

DESCRIPTION

TITLE OF INVENTION: ANTENNA DEVICE

CROSS REFERENCE TO RELATED APPLICATION

5 [0001]

This application is based on Japanese Patent Application No. 2016-207044 filed on October 21, 2016, the disclosure of which is incorporated herein by reference.

10 TECHNICAL FIELD

[0002]

The present disclosure relates to an antenna device including a ground plate which is a conductive member that is a flat plate shape, provides a ground potential and is connected with an external conductor of a coaxial cable.

15

BACKGROUND ART

[0003]

Conventionally, as an antenna device including a ground plane, various antenna devices, such as a monopole antenna, a patch antenna and the like, are developed (e.g., Patent Literature 1). In the antenna device using a current flowing through the ground plane, when an area (hereinafter, ground area) of the ground plane is insufficient relative to a wavelength of a radio wave that is a target of transmission and reception, a Miller effect caused by the ground plane is insufficient. Then, a gain in an original radiation direction is reduced. When 20 the area of the ground plane is insufficient, a current (hereinafter, leaked current) leaked from the ground plane to an external conductor of a coaxial cable increases and the gain decreases.

[0004]

In other words, it is necessary to provide the ground plane having the area in response to the wavelength of the radio wave (hereinafter, target radio wave) that is the target of transmission and reception to sufficiently stabilize a property of the antenna device. Thus, when the area of the ground plane is 30

miniaturized for downsizing, the property of the antenna device becomes unstable.

[0005]

In the antenna device using the ground plane that is a rectangular shape,
5 it is generally known that it is necessary to set a length of per edge of the ground plane to be greater than or equal to a half wavelength (e.g., 0.75 wavelength) of the target radio wave, to sufficiently stabilize the property of the antenna device.

PRIOR ART LITERATURE

10 PATENT LITERATURE

[0006]

Patent Literature 1: JP2010-226633A

SUMMARY OF INVENTION

15 [0007]

It is requested that the antenna device to be further miniaturized. Further, it is also requested that another component is located around the ground plane. When a component is located around the ground plane, an area (hereinafter, antenna area) of the entire of the antenna device viewed in a top
20 view is increased by an area necessary for arranging the component which is added. On the other hand, when the area of the ground plane is reduced for arranging the component which is added, a gain of the antenna device is deteriorated.

[0008]

25 It is an object of the present disclosure to provide an antenna device which can suppress a reduction of a gain and can reduce an area of a ground plane.

[0009]

To achieve the above object, the antenna device according to a first
30 aspect includes a radiation element that is a conductive member electrically connected with an internal conductor of a coaxial cable, and a flat plate part that is a conductive member being a flat plate shape and electrically connected with an external conductor of the coaxial cable. The radiation element is to be located

to be opposite to the flat plate part with a separation that is predetermined or to be located to extend from the flat plate part. The flat plate part is a line symmetrical shape and is a shape including a width arrangement region that is a part where a length from one end part to another end part opposite to the one
5 end part via a symmetrical axis of the flat plate part is set to be shorter than a half wavelength of a radio wave that is a target of transmission and reception. At least one of the two end parts that are parallel to the symmetrical axis and define the width arrangement region is provided with a side wall part that is a conductive member to extend along the at least one of the two end parts toward
10 a direction viewed from the flat plate part where the radiation element does not exist.

[0010]

Generally, when a length of a ground plane is shorter than a half wavelength, a reverse phase current is generated on the ground plane and the
15 gain of the antenna is deteriorated. According to the above configuration, the end part of the width arrangement region is provided with the side wall part that is the conductive member being a plate shape to extend toward a direction where the radiation element does not exist. According to the above configuration, a current is distributed to not only the flat plate part but also the side wall part.
20 Thus, a quantity of the current at a reverse phase generated on the flat plate part as the ground plane can be suppressed. As a result, a reduction of the gain can be suppressed and an area of the ground plane can be reduced.

[0011]

To achieve the above object, the antenna device according to a second
25 aspect includes a radiation element that is a conductive member electrically connected with an internal conductor of a coaxial cable, and a flat plate part that is a conductive member being a flat plate shape and electrically connected with an external conductor of the coaxial cable. The radiation element is to be located to be opposite to the flat plate part with a separation that is predetermined or to
30 be located to extend from the flat plate part. The flat plate part is a shape including a first edge part and a second edge part which are straight shape and opposite to each other. A distance between the first edge part and the second edge part is set to be shorter than a half wavelength of a radio wave that is a

target of transmission and reception. At least one of the first edge part and the second edge part is provided with a side wall part that is a conductive member to extend along the at least one of the first edge part and the second edge part toward a direction viewed from the flat plate part where the radiation element
5 does not exist.

[0012]

According to the above configuration, similar to the first aspect, the reduction of the gain can be suppressed and the area of the ground plane can be reduced.

10

BRIEF DESCRIPTION OF DRAWINGS

[0013]

The above and other objects, features and advantages of the present disclosure will become more apparent from the following detailed description
15 made with reference to the accompanying drawings. In the drawings:

Fig. 1 is a downward perspective view of an antenna device according to an embodiment;

Fig. 2 is an upward perspective view of the antenna device;

Fig. 3 is a cross-sectional view of the antenna device taken along a line
20 III-III shown in Fig. 1;

Fig. 4 is a top view of the antenna device;

Fig. 5 is a diagram showing a configuration of a general patch antenna;

Fig. 6 is a graph illustrating a length of a ground plate in a Y-axis direction and a current distribution in the Y-axis direction;

Fig. 7 is a graph showing a simulation result for a relationship between the length of the ground in the Y-axis direction and a gain;

Fig. 8 is a graph illustrating an operation of the antenna device according to the embodiment;

Fig. 9 is a graph showing a simulation result of a relationship between a
30 height of a side wall part, a length of a back surface part and a gain;

Fig. 10 is a diagram showing an effect obtained by providing the side wall part and the back surface part;

Fig. 11 is a diagram showing a modification example of the antenna device;

Fig. 12 is a diagram showing a modification example of a ground pattern;

Fig. 13 is a diagram showing a modification example of a ground pattern;

5 Fig. 14 is a diagram showing a modification example of the antenna device;

Fig. 15 is a rear view of the antenna device shown in Fig. 14;

Fig. 16 is a diagram showing a modification example of the antenna device; and

10 Fig. 17 is a diagram showing a modification example of the antenna device.

DESCRIPTION OF EMBODIMENTS

[0014]

15 [Embodiment]

Hereinafter, embodiments of the present disclosure will be described with reference to the drawings. An antenna device 100 according to the present embodiment, generally, is configured to transmit and receive a circularly polarized wave of a predetermined frequency by an operation principle the same as a known patch antenna. Of course, the antenna device 100 may be provided for only one of a transmission and a reception.

[0015]

25 A radio wave (hereinafter, target radio wave) that is a target of the transmission and the reception may be designed appropriately. For example, the target radio wave is a radio wave of 1.575GHz. Of course, the target radio wave may be appropriately designed, and for example, the target radio wave may be a radio wave of 300MHz, 760MHz, 900MHz or 5.9GHz or the like. Hereafter, a frequency of the target radio wave is referred to as a target frequency, and a wavelength of the target radio wave is referred to as a target wavelength.

30 [0016]

The antenna device 100 is connected with a radio that is not shown via, for example, a coaxial cable, and a signal received by the antenna device 100 is sequentially output to the radio. In addition, the antenna device 100 converts an

electric signal input from the radio into a radio wave and radiates the radio wave into space. The radio uses the signal received by the antenna device 100 as well as supplies to the antenna device 100 high frequency power depending on a transmission signal. The antenna device 100 and the radio may be connected via
5 a known matching circuit, a filter circuit, or the like besides the coaxial cable.

[0017]

Hereinafter, a specific configuration of the antenna device 100 will be described. As shown in Figs. 1 to 4, the antenna device 100 includes a patch pattern 10, a ground pattern 20 and a power supply unit 30. Fig. 1 is a view (i.e.,
10 downward perspective view) showing an outline of the antenna device 100 when viewed from an obliquely upward direction, and Fig. 2 is a view (i.e., upward perspective view) showing an outline of the antenna device 100 when viewed from an obliquely downward direction. An upward direction of the antenna device 100 is a direction from the ground pattern 20 toward the patch pattern 10.

15 [0018]

The patch pattern 10 is a conductive member having a plate shape whose material is a conductor such as copper. In this case, the plate shape includes a thin film shape, for example, like a foil. The patch pattern 10 is located to face the ground pattern 20 via a support member that is not shown.
20 The support member may be provided by using a dielectric substance such as a resin. The support member may be a plate shape, or may be plural pillars which support the ground pattern 20 and the patch pattern 10 to be opposite to each other at a predetermined interval.

[0019]

25 A shape (hereinafter, planar shape) of the patch pattern 10 in a top view is a shape where notch parts 11 are provided at diagonal parts of a square which are a set. Each of the notch part 11 has a constitution for radiating the circularly polarized wave, and is equivalent to a known degeneracy separation element or a known perturbation element. An area of parts which are cut by the
30 notch parts 11 from an original square may be an area which is defined by a known degeneracy separation method. According to the present embodiment, it is configured to transmit and receive the circularly polarized wave by providing the notch parts 11 at the patch pattern 10. However, as another embodiment, it

is configured to transmit and receive the circularly polarized wave by a mode (two-point power supply mode) where two power supply points are provided.

[0020]

A length L_p of one edge of the patch pattern 10 is an electrical length
5 about a half of the target wavelength. In this case, the electrical length is an effective length in consideration of a fringing electric field, a wavelength shortening effect by a dielectric substance, and the like. When the wavelength of the target radio wave is shortened by the support member that is not shown, the electrical length becomes a half of the wavelength that is shortened. In addition,
10 the length of one edge of the patch pattern 10 is a length of one edge of a square without respect to the notch parts 11.

[0021]

For example, the electrical length (hereinafter, λ) of the target wavelength is 50mm by the wavelength shortening effect of the support member.
15 The length L_p of one edge of the patch pattern 10 is set to a value (e.g., 23mm) slightly shorter than 25mm that is a half wavelength (i.e., $\lambda/2$) of the target radio wave, in consideration of influence of the fringing electric field and the like.

[0022]

According to the present embodiment, the planar shape of the patch
20 pattern 10 is a shape where the notch parts 11 are provided in a square. However, the planar shape is not limited. As another configuration, the planar shape of the patch pattern 10 may be a rectangular shape or a shape other than a rectangular shape (e.g., a circular shape, an octagon shape, or the like).

[0023]

25 The patch pattern 10 is directly or indirectly connected with an internal conductor of the coaxial cable by the power supply part 30. A configuration where the patch pattern 10 is indirectly connected with the internal conductor includes a configuration where the patch pattern 10 is connected with the internal conductor via an impedance matching circuit or a filter circuit or the like,
30 and a configuration where the patch pattern 10 is indirectly connected with the internal conductor by an electromagnetic coupling. In other words, the patch pattern 10 is electrically connected with the internal conductor of the coaxial cable. The patch pattern 10 is equivalent to a radiation element.

[0024]

For convenience, hereafter, a configuration of the antenna device 10 will be described by providing a concept of a three-dimension coordinate system including an X-axis, a Y-axis and a Z-axis which intersect each other at right angles. The X-axis is an axis parallel to one edge of the patch pattern 10, and the Y-axis is an axis orthogonal to the X-axis on a planar surface parallel to the patch pattern 10. The Z-axis is an axis orthogonal to the X-axis and the Y-axis and has a positive direction from the ground pattern 20 toward the patch pattern 10.

10 [0025]

The ground pattern 20 is achieved by a conductor such as copper and the like. The ground pattern 20 is electrically connected with an external conductor of the coaxial cable and is configured to provide a ground potential in the antenna device 100.

15 [0026]

The ground pattern 20 includes a patch facing part 21 that is a flat plate shape and faces the patch pattern 10, side wall parts 22 that extend from part of edge parts of the patch facing part 21 toward a direction where the patch pattern 10 does not exist, and a back surface part 23 that is located to face the patch facing part 21 via the side wall parts 22. The patch facing part 21 includes a connection point that is connected with the coaxial cable. Thus, the patch facing part 21 is equivalent to a flat plate part.

[0027]

The direction where the patch pattern 10 does not exist for the patch facing part 21 is equivalent to a negative direction of the Z-axis. Since the side wall parts 22 are perpendicular to the patch facing part 21 and the back surface part 23 overlaps the patch facing part 21 in a top view, an area (hereinafter, ground area) of the ground pattern 20 matches an area of the patch facing part 21, when the antenna device 100 is viewed from above.

30 [0028]

As shown in Fig. 4, the patch facing part 21 is a rectangular shape and includes edges parallel to the X-axis and edges parallel to the Y-axis. A length L_x of the patch facing part 21 in an X-axis direction may be set to be an electrical

length longer than or equal to $\lambda/2$. For example, the length L_x of the patch facing part 21 in the X-axis direction is set to be an electrical length that is $\lambda/2$ (i.e., 25mm). A length L_y of the patch facing part 21 in a Y-axis direction is set to an electrical length shorter than $\lambda/2$ (e.g., 18mm).

5 [0029]

For convenience, hereafter, among four edges of the patch facing part 21 that is a re shape, edges parallel to the X-axis are referred to as long edge parts, and edges parallel to the Y-axis are referred to as short edge parts. The long edge parts and the short edge parts are equivalent to long sides and narrow
10 sides in a rectangle, respectively. The patch facing part 21 includes two long edge parts which are opposite to each other, and two short edge parts which are opposite to each other. In the two long edge parts, the long edge part located at a relatively negative direction of the X-axis is referred to as a first long edge part, and the long edge part located at a relatively positive direction of the X-axis is
15 referred to as a second long edge part.

[0030]

The first long edge part and the second long edge part are equivalent to two end parts which are parallel to a symmetric axis defining a width arrangement region in claims. In addition, the entire region of the patch facing
20 part 21 is equivalent to the width arrangement region in claims. Further, the first long edge part is equivalent to a first edge part and the second long edge part is equivalent to a second edge part in claims.

[0031]

The ground pattern 20 is located at a position where a center of the
25 patch facing part 21 overlaps a center of the patch pattern 10 in a top view. Since the patch facing part 21 is longer than the patch pattern 10 in the X-axis direction and is shorter than the patch pattern 10 in the Y-axis direction, only the end parts of the patch facing part 21 in the X-axis direction are exposed from the patch pattern 10 in the top view. In two surfaces included by the patch facing
30 part 21, the surface that faces the patch pattern 10 is referred to as a patch facing surface, and the surface that is opposite to the patch facing surface is referred to as a rear side surface.

[0032]

According to the present embodiment, a shape (hereinafter, planar shape) of the patch facing part 21 in a top view is a rectangular shape. However, the shape of the patch facing part 21 is not limited. The patch facing part 21, for example, may be an axial symmetry shape such as a rhombus shape, a circular shape, a regular hexagon shape, a regular octagon shape and the like. In this case, the circular shape includes an elliptic shape. Further, the patch facing part 21 may be a substantially axial symmetry shape. Thus, the axial symmetry shape may include shapes of the above where an outer edge part is cut, shapes of the above where a protrusion part is provided, shapes of the above where an outer periphery is a meander shape, and the like.

[0033]

The side wall parts 22 are plate-shaped conductive members that are a rectangular shape and extend from the long edge parts included by the patch facing part 21 toward a negative direction of the Z-axis along the long edge parts. The side wall parts 22 are located at the first long edge part and the second long edge part. For convenience, when it is necessary to distinguish the side wall parts 22, the side wall part 22 located at the first long edge part is referred to as a first side wall part 22A, and the side wall part 22 located at the second long edge part is referred to as a second side wall part 22B. The first side wall part 22A is the side wall part 22 that is located along the first long edge part, and the second side wall part 22B is the side wall part 22 that is located along the second long edge part.

[0034]

As shown in Fig. 3, H represents a length (in other words, height) of the side wall part 22 in a Z-axis direction. The height H of the side wall part 22 may be appropriately designed in accordance with a length γ of the back surface part 23 in the Y-axis direction.

[0035]

For convenience, a part of the side wall part 22 which adjoins to the patch facing part 21 is referred to as an upper end part. An end part (i.e., end part that is located relatively downward) of the side wall unit at a side of the negative direction of the Z-axis is referred to as a lower end part. Since the side

wall part 22 is a plate-shaped member that is a rectangular shape in a side view, the lower end part is also parallel to the patch facing part 21.

[0036]

5 The back surface part 23 is a conductive member that is a plate shape and extends from the lower end part of the side wall part 22 to face the rear side surface of the patch facing part 21. The back surface part 23 is a rectangular shape along the lower end part of the side wall part 22. Two back surface parts 23 are located at the lower end parts of the first side wall part 22A and the second side wall part 22B.

10 [0037]

For convenience, when it is necessary to distinguish the back surface parts 23, the back surface part 23 located along the lower end part of the first side wall part 22A is referred to as a first back surface part 23A, and the back surface part 23 located along the lower end part of the second side wall part 22B is referred to as a second back surface part 23B.

[0038]

20 The first back surface part 23A is the back surface part 23 facing the lower end part of the second side wall part 22B from the lower end part of the first side wall part 22A. An end part of the first back surface part 23A at a side of a positive direction of the Y-axis is a free end that is not connected with any members. The second back surface part 23B is the back surface part 23 facing the lower end part of the first side wall part 22A from the lower end part of the second side wall part 22B. An end part of the second back surface part 23B at a side of a negative direction of the Y-axis is a free end that is not connected with

25 any members.

[0039]

A length of the back surface part 23 in the X-axis direction is equal to the length L_x of the patch facing part 21 and the side wall part 22 in the X-axis direction. A length λ of the back surface part 23 in the Y-axis direction, as the

30 above description, may be defined by test and the like to match the height H of the side wall part 22.

[0040]

A sum of the length L_y of the patch facing part 21 in the Y-axis direction and a value obtained by multiplying the height H of the side wall part 22 by two is set to be shorter than the half wavelength (i.e., $\lambda/2$) of the target radio wave. A sum (hereinafter, total length) of the length L_y of the patch facing part 21 in the Y-axis direction, the value obtained by multiplying the height H of the side wall part 22 by two, and a value obtained by multiplying the length γ of the back surface part 23 by two, is set to be longer than $\lambda/2$ of the target radio wave. In other words, L_y , H and λ are set to satisfy a following formula. (Formula) $L_y + H \times 2 < \lambda / 2 < L_y + H \times 2 + \gamma \times 2$

10 For example, the height H is set to 2mm. Further, the length γ is set to 6mm. Then, the total length according to the present embodiment is set to 34mm. The total length is equivalent to a length (i.e., peripheral length) along a surface of the ground pattern 20 from the free end of the first back surface part 23A to the free end of the second back surface part 23B. The total length is
15 equivalent to a peripheral length in claims.

[0041]

According to the present embodiment, the side wall parts 22 and the back surface parts 23 are located at both of the long edge parts included in the patch facing part 21. However, for example, as a seventh modification example,
20 only one side wall part 22 or only one back surface part 23 may be provided.

[0042]

The power supply unit 30 is constituted by the internal conductor of the coaxial cable and the patch pattern 10 which are electrically connected with each other. According to the present embodiment, the power supply unit 30, for
25 example, is achieved by using a pin 31 (hereinafter, power supply pin) with an electric conductive. The power supply pin 31 is electrically connected with the patch pattern 10 while passing through a hole part which is not shown and is located at the center of the patch facing part 21 included in the ground pattern 20.

30 [0043]

A connection point (hereinafter, power supply point) between the power supply pin 31 and the patch pattern 10 may be located at a position where impedances of the coaxial cable and the antenna device 100 match each other at

the target frequency. According to the present embodiment, the power supply point is located at the center of the patch pattern 10. However, the power supply point may be located at other positions. A state where the impedances match each other is not limited to a fully matching state and includes a state
5 where a loss caused by a mismatch of the impedances is in an allowable range that is predetermined.

[0044]

The ground pattern 20 and the power supply pin 31 are held to be in an electrical non-connection state by the hole part located at the patch facing part
10 21. A connection point (hereinafter, ground point) between the external conductor of the coaxial cable and the ground pattern 20 is located in the vicinity of the hole part included by the patch facing part 21 where the power supply pin 31 passes through. According to the present embodiment, a power supply mode of the antenna device 100 uses a direct-connection power supply mode.
15 However, the power supply mode may use an electromagnetic-connection power supply mode where a microstrip line and the like are used.

[0045]

Next, reasons why a ground area can be reduced and a decrease of a gain can be suppressed according to the present embodiment will be described,
20 by using a conventional patch antenna 100X shown in Fig. 5. The conventional patch antenna 100X has a configuration where the side wall parts 22 and the back surface parts 23 are removed from the antenna device 100 of the present embodiment, and includes a patch part 10X and a ground plate 20X.

[0046]

25 The patch part 10X is a member equivalent to the patch pattern 10 of the present embodiment, and has dimensions the same as dimensions of the patch pattern 10. The ground plate 20X is a member that is a flat plate shape and is connected with the external conductor of the coaxial cable. A length of the ground plate 20X in the X-axis direction, similar to the present embodiment, is
30 $\lambda/2$ of the target radio wave.

[0047]

A dashed line indicated by a notation Ln1 in the drawing is a straight line parallel to the Y-axis the passes through a center of the ground plate 20X, and a

point indicated by a notation M represents a cross point between a straight line L1 and an edge part (hereinafter, Y-axis parallel edge part) parallel to the Y-axis. The cross point M is equivalent to a midpoint of the Y-axis parallel edge part. L_a in the drawing represents a length of the ground plate 20X in the Y-axis direction.

5 [0048]

(A) of Fig. 6 is a graph conceptually showing a current distribution at the Y-axis parallel edge part. As shown in Fig. 6, a standing wave is generated around the midpoint M as a center at the Y-axis parallel edge part. As shown in (B-1) of Fig. 6, when the length L_a in the Y-axis direction is shorter than $\lambda/2$, a current (hereinafter, protrusion component) in response to an area indicated by a notation I_m in (A) of Fig. 6 becomes a reverse phase current. The protrusion component I_m is configured to radiate a radio wave at a rear side of the ground plate 20X. In other words, when the length L_a in the Y-axis direction is less than $\lambda/2$, the protrusion component I_m functions as the reverse phase current. Thus, 15 the gain for the antenna is deteriorated.

[0049]

When the length L_a in the Y-axis direction becomes $\lambda/2$, the end part of the Y-axis parallel edge part matches a node of the standing wave. Thus, it is unlikely that the reverse phase current is generated. In other words, it is unlikely 20 that the decrease of the gain is generated. Then, generally, one side of the ground plate 20X is designed to be at least longer than or equal to $\lambda/2$ as shown in Fig. 7. Fig. 7 shows a simulation result for a change of the gain when the length L_a in the Y-axis direction is caused to change while the length of the ground plate 20X in the X-axis direction is set to be $\lambda/2$.

25 [0050]

According to a configuration of the present embodiment, a peripheral length (i.e., total length) from the free end of the first back surface part 23A to the free end of the second back surface part 23B is set to be longer than $\lambda/2$. Thus, as shown in Fig. 8, the current flows through not only the patch facing part 21 but also the side wall parts 22 and the back surface parts 23. Specifically, the protrusion component I_m is distributed from the side wall parts 22 to an 30 intermediate part of the back surface parts 23. An opposite phase component I_n

is distributed in a surplus region that is a part of the back surface part 23 where the protrusion component I_m is not distributed.

[0051]

When a component I_{ma} that is a part of the protrusion component I_m which is distributed in the back surface part 23 is equal to the opposite phase component I_n in magnitude, the component I_{ma} and the opposite phase component I_n cancel each other, and the current distribution is substantially shown in (C) of Fig. 8. In other words, a current with an opposite phase relative to a current distributed in the patch facing part 21 does not exist.

10 [0052]

Thus, the length L_y in the Y-axis direction can be shorter than $\lambda/2$ and the decrease of the gain can be suppressed, by adjusting the height H of the side wall part 22 and the length γ of the back surface part 23. Fig. 9 shows a simulation result for the gain when the length γ of the back surface part 23 is caused to change from 0mm to 9mm in a configuration where the height H of the side wall part 22 is set to 1mm, 2mm and 3mm. As shown in Fig. 9, a long-dashed line indicates the simulation result when it is set that $H = 1\text{mm}$, a dotted-dashed line indicates the simulation result when it is set that $H = 2\text{mm}$, and a two-dotted dashed line indicates the simulation result when it is set that $H =$
15 3mm.
20

[0053]

Further, a dotted line indicates the simulation result when the length L_a of the ground plate 20X in the Y-axis direction is set to $\lambda/2$ in the patch antenna 100X shown in Fig. 5. In other words, the dotted line indicates the simulation result of the conventional (in other words, basic) patch antenna 100X (hereinafter, basic patch antenna) which includes the ground plate 20X having a sufficient size.

[0054]

A short dashed line indicates the simulation result when the size of the ground plate 20X is set to be the same as the patch facing part 21 included by the antenna device 100 according to the present embodiment ($L_a = L_y = 18\text{mm}$). The patch antenna 100X where the size of the ground plate 20X is set to be the same as the pat 21 is equivalent to the antenna device 100 according to the
30

present embodiment where the side wall parts 22 and the back surface parts 23 are removed (hereinafter, non-side-wall non-back-surface configuration).

[0055]

As shown in Fig. 9, even though $\gamma = 0$ (i.e., back surface part is removed), the gain greater than that of the non-side-wall non-back-surface configuration shown by the short dashed line can be obtained, without respect to H. In other words, as long as the side wall part 22 is provided, the gain can be improved relative to that of the non-side-wall non-back-surface configuration.

[0056]

The gain can be improved by increasing the length γ of the back surface part 23 even though the height H of the side wall part 22 is set to be short as shown in Fig. 9. The gain greater than or equal to that of the basic patch antenna can be achieved by adjusting γ without respect to H. For example, when it is set that $H = 1\text{mm}$, the gain as the same as the gain of the basic patch antenna can be achieved by setting that $\gamma = 8\text{mm}$. When it is set that $H = 2\text{mm}$, the gain greater than the gain of the basic patch antenna can be achieved by setting that $\gamma = 6\text{mm}$. When it is set that $H = 3\text{mm}$, the gain equivalent to the gain of the basic patch antenna can be achieved by setting γ from 2mm to 5mm.

[0057]

Fig. 10 shows a comparison result between a radiation directivity of the non-side-wall non-back-surface configuration and a radiation directivity of the antenna device 100 according to the present embodiment. As shown in Fig. 10, a solid line indicates the radiation directivity of the antenna device 100 according to the present embodiment, and a dashed line indicates the radiation directivity of the non-side-wall non-back-surface configuration. As shown in Fig. 10, a radiation of the radio wave in the negative direction of the Z-axis can be suppressed and the gain in the positive direction (i.e., rear side of antenna) of the Z-axis can be improved, by providing the side wall part 22 and the back surface part 23.

[0058]

According to the above configuration, it can be suppressed that the gain is reduced by adding the side wall part 22 and the back surface part 23 to the patch facing part 21, even though the length L_y of the patch facing part 21 in the

Y-axis direction is set to be shorter than a half of the target wavelength. Further, the gain can be improved relative to the gain of the basic patch antenna by adjusting the height H of the side wall part 22 and the length γ of the back surface part 23.

5 [0059]

The ground area in the above configuration is equivalent to the area of the patch facing part 21. According to the above configuration, the length L_y of the patch facing part 21 in the Y-axis direction can be reduced by 7mm relative to the basic patch antenna. In other words, the area according to the above
10 configuration can be reduced by 28% relative to the basic patch antenna. Since other components can be arranged at a space that is saved by the above reduction, it can be suppressed that an area of the antenna increases due to an arrangement of an extra component.

[0060]

15 The patch facing part 21, the side wall part 22 and the back surface part 23 constituting the ground pattern 20 may be formed from one sheet metal by a folding processing. Alternatively, the side wall part 22 and the back surface part 23 may be formed from a sheet metal and then be soldered to the patch facing part 21. The patch facing part 21 may be patterned on a surface of a printed
20 substrate by a known method such as an additive method, a subtractive method or the like.

[0061]

[First modification example]

The side wall part 22 may be achieved by arranging plural conductive
25 pins in a row. When the patch facing part 21 is located at one layer (e.g., surface) of the printed substrate and the back surface part 23 is located at other layers of the printed substrate, the side wall part 22 may be achieved, by arranging through vias connecting two layers where the patch facing part 21 and the back surface part 23 are located, in a row along an edge part of the patch
30 facing part 21.

[0062]

[Second modification example]

As shown in Fig. 11, the ground pattern 20 may not include the back surface part 23. In other words, the ground pattern 20 may include the patch facing part 21 and the side wall part 22. The height H of the side wall part 22 may be designed appropriately. When the side wall part 22 is provided, it is confirmed by a simulation that a gain, higher than that of an assumed configuration where the side wall part 22 is not provided, can be obtained.

[0063]

It is preferable that the length (i.e., peripheral length) along the surface of the ground pattern 20 from the end part of the first side wall part 22A at a side of the negative direction of the Z-axis to the end part of the second side wall part 22B at a side of the negative direction of the Z-axis is $\lambda/2$ of the target radio wave. According to the second modification example, the peripheral length is equal to $L_y + H \times 2$. In other words, it is preferable that L_y and H are set such that $L_y + H \times 2$ electrically matches $\lambda/2$. In addition, in a state where two values match each other, the two values may completely match each other, or the two values may substantially match each other. A range where the two values substantially match each other is equivalent to a range where a sufficient gain can be obtained in the antenna device 100. For example, the range may be from -25% to +25%.

[0064]

[Third modification example]

According to the above description, the lengths of the patch facing part 21 in the Y-axis direction of the entire region of the patch facing part 21 is less than $\lambda/2$. However, it is not limited. As shown in Fig. 12, only a part of the lengths may be less than the half wavelength. As shown in Fig.12, a length of the ground pattern 20 from an end part at a side of the negative direction of the Y-axis to an end part at a side of the positive direction of the Y-axis in the vicinity of a center part in the X-axis direction is set to be less shorter than $\lambda/2$ of the target radio wave. The patch facing part 21 is a line symmetrical shape about a dashed line $Ln2$ as a symmetrical axis. A region Ar having a hatching dot pattern shown in Fig. 12 is equivalent to the width arrangement region in claims. In addition, as shown in Fig. 12, the first side wall part 22A is caused to be transparent to indicate the width arrangement region Ar .

[0065]

As shown in Fig. 12, Ly1 represents the length of the entire of the patch facing part 21 in the Y-axis direction. For example, Ly1 is set to be $\lambda/2$. Ly2 represents the length of the width arrangement region Ar in the Y-axis direction, and is set to be less than $\lambda/2$. For example, Ly2 may be set to 0.36λ .

[0066]

Lx1 represents the length of the entire of the patch facing part 21 in the X-axis direction. For example, Lx1 is set to be $\lambda/2$. Lx2 represents the length of the width arrangement region Ar in the Y-axis direction, and may be a value designed appropriately. When Lx2 becomes larger, a reduction quantity of the ground area can be made larger. In other words, it is preferable that Lx2 is larger. In addition, an upper limit of Lx2 is Lx1. A configuration where $Lx2 = Lx1$ is equivalent to the ground pattern 20 in the second modification example. According to a third modification example, the back surface part 23 may be located at the side wall part 22.

[0067]

[Fourth modification example]

According to the above description, two side wall parts 22 are located to be opposite to each other. However, it is not limited. As shown in Fig. 13, the patch facing part 21 may be a T-shape, and the first side wall part 22A, the second side wall part 22B, and a third side wall part 22C may be provided.

[0068]

In the above configuration, the length Lx in the X-axis direction relative to the basic patch antenna can be reduced. A notation Ln2 in the drawing represents a symmetry axis of the patch facing part 21. The patch facing part 21 is a line symmetrical shape about a dashed line Ln2 as the symmetry axis. According to a fourth modification example, the back surface part 23 may be located at each of the side wall parts 22.

[0069]

[Fifth modification example]

As shown in Figs. 14 and 15, the patch facing part 21 may be a rectangular shape, and a side wall part 22 may be located at each of four edge parts of the patch facing part 21. In other words, the ground pattern 20 may

include the first side wall part 22A, the second side wall part 22B, the third side wall part 22C and a fourth side wall part 22D.

[0070]

The third side wall part 22C and the fourth side wall part 22D are side wall parts 22 which are next to the first side wall part 22A. CL shown in Fig. 15 represents a separation between the first side wall part 22A and the third side wall part 22C and a separation between the first side wall part 22A and the fourth side wall part 22D. The separation CL that is predetermined is provided between the first side wall part 22A and the third side wall part 22C such that the first side wall part 22A and the third side wall part 22C are not electromagnetically coupled to each other, and is provided between the first side wall part 22A and the fourth side wall part 22D such that the first side wall part 22A and the fourth side wall part 22D are not electromagnetically coupled to each other. Other side wall parts 22 are similar to the above description.

[0071]

When one side wall part 22 is electromagnetically coupled to another side wall part 22, a current path is changed, and the above effects cannot be obtained. The separation CL may be a value greater than or equal to one hundredth of a wavelength of the target radio wave.

[0072]

According to the above configuration, the length L_x of the patch facing part 21 in the X-axis direction can be further reduced than that according to the fourth modification example. Further, according to the above configuration, the entire region of the patch facing part 21 is equivalent to the width arrangement region Ar.

[0073]

[Sixth modification example]

As shown in Fig. 16, a combination of the side wall part 22 and the back surface part 23 may be located at each of four edges of the patch facing part 21 that is a rectangular shape. In other words, the ground pattern 20 may include the first back surface part 23A, the second back surface part 23B, a third back surface part 23C and a fourth back surface part 23D. Each of the back surface parts 23 is separated from a back surface part 23 that is next to the each of the

back surface parts 23 by a separation CL that is predetermined. For example, each of the back surface parts 23 may be an isosceles trapezoid shape.

[0074]

[Seventh modification example]

5 As shown in Fig. 17, a total number of the side wall parts 22 and a total number of the back surface parts 23 in the antenna device 100 may be one. Alternatively, one side wall part 22 may be located along one edge part of the patch facing part 21 that is a rectangular shape, without the back surface part 23.

[0075]

10 [Eighth modification example]

The side wall part 22 may not be located at an edge part parallel to the symmetrical axis included by a line symmetrical figure. For example, the patch facing part 21 according to the fourth modification example is not line symmetrical in a direction parallel to the Y-axis. However, in the patch facing
15 part 21 according to the fourth modification example, only the third side wall part 22C may be provided without the first side wall part 22A and the second side wall part 22B. According to the above configuration, a reduction of the ground area and a maintenance of the gain can be compatible to each other.

[0076]

20 As shown in Fig. 13, two edge parts which are parallel to the Y-axis and opposite to each other are equivalent to the first edge part and the second edge part in claims. The side wall part 22 may be located at the edge part at a side of a negative direction of the X-axis between edge parts parallel to the Y-axis. In other words, the side wall part may be located at only one of the first edge part
25 and the second edge part, or side wall parts may be located at both the first edge part and the second edge part. In the antenna device 100 according to an eighth modification example, it is unnecessary to make the patch facing part 21 be a line symmetrical shape. The patch facing part 21 may be a shape including a pair of outer edge parts which are straight shape and opposite to each other.

30 [0077]

When the side wall parts are located at a first outer edge part and a second outer edge part which are outer edge parts being straight shape and opposite to each other, as described in the second modification example, it is

preferable that a peripheral length from an end part at a side of the negative direction of the Z-axis in the side wall part located at the first outer edge part to an end part at a side of the negative direction of the Z-axis in the side wall part located at the second outer edge part is $\lambda/2$ of the target radio wave.

5 [0078]

Further, the back surface part 23 may be located at the side wall part 22 as the above description. When the side wall part 22 and the back surface part 23 are located at each of the first outer edge part and the second outer edge part, similar to the above embodiments, it is preferable that the peripheral length
10 from an end part of the back surface part of one of the first outer edge part and the second outer edge part to the back surface part of the other one of the first outer edge part and the second outer edge part is greater than or equal to $\lambda/2$ of the target radio wave.

[0079]

15 [Ninth modification example]

According to the above description, the embodiment of the patch antenna where the present disclosure is applied is described. However, it is not limited. For example, the present disclosure may be applied to a monopole antenna. In other words, the conductive member that is a linear shape and is
20 used as the radiation element may be applied to a configuration where the conductive member extends from the ground pattern 20. In this case, the side wall part 22 may be located along a part of the edge part of the conductive member (hereinafter, flat plate part) which is a planar plate shape and is equivalent to the patch facing part 21, to face a side opposite to the conductive
25 member that is a linear shape. The present disclosure is applicable to an unbalanced feed type antenna using a conductor that is a flat plate shape and provides a ground potential.

[0080]

While the present disclosure has been described with reference to the
30 embodiments thereof, it is to be understood that the disclosure is not limited to the embodiments and constructions. The present disclosure is intended to cover various modification and equivalent arrangements. In addition, while the various combinations and configurations, which are preferred, other combinations and

configurations, including more, less or only a single element, are also within the spirit and scope of the present disclosure.

CLAIMS

1. An antenna device comprising:

a radiation element that is a conductive member electrically connected with an internal conductor of a coaxial cable; and

a flat plate part that is a conductive member being a flat plate shape and electrically connected with an external conductor of the coaxial cable, wherein

the radiation element is to be located to be opposite to the flat plate part with a separation that is predetermined or to be located to extend from the flat plate part,

the flat plate part is a line symmetrical shape and is a shape including a width arrangement region that is a part where a length from one end part to another end part opposite to the one end part via a symmetrical axis of the flat plate part is set to be shorter than a half wavelength of a radio wave that is a target of transmission and reception,

at least one of the two end parts that are parallel to the symmetrical axis and define the width arrangement region is provided with a side wall part that is a conductive member to extend along the at least one of the two end parts toward a direction viewed from the flat plate part where the radiation element does not exist, and

the radiation element outwardly projects from the flat plate part beyond each of the two end parts of the flat plate part in a direction parallel to a plane of the flat plate part.

2. The antenna device according to claim 1, wherein

the side wall part includes a first side wall part and a second side wall part that are located at the two end parts parallel to the symmetrical axis which define the width arrangement region.

3. The antenna device according to claim 2, wherein

the first side wall part and the second side wall part have lengths in a direction orthogonal to the flat plate part which are set in a manner that a peripheral length from an end part of the first side wall part which is not in contact

with the flat plate part to an end part of the second side wall part which is not in contact with the flat plate part matches a half wavelength of the radio wave.

4. The antenna device according to claim 1, wherein
an end part, which is not in contact with the flat plate part, of the end parts included in the side wall parts in a direction orthogonal to the flat plate part, is provided with a back surface part that is a conductive member being a flat plate shape to be opposite to the flat plate part.

5. The antenna device according to claim 4, wherein
the side wall part includes a first side wall part and a second side wall part that are located at the two end parts parallel to the symmetrical axis which define the width arrangement region, and
the back surface part includes a first back surface part and a second back surface part that are located at the first side wall part and the second side wall part, respectively.

6. The antenna device according to claim 5, wherein
the width arrangement region, the first side wall part and the second side wall part are defined in a manner that a peripheral length from an end part of the first side wall part which is not in contact with the flat plate part to an end part of the second side wall part which is not in contact with the flat plate part is shorter than a half wavelength of the radio wave.

7. The antenna device according to claim 6, wherein
a peripheral length from an end part of the first back surface part that is the back surface part located at the first side wall part where the second side wall part exists to an end part of the second back surface part that is the back surface part located at the second side wall part where the first side wall part exists, is longer than the half wavelength of the radio wave.

8. The antenna device according to any one of claims 1 to 7, wherein

the flat plate part is defined to be a rectangular shape where a length of each of edges of the flat plate part is set to be less than the half wavelength of the radio wave,

the side wall part is located at each of the edges of the flat plate part, and one of the side wall parts and a side wall part next to the one of the side wall parts define a separation that is predetermined.

9. An antenna device comprising:

a radiation element that is a conductive member electrically connected with an internal conductor of a coaxial cable; and

a flat plate part that is a conductive member being a flat plate shape and electrically connected with an external conductor of the coaxial cable, wherein

the radiation element is to be located to be opposite to the flat plate part with a separation that is predetermined or to be located to extend from the flat plate part,

the flat plate part is a shape including a first edge part and a second edge part which are straight shape and opposite to each other,

a distance between the first edge part and the second edge part is set to be shorter than a half wavelength of a radio wave that is a target of transmission and reception,

at least one of the first edge part and the second edge part is provided with a side wall part that is a conductive member to extend along the at least one of the first edge part and the second edge part toward a direction viewed from the flat plate part where the radiation element does not exist, and

the radiation element outwardly projects from the flat plate part beyond each of the first edge part and the second edge part of the flat plate part in a direction parallel to a plane of the flat plate part.

10. The antenna device according to claim 9, wherein

an end part, which is not in contact with the flat plate part, of the end parts included in the side wall parts in a direction orthogonal to the flat plate part, is provided with a back surface part that is a conductive member being a flat plate shape to be opposite to the flat plate part.

11. The antenna device configured to operate as a patch antenna according to any one of claims 1 to 9, wherein
the radiation element is located to be parallel to the flat plate part.