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(54) **ANTENNA DEVICE AND WIRELESS POWER TRANSMISSION DEVICE HAVING THE SAME**

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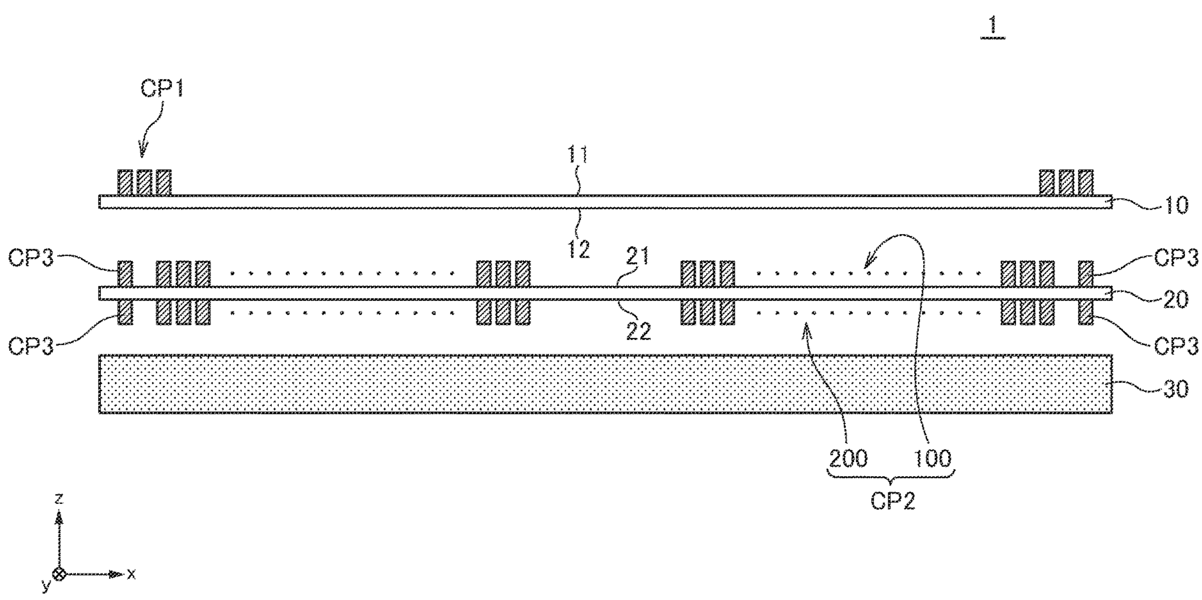
(57) **ABSTRACT**

Disclosed herein is an antenna device that includes a first coil pattern having at least first, second, and third turns. As viewed in a coil axis direction, each of the first, second, and third turns has an opening with a width larger in a first direction than in a second direction orthogonal to the first direction. The width of the opening of the second turn in the second direction is larger than a width of the opening of the first turn in the second direction. The width of the opening of the third turn in the second direction is larger than the width of the opening of the second turn in the second direction and smaller than a width of the opening of the first turn in the first direction.



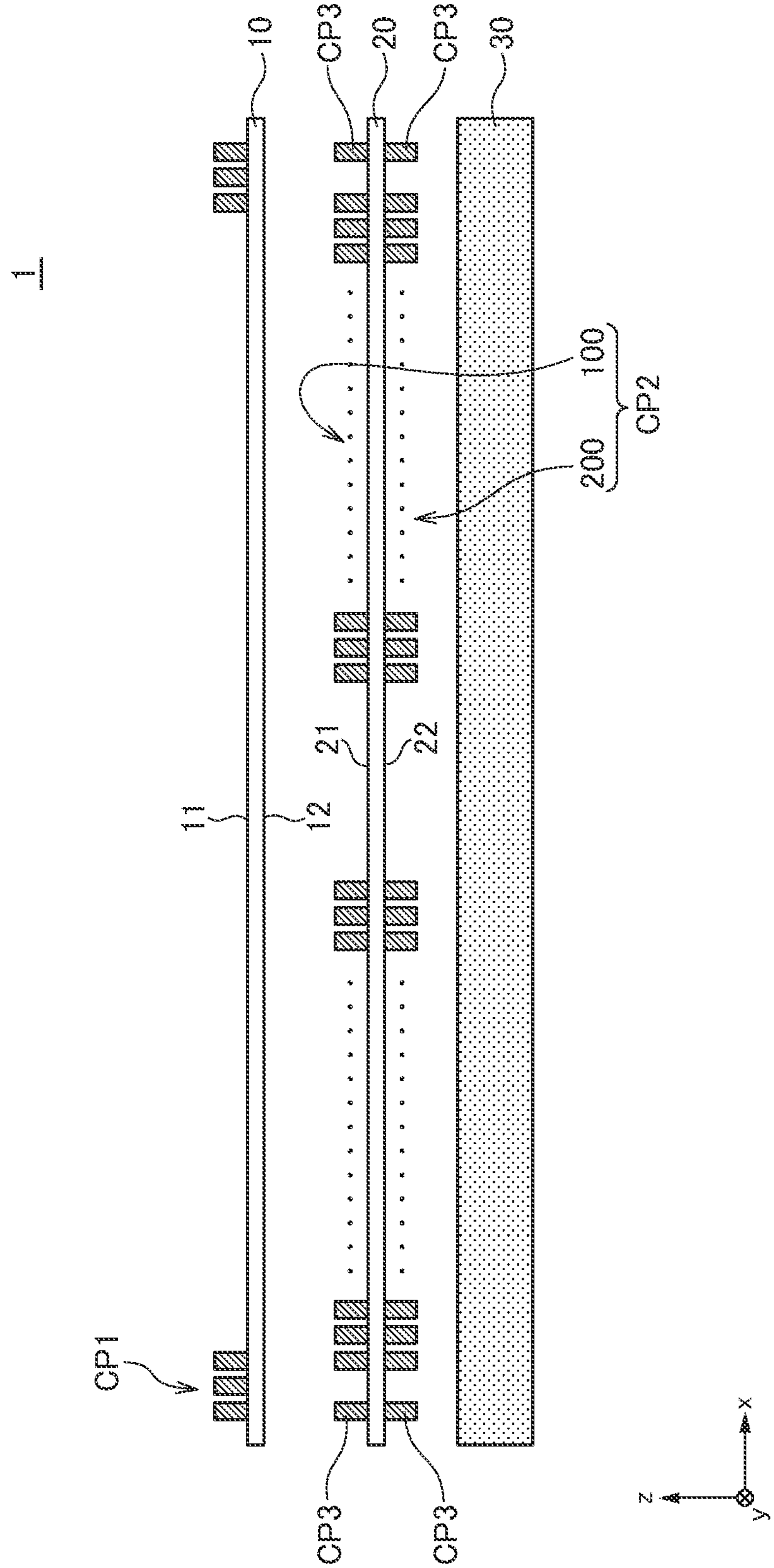


FIG. 1

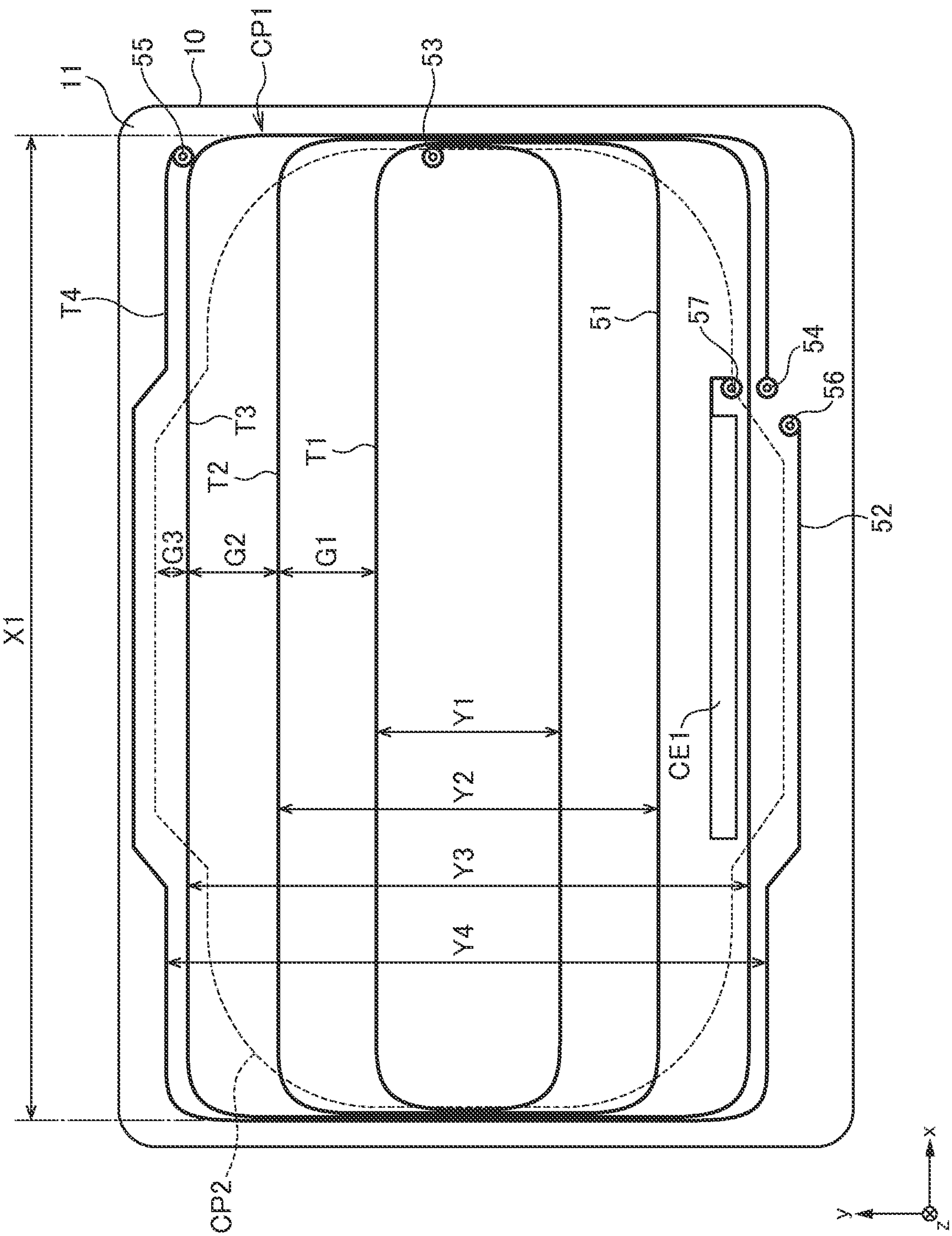

11
55
10
CP1
53
T4
51
57
54
56
T3
T2
T1
52
G3
G2
G1
X1
Y1
Y2
Y3
Y4
CE1
CP2
x
y
z

FIG. 2

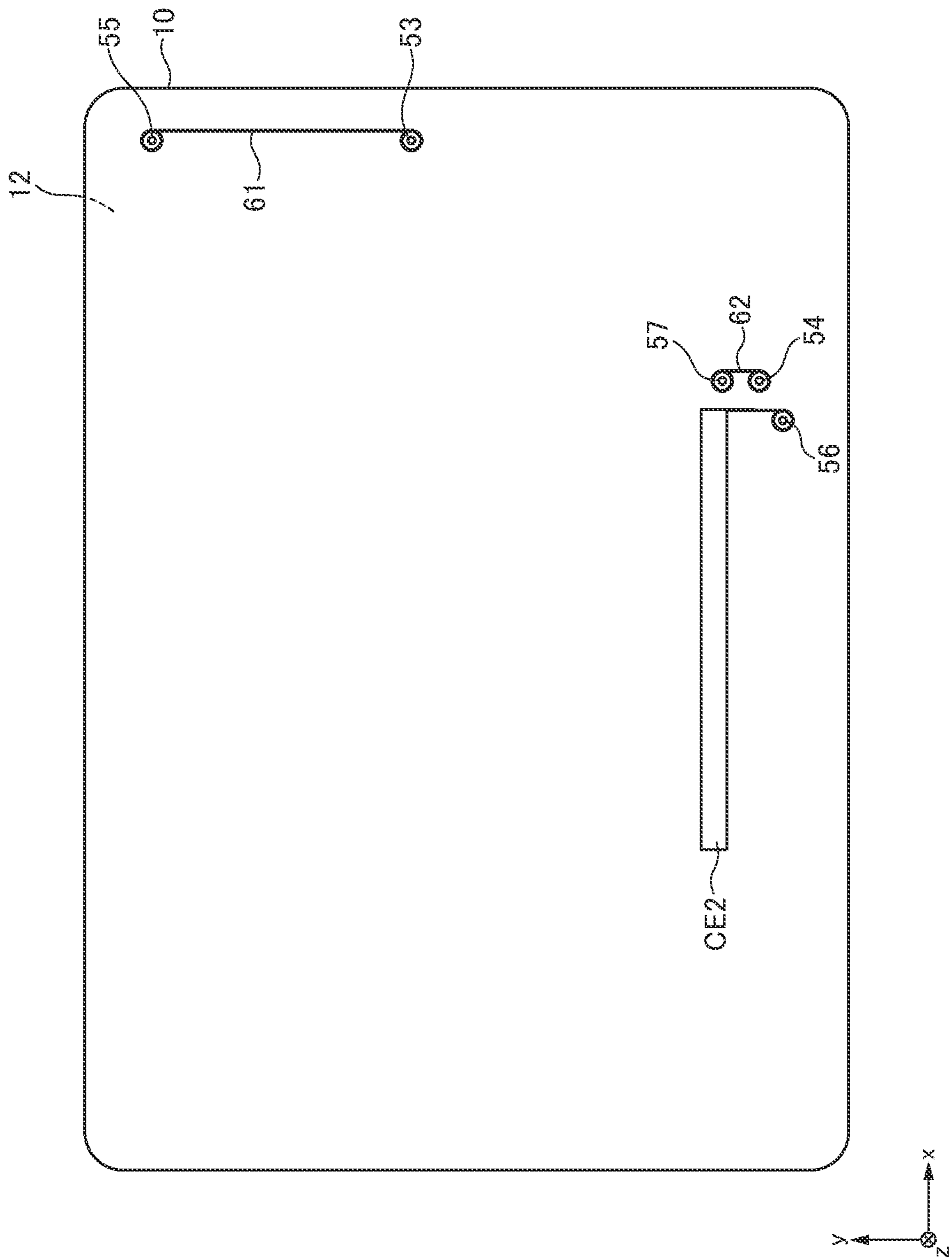


FIG. 3

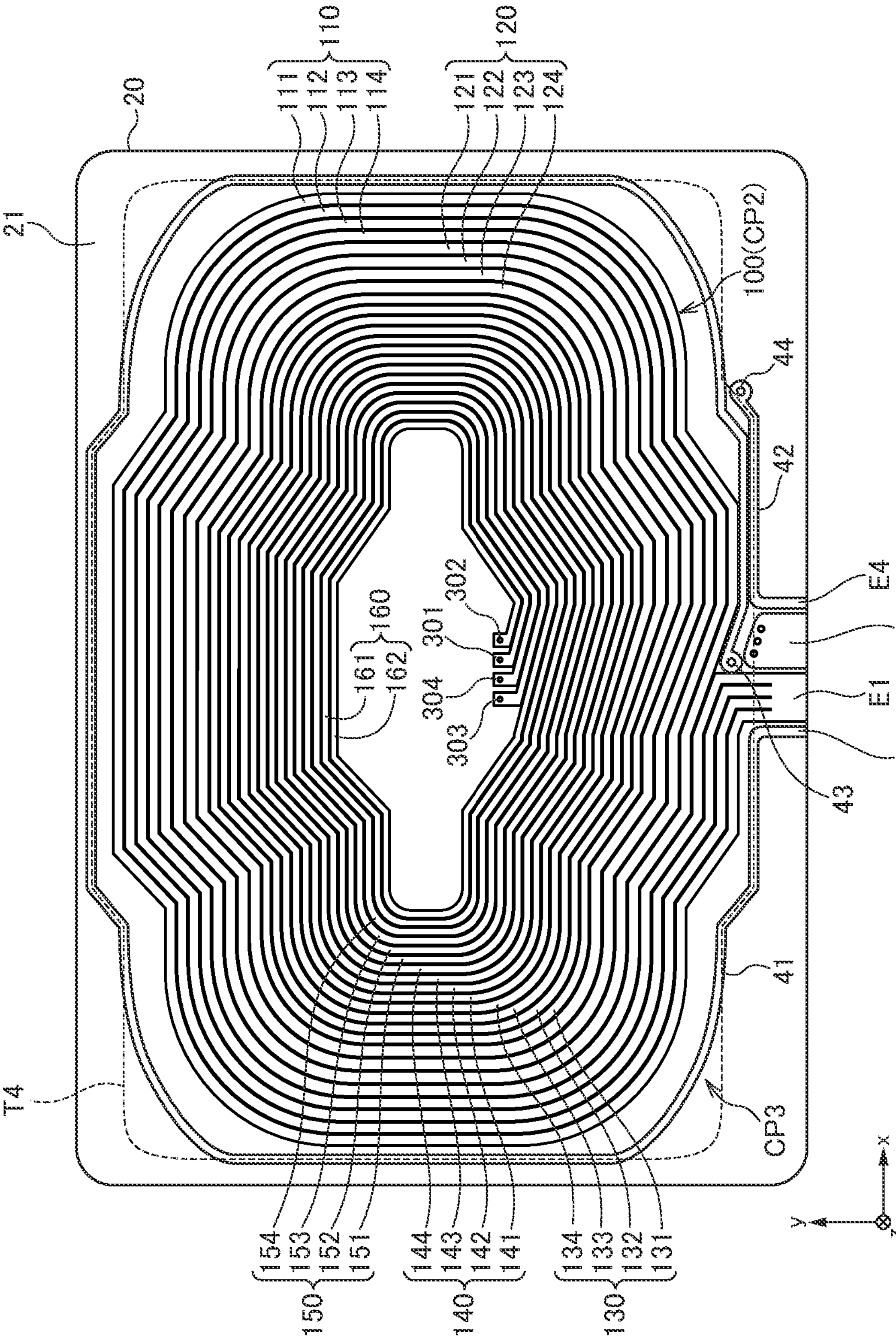

20
21
110
111
112
113
114
120
121
122
123
124
100(CP2)
44
42
E4
E2
E1
E3
43
41
CP3
T4
160
161
162
301
302
303
304
130
131
132
133
134
140
141
142
143
144
150
151
152
153
154
x
y
z

FIG. 4

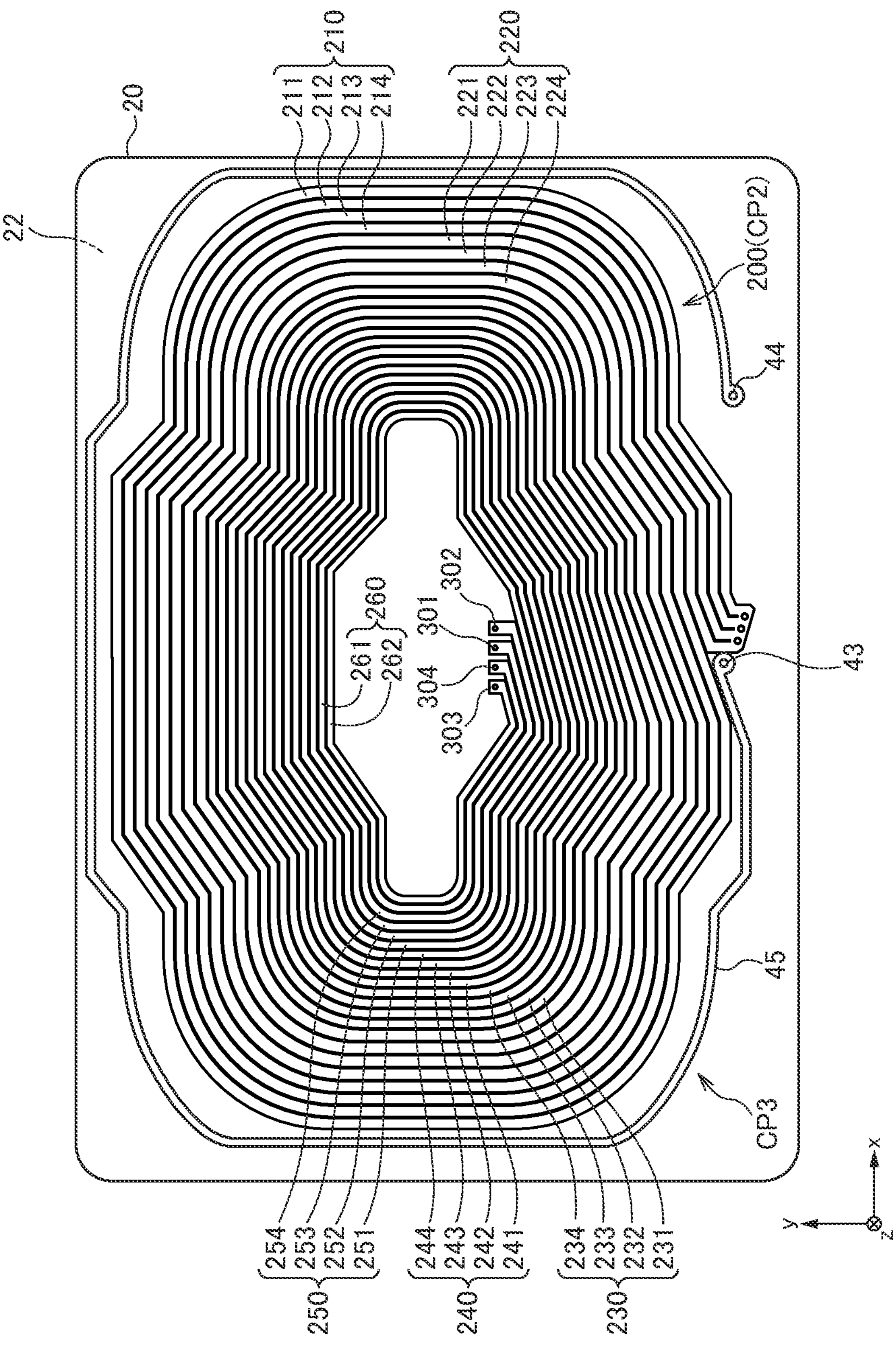

20
22
210
211
212
213
214
220
221
222
223
224
200(CP2)
44
43
45
CP3
260
261
262
301
302
303
304
230
231
232
233
234
240
241
242
243
244
250
251
252
253
254
x
y
z

FIG. 5

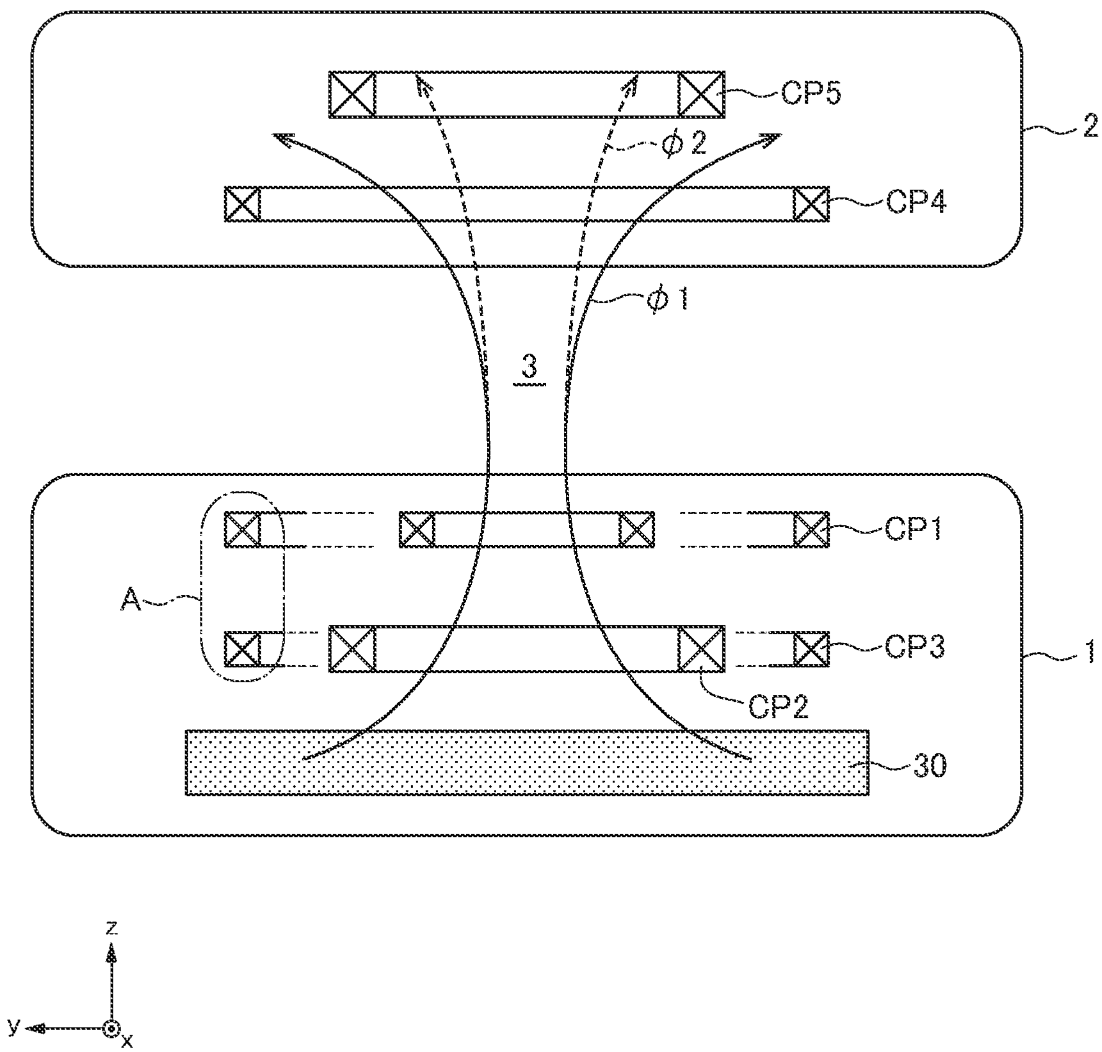


FIG. 6

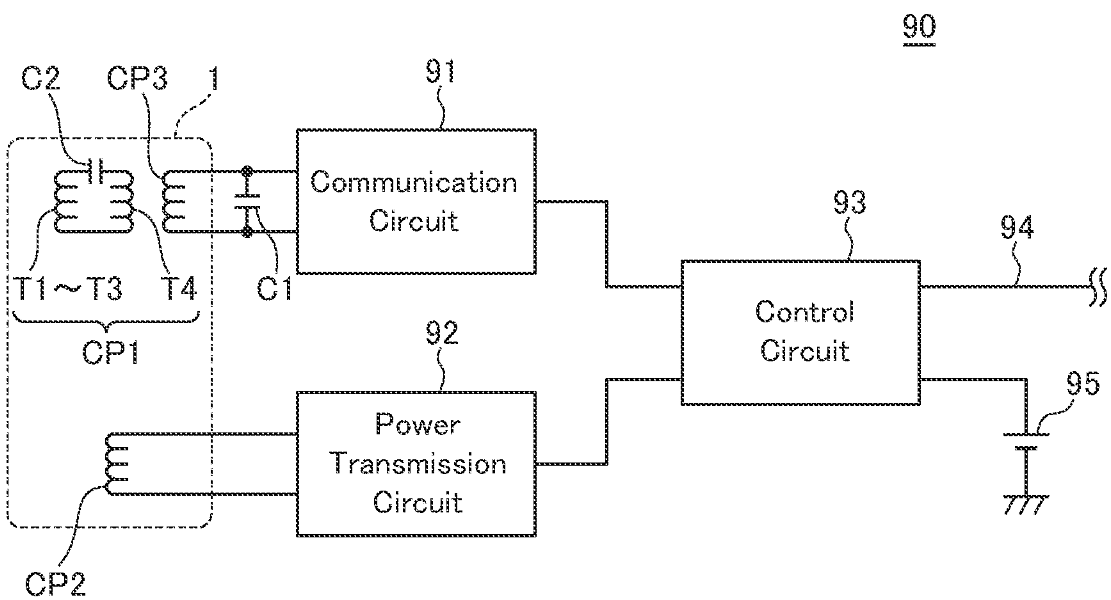

90
C2
CP3
1
91
Communication Circuit
93
94
T1～T3
T4
C1
Control Circuit
CP1
92
95
Power Transmission Circuit
CP2

FIG. 7

ANTENNA DEVICE AND WIRELESS POWER TRANSMISSION DEVICE HAVING THE SAME

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of Japanese Patent Application No. 2021-086647, filed on May 24, 2021, the entire disclosure of which is incorporated by reference herein.

BACKGROUND

Field

[0002] The present disclosure relates to an antenna device and a wireless power transmission device having the same.

Description of Related Art

[0003] JP 2002-298095A discloses a reader/writer performing data communication with an IC card in a non-contact manner.

[0004] An antenna coil provided in the reader/writer described in JP 2002-298095A has a circular shape, so that communication may become unstable depending on the position of an antenna coil incorporated in an IC card.

SUMMARY

[0005] It is therefore an object of the present disclosure to provide an antenna device capable of achieving satisfactory communication characteristics irrespective of the position of an antenna coil incorporated in an IC card and a wireless power communication device having such an antenna device.

[0006] An antenna device according to the present disclosure includes a first coil pattern having at least first, second, and third turns. As viewed in the coil axis direction, each of the first, second, and third turns has an opening with a width larger in a first direction than in a second direction orthogonal to the first direction, the width of the opening of the second turn in the second direction is larger than the width of the opening of the first turn in the second direction, and the width of the opening of the third turn in the second direction is larger than the width of the opening of the second turn in the second direction and smaller than the width of the opening of the first turn in the first direction.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] 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:

[0008] FIG. **1** is a schematic cross-sectional view for explaining the structure of an antenna device **1** according to an embodiment of the present disclosure;

[0009] FIG. **2** is a schematic plan view illustrating the shape of a conductor pattern formed on the surface **11** of the first substrate **10**;

[0010] FIG. **3** is a schematic transparent plan view illustrating the shape of a conductor pattern formed on the surface **12** of the first substrate **10** as viewed from the surface **11** side of the first substrate **10**;

[0011] FIG. **4** is a schematic plan view illustrating the shape of a conductor pattern formed on the surface **21** of the second substrate **20**;

[0012] FIG. **5** is a schematic transparent plan view illustrating the shape of a conductor pattern formed on the surface **22** of the second substrate **20** as viewed from the surface **21** side of the second substrate **20**;

[0013] FIG. **6** is a schematic view for explaining the function of the antenna device **1**; and

[0014] FIG. **7** is a block diagram of a wireless power transmission device **90** using the antenna device **1**.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0015] Preferred embodiments of the present disclosure will be explained below in detail with reference to the accompanying drawings.

[0016] FIG. **1** is a schematic cross-sectional view for explaining the structure of an antenna device **1** according to an embodiment of the present disclosure.

[0017] As illustrated in FIG. **1**, the antenna device **1** according to the embodiment includes a first substrate **10** and a second substrate **20** each of which is made of a PET film, a first coil pattern CP**1** provided on one surface **11** of the first substrate **10**, a second coil pattern CP**2** and a third coil pattern CP**3** which are each provided on one surface **21** and the other surface **22** of the second substrate **20**, and a magnetic sheet **30**. The first coil pattern CP**1** and third coil pattern CP**3** are each an antenna coil for NFC (Near Field Communication), and the second coil pattern CP**2** is a transmitting coil for wireless power transmission.

[0018] The first coil pattern CP**1** and second coil pattern CP**2** overlap each other in the coil axis direction. The coil axis direction of each of the first to third coil patterns CP**1** to CP**3** is the z-direction, and the first substrate **10**, second substrate **20**, and magnetic sheet **30** are arranged in this order from the top so as to overlap one another. Specifically, the second substrate **20** is disposed between the first substrate **10** and the magnetic sheet **30**, and thus the distance between the magnetic sheet **30** and the first substrate **10** in the z-direction is larger than the distance between the magnetic sheet **30** and the second substrate **20** in the z-direction.

[0019] FIG. **2** is a schematic plan view illustrating the shape of a conductor pattern formed on the surface **11** of the first substrate **10**.

[0020] As illustrated in FIG. **2**, there are formed, on the surface **11** of the first substrate **10**, conductor patterns **51** and **52** constituting the first coil pattern CP**1** and a capacitor electrode pattern CE**1**. The conductor pattern **51** includes a first turn T**1**, a second turn T**2**, and a third turn T**3** which are each wound in a substantially rectangular shape, and one end and the other end thereof are connected respectively to through hole conductors **53** and **54** penetrating the first substrate **10**. The first turn T**1** is the innermost turn of the first coil pattern CP**1**. The opening of the first turn T**1** has a width Y**1** in the y-direction and a width X**1** in the x-direction. The x-direction is, for example, a first direction, and the y-direction is, for example, a second direction. The second turn T**2** is wound outside the first turn T**1**. The opening of the second turn T**2** has a width Y**2** in the y-direction, which is larger than the opening width Y**1** of the first turn T**1** (Y2>Y1). The third turn T**3** is wound outside the second turn T**2**. The opening of the third turn T**3** has a width Y**3** in the y-direction, which is larger than the opening width Y2 of the second turn T2 (Y3>Y2) and smaller than the opening width X1 of the first turn T1 (Y3<X1). As described above, the opening widths of the openings of the second and third turns T2 and T3 in the x-direction are almost the same as the opening width X1 of the first turn T1. Accordingly, the first, second, and third turns T1, T2, and T3 all have a laterally elongated shape in which a section extending in the x-direction is the long side, and a section extending in the y-direction is a short side.

[0021] The conductor pattern **52** constitutes a fourth turn T**4**, and one end and the other end thereof are connected respectively to through hole conductors **55** and **56** penetrating the first substrate **10**. The fourth turn T**4** also has a laterally elongated shape in which a section extending in the x-direction is the long side, and a section extending in the y-direction is a short side. The fourth turn T**4** is the outermost turn of the first coil pattern CP**1**. The opening of the fourth turn T**4** has a width Y**4** in the y-direction, which is larger than the opening width Y**3** of the third turn T**3** (Y**4**>Y**3**). The opening width of the fourth turn T**4** in the x-direction is almost the same as the opening width X**1** of the first turn T**1**. The capacitor electrode pattern CE**1** is disposed in a y-direction gap formed between the long side of the second turn T**2** and the long side of the third turn T**3** as viewed in the z-direction and connected to a through hole conductor **57**.

[0022] FIG. **3** is a schematic transparent plan view illustrating the shape of a conductor pattern formed on the surface **12** of the first substrate **10** as viewed from the surface **11** side of the first substrate **10**.

[0023] As illustrated in FIG. **3**, there are formed, on the surface **12** of the first substrate **10**, conductor patterns and **62** constituting the first coil pattern CP**1** and a capacitor electrode pattern CE**2**. Both ends of the conductor pattern **61** are connected respectively to the through hole conductors **53** and **55**, whereby the one end of the conductor pattern **51** and the one end of the conductor pattern **52** are short-circuited. Further, both ends of the conductor pattern **62** are connected respectively to the through hole conductors **54** and **57**, whereby the other end of the conductor pattern **51** and the capacitor electrode pattern CE**1** are short-circuited. The capacitor electrode pattern CE**2** is disposed at a position overlapping the capacitor electrode pattern CE**1** as viewed in the z-direction. The capacitor electrode pattern CE**2** is connected to the through hole conductor **56**, whereby the other end of the conductor pattern **52** and the capacitor electrode pattern CE**2** are short-circuited.

[0024] The capacitor electrode patterns CE**1** and CE**2** face each other through the first substrate **10** to constitute a second capacitor C**2** (see FIG. **7**). The first coil pattern CP**1** is connected to the pair of capacitor electrode patterns CE**1** and CE**2** at its one end and the other end to constitute a closed circuit connected to no external circuit. The resonance frequency of the first coil pattern CP**1** can be controlled by the areas of the capacitor electrode patterns CE**1** and CE**2**. Although the first substrate **10** is disposed such that the surface **12** faces the surface of the magnetic sheet **30** in the present embodiment, it may be disposed such that the surface **11** faces the surface of the magnetic sheet **30**.

[0025] FIG. **4** is a schematic plan view illustrating the shape of a conductor pattern formed on the surface **21** of the second substrate **20**.

[0026] As illustrated in FIG. **4**, there are formed, on the surface **21** of the second substrate **20**, a spiral conductor pattern **100** constituting the second coil pattern CP**2** and conductor patterns **41** and **42** constituting the third coil pattern CP**3**.

[0027] The conductor pattern **100** constituting the second coil pattern CP**2** has a six-turn configuration constituted of turns **110**, **120**, **130**, **140**, **150**, and **160**, wherein the turns **110** and **160** are positioned at the outer and inner peripheries, respectively. The turns **110**, **120**, **130**, **140**, and **150** are each radially divided into four by three spiral slits. The turn **160** is radially divided into two by a single spiral slit. Thus, the turn **110** is divided into four lines **111** to **114**, the turn **120** is divided into four lines **121** to **124**, the turn **130** is divided into four lines **131** to **134**, the turn **140** is divided into four lines **141** to **144**, the turn **150** is divided into four lines **151** to **154**, and the turn **160** is divided into two lines **161** and **162**.

[0028] The lines **111**, **121**, **131**, **141**, **151**, and **161** are continuous lines spirally wound in six turns and are each positioned at the outermost periphery in its corresponding turn. The lines **112**, **122**, **132**, **142**, **152**, and **162** are continuous lines spirally wound in six turns and are each the second line counted from the outermost peripheral line in its corresponding turn. The lines **113**, **123**, **133**, **143**, and **153** are continuous lines spirally wound in five turns and are each the second line counted from the innermost peripheral line in its corresponding turn. The lines **114**, **124**, **134**, **144**, and **154** are continuous lines spirally wound in five turns and are each the innermost line positioned at the innermost periphery in its corresponding turn.

[0029] The outer peripheral ends of the lines **111** to **114** are connected in common to a terminal electrode El. The inner peripheral ends of the lines **161**, **162**, **153**, and **154** are connected respectively to through hole conductors **301** to **304** penetrating the second substrate **20**.

[0030] The conductor patterns **41** and **42** constituting the third coil pattern CP**3** are disposed outside the conductor pattern **100** constituting the second coil pattern CP**2**. The conductor pattern **41** is a continuous line wound in about one turn, and the conductor pattern **100** is disposed in the opening area (inner diameter area) of the conductor pattern **41**. One end of the conductor pattern **41** is connected to a terminal electrode E**3**, and the other end thereof is connected to a through hole conductor **43** penetrating the second substrate **20**. One end of the conductor pattern **42** is connected to a terminal electrode E**4**, and the other end thereof is connected to a through hole conductor **44** penetrating the second substrate **20**.

[0031] FIG. **5** is a schematic transparent plan view illustrating the shape of a conductor pattern formed on the surface **22** of the second substrate **20** as viewed from the surface **21** side of the second substrate **20**.

[0032] As illustrated in FIG. **5**, there are formed, on the surface **22** of the second substrate **20**, a spiral conductor pattern **200** constituting the second coil pattern CP**2** and a conductor pattern **45** constituting the third coil pattern CP**3**. Although the second substrate **20** is disposed such that the surface **22** faces the surface of the magnetic sheet **30** in the present embodiment, it may be disposed such that the surface **21** faces the surface of the magnetic sheet **30**.

[0033] The conductor pattern **200** constituting the second coil pattern CP**2** has the same pattern shape as the conductor pattern **100**. The conductor pattern **200** has a six-turn configuration constituted of turns **210**, **220**, **230**, **240**, **250**, and **260**, wherein the turns **210** and **260** are positioned at the outer and inner peripheries, respectively. The turns **210**, **220**, **230**, **240**, and **250** are each radially divided into four by three spiral slits. The turn **260** is radially divided into two by a single spiral slit. Thus, the turn **210** is divided into four lines **211** to **214**, the turn **220** is divided into four lines **221** to **224**, the turn **230** is divided into four lines **231** to **234**, the turn **240** is divided into four lines **241** to **244**, the turn **250** is divided into four lines **251** to **254**, and the turn **260** is divided into two lines **261** and **262**.

[0034] The lines **211**, **221**, **231**, **241**, **251**, and **261** are continuous lines spirally wound in six turns and are each positioned at the outermost periphery in its corresponding turn. The lines **212**, **222**, **232**, **242**, **252**, and **262** are continuous lines spirally wound in six turns and are each the second line counted from the outermost peripheral line in its corresponding turn. The lines **213**, **223**, **233**, **243**, and **253** are continuous lines spirally wound in five turns and are each the second line counted from the innermost peripheral line in its corresponding turn. The lines **214**, **224**, **234**, **244**, and **254** are continuous lines spirally wound in five turns and are each the innermost line positioned at the innermost periphery in its corresponding turn.

[0035] The outer peripheral ends of the lines **211** to **214** are connected in common to a terminal electrode E**2** via through hole conductors. The inner peripheral ends of the lines **261**, **262**, **253**, and **254** are connected respectively to the through hole conductors **304**, **303**, **302**, and **301**. As a result, four lines each having **11** turns are connected in parallel between the terminal electrodes El and E**2**.

[0036] The conductor pattern **45** constituting the third coil pattern CP**3** is a continuous line wound in about one turn and disposed outside the conductor pattern **200** constituting the second coil pattern CP**2**. That is, the conductor pattern **200** is disposed in the opening area (inner diameter area) of the conductor pattern **45**. One end and the other end of the conductor pattern **45** are connected respectively to the through hole conductors **43** and **44**. As a result, the third coil pattern CP**3** has about two turns in total.

[0037] As denoted by the dashed line in FIG. **4**, the third coil pattern CP**3** partly overlaps the fourth turn T**4** of the first coil pattern CP**1**, whereby the first coil pattern CP**1** is coupled to the third coil pattern CP**3**. Unlike the second and third coil patterns CP**2** and CP**3**, the first coil pattern CP**1** does not have a terminal electrode for external connection and constitutes a closed circuit formed by the conductor patterns formed on the surfaces **11** and **12** of the first substrate **10**. The first coil pattern CP**1** functions as a booster antenna by being coupled to the third coil pattern CP**3**. That is, in the present embodiment, NFC-based communication is achieved by the third coil pattern CP**3** as a main antenna and the first coil pattern CP**1** as a booster antenna.

[0038] The first coil pattern CP**1** as a booster antenna has the first turn T**1** having the opening width Y**1** in the y-direction, the second turn T**2** having the opening width Y**2** (>Y**1**) in the y-direction, and the third turn T**3** having the opening width Y**3** (>Y**2**) in the y-direction, wherein the opening width Y**3** of the third turn T**3** in the y-direction is smaller than the opening width X**1** of the first turn T**1** in the x-direction. This can enhance communication characteristics for an IC card having a laterally elongated shape like a credit card and make communication characteristics satisfactory irrespective of the y-direction position of an antenna coil incorporated in such an IC card.

[0039] Further, as denoted by the dashed line in FIG. **2**, the first turn T**1** of the first coil pattern CP**1** entirely overlaps the pattern area of the second coil pattern CP**2** in the z-direction, whereas the second and third turns T**2** and T**3** of the first coil pattern CP**1** each do not partly overlap the pattern area of the second coil pattern CP**2**. The pattern area of the second coil pattern CP**2** refers to the area where the conductor pattern constituting the second coil pattern CP**2** exists in a plan view, and the dimension in a direction (radial direction) orthogonal to the extending direction (peripheral direction) of the conductor pattern is the winding width of the pattern area.

[0040] This reduces coupling between the first and second coil patterns CP**1** and CP**2** while reducing the planar size of the first coil pattern CP**1**, whereby satisfactory communication characteristics can be obtained.

[0041] Assuming that a gap in the y-direction between the long side of the first turn T**1** and the long side of the second turn T**2** is G**1**, a gap in the y-direction between the long side of the second turn T**2** and the long side of the third turn T**3** is G**2**, and a gap in the y-direction between the long side of the third turn T**3** and the long side of the fourth turn T**4** is G**3**, the gaps G**1** and G**2** are almost the same as each other and each about half the opening width Y**1**, and the gap G**3** is smaller than the gaps G**1** and G**2**. This can make communication characteristics satisfactory irrespective of the y-direction position of an antenna coil incorporated in the IC card and reduce the y-direction size of the antenna device **1**. Further, as illustrated in FIG. **2**, the fourth turn T**4** of the first coil pattern CP**1** is enlarged in opening width in the y-direction at the center portion in the x-direction so as not to overlap the second coil pattern CP**2**. This makes it possible to increase coupling between the first coil pattern CP**1** and the third coil pattern CP**3** while reducing coupling between the first coil pattern CP**1** and the second coil pattern CP**2**.

[0042] Further, the capacitor electrode patterns CE**1** and CE**2** overlap the pattern area of the second coil pattern CP**2** as viewed in the z-direction. This makes magnetic flux generated from the second coil pattern CP**2** less likely to be applied to the capacitor electrode patterns CE**1** and CE**2**, thereby reducing an eddy current. In particular, the capacitor electrode patterns CE**1** and CE**2** are disposed in the y-direction gap between the long side of the second turn T**2** of the first coil pattern CP**1** and the long side of the third turn T**3** as viewed in the z-direction and, accordingly, the positions of the capacitor electrode patterns CE**1** and CE**2** are offset outward from the center position of the winding width of the pattern area of the second coil pattern CP**2**. This increases the distance between the opening area of the second coil pattern CP**2** where the density of magnetic flux generated from the second coil pattern CP**2** is highest and the capacitor electrode patterns CE**1** and CE**2** to thereby effectively reduce an eddy current.

[0043] FIG. **6** is a schematic view for explaining the function of the antenna device **1**.

[0044] As illustrated in FIG. **6**, when the antenna device **1** according to the present embodiment and a counterpart device **2** as a communication target are made to face each other through a space **3**, magnetic flux **4)1** generated from the first and third coil patterns CP**1** and CP**3** interlinks a fourth coil pattern CP**4** included in the counterpart device **2**, thereby achieving NFC-based wireless communication. Signals transmitted by wireless communication are supplied to the third coil pattern CP**3** through the terminal electrodes E**3** and E**4**. The third coil pattern CP**3** as a main antenna is coupled to the first coil pattern CP**1** as denoted by the symbol A in FIG. **6**. Thus, signals are supplied also to the first coil pattern CP**1** as a booster antenna. Magnetic flux ϕ**2** generated from the second coil pattern CP**2** interlinks a fifth coil pattern CP**5** included in the counterpart device **2**, thereby achieving wireless power transmission.

[0045] FIG. **7** is a block diagram of a wireless power transmission device **90** using the antenna device **1** according to the present embodiment.

[0046] The wireless power transmission device **90** illustrated in FIG. **7** includes the antenna device **1** having the first to third coil patterns CP**1** to CP**3**, a communication circuit connected to the third coil pattern CP**3**, and a power transmission circuit **92** connected to the second coil pattern CP**2**. The communication circuit **91** and power transmission circuit **92** are connected to a control circuit **93**. Thus, data to be transmitted/received through a communication line **94** can communicate through the first and third coil patterns CP**1** and CP**3** for NFC, and power supplied from a power supply **95** can be transmitted wirelessly through the second coil pattern CP**2** adapted for wireless power transmission. In the present embodiment, the third coil pattern CP**3** of the antenna device **1** is connected to the communication circuit **91**; however, the first coil pattern CP**1** may be connected to the communication circuit **91** with the third coil pattern CP**3** omitted to achieve NFC-based communication using the first coil pattern CP**1** as a main antenna.

[0047] As illustrated in FIG. **7**, the first coil pattern CP**1** is connected with the second capacitor C**2**, and the third coil pattern CP**3** is connected with a first capacitor C**1**. In FIG. **7**, the first capacitor C**1** is connected in parallel to the second coil pattern CP**2**; however, in place of or in addition to this, the first capacitor C**1** may be connected in series to the second coil pattern CP**2**.

[0048] 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.

[0049] The technology according to the present disclosure includes the following configuration examples, but not limited thereto.

[0050] An antenna device according to the present disclosure includes a first coil pattern having at least first, second, and third turns. As viewed in the coil axis direction, each of the first, second, and third turns has an opening with a width larger in a first direction than in a second direction orthogonal to the first direction, the width of the opening of the second turn in the second direction is larger than the width of the opening of the first turn in the second direction, and the width of the opening of the third turn in the second direction is larger than the width of the opening of the second turn in the second direction and smaller than the width of the opening of the first turn in the first direction. With this configuration, there can be provided an antenna device capable of achieving satisfactory communication characteristics irrespective of the position of an antenna coil incorporated in an IC card.

[0051] The antenna device according to the present disclosure may further include a second coil pattern overlapping the first coil pattern in the coil axis direction, and each of the second and third turns of the first coil pattern may have a section overlapping the second coil pattern in the coil axis direction and another section not overlapping the second coil pattern in the coil axis direction. This reduces coupling between the first and second coil patterns while reducing the planar size of the first coil pattern, whereby satisfactory communication characteristics can be obtained.

[0052] The antenna device according to the present disclosure may further include: a first substrate on which the first coil pattern is formed; a second substrate on which the second coil pattern is formed; a pair of capacitor electrode patterns provided respectively on one surface and the other surface of the first substrate so as to face each other through the first substrate; and a third coil pattern provided on one surface or the other surface of the second substrate so as to surround the second coil pattern. The first coil pattern may be connected to the pair of capacitor electrode patterns at its one and the other end to constitute a closed circuit and may further include a fourth turn positioned outside the third turn and at least partly overlap the third coil pattern as viewed in the coil axis direction. Thus, the third coil pattern functions as a main antenna, and the first coil pattern functions as a booster antenna.

[0053] As viewed in the coil axis direction, the width of the opening of the fourth turn may be larger in the first direction than in the second direction, and a gap in the second direction between the section of the fourth turn that extends in the first direction and the section of the third turn that extends in the first direction may be narrower than a gap in the second direction between the section of the third turn that extends in the first direction and the section of the second turn that extends in the first direction. This can make communication characteristics satisfactory irrespective of the second direction position of an antenna coil incorporated in an IC card and reduce the second direction size of the antenna device.

[0054] Further, the pair of capacitor electrode patterns may be disposed in a gap in the second direction between the section of the third turn that extends in the first direction and the section of the second turn that extends in the first direction, as viewed in the coil axis direction. This can reduce the influence of an eddy current.

[0055] Further, a wireless power transmission device according to the present disclosure includes: the above-described antenna device; a communication circuit connected to the third coil pattern; and a power transmission circuit connected to the second coil pattern. With this configuration, wireless power transmission and NFC-based communication can be achieved.

What is claimed is:

1. An antenna device comprising a first coil pattern having at least first, second, and third turns,

wherein, as viewed in a coil axis direction, each of the first, second, and third turns has an opening with a width larger in a first direction than in a second direction orthogonal to the first direction,

wherein a width of the opening of the second turn in the second direction is larger than a width of the opening of the first turn in the second direction, and

wherein a width of the opening of the third turn in the second direction is larger than the width of the opening of the second turn in the second direction and smaller than a width of the opening of the first turn in the first direction.

2. The antenna device as claimed in claim **1**, further comprising a second coil pattern overlapping the first coil pattern in the coil axis direction,

wherein each of the second and third turns of the first coil pattern has a section overlapping the second coil pattern in the coil axis direction and another section not overlapping the second coil pattern in the coil axis direction.

3. The antenna device as claimed in claim **2**, further comprising:

a first substrate on which the first coil pattern is formed;

a second substrate on which the second coil pattern is formed;

a pair of capacitor electrode patterns provided respectively on one surface and other surface of the first substrate so as to face each other through the first substrate; and

a third coil pattern provided on one surface or other surface of the second substrate so as to surround the second coil pattern,

wherein the first coil pattern is connected to the pair of capacitor electrode patterns at its one and other end to constitute a closed circuit, and

wherein the first coil pattern further includes a fourth turn positioned outside the third turn and at least partly overlap the third coil pattern as viewed in the coil axis direction.

4. The antenna device as claimed in claim **3**,

wherein, as viewed in the coil axis direction, a width of an opening of the fourth turn is larger in the first direction than in the second direction, and

wherein a gap in the second direction between a section of the fourth turn that extends in the first direction and a section of the third turn that extends in the first direction is narrower than a gap in the second direction between the section of the third turn that extends in the first direction and a section of the second turn that extends in the first direction.

5. The antenna device as claimed in claim **4**, wherein the pair of capacitor electrode patterns are disposed in a gap in the second direction between the section of the third turn that extends in the first direction and the section of the second turn that extends in the first direction, as viewed in the coil axis direction.

6. A wireless power transmission device comprising:

an antenna device comprising:

a first substrate on which a first coil pattern is formed;

a second substrate on which a second coil pattern overlapping the first coil pattern in a coil axis direction is formed;

a pair of capacitor electrode patterns provided respectively on one surface and other surface of the first substrate so as to face each other through the first substrate; and

a third coil pattern provided on one surface or other surface of the second substrate so as to surround the second coil pattern;

a communication circuit connected to the third coil pattern; and

a power transmission circuit connected to the second coil pattern,

wherein the first coil pattern has first, second, third, and fourth turns,

wherein, as viewed in the coil axis direction, each of the first, second, and third turns has an opening with a width larger in a first direction than in a second direction orthogonal to the first direction,

wherein a width of the opening of the second turn in the second direction is larger than a width of the opening of the first turn in the second direction,

wherein a width of the opening of the third turn in the second direction is larger than the width of the opening of the second turn in the second direction and smaller than a width of the opening of the first turn in the first direction,

wherein each of the second and third turns of the first coil pattern has a section overlapping the second coil pattern in the coil axis direction and another section not overlapping the second coil pattern in the coil axis direction,

wherein the first coil pattern is connected to the pair of capacitor electrode patterns at its one and other end to constitute a closed circuit, and

wherein the fourth turn of the first coil pattern is positioned outside the third turn and at least partly overlap the third coil pattern as viewed in the coil axis direction.

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