

## DESCRIPTION

### Title of Invention: ANTENNA DEVICE AND METHOD FOR CONTROLLING ANTENNA DEVICE

#### Technical Field

5 [0001]

The present disclosure relates to an antenna device and a method for controlling the antenna device.

#### Background Art

[0002]

10 PTL 1 discloses a GPS antenna device that combines outputs of a plurality of sets of dipole antennas.

#### Citation List

##### Patent Literature

[0003]

15 PTL 1: JP 2008-072598 A

#### Summary of Invention

##### Technical Problem

[0004]

20 However, in the GPS antenna device described in PTL 1, a noise figure for an antenna output increases as a distance from a feeding unit, which supplies power to the dipole antennas, to the dipole antenna increases.

[0005]

25 It is an object of the present disclosure to provide an antenna device that solves the above problem.

##### Solution to Problem

[0006]

A first aspect of the present disclosure provides an antenna device including: an antenna pole; a first antenna disposed on the antenna pole; a

second antenna disposed on the antenna pole at a predetermined interval from the first antenna; a combining unit that supplies power to the first antenna and combines signals received by the first antenna; and an amplification unit that is connected between the first antenna and the combining unit and amplifies the signals.

[0007]

A second aspect of the present disclosure provides a method for controlling an antenna device including: an antenna pole; a first antenna disposed on the antenna pole; and a second antenna disposed on the antenna pole at a predetermined interval from the first antenna, in which the method for controlling the antenna device includes: a combining step of supplying power to the first antenna and combining signals received by the first antenna; and an amplification step of amplifying the signals.

Advantageous Effects of Invention

[0008]

According to the present disclosure, it is possible to provide an antenna device that reduces a noise figure for an antenna output.

Brief Description of Drawings

[0009]

[Fig. 1] Fig. 1 is a schematic diagram illustrating an antenna device according to an example embodiment of the present disclosure.

[Fig. 2] Fig. 2 is a schematic diagram illustrating an outline of a feed element according to the example embodiment of the present disclosure.

[Fig. 3] Fig. 3 is a schematic diagram illustrating an outline of a parasitic element according to the example embodiment of the present disclosure.

[Fig. 4] Fig. 4 is a block diagram illustrating a configuration of the feed element according to the example embodiment of the present

disclosure.

[Fig. 5] Fig. 5 is a block diagram illustrating a configuration of the feed element according to the example embodiment of the present disclosure.

5 [Fig. 6] Fig. 6 is a block diagram illustrating a configuration of the feed element according to the example embodiment of the present disclosure.

[Fig. 7] Fig. 7 is a block diagram illustrating a configuration of a control device according to the example embodiment of the present  
10 disclosure.

[Fig. 8] Fig. 8 is a block diagram illustrating a configuration of the antenna device according to the example embodiment of the present disclosure.

[Fig. 9] Fig. 9 is a block diagram illustrating an antenna device  
15 according to an example embodiment of the present disclosure.

#### Example Embodiment

[0010]

An antenna device according to an example embodiment of the present disclosure will be described below with reference to the drawings.

20 [0011]

Fig. 1 is a schematic diagram illustrating the antenna device according to the example embodiment of the present disclosure. An antenna device 1 is a reception device that receives a signal from a global positioning system (GPS) satellite. The antenna device 1 is used for, for  
25 example, an aircraft landing guidance system such as a Ground-Based Augmentation System (GBAS). The antenna device 1 includes a multi-path limiting antenna 2, a divider/combiner 5, and a control device 7.

[0012]

The multi-path limiting antenna 2 (MLA) is an antenna having a

substantially hemispherical directional characteristic with respect to an installation surface (X-Y plane in Fig. 1). The multi-path limiting antenna 2 includes a plurality of feed elements 21, a plurality of parasitic elements 22, and an antenna mast 23. The multi-path limiting antenna 2 may further include a radome. The multi-path limiting antenna 2 may include, for example, an odd number of the feed elements 21 and an even number of the parasitic elements 22. The number of the feed elements 21 and the number of the parasitic elements 22 are not limited to the numbers described above. In the present disclosure, a configuration of the multi-path limiting antenna 2 will be described, taking as an example a case where the multi-path limiting antenna 2 includes 11 feed elements 21A to 21K and 10 parasitic elements 22B to 22K. The antenna mast 23 extends in a vertical direction (Z direction) with respect to the installation surface. The antenna mast 23 is a columnar or quadrangular prism structure, and is constituted by, for example, resin. In the antenna mast 23, the plurality of feed elements 21 and the plurality of parasitic elements 22 are installed at a predetermined interval in the Z direction.

[0013]

The feed element 21 is a Lindenblad antenna, and has a plurality of dipole antennas, a circuit board, and the like. The feed element 21 is supplied with power from the divider/combiner 5 via a feed line 3. Similarly to the feed element 21, the parasitic element 22 is a Lindenblad antenna, and has a plurality of dipole antennas, but the parasitic element 22 is not connected to the divider/combiner 5.

[0014]

In the plurality of feed elements 21, the feed element 21A is installed in a substantially middle portion of the antenna mast 23 in the Z direction such that a circuit board surface of the feed element 21 is substantially parallel to the installation surface.

[0015]

The feed element 21B is installed below the feed element 21A at a predetermined interval D1 from the feed element 21A such that the circuit board surface of the feed element 21B is substantially parallel to the installation surface. The parasitic element 22B is installed below the feed element 21B at a predetermined interval D2 from the feed element 21B such that the circuit board surface of the parasitic element 22B is substantially parallel to the installation surface. The feed element 21C (not illustrated) is installed below the parasitic element 22B at the predetermined interval D2 from the parasitic element 22B such that the circuit board surface of the feed element 21C is substantially parallel to the installation surface. The parasitic element 22C (not illustrated) is installed below the feed element 21C at the predetermined interval D2 from the feed element 21C such that the circuit board surface of the parasitic element 22C is substantially parallel to the installation surface. Similarly, the feed elements 21D, 21E, and 21F and the parasitic elements 22D, 22E, and 22F are alternately installed at the predetermined interval D2. That is, the feed elements 21B to 21F and the parasitic elements 22B to 22F are alternately installed below the feed element 21A at the predetermined interval D2 such that the circuit board surfaces are substantially parallel to each other.

[0016]

The feed element 21G is installed above the feed element 21A at the predetermined interval D1 from the feed element 21A such that the circuit board surface of the feed element 21G is substantially parallel to the installation surface. The parasitic element 22G is installed above the feed element 21G at the predetermined interval D2 from the feed element 21G such that the circuit board surface of the parasitic element 22G is substantially parallel to the installation surface. The feed element 21H

(not illustrated) is installed above the parasitic element 22G at the predetermined interval D2 from the parasitic element 22G such that the circuit board surface of the feed element 21H is substantially parallel to the installation surface. The parasitic element 22H (not illustrated) is installed above the feed element 21H at the predetermined interval D2 from the feed element 21H such that the circuit board surface of the parasitic element 22H is substantially parallel to the installation surface. Similarly, the feed elements 21I, 21J, and 21K and the parasitic elements 22I, 22J, and 22K are alternately installed at the predetermined interval D2. That is, the feed elements 21G to 21K and the parasitic elements 22G to 22K are alternately installed above the feed element 21A at the predetermined interval D2 such that the circuit board surfaces are substantially parallel to each other.

[0017]

The predetermined interval D1 and the predetermined interval D2 provided between the feed elements 21 and the parasitic elements 22 may be determined in accordance with a wavelength of a signal received by the multi-path limiting antenna 2 or the like. For example, the predetermined interval D2 may be a length less than half the wavelength of the signal received by the multi-path limiting antenna 2. The predetermined interval D1 may be half the predetermined interval D2, or the predetermined interval D1 and the predetermined interval D2 may be the same in length. The present disclosure describes a configuration of the present disclosure in a case where the predetermined interval D1 and the predetermined interval D2 are the same in length.

[0018]

The multi-path limiting antenna 2 is connected to the divider/combiner 5 via a plurality of feed lines 3. The plurality of feed lines 3 electrically connects each of the feed elements 21A to 21K with

the divider/combiner 5. It is desirable that the lengths of the feed lines 3 from the feed elements 21A to 21K to the divider/combiner 5 be substantially the same. The divider/combiner 5 supplies power to the feed elements 21A to 21K, receives signals from the feed elements 21A to 21K, and combines a predetermined combination of signals. The divider/combiner 5 supplies power to the feed elements 21A to 21K and combines antenna patterns such that the multi-path limiting antenna 2 is characterized by a hemispherical antenna pattern and has low elevation angle sharp cutoff characteristics. The divider/combiner 5 transmits the combined signal to a GPS receiver. The control device 7 controls the divider/combiner 5. The control device 7 may control the configuration of electric circuits or the like of the feed elements 21A to 21K.

[0019]

Fig. 2 is a schematic diagram illustrating an outline of the feed element according to the example embodiment of the present disclosure, and is a top view of II-II in Fig. 1. The feed element 21A is a Lindenblad antenna, and has dipole antennas 211a, 211b, 211c, and 211d, an installation fixture 212, and a circuit board 213. The feed elements 21B to 21K also have the same configuration as the feed element 21A. Hereinafter, the outline of the feed elements 21 will be described with the feed elements 21A to 21K as the feed elements 21.

[0020]

The dipole antenna 211a has two substantially triangular antenna elements, and is electrically connected to the circuit board 213 via the installation fixture 212. The two antenna elements are connected to the installation fixture 212 at one corner of the triangle. The two antenna elements are disposed to be substantially line-symmetric with respect to the installation fixture 212.

In a side view, one antenna element forms a predetermined angle

with one surface of the circuit board 213. In a top view, at least a part of the one antenna element is disposed over the circuit board 213. In a side view, the other antenna element forms a predetermined angle with the other surface of the circuit board 213. In a top view, at least a part of the other antenna element is disposed under the circuit board 213. The predetermined angle may be, for example, 30 degrees. That is, in a top view, at least a part of the dipole antenna 211a is located over the circuit board 213, and at least a part of the dipole antenna 211a is located under the circuit board 213. The dipole antennas 211b, 211c, and 211d also have the same configuration as the dipole antenna 211a.

[0021]

A part of the one antenna element of the dipole antenna 211a is disposed over the other antenna element of the dipole antenna 211b. A part of one antenna element of the dipole antenna 211b is disposed over the other antenna element of the dipole antenna 211c. A part of one antenna element of the dipole antenna 211c is disposed over the other antenna element of the dipole antenna 211d. A part of one antenna element of the dipole antenna 211d is disposed over the other antenna element of the dipole antenna 211a.

[0022]

The circuit board 213 includes a connection line, a termination resistor, a coupler, an amplifier, and the like, and is electrically connected to the divider/combiner 5 via the feed lines 3. The circuit board 213 has a through hole at the center and allows the antenna mast 23 to pass through. As long as the circuit board 213 can be attached to the antenna mast 23, the circuit board 213 may have a cutout or the like instead of the through hole.

[0023]

Fig. 3 is a schematic diagram illustrating an outline of the

parasitic element according to the example embodiment of the present disclosure, and is a top view of III-III in Fig. 1. The parasitic element 22B is a Lindenblad antenna, and has dipole antennas 221a, 221b, 221c, and 221d, an installation fixture 222, and a circuit board 223. The parasitic elements 22C to 22K also have the same configuration as the parasitic element 22B. Hereinafter, the outline of the parasitic elements 22 will be described with the parasitic elements 22B to 22K as the parasitic elements 22.

[0024]

The dipole antenna 221a has two substantially triangular antenna elements, and is electrically connected to the circuit board 223 via the installation fixture 222. The two antenna elements are connected to the installation fixture 222 at one corner of the triangle. The two antenna elements are disposed to be substantially line-symmetric with respect to the installation fixture 222.

In a side view, one antenna element forms a predetermined angle with one surface of the circuit board 223. In a top view, at least a part of the one antenna element is disposed over the circuit board 223. In a side view, the other antenna element forms a predetermined angle with the other surface of the circuit board 223. In a top view, at least a part of the other antenna element is disposed under the circuit board 223. The predetermined angle may be, for example, 30 degrees. That is, in a top view, at least a part of the dipole antenna 221a is located over the circuit board 223, and at least a part of the dipole antenna 221a is located under the circuit board 223. The dipole antennas 221b, 221c, and 221d also have the same configuration as the dipole antenna 221a.

[0025]

A part of the one antenna element of the dipole antenna 221a is disposed over the other antenna element of the dipole antenna 221b. A

part of one antenna element of the dipole antenna 221b is disposed over the other antenna element of the dipole antenna 221c. A part of one antenna element of the dipole antenna 221c is disposed over the other antenna element of the dipole antenna 221d. A part of one antenna  
5 element of the dipole antenna 221d is disposed over the other antenna element of the dipole antenna 221a.

[0026]

Unlike the circuit board 213, the circuit board 223 does not include a coupler, an amplifier, and the like, and is not electrically  
10 connected to the divider/combiner 5. That is, the dipole antennas 221a, 221b, 221c, and 221d are not electrically connected to the divider/combiner 5, and are terminated using a termination resistor or the like. The circuit board 223 has a through hole at the center and allows the antenna mast 23 to pass through. As long as the circuit board 223  
15 can be attached to the antenna mast 23, the circuit board 223 may have a cutout or the like instead of the through hole.

[0027]

In Figs. 1 to 3, for example, the dipole antenna 211a in the feed element 21B and the dipole antenna 221a in the parasitic element 22B are  
20 substantially parallel to each other in the Z direction. Similarly, the dipole antenna 211b in the feed element 21B and the dipole antenna 221b in the parasitic element 22B, the dipole antenna 211c in the feed element 21B and the dipole antenna 221c in the parasitic element 22B, and the dipole antenna 211d in the feed element 21B and the dipole antenna 221d  
25 in the parasitic element 22B are substantially parallel to each other in the Z direction. Similarly, the dipole antennas of the feed elements 21C to 21K and the parasitic elements 22C to 22K are substantially parallel to each other in the Z direction.

[0028]

Fig. 4 is a block diagram illustrating a configuration of the feed element according to the example embodiment of the present disclosure. The feed element 21 includes a coupler 215a, a coupler 215b, a coupler 215c, and low noise amplifiers 216. The coupler 215a is a 180-degree hybrid coupler, and is mounted on the circuit board 213. The coupler 215a includes an input terminal, a 0-degree output terminal, and a 180-degree output terminal. The coupler 215b and the coupler 215c are 90-degree hybrid couplers, and are mounted on the circuit board 213. The coupler 215b and the coupler 215c include an input terminal, a 0-degree output terminal, and a 90-degree output terminal. The couplers 215a to 215c are couplers that apply a rotation phase in a forward rotation direction of a feeding phase. The coupler 215b is connected to the 0-degree output terminal of the coupler 215a, and the coupler 215c is connected to the 180-degree output terminal of the coupler 215a. A feeding phase difference between the 0-degree output terminal of the coupler 215b and the input terminal of the coupler 215a is 0 degrees. A feeding phase difference between the 90-degree output terminal of the coupler 215b and the input terminal of the coupler 215a is 90 degrees. A feeding phase difference between the 0-degree output terminal of the coupler 215c and the input terminal of the coupler 215a is 180 degrees. A feeding phase difference between the 90-degree output terminal of the coupler 215c and the input terminal of the coupler 215a is 270 degrees. With such a configuration, it is possible to provide feeding phase differences of 0 degrees, 90 degrees, 180 degrees, and 270 degrees in the dipole antennas 211a to 211d, respectively. The low noise amplifiers 216, which are amplifiers that amplify weak signals with low noise, are provided on the circuit board 213 and amplify signals received by the dipole antennas 211a to 211d with a predetermined gain or a variable gain. The gain of the low noise amplifiers 216 can be controlled by the control

device 7.

[0029]

The input terminal of the coupler 215a is electrically connected to the divider/combiner 5 via the feed line 3. The 0-degree output terminal of the coupler 215a is electrically connected to the input terminal of the coupler 215b. The 180-degree output terminal of the coupler 215a is electrically connected to the input terminal of the coupler 215c. The 0-degree output terminal of the coupler 215b is electrically connected to the dipole antenna 211a via the low noise amplifier 216. The 90-degree output terminal of the coupler 215b is electrically connected to the dipole antenna 211b via the low noise amplifier 216. The 0-degree output terminal of the coupler 215c is electrically connected to the dipole antenna 211c via the low noise amplifier 216. The 90-degree output terminal of the coupler 215c is electrically connected to the dipole antenna 211d via the low noise amplifier 216. With the configuration in Fig. 4, the dipole antennas 211a to 211d are supplied with power with phases of 0 degrees, 90 degrees, 180 degrees, and 270 degrees, respectively. The configuration of the couplers 215a, 215b, and 215c and connection wiring is not limited to the above. The configuration is only required to allow the dipole antennas 211a to 211d to be combined so as to have phase delays of 0 degrees, 90 degrees, 180 degrees, and 270 degrees, respectively. For example, the feeding phases of the dipole antennas 211a to 211d may be controlled by changing a line length between the dipole antenna and the coupler. Alternatively, the feeding phases of the dipole antennas 211a to 211d may be controlled by reversing polarities of attachment of the dipole antennas (reversing plus and minus). The configuration of the feed elements 21A to 21K may be similar to the configuration illustrated in Fig. 4. With the configuration illustrated in Fig. 4, signals received by the dipole antennas 211a to 211d are

transmitted to the divider/combiner 5 via the feed line 3.

[0030]

By providing the low noise amplifiers 216 between the dipole antenna 211a and the dipole antenna 211b and the coupler 215b and  
5 between the dipole antenna 211c and the dipole antenna 211d and the coupler 215c, it is possible to reduce a noise figure for signals received by the dipole antennas 211a to 211d in signal paths from the dipole antennas 211a to 211d to the divider/combiner 5.

[0031]

10 Fig. 5 is a block diagram illustrating a configuration of the feed element according to the example embodiment of the present disclosure. The feed element 21 includes the coupler 215a, the coupler 215b, the coupler 215c, and the low noise amplifiers 216. The coupler 215a is a 180-degree hybrid coupler, and is mounted on the circuit board 213. The  
15 coupler 215a includes an input terminal, a 0-degree output terminal, and a 180-degree output terminal. The coupler 215b and the coupler 215c are 90-degree hybrid couplers, and are mounted on the circuit board 213. The coupler 215b and the coupler 215c include an input terminal, a 0-degree output terminal, and a 90-degree output terminal. The couplers  
20 215a to 215c are couplers that apply a rotation phase in the forward rotation direction of the feeding phase. The coupler 215b is connected to the 0-degree output terminal of the coupler 215a, and the coupler 215c is connected to the 180-degree output terminal of the coupler 215a. A feeding phase difference between the 0-degree output terminal of the  
25 coupler 215b and the input terminal of the coupler 215a is 0 degrees. A feeding phase difference between the 90-degree output terminal of the coupler 215b and the input terminal of the coupler 215a is 90 degrees. A feeding phase difference between the 0-degree output terminal of the coupler 215c and the input terminal of the coupler 215a is 180 degrees.

A feeding phase difference between the 90-degree output terminal of the coupler 215c and the input terminal of the coupler 215a is 270 degrees. With such a configuration, it is possible to provide feeding phase differences of 0 degrees, 90 degrees, 180 degrees, and 270 degrees in the dipole antennas 211a to 211d, respectively. The low noise amplifiers 216, which are amplifiers that amplify weak signals with low noise, are provided on the circuit board 213 and amplify signals received by the dipole antennas 211a to 211d with a predetermined gain or a variable gain. In the configuration in Fig. 5, the low noise amplifiers 216 amplify combined signals of the dipole antenna 211a and the dipole antenna 211b, and combined signals of the dipole antenna 211c and the dipole antenna 211d.

[0032]

The input terminal of the coupler 215a is electrically connected to the divider/combiner 5 via the feed line 3. The 0-degree output terminal of the coupler 215a is electrically connected to the input terminal of the coupler 215b via the low noise amplifier 216. The 180-degree output terminal of the coupler 215a is electrically connected to the input terminal of the coupler 215c via the low noise amplifier 216. The 0-degree output terminal of the coupler 215b is electrically connected to the dipole antenna 211a. The 90-degree output terminal of the coupler 215b is electrically connected to the dipole antenna 211b. The 0-degree output terminal of the coupler 215c is electrically connected to the dipole antenna 211c. The 90-degree output terminal of the coupler 215c is electrically connected to the dipole antenna 211d. With the configuration in Fig. 5, the dipole antennas 211a to 211d are supplied with power with phases of 0 degrees, 90 degrees, 180 degrees, and 270 degrees, respectively. The configuration of the couplers 215a, 215b, and 215c and connection wiring is not limited to the above. The configuration is

only required to allow the dipole antennas 211a to 211d to be combined so as to have phase delays of 0 degrees, 90 degrees, 180 degrees, and 270 degrees, respectively. For example, the feeding phases of the dipole antennas 211a to 211d may be controlled by changing the line length  
5 between the dipole antenna and the coupler. Alternatively, the feeding phases of the dipole antennas 211a to 211d may be controlled by reversing the polarities of attachment of the dipole antennas (reversing plus and minus). The configuration of the feed elements 21A to 21K may be similar to the configuration illustrated in Fig. 5. With the configuration  
10 illustrated in Fig. 5, signals received by the dipole antennas 211a to 211d are transmitted to the divider/combiner 5 via the feed line 3.

[0033]

By providing the low noise amplifiers 216 between the coupler 215a and the coupler 215b and between the coupler 215a and the coupler  
15 215c, it is possible to reduce the noise figure for signals received by the dipole antennas 211a to 211d in the signal paths from the dipole antennas 211a to 211d to the divider/combiner 5. Comparing the configuration in Fig. 4 with the configuration in Fig. 5, the configuration in Fig. 5 can reduce the number of low noise amplifiers 216. As a result, a circuit  
20 scale in the configuration in Fig. 5 can be made smaller than a circuit scale in the configuration in Fig. 4.

[0034]

Fig. 6 is a block diagram illustrating a configuration of the feed element according to the example embodiment of the present disclosure.

25 The feed element 21 includes the coupler 215a, the coupler 215b, the coupler 215c, and the low noise amplifier 216. The coupler 215a is a 180-degree hybrid coupler, and is mounted on the circuit board 213. The coupler 215a includes an input terminal, a 0-degree output terminal, and a 180-degree output terminal. The coupler 215b and the coupler 215c are

90-degree hybrid couplers, and are mounted on the circuit board 213.

The coupler 215b and the coupler 215c include an input terminal, a 0-degree output terminal, and a 90-degree output terminal. The couplers 215a to 215c are couplers that apply a rotation phase in the forward

rotation direction of the feeding phase. The coupler 215b is connected to the 0-degree output terminal of the coupler 215a, and the coupler 215c is connected to the 180-degree output terminal of the coupler 215a. A

feeding phase difference between the 0-degree output terminal of the coupler 215b and the input terminal of the coupler 215a is 0 degrees. A

feeding phase difference between the 90-degree output terminal of the coupler 215b and the input terminal of the coupler 215a is 90 degrees. A feeding phase difference between the 0-degree output terminal of the coupler 215c and the input terminal of the coupler 215a is 180 degrees.

A feeding phase difference between the 90-degree output terminal of the coupler 215c and the input terminal of the coupler 215a is 270 degrees.

With such a configuration, it is possible to provide feeding phase differences of 0 degrees, 90 degrees, 180 degrees, and 270 degrees in the dipole antennas 211a to 211d, respectively. The low noise amplifier 216, which is an amplifier that amplifies weak signals with low noise, is

provided on the circuit board 213 and amplifies signals received by the dipole antennas 211a to 211d with a predetermined gain or a variable gain.

In the configuration in Fig. 6, the low noise amplifier 216 amplifies combined signals of the dipole antennas 211a to 211d.

[0035]

The input terminal of the coupler 215a is electrically connected to the divider/combiner 5 via the low noise amplifier 216 and the feed line 3. The 0-degree output terminal of the coupler 215a is electrically connected to the input terminal of the coupler 215b. The 180-degree output terminal of the coupler 215a is electrically connected to the input terminal

of the coupler 215c. The 0-degree output terminal of the coupler 215b is electrically connected to the dipole antenna 211a. The 90-degree output terminal of the coupler 215b is electrically connected to the dipole antenna 211b. The 90-degree output terminal of the coupler 215c is electrically connected to the dipole antenna 211c. The 0-degree output terminal of the coupler 215c is electrically connected to the dipole antenna 211d. With the configuration in Fig. 6, the dipole antennas 211a to 211d are supplied with power with phases of 0 degrees, 90 degrees, 180 degrees, and 270 degrees, respectively. The configuration of the couplers 215a, 215b, and 215c and connection wiring is not limited to the above. The configuration is only required to allow the dipole antennas 211a to 211d to be combined so as to have phase delays of 0 degrees, 90 degrees, 180 degrees, and 270 degrees, respectively. For example, the feeding phases of the dipole antennas 211a to 211d may be controlled by changing the line length between the dipole antenna and the coupler. Alternatively, the feeding phases of the dipole antennas 211a to 211d may be controlled by reversing the polarities of attachment of the dipole antennas (reversing plus and minus). The configuration of the feed elements 21A to 21K may be similar to the configuration illustrated in Fig. 6. With the configuration illustrated in Fig. 6, signals received by the dipole antennas 211a to 211d are transmitted to the divider/combiner 5 via the low noise amplifier 216 and the feed line 3.

[0036]

By providing the low noise amplifier 216 between the coupler 215a and the divider/combiner 5, it is possible to reduce the noise figure for signals received by the dipole antennas 211a to 211d in the signal paths from the dipole antennas 211a to 211d to the divider/combiner 5. Comparing the configuration in Fig. 4 and the configuration in Fig. 5 with the configuration in Fig. 6, the configuration in Fig. 6 can further reduce

the number of low noise amplifiers 216 as compared with the configuration in Fig. 5. As a result, a circuit scale in the configuration in Fig. 6 can be made smaller than the circuit scale in the configuration in Fig. 5. The configuration in which the phases of the dipole antennas 211a to 211d are shifted and received signals are combined is not limited to the configurations illustrated in Figs. 4 to 6. As described above, the feeding phases of the dipole antennas 211a to 211d may be controlled by making the line lengths between the dipole antennas 211a to 211d and the coupler different from each other, or the feeding phases of the dipole antennas 211a to 211d may be controlled by making the polarities of attachment of the dipole antennas 211a to 211d different from each other. [0037]

Fig. 7 is a block diagram illustrating a hardware configuration of the control device 7 according to the example embodiment of the present disclosure. The control device 7 includes a CPU 71, a ROM 72, a RAM 73, a storage device 74, a display device 75, an input/output IF 76, and a communication IF 77. The CPU 71, the ROM 72, the RAM 73, the storage device 74, the display device 75, the input/output IF 76, and the communication IF 77 are communicably connected to each other via a bus 79. [0038]

The CPU 71 is a central processing unit. The CPU 71 controls each unit of the control device 7 using an application program. The ROM 72 is a read only memory. The ROM 72 is constituted by a nonvolatile memory, and stores an application program for controlling each unit of the control device 7. The RAM 73 is a random access memory. The RAM 73 provides a memory area necessary for an operation of the CPU 71. The storage device 74 is a mass storage device such as a hard disc drive.

[0039]

The display device 75 may be a liquid crystal display, an organic electroluminescence (EL) display, or the like. The input/output IF 76 is an input/output interface to which a mouse, a trackball, a keyboard, a

5 speaker, or the like is connected. An operator may operate the control device 7 via the input/output IF 76. A sensor or the like may be connected to the input/output IF 76. For example, frequency

characteristics or the like may be acquired for circuit configurations or the like between the feed elements 21A to 21K and the divider/combiner

10 5. The communication IF 77 performs data communication between the control device 7 and the divider/combiner 5 via wired communication or/and wireless communication. The control device 7 may control the low noise amplifiers 216 of the feed elements 21A to 21K via the

communication IF 77. The gains of the low noise amplifiers 216 may be

15 controlled based on the frequency characteristics or the like between the feed elements 21A to 21K and the divider/combiner 5. As a result, it is possible to correct manufacturing errors in the circuit configurations of

the divider/combiner 5 corresponding to the feed elements 21A to 21K and to reduce distortion of the antenna pattern of the multi-path limiting

20 antenna 2. The manufacturing errors in the circuit configurations of the divider/combiner 5 may be measured in advance, and the gains of the low noise amplifiers 216 may be controlled based on results of the measurement.

[0040]

25 Fig. 8 is a block diagram illustrating a configuration of the antenna device according to the example embodiment of the present disclosure.

Reception signals transmitted from the feed elements 21A to 21K are input to the divider/combiner 5 via the feed lines 3. The

divider/combiner 5 includes couplers 51a, 51b, 51d, 51f, and 51h, and

dividing/combining circuits 51c, 51e, 51g, 51i, and 51j. The couplers 51a, 51b, 51d, 51f, and 51h may be 180-degree hybrid couplers. The dividing/combining circuits 51c, 51e, 51g, 51i, and 51j include two output terminals and an input terminal. The dividing/combining circuits 51c,  
5 51e, 51g, 51i, and 51j combine and output the reception signals from the feed elements 21A to 21K.

[0041]

A 0-degree output terminal of the coupler 51a is electrically connected to the feed element 21F via the feed line 3. A 180-degree  
10 output terminal of the coupler 51a is electrically connected to the feed element 21K via the feed line 3. The coupler 51a transmits a combined signal obtained by combining a reception signal in the feed element 21F and a reception signal in the feed element 21K.

[0042]

15 A 0-degree output terminal of the coupler 51b is electrically connected to the feed element 21E via the feed line 3. A 180-degree output terminal of the coupler 51b is electrically connected to the feed element 21J via the feed line 3. The coupler 51b transmits a combined signal obtained by combining a reception signal in the feed element 21E  
20 and a reception signal in the feed element 21J.

[0043]

One output terminal of the dividing/combining circuit 51c is electrically connected to an input terminal of the coupler 51a. The other output terminal of the dividing/combining circuit 51c is electrically  
25 connected to an input terminal of the coupler 51b. The dividing/combining circuit 51c transmits a combined signal obtained by combining a combined signal of the coupler 51a and a combined signal of the coupler 51b.

[0044]

A 0-degree output terminal of the coupler 51d is electrically connected to the feed element 21D via the feed line 3. A 180-degree output terminal of the coupler 51d is electrically connected to the feed element 21I via the feed line 3. The coupler 51d transmits a combined signal obtained by combining a reception signal in the feed element 21D and a reception signal in the feed element 21I. One output terminal of the dividing/combining circuit 51e is electrically connected to the input terminal of the dividing/combining circuit 51c. The other output terminal of the dividing/combining circuit 51e is electrically connected to an input terminal of the coupler 51d. The dividing/combining circuit 51e transmits a combined signal obtained by combining a combined signal of the dividing/combining circuit 51c and a combined signal of the coupler 51d.

[0045]

A 0-degree output terminal of the coupler 51f is electrically connected to the feed element 21C via the feed line 3. A 180-degree output terminal of the coupler 51f is electrically connected to the feed element 21H via the feed line 3. The coupler 51f transmits a combined signal obtained by combining a reception signal in the feed element 21C and a reception signal in the feed element 21H. One output terminal of the dividing/combining circuit 51g is electrically connected to the input terminal of the dividing/combining circuit 51e. The other output terminal of the dividing/combining circuit 51g is electrically connected to an input terminal of the coupler 51f. The dividing/combining circuit 51g transmits a combined signal obtained by combining a combined signal of the dividing/combining circuit 51e and a combined signal of the coupler 51f.

[0046]

A 0-degree output terminal of the coupler 51h is electrically

connected to the feed element 21B via the feed line 3. A 180-degree output terminal of the coupler 51h is electrically connected to the feed element 21G via the feed line 3. The coupler 51h transmits a combined signal obtained by combining a reception signal in the feed element 21B and a reception signal in the feed element 21G. One output terminal of the dividing/combining circuit 51i is electrically connected to the input terminal of the dividing/combining circuit 51g. The other output terminal of the dividing/combining circuit 51i is electrically connected to an input terminal of the coupler 51h. The dividing/combining circuit 51i transmits a combined signal obtained by combining a combined signal of the dividing/combining circuit 51g and a combined signal of the coupler 51h.

[0047]

One output terminal of the dividing/combining circuit 51j is electrically connected to the input terminal of the dividing/combining circuit 51i. The other output terminal of the dividing/combining circuit 51j is electrically connected to the feed element 21A via the feed line 3. The dividing/combining circuit 51j transmits, to a GPS receiver or the like, a combined signal obtained by combining a combined signal of the dividing/combining circuit 51i and a reception signal of the feed element 21A.

[0048]

By providing the low noise amplifiers between the feed elements and the divider/combiner, it is possible to adjust the gains of reception signals of the feed elements. As a result, it is possible to reduce the noise figure for the reception signals in the signal paths from the feed elements to the divider/combiner.

[0049]

In an example of GPS L1 frequency (1575.42 MHz), the

predetermined interval D1 and the predetermined interval D2 in the multi-path limiting antenna of the present disclosure are half the wavelength of the signals ( $\lambda/2 \approx 9.5$  cm). The feed lines from the feed elements to the divider/combiner of the multi-path limiting antenna may be about 200 cm  
5 in length (spacing  $20 \times 9.5$  cm+ routing length 10.0 cm). In a case where the feed lines connecting the feed elements to the divider/combiner are long, it is possible to obtain a remarkable effect of improving a carrier to noise density ratio (C/N0) by providing the low noise amplifiers in the feed elements as in the example embodiment of the present disclosure.

10 [0050]

Furthermore, by the control device 7 controlling the gains of the low noise amplifiers 216 for each of the circuit configurations of the divider/combiner 5 corresponding to the feed elements 21A to 21K, it is possible to correct differences in characteristics between the circuit  
15 configurations of the divider/combiner 5 in accordance with the manufacturing errors in the divider/combiner 5, and reduce distortion of the antenna pattern of the multi-path limiting antenna 2.

[0051]

[Other Example Embodiments]

20 Fig. 9 is a block diagram illustrating an antenna device according to an example embodiment of the present disclosure. An antenna device 9 includes an antenna 91, an amplification unit 92, and a combining unit 93. The antenna 91 receives signals. The amplification unit 92 amplifies the signals received by the antenna 91, and transmits the signals  
25 to the combining unit 93. The combining unit 93 combines the signals received from the amplification unit 92, and transmits the combined signals to a GPS receiver.

[0052]

The scope of each example embodiment also includes a processing

method of causing a recording medium to record a program for operating the configuration of each of the above example embodiments so as to achieve the functions of each of the above example embodiments, reading the program recorded in the recording medium as a code, and executing the program in a computer. That is, a computer-readable recording medium is also included in the scope of each example embodiment. Each example embodiment includes not only the recording medium in which the above-described computer program is recorded, but also the computer program itself.

[0053]

Examples of the recording medium to be used include a floppy (registered trademark) disk, a hard disk, an optical disk, a magneto-optical disk, a compact disc-read only memory (CD-ROM), a magnetic tape, a nonvolatile memory card, and a ROM. The scope of each example embodiment includes not only executing processing solely by the program recorded in the recording medium, but also executing processing by operation on an operating system (OS) in cooperation with other software and functions of an extension board.

[0054]

While the present disclosure has been particularly shown and described with reference to example embodiments thereof, the present disclosure is not limited to these example embodiments. It will be understood by those of ordinary skill in the art that various changes in form and detailed description may be made therein without departing from the spirit and scope of the present disclosure as defined by the claims. Each example embodiment can be appropriately combined with other example embodiments.

[0055]

According to the present example embodiment, it is possible to

provide an antenna device that reduces a noise figure for an antenna output.

[0056]

Some or all of the above example embodiments may also be  
5 described as, but are not limited to, the following Supplementary Notes.

[0057]

(Supplementary Note 1)

An antenna device including:

an antenna pole;

10 a first antenna disposed on the antenna pole;

a second antenna disposed on the antenna pole at a predetermined interval from the first antenna;

a combining unit that supplies power to the first antenna and combines signals received by the first antenna; and

15 an amplification unit that is connected between the first antenna and the combining unit and amplifies the signals.

[0058]

(Supplementary Note 2)

The antenna device according to Supplementary Note 1, in which  
20 the first antenna includes:

a plurality of dipole antennas; and

a connection unit that connects a pair of dipole antennas in the plurality of dipole antennas, and

the amplification units are provided between the plurality of dipole  
25 antennas and the connection unit.

[0059]

(Supplementary Note 3)

The antenna device according to Supplementary Note 1, in which the first antenna includes:

a plurality of dipole antennas;  
a first connection unit that connects a pair of dipole  
antennas in the plurality of dipole antennas; and  
a second connection unit that connects a pair of dipole  
5 antennas in the plurality of dipole antennas different from the pair of  
dipole antennas, and

the amplification units are provided between the first connection  
unit and the combining unit and between the second connection unit and  
the combining unit.

10 [0060]

(Supplementary Note 4)

The antenna device according to Supplementary Note 1, in which  
the first antenna includes:

a plurality of dipole antennas;  
15 a first connection unit that connects a pair of dipole  
antennas in the plurality of dipole antennas;  
a second connection unit that connects a pair of dipole  
antennas in the plurality of dipole antennas different from the pair of  
dipole antennas; and

20 a third connection unit that connects the first connection  
unit and the second connection unit, and

the amplification unit is provided between the third connection  
unit and the combining unit.

[0061]

25 (Supplementary Note 5)

The antenna device according to any one of Supplementary Notes 1  
to 4, in which

the second antenna includes a plurality of dipole antennas, and  
the plurality of dipole antennas in the second antenna are not

supplied with the power from the combining unit.

[0062]

(Supplementary Note 6)

The antenna device according to any one of Supplementary Notes 1  
5 to 5, in which the predetermined interval is less than half a wavelength of  
the signals.

[0063]

(Supplementary Note 7)

The antenna device according to any one of Supplementary Notes 1  
10 to 6, in which

a plurality of the first antennas are disposed on the antenna pole,  
and

a plurality of feed lines connecting the plurality of the first  
antennas and the combining unit are identical in length to each other.

15 [0064]

(Supplementary Note 8)

The antenna device according to Supplementary Note 2, in which  
the first connection unit connects the dipole antennas adjacent to each  
other.

20 [0065]

(Supplementary Note 9)

The antenna device according to any one of Supplementary Notes 3  
to 7, in which the first connection unit and the second connection unit  
connect the dipole antennas adjacent to each other.

25 [0066]

(Supplementary Note 10)

A method for controlling an antenna device including:

an antenna pole;

a first antenna disposed on the antenna pole; and

a second antenna disposed on the antenna pole at a predetermined interval from the first antenna,

in which the method for controlling the antenna device includes:

a combining step of supplying power to the first antenna

5 and combining signals received by the first antenna; and

an amplification step of amplifying the signals.

[0067]

(Supplementary Note 11)

The method for controlling the antenna device according to

10 Supplementary Note 10, in which

the first antenna includes:

a plurality of dipole antennas; and

a connection unit that connects a pair of dipole antennas in the plurality of dipole antennas, and

15 the amplification units are provided between the plurality of dipole antennas and the connection unit.

[0068]

(Supplementary Note 12)

The method for controlling the antenna device according to

20 Supplementary Note 10, in which

the first antenna includes:

a plurality of dipole antennas;

a first connection unit that connects a pair of dipole antennas in the plurality of dipole antennas; and

25 a second connection unit that connects a pair of dipole antennas in the plurality of dipole antennas different from the pair of dipole antennas, and

the amplification units are provided between the first connection unit and the combining unit and between the second connection unit and

the combining unit.

[0069]

(Supplementary Note 13)

The method for controlling the antenna device according to

5 Supplementary Note 10, in which

the first antenna includes:

a plurality of dipole antennas;

a first connection unit that connects a pair of dipole  
antennas in the plurality of dipole antennas;

10 a second connection unit that connects a pair of dipole  
antennas in the plurality of dipole antennas different from the pair of  
dipole antennas; and

a third connection unit that connects the first connection  
unit and the second connection unit, and

15 the amplification unit is provided between the third connection  
unit and the combining unit.

[0070]

(Supplementary Note 14)

The method for controlling the antenna device according to any

20 one of Supplementary Notes 10 to 13, in which

the second antenna includes a plurality of dipole antennas, and

the plurality of dipole antennas in the second antenna are not  
supplied with the power from the combining unit.

[0071]

25 (Supplementary Note 15)

The method for controlling the antenna device according to any  
one of Supplementary Notes 10 to 14, in which the predetermined interval  
is less than half a wavelength of the signals.

[0072]

(Supplementary Note 16)

The method for controlling the antenna device according to any one of Supplementary Notes 10 to 15, in which

a plurality of the first antennas are disposed on the antenna pole,

5 and

a plurality of feed lines connecting the plurality of the first antennas and the combining unit are identical in length to each other.

[0073]

(Supplementary Note 17)

10 The method for controlling the antenna device according to Supplementary Note 11, in which the first connection unit connects the dipole antennas adjacent to each other.

[0074]

(Supplementary Note 18)

15 The method for controlling the antenna device according to any one of Supplementary Notes 12 to 16, in which the first connection unit and the second connection unit connect the dipole antennas adjacent to each other.

Reference Signs List

20 [0075]

1 antenna device

2 multi-path limiting antenna

21 feed element

22 parasitic element

25 211 dipole antenna

212 installation fixture

213 circuit board

215 coupler

216 low noise amplifier

|    |     |                     |
|----|-----|---------------------|
|    | 217 | feed element output |
|    | 23  | antenna mast        |
|    | 3   | feed line           |
|    | 5   | divider/combiner    |
| 5  | 7   | control device      |
|    | 71  | CPU                 |
|    | 72  | ROM                 |
|    | 73  | RAM                 |
|    | 74  | storage device      |
| 10 | 75  | display device      |
|    | 76  | input/output IF     |
|    | 77  | communication IF    |
|    | 79  | bus                 |
|    | 9   | antenna device      |
| 15 | 91  | antenna             |
|    | 92  | amplification unit  |
|    | 93  | combining unit      |

## CLAIMS

### [Claim 1]

An antenna device comprising:

an antenna pole;

5 a first antenna disposed on the antenna pole;

a second antenna disposed on the antenna pole at a predetermined interval from the first antenna;

a combining unit that supplies power to the first antenna and combines signals received by the first antenna; and

10 an amplification unit that is connected between the first antenna and the combining unit and amplifies the signals.

### [Claim 2]

The antenna device according to claim 1, wherein

the first antenna includes:

15 a plurality of dipole antennas; and

a connection unit that connects a pair of dipole antennas in the plurality of dipole antennas, and

the amplification units are provided between the plurality of dipole antennas and the connection unit.

### 20 [Claim 3]

The antenna device according to claim 1, wherein

the first antenna includes:

a plurality of dipole antennas;

a first connection unit that connects a pair of dipole antennas in the plurality of dipole antennas; and

25 a second connection unit that connects a pair of dipole antennas in the plurality of dipole antennas different from the pair of dipole antennas, and

the amplification units are provided between the first connection

unit and the combining unit and between the second connection unit and the combining unit.

[Claim 4]

The antenna device according to claim 1, wherein

5 the first antenna includes:

a plurality of dipole antennas;

a first connection unit that connects a pair of dipole antennas in the plurality of dipole antennas;

a second connection unit that connects a pair of dipole antennas in the plurality of dipole antennas different from the pair of dipole antennas; and

a third connection unit that connects the first connection unit and the second connection unit, and

the amplification unit is provided between the third connection unit and the combining unit.

[Claim 5]

The antenna device according to any one of claims 1 to 4, wherein the second antenna includes a plurality of dipole antennas, and the plurality of dipole antennas in the second antenna are not

20 supplied with the power from the combining unit.

[Claim 6]

The antenna device according to any one of claims 1 to 5, wherein a plurality of the first antennas are disposed on the antenna pole, and

25 a plurality of feed lines connecting the plurality of the first antennas and the combining unit are identical in length to each other.

[Claim 7]

The antenna device according to claim 2, wherein the first connection unit connects the dipole antennas adjacent to

each other.

[Claim 8]

The antenna device according to any one of claims 3 to 6, wherein  
the first connection unit and the second connection unit connect  
5 the dipole antennas adjacent to each other.

[Claim 9]

A method for controlling an antenna device including:  
an antenna pole;  
a first antenna disposed on the antenna pole; and  
10 a second antenna disposed on the antenna pole at a predetermined  
interval from the first antenna,  
wherein the control method comprises:  
supplying power to the first antenna and combining signals  
received by the first antenna; and  
15 amplifying the signals.