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### Antenna module

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#### Abstract

Disclosed herein is an antenna module that includes a substrate, a coil pattern formed on the first surface of the substrate, and a magnetic member covering the second surface of the substrate and having a through hole formed therein. The coil pattern has first and second coil sections. The second coil section is disposed in the opening of the first coil section. The inner peripheral end of the first coil section is connected to the outer peripheral end of the second coil section. The second coil section has a first extending section extending along the first coil section and a second extending section protruding from the first extending section toward the through hole in a plan view and wound in an opposite direction to a winding direction of the first extending section in a state overlapping the through hole.

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## Background/Summary

### CROSS-REFERENCE TO RELATED APPLICATION

(1) This application claims the benefit of Japanese Patent Application No. 2022-028874, filed on Feb. 28, 2022, the entire disclosure of which is incorporated by reference herein.

### BACKGROUND

(2) The present disclosure relates to an antenna module.

(3) JP 2020-195050A discloses an IC card having a wireless communication function. The IC card described in JP 2020-195050A incorporates therein: a magnetic member; an antenna module

having an antenna coil overlapping the magnetic member and a coupling coil overlapping a through hole formed in the magnetic member; and an IC module electromagnetic-field coupled with the coupling coil.

(4) In the antenna module described in JP 2020-195050A, the antenna coil is formed on one surface of a substrate, and a coupling coil is formed on the other surface of the substrate. That is, it is necessary to form a conductor pattern on both surfaces of the substrate and thus necessary to provide a via conductor for connecting the conductor patterns on both surfaces of the substrate, requiring improvement in terms of a manufacturing process.

## SUMMARY

(5) An antenna module according to the present disclosure includes: a substrate; a coil pattern formed on one surface of the substrate; and a magnetic member covering the other surface of the substrate and having a through hole formed therein. The coil pattern has first and second coil sections. The second coil section is disposed in the opening of the first coil section. The inner peripheral end of the first coil section is connected to the outer peripheral end of the second coil section. The second coil section has a first extending section extending along the first coil section and a second extending section protruding from the first extending section toward the through hole in a plan view and wound in the opposite direction to the winding direction of the first extending section in a state overlapping the through hole.

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## Description

### BRIEF DESCRIPTION OF THE DRAWINGS

(1) The above features and advantages of the present disclosure will be more apparent from the following description of certain preferred embodiments taken in conjunction with the accompanying drawings, in which:

(2) FIG. 1 is a schematic perspective view illustrating the outer appearance of an IC card 2 having an antenna module according to one embodiment of the present disclosure;

(3) FIG. 2 is a schematic exploded perspective view for explaining the structure of the IC card 2 having an antenna module 1 according to the one embodiment of the present disclosure;

(4) FIG. 3 is a schematic plan view illustrating the pattern shape of the coil pattern CP formed on one surface of the substrate 30;

(5) FIG. 4 is a schematic perspective view of the IC module as viewed from the back surface side thereof;

(6) FIG. 5 is a schematic plan view illustrating the pattern shape of the coil pattern CP according to a first modification; and

(7) FIG. 6 is a schematic plan view illustrating the pattern shape of the coil pattern CP according to a second modification.

### DETAILED DESCRIPTION OF THE EMBODIMENTS

(8) An object of the present disclosure is to provide an antenna module capable of being manufactured with a simpler process.

(9) Preferred embodiments of the present disclosure will be explained below in detail with reference to the accompanying drawings.

(10) FIG. 1 is a schematic perspective view illustrating the outer appearance of an IC card 2 having an antenna module according to one embodiment of the present disclosure.

(11) As illustrated in FIG. 1, the IC card 2 according to the present embodiment is a plate-like body in which the Y-direction is a long side direction, the X-direction is a short side direction, and the Z-direction is the thickness direction and has a top surface 2a and a back surface 2b which constitute the YX plane. The IC card 2 incorporates therein an IC module to be described later, and a terminal electrode E of the IC module is exposed to the top surface 2a of the IC card 2. The IC card 2 can

perform communication in a state where the back surface **2b** faces a card reader **4**.

(12) FIG. **2** is a schematic exploded perspective view for explaining the structure of the IC card **2** having an antenna module **1** according to the one embodiment of the present disclosure.

(13) The IC card **2** illustrated in FIG. **2** has a structure in which a metal plate **10**, a magnetic member **20**, a substrate **30**, and a cover layer **40** are stacked in this order from the one surface (top surface) **2a** side toward the other surface **2b** (back surface **2b**) side. The metal plate **10** is made of a metal material such as stainless steel or titanium, and the surface thereof constitutes the one surface **2a** of the IC card **2**. The metal plate **10** has an opening **11**, and an IC module **50** is disposed inside the opening **11**.

(14) The substrate **30** is a film made of an insulating resin material such as PET (Poly Ethylene Terephthalate), and a coil pattern CP which is a conductor pattern made of a good conductor such as copper is formed on one surface of the substrate **30**. No conductor pattern is formed on the other surface of the substrate **30**, and thus there is no via conductor penetrating the substrate **30**. The other surface of the substrate **30** is covered with the magnetic member **20**. The magnetic member **20** has a through hole **21**. The magnetic member **20** may be a cured paste member which is a mixture of magnetic particles and resin or may be a sheet-like member. The antenna module **1** according to the present embodiment is constituted by the substrate **30**, the conductor pattern formed on the substrate **30**, and the magnetic member **20**.

(15) FIG. **3** is a schematic plan view illustrating the pattern shape of the coil pattern CP formed on one surface **31** of the substrate **30**. In FIG. **3**, the through hole **21** of the magnetic member **20** positioned on the other surface **32** side of the substrate **30** is denoted by the dashed line.

(16) As illustrated in FIG. **3**, the coil pattern CP formed on the surface **31** of the substrate **30** includes first and third coil sections **100** and **300** functioning as an antenna coil and a second coil section **200** functioning as an antenna coil and a coupling coil. The first, second, and third coil sections **100**, **200**, and **300** are connected in series in this order from the outer peripheral end toward the inner peripheral end of the coil pattern CP. Specifically, the inner peripheral end of the first coil section **100** is connected to the outer peripheral end of the second coil section **200**, and the inner peripheral end of the second coil section **200** is connected to the outer peripheral end of the third coil section **300**. Accordingly, the second coil section **200** is disposed in the opening of the first coil section **100**, and the third coil section **300** is disposed in the opening of the second coil section **200**.

(17) Both ends of the coil pattern CP, i.e., the outer peripheral end of the first coil section **100** and the inner peripheral end of the third coil section **300** are opened. That is, the outer peripheral end of the first coil section **100** and the inner peripheral end of the third coil section **300** each terminate without being connected to another conductor pattern or a circuit element. Thus, although a DC current does not flow in the coil pattern CP, an LC circuit is formed by a parasitic capacitance generated between adjacent conductor patterns, so that resonance occurs at a predetermined frequency band. By making the predetermined frequency band in which the resonance occurs coincide with the frequency band (e.g., 13.56 MHz band) of near field wireless communication, the antenna module **1** can perform near field wireless communication.

(18) The first coil section **100** has sections **101** and **102** extending in the X-direction (short side direction) and sections **103** and **104** extending in the Y-direction (long side direction). Each of the sections **101** to **104** constituting the first coil section **100** completely overlap the magnetic member **20** without overlapping the through hole **21**. In the example illustrated in FIG. **3**, the first coil section **100** has about three turns.

(19) The first coil section **100** is a conductor pattern wound in a rectangular shape corresponding to the outer shape of the IC card **2** in a plan view (as viewed in the Z-direction). However, the first coil section **100** need not necessarily be strictly rectangular but may be approximately rectangular. For example, as illustrated in FIG. **3**, four corners of the first coil section **100** may be rounded. In this case, the short side of the first coil section **100** may be defined as a straight line section

extending in the X-direction, and the long side of the first coil section **100** may be defined as a straight line section extending in the Y-direction.

(20) The second coil section **200** has a first extending section **210** extending along the first coil section **100** and a second extending section **220** protruding toward the through hole **21** of the magnetic member **20** from the first extending section **210** in a plan view (as viewed in the Z-direction) and overlapping the through hole **21** in a plan view. The second extending section **220** is smaller in pattern width than the first extending section **210**. That is, lines constituting the conductor pattern of the second extending section **220** are wound with higher density than those of the first extending section **210**. This makes it possible to sufficiently ensure the number of lines in the second extending section **220** wound in a narrow area while reducing a resistance value of the first extending section **210**. In the example illustrated in FIG. 3, the second coil section **200** has about seven turns.

(21) The first extending section **210** of the second coil section **200** has sections **211**, **212**, **213**, and **214** wound respectively along the sections **101**, **102**, **103**, and **104** of the first coil section **100**. Each of the sections **211** to **214** constituting the first extending section **210** completely overlap the magnetic member **20** without overlapping the through hole **21**. The through hole **21** is formed in the vicinity of the section **211**, and the second coil section **200** transits from the first extending section **210** to the second extending section **220** at a position overlapping the through hole **21** in the Y-direction. The second extending section **220** of the second coil section **200** has first, second, and third sections **221**, **222**, and **223** extending respectively along second, third, and fourth sides L2, L3, and L4 of the through hole **21**. Thus, a large part of the second extending section **220** constituted by the first to third sections **221** to **223** does not overlap the magnetic member **20**. The first and second sides L1 and L2 of the through hole **21** extend in the X-direction along the short side of the first coil section **100** and positioned on mutually opposite sides. The third and fourth sides L3 and L4 of the through hole **21** extend in the Y-direction along the long side of the first coil section **100** and positioned on mutually opposite sides. The first side L1 of the through hole **21** is positioned closer to the first coil section **100** than the second side L2. The second extending section **220** thus has the first section **221** extending in the X-direction and second and third sections **222** and **223** extending in the Y-direction, so that it does not completely make one round at a portion overlapping the through hole **21** but turned by 270°, thus allowing the second coil section **200** to function as an antenna coil which is electromagnetic-field coupled with the IC module **50**. The second and third sections **222** and **223** each mostly overlap the through hole **21** but each do not overlap the through hole **21** in the vicinity of the portion connecting with the first extending section **210**.

(22) Thus, when a current is made to flow in the coil pattern CP from its outer peripheral end to inner peripheral end, the current flows counterclockwise in the first extending section **210** of the second coil section **200**, while the current flows clockwise in the second extending section **220** of the second coil section **200**. That is, the winding direction of the first extending section **210** overlapping the magnetic member **20** and the winding direction of the second extending section **220** not overlapping the magnetic member **20** are opposite to each other. The second extending section **220** of the second coil section **200** does not have a section extending along the first side L1 of the through hole **21**, so that the second section **222** extending in the Y-direction is directly connected to the section **211** extending in the X-direction not through the section extending along the first side L1. Similarly, the third section **223** extending in the Y-direction is directly connected to the section **211** extending in the X-direction not through the section extending along the first side L1.

(23) The third coil section **300** has sections **301** and **302** extending in the X-direction (short side direction) and sections **303** and **304** extending in the Y-direction (long side direction). Each of the sections **301** to **304** constituting the third coil section **300** completely overlaps the magnetic member **20** without overlapping the through hole **21**. In the example illustrated in FIG. 3, the

number of turns of the third coil section **300** is larger than that of the first coil section **100** and is about nine.

(24) With such a configuration as described above, the first coil section **100**, the first extending section **210** of the second coil section **200**, and third coil section **300**, all of which overlap the magnetic member **20**, function as an antenna coil, thus allowing communication to be performed at the surface **2b** side of the IC card **2**. On the other hand, the second extending section **220** of the second coil section **200** does not overlap the magnetic member **20** and faces the IC module **50** through the through hole **21** formed in the magnetic member **20** to be electromagnetic-field coupled with the IC module **50**. As a result, the first coil section **100**, the first extending section **210** of the second coil section **200**, and the third coil section **300** functioning as an antenna coil are connected to the IC module **50** through the second extending section **220** functioning as a coupling coil.

(25) Further, in the antenna module **1** according to the present embodiment, the coil pattern CP is provided only on the surface **31** of the substrate **30**, and no conductor pattern is provided on the surface **32** of the substrate **30**. This allows the antenna module **1** to be manufactured in a very simple process. In addition, in the present embodiment, the third coil section **300** which is positioned at the inner peripheral side and in which the line length per turn is shorter is larger in the number of turns than the first coil section **100** which is positioned at the outer peripheral side and in which the line length per turn is longer. Accordingly, the second extending section **220** of the second coil section **200** functioning as a coupling coil is positioned closer to the center of the line length, thereby making it possible to increase an output by electromagnetic field coupling through the second extending section **220**.

(26) FIG. **4** is a schematic perspective view of the IC module as viewed from the back surface side thereof.

(27) As illustrated in FIG. **4**, the IC module **50** has a module board **51** and an IC chip **52** mounted on or incorporated in the module board **51**, and a coupling coil CC is formed on the back surface of the module board **51**. On the front surface side of the module board **51**, the terminal electrode

(28) E illustrated in FIG. **1** is provided. When the coupling coil CC and the second extending section **220** of the second coil section **200** of the coil pattern CP formed on the substrate **30** overlap each other, electromagnetic field coupling occurs. This makes it possible to AC-connect the first coil section **100**, first extending section **210** of the second coil section **200**, and third coil section **300** of the coil pattern CP functioning as an antenna coil to the IC module **50** through the coupling coil CC without directly connecting them using a terminal electrode or the like.

(29) FIG. **5** is a schematic plan view illustrating the pattern shape of the coil pattern CP according to a first modification.

(30) The coil pattern CP according to the first modification illustrated in FIG. **5** differs from the coil pattern CP illustrated in FIG. **3** in that the third coil section **300** is wound along the first and second extending sections **210** and **220** of the second coil section **200**. Other basic configurations are the same as those of the coil pattern CP illustrated in FIG. **3**, so the same reference numerals are given to the same elements, and overlapping description will be omitted.

(31) In the coil pattern CP according to the first modification, the third coil section **300** includes sections **301** to **305**, of which the sections **301**, **302**, **303**, and **304** are wound respectively along the sections **211**, **212**, **213**, **214** of the first extending section **210**, and the section **305** is wound along the second extending section **220**. Thus, when a current is made to flow in the coil pattern CP from its outer peripheral end to inner peripheral end, the current flows counterclockwise in the sections **301** to **304** of the third coil section **300**, while the current flows clockwise in the section **305** of the third coil section **300**. By thus winding the third coil section **300** along the first and second extending sections **210** and **220** of the second coil section **200**, a parasitic capacitance increases, allowing a reduction in self-resonance frequency.

(32) FIG. **6** is a schematic plan view illustrating the pattern shape of the coil pattern CP according to a second modification.

(33) The coil pattern CP according to the second modification illustrated in FIG. 6 differs from the coil pattern CP illustrated in FIG. 3 in that the second extending section **220** of the second coil section **200** further includes a fourth section **224** extending along the first side **L1** of the through hole **21**. Other configurations are the same as those of the coil pattern CP illustrated in FIG. 3, so the same reference numerals are given to the same elements, and overlapping description will be omitted.

(34) In the coil pattern CP according to the second modification, the total area of the second extending section **220** that overlaps the through hole **21** increases. As exemplified by the second modification, the second and third sections **222** and **223** extending in the Y-direction may be connected to the section **211** extending in the X-direction through the fourth section **224** extending along the first side **L1**.

(35) While the preferred embodiment of the present disclosure has been described, the present disclosure is not limited to the above embodiment, and various modifications may be made within the scope of the present disclosure, and all such modifications are included in the present disclosure.

(36) For example, although the coil pattern CP is constituted by the first, second, and third coil sections **100**, **200**, and **300** in the above embodiment, the third coil section **300** may be omitted. Further, the number of the second extending sections **220** included in the second coil section **200** is not limited to one, and when a plurality of IC modules **50** exist, a plurality of second extending sections **220** may be provided so as to overlap the plurality of the respective IC modules **50** each through the through hole **21**.

(37) The technology according to the present disclosure includes the following configuration examples but not limited thereto.

(38) An antenna module according to the present disclosure includes: a substrate; a coil pattern formed on one surface of the substrate; and a magnetic member covering the other surface of the substrate and having a through hole formed therein. The coil pattern has first and second coil sections. The second coil section is disposed in the opening of the first coil section. The inner peripheral end of the first coil section is connected to the outer peripheral end of the second coil section. The second coil section has a first extending section extending along the first coil section and a second extending section protruding from the first extending section toward the through hole in a plan view and wound in the opposite direction to the winding direction of the first extending section in a state overlapping the through hole. This eliminates the need to form a conductor pattern on the other surface of the substrate, making it possible to simplify a manufacturing process.

(39) Both ends of the coil pattern may be opened. This eliminates the need to connect the coil pattern to another circuit element, making it possible to further simplify a manufacturing process.

(40) The through hole may have first and second sides extending in the short side direction of the first coil section and positioned on mutually opposite sides and third and fourth sides extending in the long side direction of the first coil section and positioned on mutually opposite sides, and the second extending section may have first, second, and third sections extending respectively along the second, third, and fourth sides. This makes it possible to achieve sufficient electromagnetic field coupling with an IC module. In this case, the second and third sections may be connected to the first extending section not through a section extending along the first side. This prevents canceling between magnetic fields generated by the turning of the conductor pattern from occurring, thereby making it possible to improve communication characteristics.

(41) The pattern width of the second extending section may be smaller than the pattern width of the first extending section. This makes it possible to sufficiently ensure the number of lines in the second extending section wound in a narrow area while reducing a resistance value of the first extending section.

(42) The coil pattern may further have a third coil section disposed in the opening of the second coil section and not overlapping the through hole, and the inner peripheral end of the second coil

section may be connected to the outer peripheral end of the third coil section. This makes it possible to further improve communication characteristics and to reduce self-resonance frequency. In this case, the third coil section may be wound along the first and second extending sections of the second coil section. This allows a further reduction in self-resonance frequency. Further, the number of turns of the third coil section may be larger than the number of turns of the first coil section. This allows the second coil section to be positioned closer to the center of the line length.

## Claims

1. An antenna module comprising: a substrate having first and second surfaces opposite to each other; a coil pattern formed on the first surface of the substrate; and a magnetic member covering the second surface of the substrate and having a through hole formed therein, wherein the coil pattern has first and second coil sections, wherein the second coil section is disposed in an opening of the first coil section, wherein an inner peripheral end of the first coil section is connected to an outer peripheral end of the second coil section, wherein the second coil section has a first extending section extending along the first coil section and a second extending section protruding from the first extending section toward the through hole in a plan view and wound in an opposite direction to a winding direction of the first extending section in a state overlapping the through hole, and wherein there is no coil pattern on the second surface of the substrate.
2. The antenna module as claimed in claim 1, wherein both ends of the coil pattern are opened.
3. The antenna module as claimed in claim 1, wherein the through hole has first and second sides extending in a short side direction of the first coil section and positioned on mutually opposite sides and third and fourth sides extending in a long side direction of the first coil section and positioned on mutually opposite sides, and wherein the second extending section has first, second, and third sections extending respectively along the second, third, and fourth sides.
4. The antenna module as claimed in claim 3, wherein the second and third sections are connected to the first extending section not through a section extending along the first side.
5. The antenna module as claimed in claim 3, wherein: the substrate has opposing short sides and opposing long sides, the first side of the through hole is parallel with and proximate to one short side and the second side of the through hole is parallel with and distal to the one short side, and the second extending section does not extend parallel and adjacent to the first side of the through hole.
6. The antenna module as claimed in claim 1, wherein a pattern width of the second extending section is smaller than a pattern width of the first extending section.
7. The antenna module as claimed in claim 1, wherein the coil pattern further has a third coil section disposed in an opening of the second coil section and not overlapping the through hole, and wherein an inner peripheral end of the second coil section is connected to an outer peripheral end of the third coil section.
8. The antenna module as claimed in claim 7, wherein the third coil section is wound along the first and second extending sections of the second coil section.
9. The antenna module as claimed in claim 7, wherein a number of turns of the third coil section is larger than a number of turns of the first coil section.
10. An antenna module comprising: a substrate having first and second surfaces opposite to each other; a coil pattern formed on the first surface of the substrate; and a magnetic member covering the second surface of the substrate and having a through hole formed therein, wherein the coil pattern has a first extending section extending along a periphery of the substrate and a second extending section including one portion protruding from the first extending section toward the through hole in a plan view and wound in an opposite direction to a winding direction of the first extending section in a state overlapping the through hole, wherein the second extending section



includes another portion that protrudes away from the through hole back toward the first extending section in plan view, and wherein there is no coil pattern on the second surface of the substrate.

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