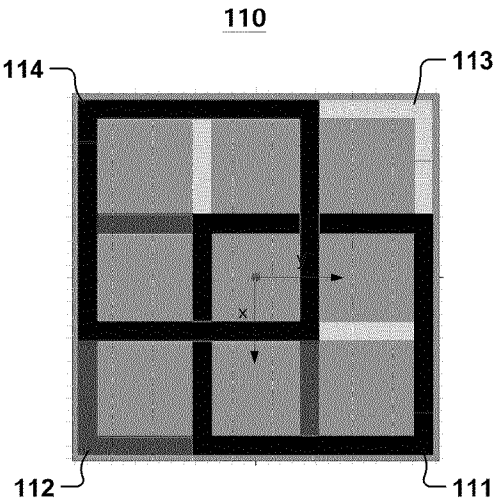
[Fig. 4]



[Fig. 5]

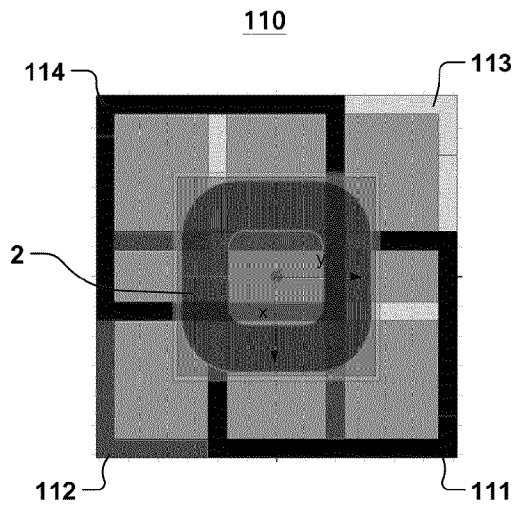


[Fig. 6]



$\begin{matrix} y \\ \backslash x \end{matrix}$	0	100	200	300
0	1111	1111	-1-111	-1-111
75	1111	1111	-1-111	-1-111
150	1111	-1-1-11	-1111	-1111
225	-11-11	-11-11	-1111	-1111
300	-11-11	-11-11	-1111	-1111

[Fig. 7]

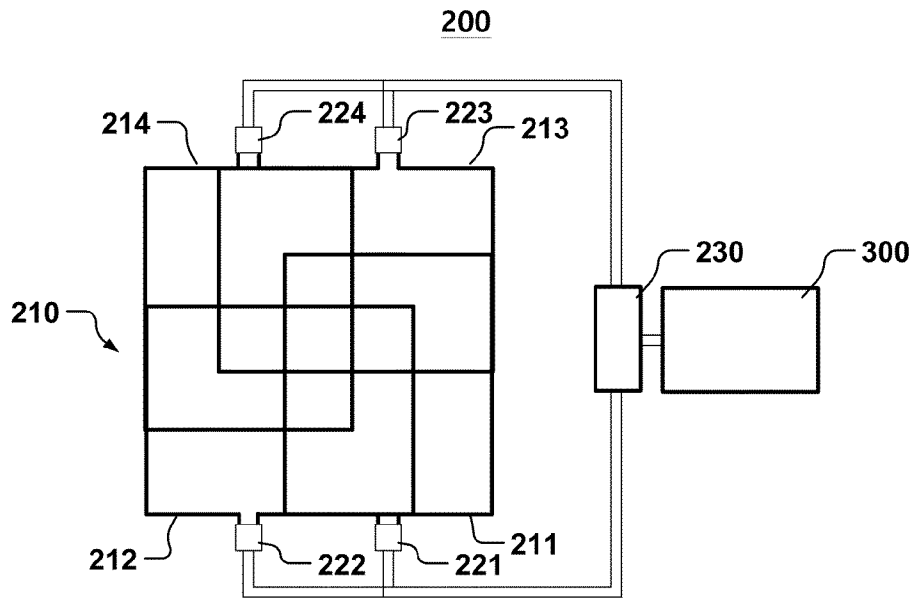


$y \backslash x$	0	100	200	300
0	1111	1111	1-11-1	1-11-1
75	1111	1111	1-11-1	1-11-1
150	11-1-1	11-1-1	1-1-1-1	1-1-1-1
225	11-1-1	11-1-1	1-1-1-1	1-1-1-1
300	11-1-1	11-1-1	1-1-1-1	1-1-1-1

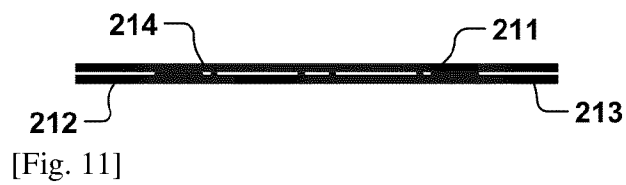
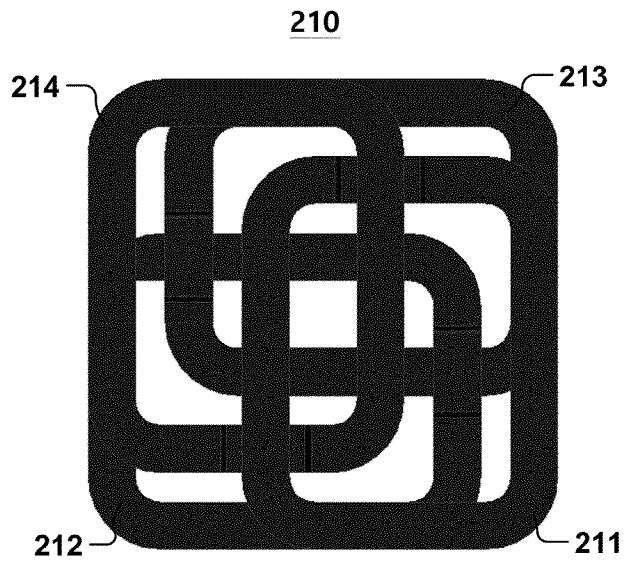
[Fig. 8]

Over-lap	Aspect ratio (width/length)		1.1/1				1/1				1/1.1			
	$y \backslash x$		0	100	200	300	0	100	200	300	0	100	200	300
about 0.475	0		464	360	328	160	471	359	309	156	468	353	287	151
	75		398	302	294	140	406	303	280	139	406	298	261	135
	150		273	237	232	135	300	251	234	142	328	275	236	148
	225		268	224	222	127	286	236	220	129	298	248	218	131
	300		155	132	143	81	160	128	139	81	166	133	136	81
about 0.525	0		526	407	322	150	533	403	303	146	528	405	280	142
	75		452	343	288	129	456	344	270	129	454	343	253	126
	150		295	253	215	122	300	255	211	127	321	269	214	134
	225		263	218	200	115	280	230	201	117	293	240	198	117
	300		146	121	130	71	150	120	124	71	154	120	121	71
about 0.575	0		579	447	307	136	585	447	289	133	580	448	268	131
	75		501	381	277	118	504	382	259	117	499	383	241	115
	150		327	262	205	112	325	267	190	117	321	268	187	122
	225		251	207	180	103	267	219	182	106	281	230	179	107
	300		133	110	115	74	137	108	113	76	140	112	110	77

[Fig. 9]

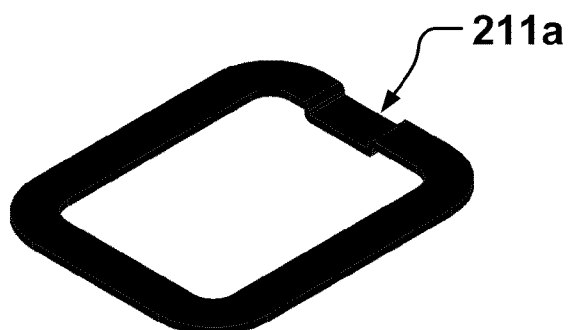


[Fig. 10]

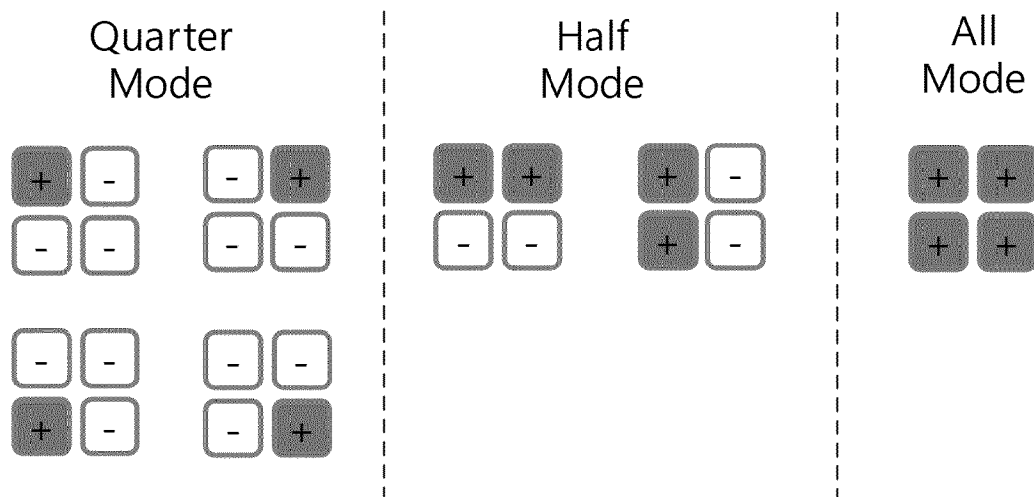


[Fig. 11]

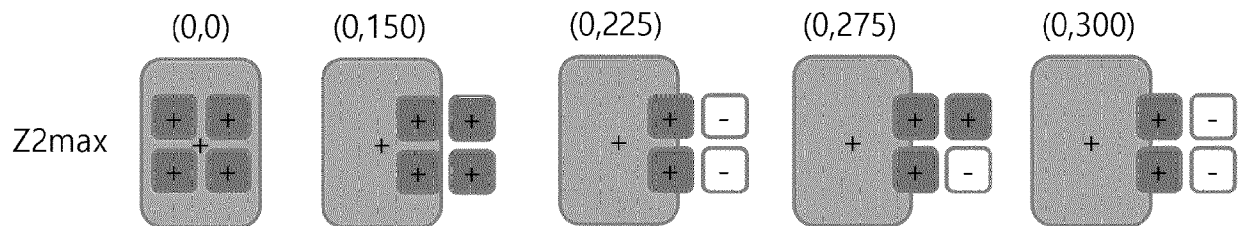
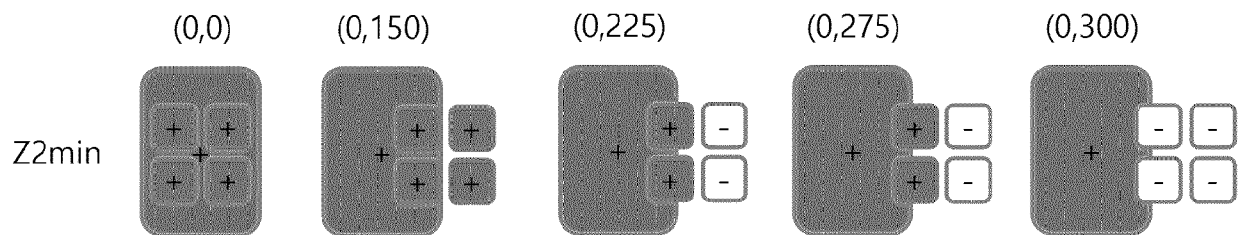
211



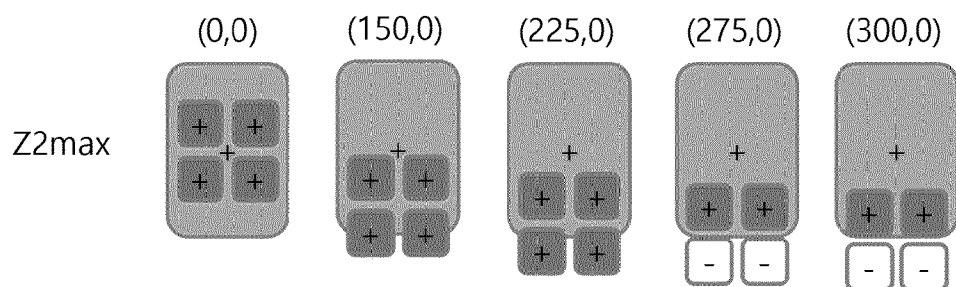
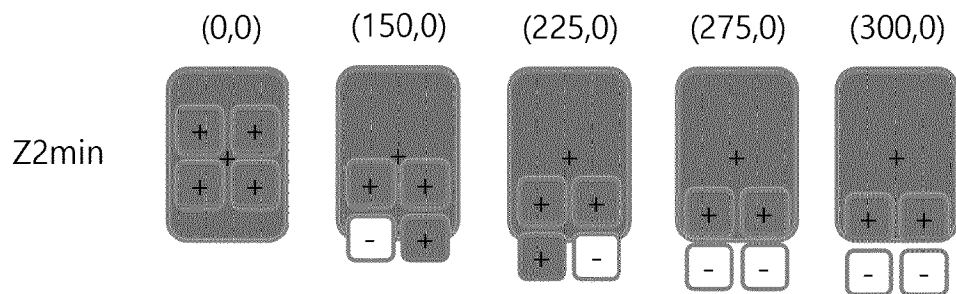
[Fig. 12]



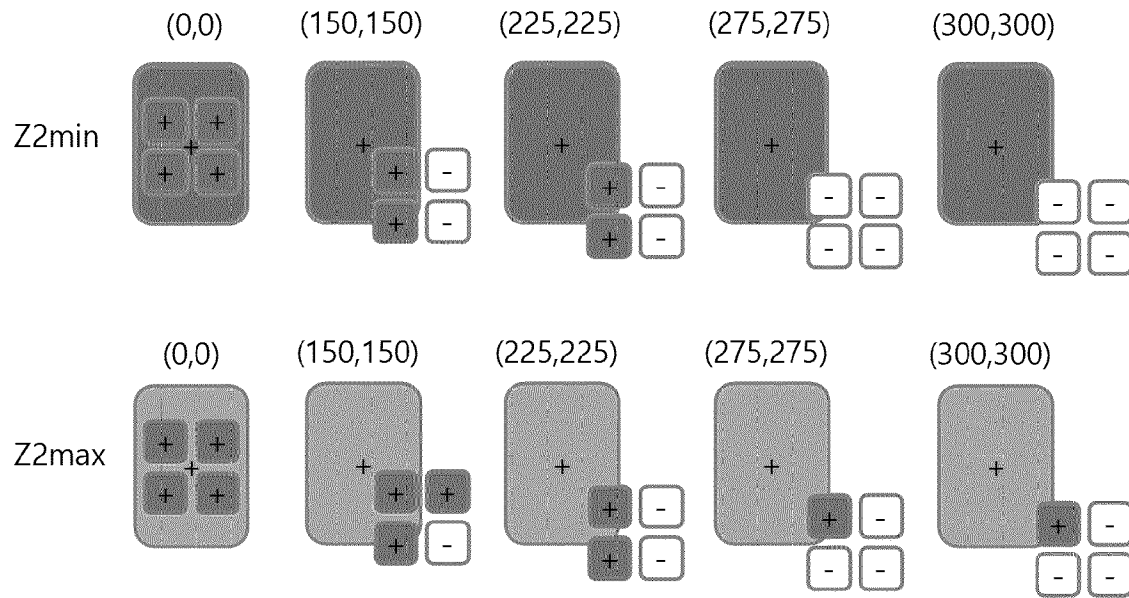
[Fig. 13a]



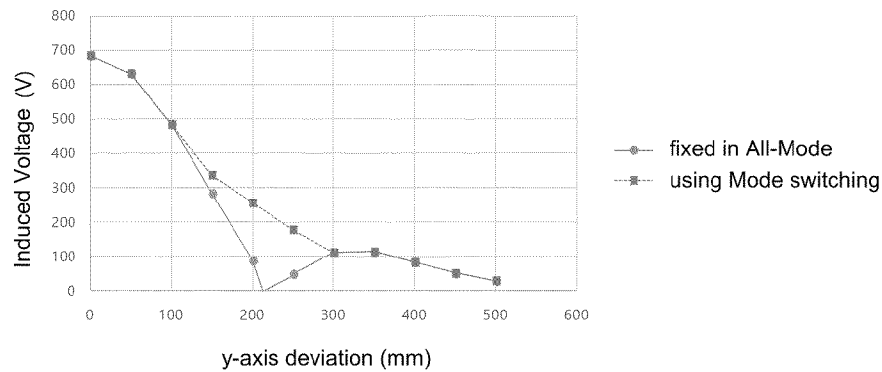
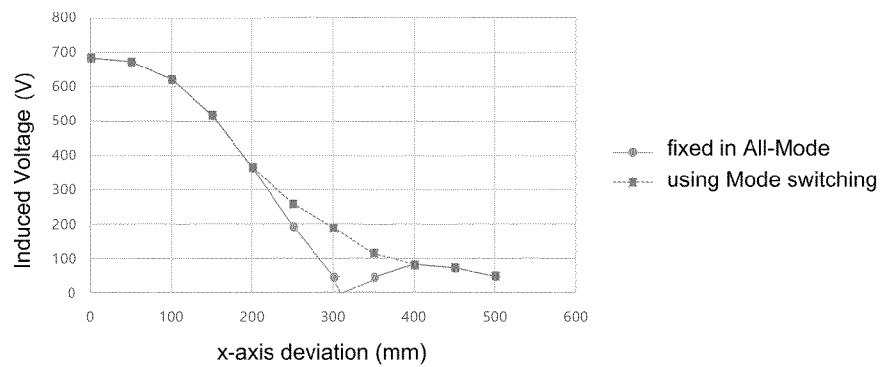
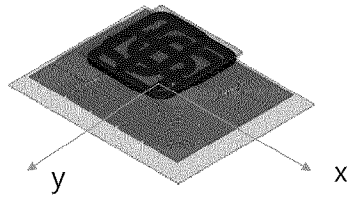
[Fig. 13b]



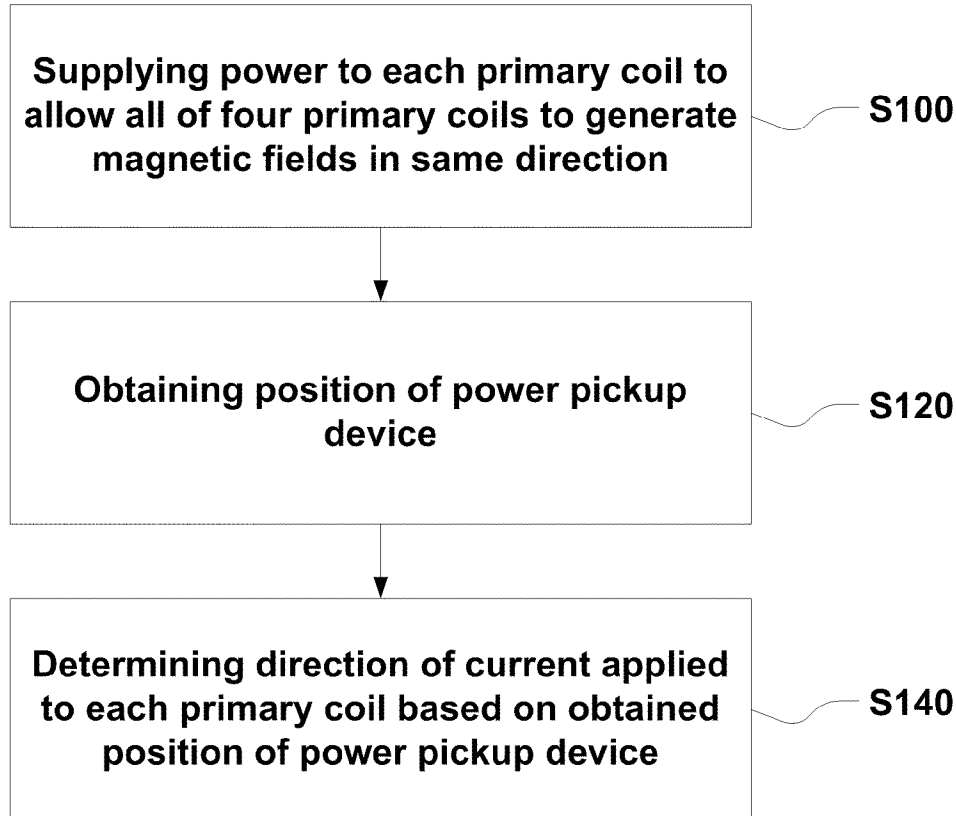
[Fig. 13c]



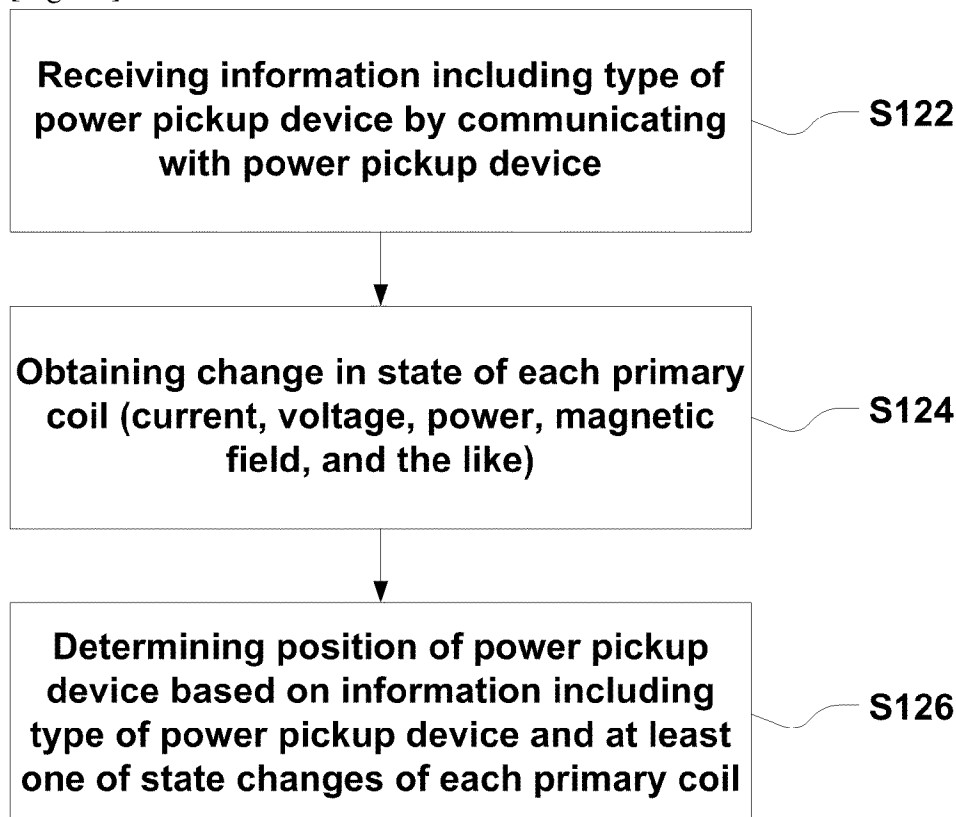
[Fig. 14]



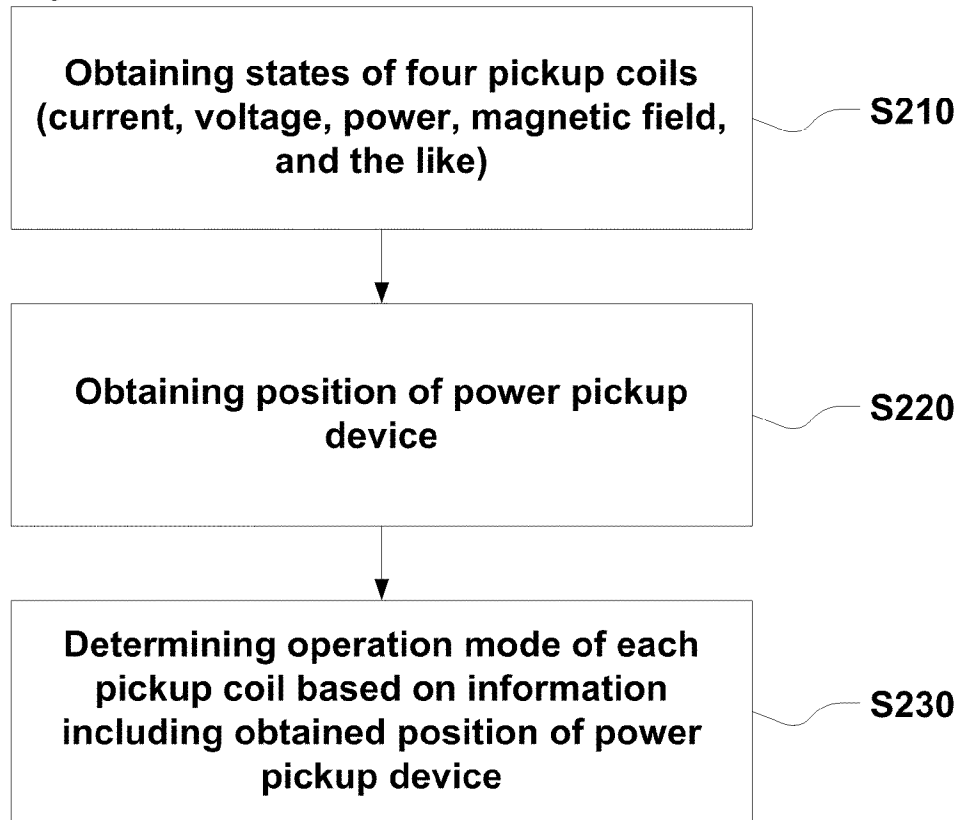
[Fig. 15]



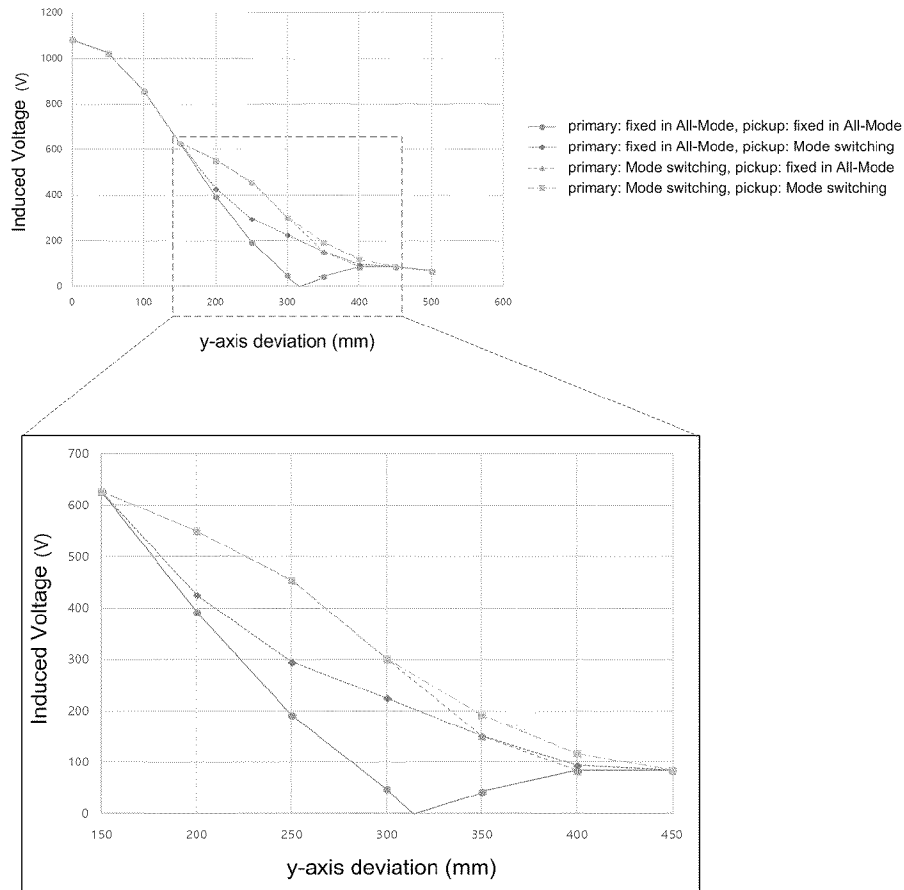
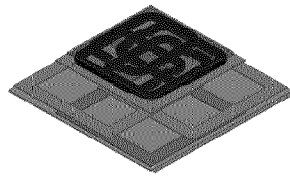
[Fig. 16]



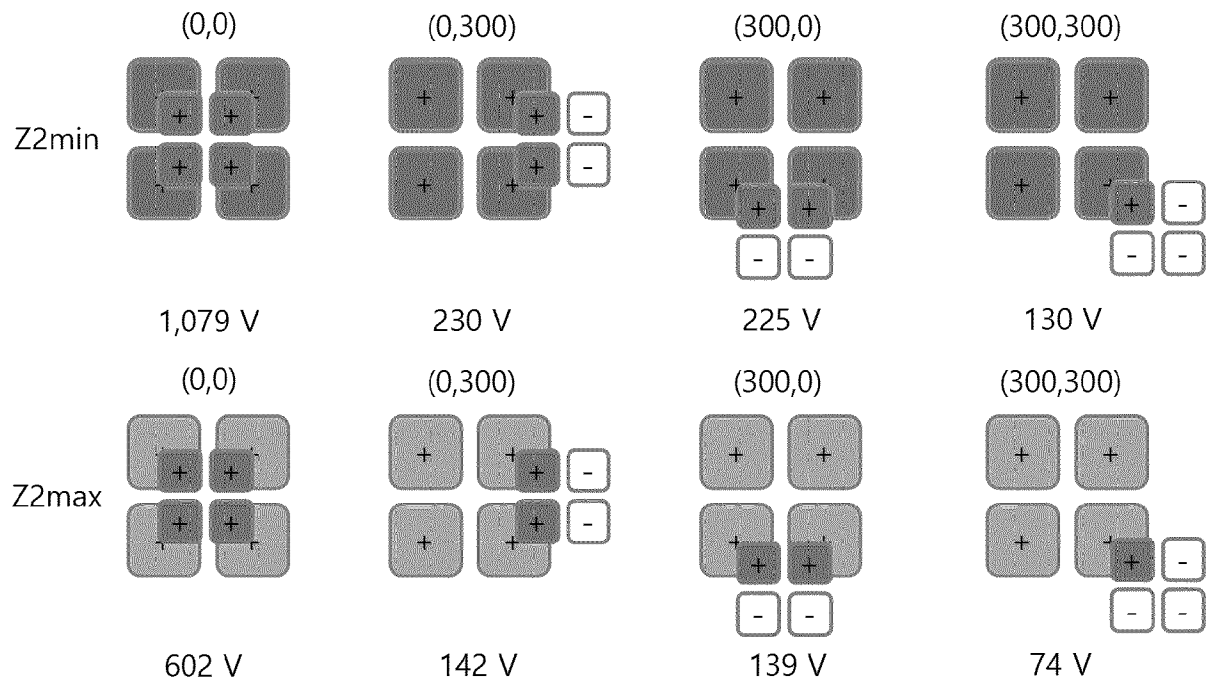
[Fig. 17]



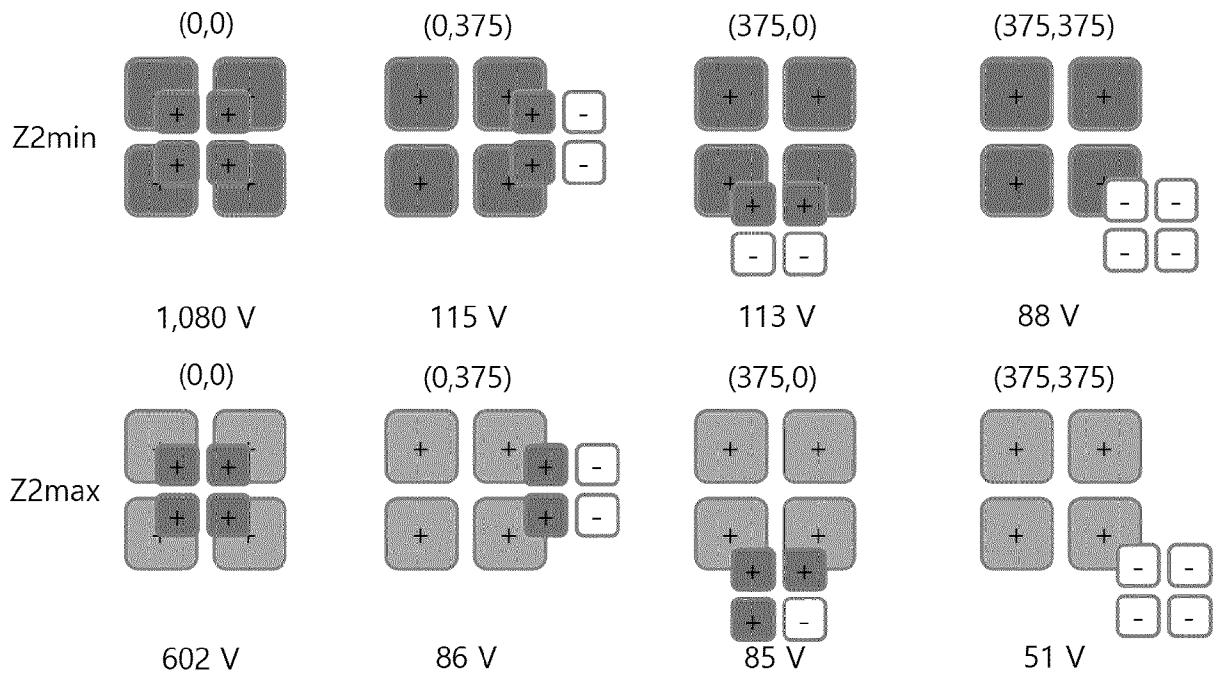
[Fig. 18]



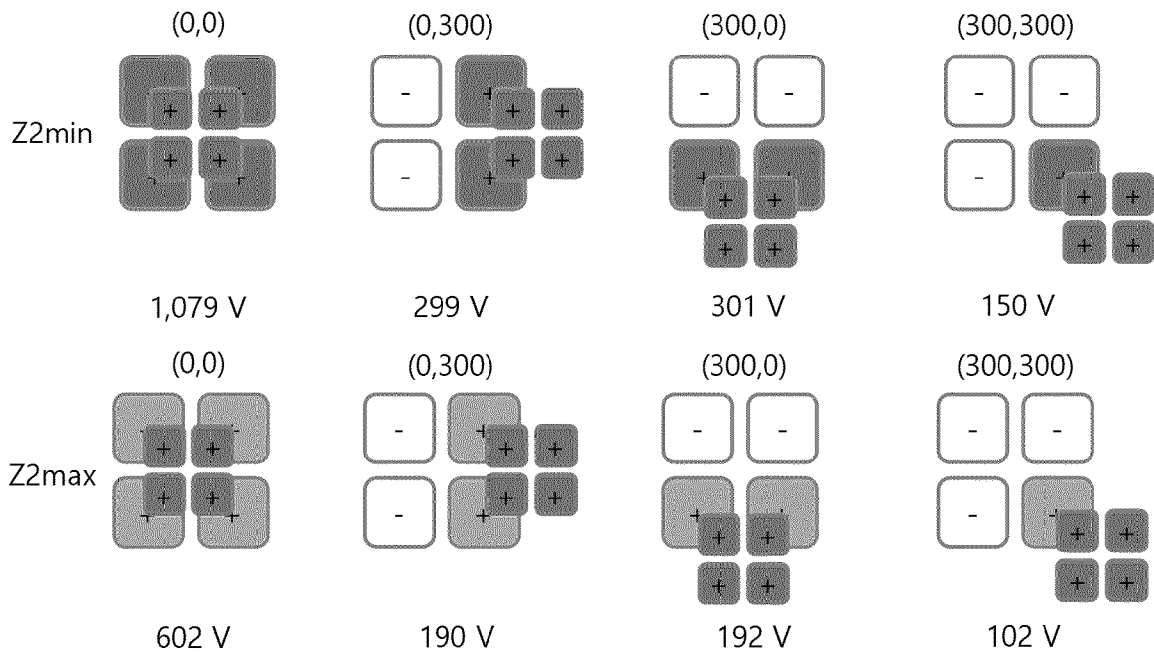
[Fig. 19a]



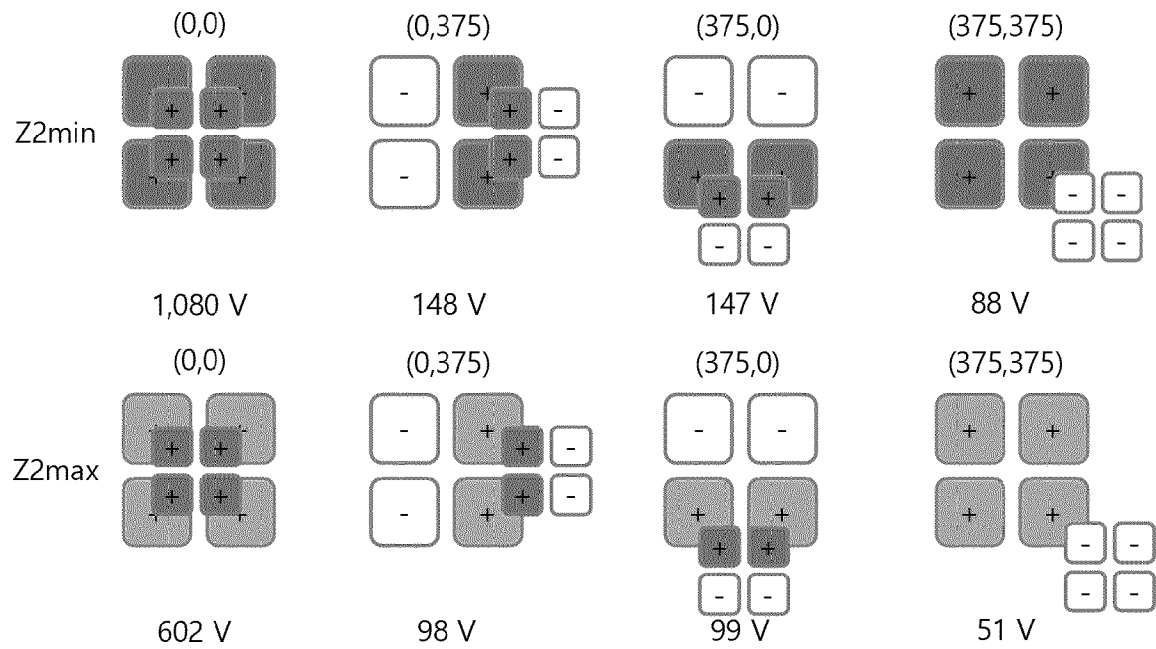
[Fig. 19b]



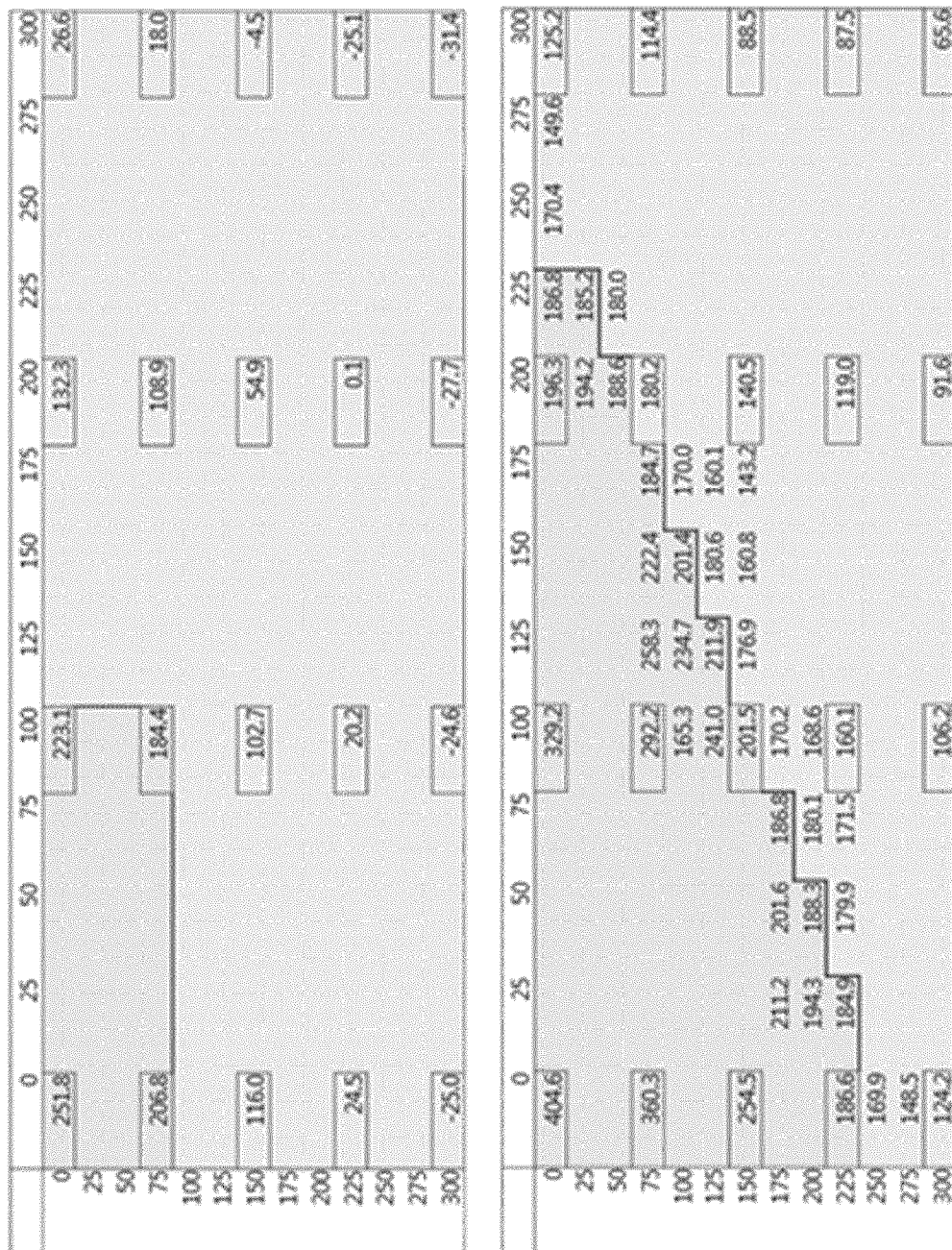
[Fig. 19c]



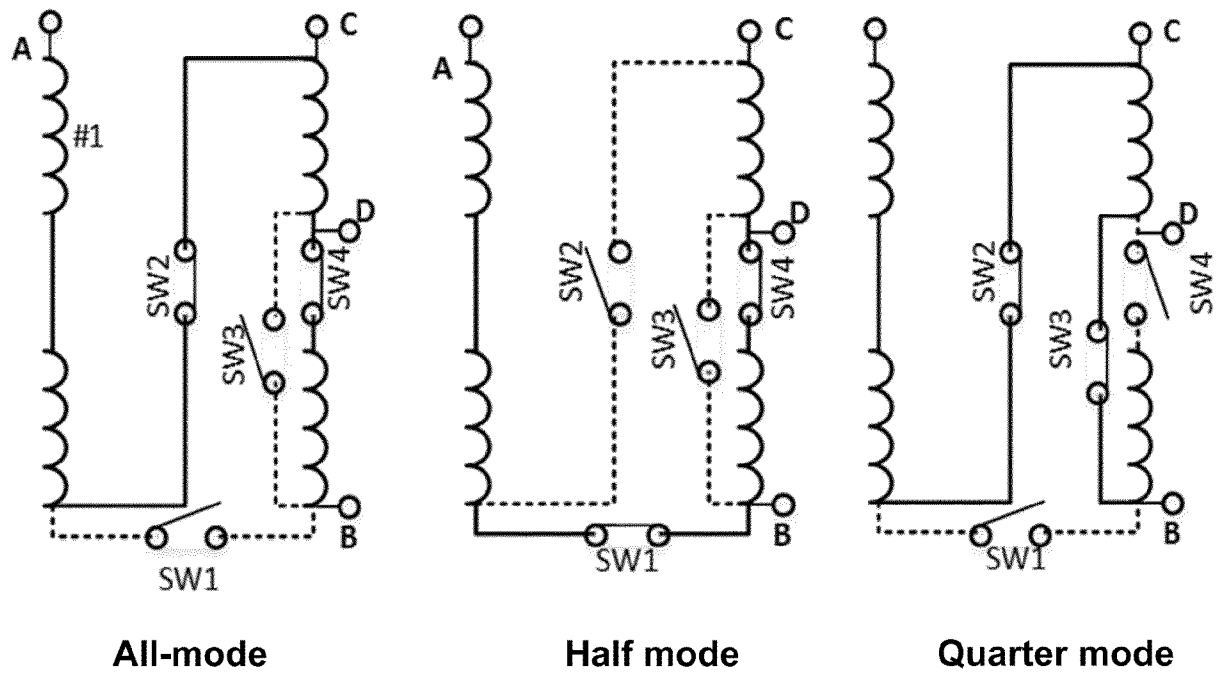
[Fig. 19d]



[Fig. 20]



[Fig. 21]



	SWA	SWB	SWC	SW1	SW2	SW3	SW4
All-mode	O	X	X	X	O	X	O
Half mode	X	O	X	O	X	X	O
Quarter mode	X	X	O	X	O	O	X

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2018/002800**A. CLASSIFICATION OF SUBJECT MATTER****H02J 50/40(2016.01)i, H01F 38/14(2006.01)i**

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)

H02J 50/40; H05K 7/14; H01M 10/46; H02J 5/00; H02J 17/00; H01F 38/14

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: four adjacent circular coils, pickup coil, wireless power charging, inductive, magnetic flux

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 8169185 B2 (AFSHIN PARTOVI et al.) 01 May 2012 See column 10, line 32 - column 38, line 30; claims 1, 3, 9, 12-13; and figures 2-3, 6, 28.	1-11, 13-20
A		12, 21
A	US 2015-0236513 A1 (AUCKLAND UNISERVICES LIMITED) 20 August 2015 See paragraphs 117-118, 132-144; and figures 1, 3, 4(a)-4(b), 5.	1-21
A	US 7872445 B2 (SHU-YUEN RON HUI) 18 January 2011 See column 7, lines 35-40; and figure 10(a).	1-21
A	US 8278784 B2 (NIGEL P COOK et al.) 02 October 2012 See column 9, lines 20-66; and figure 13.	1-21
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Further documents are listed in the continuation of Box C.



See patent family annex.

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"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

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Date of the actual completion of the international search

16 July 2018 (16.07.2018)

Date of mailing of the international search report

16 July 2018 (16.07.2018)

Name and mailing address of the ISA/KR

International Application Division

Korean Intellectual Property Office

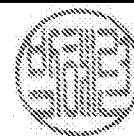
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