(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 4 131 653 A1

(12) EUROPEAN PATENT APPLICATION
published in accordance with Art. 153(4) EPC

(43) Date of publication:
08.02.2023 Bulletin 2023/06

(21) Application number: 21775949.7

(22) Date of filing: 10.02.2021

(51) International Patent Classification (IPC):
H01Q 15/02 (1968.09) H01Q 19/06 (1968.09)

(52) Cooperative Patent Classification (CPC):
H01P 1/00; H01Q 1/50; H01Q 1/52; H01Q 15/02; H01Q 15/14; H01Q 19/06

(86) International application number:
PCT/JP2021/005055

(87) International publication number:
WO 2021/192694 (30.09.2021 Gazette 2021/39)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(30) Priority: 27.03.2020 JP 2020058849

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(54) TERMINAL AND COMMUNICATION METHOD

(57) A terminal (200) comprises: a control unit (203) which determines a direction of transmitting a radio wave on the basis of a direction of arrival of a desired wave or a direction of arrival of an interference wave; and a transmission direction restriction unit (205) which is provided near an antenna (204) and restricts the direction of transmitting the radio wave in accordance with the determination of the control unit (203). The transmission direction restriction unit (205) includes a plurality of metasurface units each including a metasurface substrate, and a dielectric substrate arranged to be opposed to the metasurface substrate. The control unit (203) adjusts the distance between the metasurface substrate and the dielectric substrate of each metasurface unit.

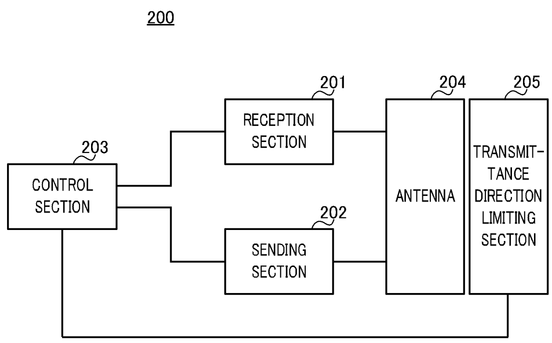

FIG. 2

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Description

Technical Field

[0001] The present disclosure relates to a terminal and a communication method.

Background Art

[0002] Long Term Evolution (LTE) has been specified for achieving a higher data rate, lower latency, and the like in a Universal Mobile Telecommunication System (UMTS) network. Future systems of LTE have also been studied for achieving a broader bandwidth and a higher speed based on LTE. Examples of the future systems of LTE include systems called LTE-Advanced (LTE-A), Future Radio Access (FRA), 5th generation mobile communication system (5G), 5G plus (5G+), Radio Access Technology (New-RAT), New Radio (NR), and the like.

[0003] Radio communication systems since 5G realize high-speed, large-capacity, and low-delay radio communication, using radio waves in a high frequency band (millimeter wave band). Radio waves in a high frequency band have high linearity, and thus the communication quality significantly degrades in a non-line-of-sight area from a base station.

[0004] Further, in 5G, a large-scale (Massive) Multiple Input Multiple Output (MIMO) that forms a sharp directivity by using a large number of antenna elements (e.g., 100 elements or more) in a high frequency band (e.g., Non-Patent Literature (hereinafter, referred to as NPL) 1) is used to realize further high-speed and interference reduction of signal transmission.

[0005] In addition, in 5G, a radio communication system that combines a small cell using a high frequency band with a Massive MIMO has been considered to deal with explosively-increasing mobile communication traffic. This enables wideband communication, and also compensation for propagation loss in a high frequency band and spatial multiplexing of a plurality of streams.

Citation List

Non-Patent Literature

[0006] NPL 1
3GPP TS 36.300 V8.12.0 "Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2 (Release 8), April 2010

Summary of Invention

[0007] However, a terminal, which is a small device, is difficult to form a sharp directivity since the antenna space is limited and the number of antenna elements is thus limited. Because of this, the influence of an interference wave (delayed wave, reflected wave) coming from a direction other than an arrival direction of a desired wave cannot be sufficiently reduced, and thus the deterioration of the reception quality is concerned.

[0008] One object of the present disclosure is to sufficiently reduce the influence of an interference wave in a terminal having a limited antenna space.

Solution to Problem

[0009] A terminal according to an embodiment of the present disclosure includes: a control section that determines a direction of transmitting a radio wave based on an arrival direction of a desired wave or an arrival direction of an interference wave; and a transmittance direction limiting section that limits a direction of transmitting a radio wave in accordance with the determination of the control section.

[0010] A communication method for the terminal according to the embodiment of the present disclosure determines a direction of transmitting a radio wave based on an arrival direction of a desired wave or an arrival direction of an interference wave, and limits a direction of transmitting a radio wave in accordance with the determination.

Advantage Effects of Invention

[0011] According to the present disclosure, it is possible to sufficiently reduce the influence of an interference wave in a terminal having a limited antenna space.

Brief Description of Drawings

[0012]

FIG. 1 is a diagram illustrating an exemplary configuration of a radio communication system;
FIG. 2 is a block diagram illustrating an exemplary configuration of a terminal;
FIG. 3A is a perspective view of an exemplary metasurface unit;
FIG. 3B is a perspective view of an exemplary dielectric substrate of the metasurface unit;
FIG. 3C is a perspective view of an exemplary metasurface substrate of the metasurface unit;
FIG. 4A is a diagram illustrating an exemplary pattern of a unit cell;
FIG. 4B is a diagram illustrating another exemplary pattern of the unit cell;
FIG. 4C is a diagram illustrating still another exemplary pattern of the unit cell;
FIG. 4D is a diagram illustrating yet another exemplary pattern of the unit cell;
FIG. 5 is a side sectional view of an exemplary metasurface unit;
FIG. 6 is a side sectional view of another exemplary metasurface unit;
FIG. 7A is a diagram illustrating an exemplary re-

flectance and transmittance of the metasurface unit;

FIG. 7B is a diagram illustrating another exemplary reflectance and transmittance of the metasurface unit;

FIG. 7C is a diagram illustrating still another exemplary reflectance and transmittance of the metasurface unit;

FIG. 7D is a diagram illustrating yet another exemplary reflectance and transmittance of the metasurface unit;

FIG. 8 is a diagram illustrating an exemplary transmittance direction limiting process;

FIG. 9 is an overhead view of a large antenna; and

FIG. 10 is a diagram illustrating an exemplary hardware configuration of a base station and a terminal.

Description of Embodiments

[0013] An embodiment will be described below with appropriate reference to the accompanying drawings. The same components are denoted by the same reference numerals throughout the present description unless otherwise specified. The following descriptions given in conjunction with the accompanying drawings are for explaining an exemplary embodiment but not for specifying the only embodiment. For example, in the case where the order of operations is described in the embodiment, the order of the operations may be appropriately changed as long as no inconsistency occurs in the operations as a whole.

[0014] When a plurality of embodiments and/or modifications are illustrated, some configurations, functions and/or operations in a certain embodiment and/or modification may be included in other embodiments and/or modifications, or may be replaced by corresponding configurations, functions and/or operations of other embodiments and/or modifications as long as no inconsistency occurs.

[0015] In addition, in the embodiment, an unnecessarily detailed description may be omitted. For example, detailed descriptions of publicly known or well-known technical matters may be omitted in order to avoid unnecessarily redundant descriptions and/or obscuring technical matters or concepts, so as to facilitate understanding by a person skilled in the art. In addition, duplicate descriptions of substantially the same configurations, functions, and/or operations may be omitted.

[0016] The accompanying drawings and the following description are provided to assist a person skilled in the art to understand the embodiment, but are not intended to limit the claimed subject. In addition, the terms used in the following description may be appropriately replaced with other terms to aid the understanding of a person skilled in the art.

<Configuration of radio communication system>

[0017] FIG. 1 is a diagram illustrating an exemplary configuration of a radio communication system according to an embodiment of the present disclosure. Radio communication system 1 illustrated in FIG. 1 includes: base station (sometimes referred to as a radio base station or gNB) 100 including a plurality of sending points 10a to 10i and signal processing device 11; and at least one terminal (sometimes referred to as a radio terminal or User Equipment (UE)) 200.

[0018] Each of sending points 10a to 10i has one or more antenna elements. Further, each of sending points 10a to 10i is connected to signal processing device 11. Note that sending point 10 may be referred to as "radio transceiver", "extension station" or "Remote Radio Head (RRH)". Further, a signal processing device may be referred to as "Baseband processing Unit (BBU)".

[0019] Sending points 10a to 10i perform radio communication with subordinate (e.g., in a cell) terminal 200. Base station 100 selects at least one sending point 10 among sending points 10a to 10i in accordance with the movement of terminal 200. The selected sending point 10 sends a signal to terminal 200.

[0020] Signal processing device 11 performs signal processing of a signal to be sent to terminal 200. The processed signal is output to at least one of sending points 10a to 10i and sent by radio to terminal 200. Further, signal processing device 11 receives signals that sending points 10a to 10i receive from terminal 200 from sending points 10a to 10i, respectively.

<Configuration of terminal>

[0021] FIG. 2 is a block diagram illustrating an exemplary configuration of terminal 200. Terminal 200 includes reception section 201, sending section 202, control section 203, antenna 204, and transmittance direction limiting section 205, for example. Terminal 200 communicates by radio with base station 100 (sending point 10), for example.

[0022] Reception section 201 receives a downlink (DL) radio-frequency signal sent from base station 100 through antenna 204, and performs a reception process, such as a downconversion, a demodulation process, and a decoding process, to the DL signal under the control of control section 203.

[0023] Sending section 202 performs a sending process, such as an encoding process, a modulation process, and an upconversion, to an uplink (DL) under the control of control section 203, and sends the UL radio-frequency signal to base station 100 through antenna 204.

[0024] Control section 203 controls communication operation of terminal 200. The communication operation includes the reception process in reception section 201 and the sending process in sending section 202. For example, control section 203 receives data, control information, and the like from an upper layer, and outputs to sending section 202. Further, for example, control section 203 outputs data and control information received from reception section 201 to an upper layer.

[0025] In addition, control section 203 determines a direction of transmitting (hereinafter, the term "transmit" means to pass through) a radio wave based on an arrival direction of an interference wave or an arrival direction of a desired wave, and controls transmittance direction limiting section 205 so that the desired wave is transmitted and the interference wave is shielded.

[0026] Transmittance direction limiting section 205 is provided close to antenna 204, and controls the direction of transmitting a radio wave, that is, controls a reception direction and a sending direction (radiation direction) of the radio wave in antenna 204, under the control of control section 203. Note that details of the configuration of transmittance direction limiting section 205 will be described later.

<Configuration of transmittance direction limiting section>

[0027] Next, the configuration of transmittance direction limiting section 205 will be described in detail.

[0028] Transmittance direction limiting section 205 uses a metasurface to limit the direction of transmitting a radio wave. The metasurface is a kind of artificial medium (metamaterial) that realizes predetermined permittivity and permeability by periodically arranging small structures relative to a wavelength, and is an artificial surface on which the periodic arrangement of the structures is two-dimensional. The metasurface has a feature that the reflection phase of a radio wave incident on the surface can be controlled.

[0029] Transmittance direction limiting section 205 has a plurality of metasurface units 20. FIG. 3A is a perspective view of an example of metasurface unit 20. FIG. 3B is a perspective view of an example of dielectric substrate 21 of metasurface unit 20. FIG. 3C is a perspective view of an example of metasurface substrate 22 of metasurface unit 20.

[0030] Metasurface unit 20 includes dielectric substrate 21 and metasurface substrate 22. Note that dielectric substrate 21 may be referred to as a movable substrate. Metasurface substrate 22 may be referred to as a metasurface reflector or a metasurface.

[0031] Dielectric substrate 21 and metasurface substrate 22 have square shapes, for example. Although not illustrated in FIGS. 3A to 3C, metasurface unit 20 includes connecting members that connect between dielectric substrate 21 and metasurface substrate 22 (e.g., see FIGS. 5 and 6).

[0032] Dielectric substrate 21 and metasurface substrate 22 are arranged to face each other as illustrated in FIG. 3A. A radio wave sent from base station 100 is made incident from the surface of dielectric substrate 22 opposite to the surface facing dielectric substrate 21. For example, a radio wave sent from base station 100 is made incident from the direction indicated by arrow A11 in FIG. 3A.

[0033] Transmittance direction limiting section 205 changes the distance between dielectric substrate 21 and metasurface substrate 22 in each metasurface unit 20 to change the transmittance of a radio wave, under the control of control section 203. For example, transmittance direction limiting section 205 changes distance D between the surfaces on which dielectric substrate 21 and metasurface substrate 22 illustrated in FIG. 3A face with each other. Distance D changes, for example, within a range of 0 μm or more and 500 μm or less when the frequency of the incident radio wave is 28 GHz. The distance between dielectric substrate 21 and metasurface substrate 22 may be referred to as a gap between dielectric substrate 21 and metasurface substrate 22.

[0034] Dielectric substrate 21 and metasurface substrate 22 may be made of, for example, a material of glass, Teflon (registered trademark), or acrylic resin. Also, dielectric substrate 21 and metasurface substrate 22 may be made of a printed substrate. Dielectric substrate 21 and metasurface substrate 22 may be made of the same material or may be made of different materials.

[0035] When different materials are used for dielectric substrate 21 and metasurface substrate 22, it is preferred to select the materials so that the permittivity of dielectric substrate 21 is larger than the permittivity of metasurface substrate 22. When the permittivity of dielectric substrate 21 is larger than the permittivity of metasurface substrate 22, the transmittance of metasurface unit 20 greatly changes relative to the small amount of change of distance D. That is, the response of the transmittance with respect to distance D is enhanced.

[0036] A metal film is not formed on dielectric substrate 21. While, a plurality of unit cells 22a are formed on metasurface substrate 22 as illustrated in FIG. 3C. Unit cell 22a is a pattern of a metal film.

[0037] Unit cells 22a may be different in size depending on the position on dielectric substrate 21. Unit cells 22a may have the same shape, or may have different shapes depending on the position on dielectric substrate 21. When the shapes of unit cells 22a are different from each other depending on the positions on dielectric substrate 21, the widths of gaps described in the following FIGS. 4A to 4D may be different depending on the position on dielectric substrate 21.

[0038] Unit cell 22a is formed on the surface of metasurface substrate 22 and on the surface on the side facing dielectric substrate 21. The size of unit cell 22a (vertical × horizontal) is, for example, set in the range of 1/10 or more to 1/5 or less of the wavelength of the incident radio wave.

[0039] FIGS. 4A to 4D are diagrams illustrating exemplary patterns of unit cell 22a. Unit cell 22a formed on metasurface substrate 22 may have the pattern shapes illustrated in FIGS. 4A to 4D.

[0040] Unit cell 22a has a pattern shape in which an electric field is locally concentrated. For example, unit cell 22a includes gap G1 as illustrated in FIGS. 4A to 4D. The electric field is locally concentrated in gap G1 of unit cell 22a. This configuration allows the transmittance of metasurface unit 20 to change greatly relative to a small amount of change of distance D.

[0041] The type of the pattern shape of unit cell 22a formed on metasurface substrate 22 may be one or a combination of two or more. For example, unit cells 22a formed on metasurface substrate 22 may be combinations of two or more of the pattern shapes illustrated in FIGS. 4A to 4D.

[0042] FIG. 5 is a side sectional view of an example of metasurface unit 20. The same components as those in FIGS. 3A to 3C are denoted by the same reference numerals in FIG. 5.

[0043] As illustrated in FIG. 5, metasurface unit 20 includes connecting members 31. Connecting members 31 are provided, for example, at the four corners of dielectric substrate 21 and metasurface substrate 22, and connects between dielectric substrate 21 and metasurface substrate 22.

[0044] Connecting members 31 each includes adjusting section 32. Adjusting section 32 may be, for example, a piezoelectric actuator. Adjusting section 32 extends and contracts in accordance with the control of control section 203, and adjusts (changes) the distance between dielectric substrate 21 and metasurface substrate 22. Note that adjusting section 32 may be referred to as an actuator.

[0045] In the example of FIG. 5, as adjusting section 32 extends, dielectric substrate 21 is away from metasurface substrate 22 and the distance between dielectric substrate 21 and metasurface substrate 22 is larger. As adjusting section 32 contracts, dielectric substrate 21 is closer to metasurface substrate 22 and the distance between dielectric substrate 21 and metasurface substrate 22 is smaller.

[0046] Adjusting sections 32 of the four connecting members 31 provided at the four corners of dielectric substrate 21 and metasurface substrate 22 may extend and contract in the same size, and may extend and contract in different sizes. Some of adjusting sections 32 of the four connecting members 31 provided at the four corners of dielectric substrate 21 and metasurface substrate 22 may extend and the rest may contract.

[0047] Based on this operation of adjusting section 32, dielectric substrate 21 and metasurface substrate 22 can be parallel to each other. Also, the distance between dielectric substrate 21 and metasurface substrate 22 can be changed in a parallel state.

[0048] Further, based on the operation of adjusting section 32, dielectric substrate 21 and metasurface substrate 22 can be non-parallel to each other (e.g., can be in a state in which dielectric substrate 21 is tilted with respect to metasurface substrate 22). In addition, the distance between dielectric substrate 21 and metasurface substrate 22 can be changed in a non-parallel state.

[0049] FIG. 6 is a side sectional view of another example of metasurface unit 20. The same components as those in FIGS. 3A to 3C are denoted by the same reference numerals in FIG. 6.

[0050] As illustrated in FIG. 6, metasurface unit 20 includes connecting members 41. Connecting members 41 are provided, for example, at the four corners of dielectric substrate 21 and metasurface substrate 22, and connects between dielectric substrate 21 and metasurface substrate 22.

[0051] Connecting members 41 each includes adjusting section 42. Adjusting section 42 may be, for example, a piezoelectric actuator. Adjusting section 42 extends and contracts in accordance with the control of control section 203, and adjusts (changes) the distance between dielectric substrate 21 and metasurface substrate 22.

[0052] In the example of FIG. 6, as adjusting section 42 extends, dielectric substrate 21 is closer to metasurface substrate 22 and the distance between dielectric substrate 21 and metasurface substrate 22 is smaller. As adjusting section 42 contracts, dielectric substrate 21 is away from metasurface substrate 22 and the distance between dielectric substrate 21 and metasurface substrate 22 is larger.

[0053] Adjusting sections 42 of the four connecting members 41 provided at the four corners of dielectric substrate 21 and metasurface substrate 22 may extend and contract in the same size, and may extend and contract in different sizes. Some of adjusting sections 42 of the four connecting members 41 provided at the four corners of dielectric substrate 21 and metasurface substrate 22 may extend and the rest may contract.

[0054] Based on this operation of adjusting section 42, dielectric substrate 21 and metasurface substrate 22 can be parallel to each other. Also, the distance between dielectric substrate 21 and metasurface substrate 22 can be changed in a parallel state.

[0055] Further, based on the operation of adjusting section 42, dielectric substrate 21 and metasurface substrate 22 can be non-parallel to each other. In addition, the distance between dielectric substrate 21 and metasurface substrate 22 can be changed in a non-parallel state.

[0056] Note that connecting members 31 and 41 may be provided in a peripherally dispersed manner between dielectric substrate 21 and metasurface substrate 22.

[0057] Further, adjusting sections 32 and 42 are not limited to piezoelectric actuators. Adjusting sections 32 and 42 may be any components as long as they are capable of adjusting the distance between dielectric substrate 21 and metasurface substrate 22. For example, adjusting sections 32 and 42 may be tubes taking air in and out.

[0058] FIGS. 7A to 7D are diagrams illustrating an exemplary transmittance of metasurface unit 20. FIGS. 7A to 7D each illustrate dielectric substrate 21 and metasurface substrate 22. Arrow A21 illustrated in FIGS. 7A to 7D indicates an incident wave of a radio wave. Arrow A22 indicates a reflection wave of a radio wave. Arrow A23 indicates a transmittance wave of a radio wave.

[0059] FIGS. 7A, 7B, and 7C each illustrate a graph of a transmittance with respect to the frequency of metasurface unit 20. The operation frequency illustrated in FIGS. 7A, 7B, and 7C is a frequency of a radio wave made incident to metasurface unit 20.

[0060] As illustrated in the graphs of FIGS. 7A, 7B, and 7C, the transmittance of metasurface unit 20 is the smallest at the resonant frequency. The shielding rate (reflectance) of metasurface unit 20 is the largest at the resonant frequency.

[0061] The resonant frequency of the transmittance of metasurface unit 20 changes in accordance with the distance between dielectric substrate 21 and metasurface substrate 22. For example, as the distance between dielectric substrate 21 and metasurface substrate 22 decreases, the resonant frequency of the transmittance of metasurface unit 20 is smaller.

[0062] FIG. 7A illustrates a graph of the transmittance of metasurface unit 20 when the distance between dielectric substrate 21 and metasurface substrate 22 is D1. When the distance between dielectric substrate 21 and metasurface substrate 22 is D1, the resonant frequency of the transmittance of metasurface unit 20 is overlapped with the operation frequency.

[0063] That is, when the distance between dielectric substrate 21 and metasurface substrate 22 is D1, the transmittance of metasurface unit 20 is the smallest. In other words, when the distance between dielectric substrate 21 and metasurface substrate 22 is D1, the shielding rate (reflectance) of metasurface unit 20 is the largest.

[0064] Note that the resonant frequency of the transmittance when the distance between dielectric substrate 21 and metasurface substrate 22 is D1 can be matched with the operation frequency based on, for example, the pattern shape, size, and the like of unit cell 22a.

[0065] FIG. 7B illustrates a graph of the transmittance of metasurface unit 20 when the distance between dielectric substrate 21 and metasurface substrate 22 is zero (dielectric substrate 21 and metasurface substrate 22 are in contact with each other). When the distance between dielectric substrate 21 and metasurface substrate 22 is zero, the resonant frequency of the transmittance of metasurface unit 20 is shifted to a frequency below the operation frequency.

[0066] That is, when the distance between dielectric substrate 21 and metasurface substrate 22 is zero, the transmittance of metasurface unit 20 is larger. In other words, the shielding rate (reflectance) of metasurface unit 20 is smaller.

[0067] Note that the transmittance when the distance between dielectric substrate 21 and metasurface substrate 22 is zero can be adjusted to be the largest based on the pattern shape, size, and the like of unit cell 22a.

[0068] FIG. 7C illustrates a graph of the transmittance of metasurface unit 20 when the distance between dielectric substrate 21 and metasurface substrate 22 is larger than zero and less than D1 (in case of distance D2). When the distance between dielectric substrate 21 and metasurface substrate 22 is D2, the resonant frequency of the transmittance of metasurface unit 20 is positioned between the resonant frequency illustrated in FIG. 7A and the resonant frequency illustrated in FIG. 7B.

[0069] Thus, metasurface unit 20 can transmit some part of the incident radio wave and reflect some part of the radio wave. Note that the state in which metasurface unit 20 transmits some part of a radio wave and reflects some part of the radio wave may be referred to as scattering.

[0070] FIG. 7D illustrates a state in which dielectric substrate 21 is tilted with respect to metasurface substrate 22. When dielectric substrate 21 is tilted with respect to metasurface substrate 22, the transmitted radio wave can be deflected.

[0071] FIG. 8 is a diagram illustrating an exemplary transmittance direction limiting process. In the example of FIG. 8, it is assumed that a desired wave has reached antenna 204 through metasurface unit 20-1 and an interference wave has reached antenna 204 through metasurface unit 20-2.

[0072] In this case, terminal 200 (control section 203) controls the distance between dielectric substrate 21 and metasurface substrate 22 in metasurface unit 20-1 so that the transmittance of metasurface unit 20-1 is the largest. Further, terminal 200 (control section 203) controls the distance between dielectric substrate 21 and metasurface substrate 22 in metasurface unit 20-2 so that the transmittance of metasurface unit 20-2 is the smallest.

[0073] Thus, antenna 204 receives the radio wave (desired wave) transmitted through metasurface unit 20-1. On the other hand, antenna 204 does not receive the interference wave due to the shielding of metasurface unit 20-2.

[0074] According to the embodiment as described above, terminal 200 (control section 203) limits the direction of transmitting a radio wave by controlling transmittance direction limiting section 205 (metasurface unit 20).

[0075] This allows terminal 200 of the limited antenna space to control the directivity (transmittance direction) of the radio wave to form a sharp directivity, and thus can sufficiently reduce the influence of an interference wave.

[0076] Note that a plurality of directions in which radio waves are transmitted can be formed in the present disclosure. This can further enhance reception quality when the reception process using a reflection wave is performed or the like.

(Variation 1)

[0077] In Variation 1, a case where the present disclosure is applied to a large antenna such as an onboard antenna will be described.

[0078] A large antenna can form some degree of sharp directivity in a plurality of directions. Application of the present disclosure to the large antenna can form even sharper directivity.

[0079] FIG. 9 is an overhead view of large antenna 204a. In the example of FIG. 9, large antenna 204a is disposed on a ceiling portion or the like of a railway vehicle, and has a cylindrical shape.

[0080] As illustrated in FIG. 9, transmittance direction limiting section 205a (metasurface unit 20a) is provided on the outer periphery of large antenna 204a (the side surface of the cylindrical shape).

[0081] In this case, the apparatus including large antenna 204a controls transmittance direction limiting section 205a (metasurface unit 20a) so that the transmittance of a desired wave is large and the transmittance of an interference wave is small.

[0082] As described above, according to Variation 1, the apparatus including large antenna 204a physically limits the direction in which a radio wave is transmitted, by controlling the transmittance direction limiting section 205a (metasurface unit 20a).

[0083] Thus, the directivity (transmittance direction) of the radio wave can be physically controlled, and the load of signal processing such as beam control can be reduced.

(Variation 2)

[0084] In Variation 2, a case where an arrival direction of a desired wave is predicted when terminal 200 moves, and terminal 200 controls the directivity (transmittance direction) of a radio wave based on the prediction result will be described.

[0085] In this case, terminal 200 stores the arrival direction of the past desired wave and predicts the arrival direction of the next desired wave based on the amount of change in the arrival direction.

[0086] For example, when the arrival direction of the desired wave at the past reception timing t_{-1} is θ_{-1} and the arrival direction of the desired wave at the current reception timing t_0 is θ_0, change amount α of the arrival direction from reception timing t_{-1} to reception timing t_0 is $\alpha = \theta_0 - \theta_{-1}$.

[0087] Terminal 200 predicts arrival direction θ_1 of the desired wave at the next reception timing t_1 as $\theta_1 = \theta_0 + \alpha = 2\theta_0 - \theta_{-1}$. Then, terminal 200 controls the directivity (transmittance direction) of the radio wave so as to transmit a radio wave in the predicted arrival direction of the desired wave.

[0088] As described above, according to Variation 2, terminal 200 predicts the arrival direction of the desired wave based on the amount of change in the arrival direction of the past desired wave, and controls the directivity (transmission direction) of the radio wave based on the prediction result. This enables reduction of the time of the beam search.

[0089] The embodiment has been described above.

(Hardware Configuration)

[0090] Note that, the block diagrams used to describe the above embodiment illustrate blocks on a function-by-function basis. These functional blocks (component sections) are implemented by any combination of at least hardware or software. A method for implementing the functional blocks is not particularly limited. That is, the functional blocks may be implemented using one physically or logically coupled apparatus. Two or more physically or logically separate apparatuses may be directly or indirectly connected (for example, via wires or wirelessly), and the plurality of apparatuses may be used to implement the functional blocks. The functional blocks may be implemented by combining software with the one apparatus or the plurality of apparatuses described above.

[0091] The functions include, but not limited to, judging, deciding, determining, computing, calculating, processing, deriving, investigating, searching, confirming, receiving, transmitting, outputting, accessing, solving, selecting, choosing, establishing, comparing, supposing, expecting, regarding, broadcasting, notifying, communicating, forwarding, configuring, reconfiguring, allocating, mapping, assigning, and the like. For example, a functional block (component section) that functions to achieve transmission is referred to as "transmitting unit," "transmission section ," or "transmitter." The methods for implementing the functions are not limited specifically as described above.

[0092] For example, the base station, terminal, and the like according to an embodiment of the present disclosure may function as a computer that executes processing of a radio communication method of the present disclosure. FIG. 10 illustrates an exemplary hardware configuration of the base station and the terminal according to one embodiment of the present disclosure. Physically, terminal 200 as described above may be a computer apparatus including processor 1001, memory 1002, storage 1003, communication apparatus 1004, input apparatus 1005, output apparatus 1006, bus 1007, and the like.

[0093] Note that the term "apparatus" in the following description can be replaced with a circuit, a device, a unit, or the like. The hardware configurations of terminal 200 may include one apparatus or a plurality of apparatuses, or may not include part of the apparatuses.

[0094] Each function of terminal 200 is implemented by predetermined software (program) loaded into hardware, such as processor 1001, memory 1002, and the like, according to which processor 1001 performs the arithmetic and controls communication performed by communication apparatus 1004 or at least one of reading and writing of data in memory 1002 and storage 1003.

[0095] Processor 1001 operates an operating system to entirely control the computer, for example. Processor 1001 may be composed of a central processing unit (CPU) including an interface with peripheral apparatuses, control apparatus, arithmetic apparatus, register, and the like. For example, control section 203 and the like described above may be implemented using processor 1001.

[0096] Processor 1001 reads a program (program code), a software module, data, and the like from at least one of storage 1003 and communication apparatus 1004 to memory 1002 and performs various types of processing according to the program (program code), the software module, the data, and the like. As the program, a program for causing the computer to perform at least a part of the operation described in the above embodiments is used. For example, control section 203 of terminal 200 may be implemented using a control program stored in memory 1002 and operated by processor 1001, and the other functional blocks may also be implemented in the same way. While it has been described that the various types of processing as described above are performed by one processor 1001, the various types of processing may be performed by two or more processors 1001 at the same time or in succession. Processor 1001 may be implemented using one or more chips. Note that the program may be transmitted from a network through a telecommunication line.

[0097] Memory 1002 is a computer-readable recording medium and may be composed of, for example, at least one of a Read Only Memory (ROM), an Erasable Programmable ROM (EPROM), an Electrically Erasable Programmable ROM (EEPROM), and a Random Access Memory (RAM). Memory 1002 may be called as a register, a cache, a main memory (main storage apparatus), or the like. Memory 1002 can save a program (program code), a software module, and the like that can be executed to carry out the radio communication method according to an embodiment of the present disclosure.

[0098] Storage 1003 is a computer-readable recording medium and may be composed of, for example, at least one of an optical disk such as a Compact Disc ROM (CD-ROM), a hard disk drive, a flexible disk, a magneto-optical disk (for example, a compact disc, a digital versatile disc, or a Blu-ray (registered trademark) disc), a smart card, a flash memory (for example, a card, a stick, or a key drive), a floppy (registered trademark) disk, and a magnetic strip. Storage 1003 may also be called as an auxiliary storage apparatus. The storage medium as described above may be, for example, a database, a server, or other appropriate media including at least one of memory 1002 and storage 1003.

[0099] Communication apparatus 1004 is hardware (transmission and reception device) for communication between computers through at least one of wired and wireless networks and is also called as, for example, a network device, a network control section, a network card, or a communication module. Communication apparatus 1004 may be configured to include a high frequency switch, a duplexer, a filter, a frequency synthesizer, and the like in order to achieve at least one of Frequency Division Duplex (FDD) and Time Division Duplex (TDD), for example. For example, reception section 201, sending section 202, and the like described above may be implemented using communication apparatus 1004.

[0100] Input apparatus 1005 is an input device (for example, a keyboard, a mouse, a microphone, a switch, a button, or a sensor) that receives input from the outside. Output apparatus 1006 is an output device (for example, a display, a speaker, or an LED lamp) which makes outputs to the outside. Note that input apparatus 1005 and output apparatus 1006 may be integrated (for example, a touch panel).

[0101] The apparatuses, such as processor 1001, memory 1002, and the like are connected by bus 1007 for communication of information. Bus 1007 may be configured using a single bus or using buses different between each pair of the apparatuses.

[0102] Furthermore, terminal 200 may include hardware, such as a microprocessor, a digital signal processor (DSP), an Application Specific Integrated Circuit (ASIC), a Programmable Logic Device (PLD), and a Field Programmable Gate Array (FPGA), and the hardware may implement part or all of the functional blocks. For example, processor 1001 may be implemented using at least one of these pieces of hardware.

(Notification of Information and Signaling)

[0103] The notification of information is not limited to the aspects or embodiments described in the present disclosure, and the information may be notified by another method. For example, the notification of information may be carried out by one or a combination of physical layer signaling (for example, Downlink Control Information (DCI) and Uplink Control Information (UCI)), upper layer signaling (for example, Radio Resource Control (RRC) signaling, Medium Access Control (MAC) signaling, notification information (Master Information Block (MIB), and System Information Block (SIB))), and other signals. The RRC signaling may be called an RRC message and may be, for example, an RRC connection setup message, an RRC connection reconfiguration message, or the like.

(Applied System)

[0104] The aspects and embodiments described in the present disclosure may be applied to at least one of a system using Long Term Evolution (LTE), LTE-Advanced (LTE-A), SUPER 3G, IMT-Advanced, 4th generation mobile communication system (4G), 5th generation mobile communication system (5G), Future Radio Access (FRA), New Radio (NR), W-CDMA (registered trademark), GSM (registered trademark), CDMA2000, Ultra Mobile Broadband (UMB), IEEE 802.11 (Wi-Fi (registered trademark)), IEEE 802.16 (WiMAX (registered trademark)), IEEE 802.20, Ultra-WideBand (UWB), Bluetooth (registered trademark), or other appropriate systems and a next-generation system extended based on the above systems. Additionally or alternatively, a combination of two or more of the systems (e.g., a combination of at least LTE or LTE-A and 5G) may be applied.

(Processing Procedure and the like)

[0105] The orders of the processing procedures, the sequences, the flow charts, and the like of the aspects and embodiments described in the present disclosure may be changed as long as there is no contradiction. For example, elements of various steps are presented in exemplary orders in the methods described in the present disclosure, and the methods are not limited to the presented specific orders.

(Operation of Base Station)

[0106] Specific operations which are described in the present disclosure as being performed by the base station may sometimes be performed by an upper node depending on the situation. Various operations performed for communication with a terminal in a network constituted by one network node or a plurality of network nodes including a base station can be obviously performed by at least one of the base station and a network node other than the base station (examples include, but not limited to, Mobility Management Entity (MME) or Serving Gateway (S-GW)). Although there is one network node in addition to the base station in the case illustrated above, a plurality of other network nodes may be combined (for example, MME and S-GW).

(Direction of Input and Output)

[0107] The information or the like (see the item of "Information and Signals") can be output from a higher layer (or a lower layer) to a lower layer (or a higher layer). The information, the signals, and the like may be input and output through a plurality of network nodes.

(Handling of Input and Output Information and the like)

[0108] The input and output information and the like may be saved in a specific place (for example, memory) or may be managed using a management table. The input and output information and the like can be overwritten, updated, or additionally written. The output information and the like may be deleted. The input information and the like may be transmitted to another apparatus.

(Determination Method)

[0109] The determination may be made based on a value expressed by one bit (0 or 1), based on a Boolean value (true or false), or based on comparison with a numerical value (for example, comparison with a predetermined value).

(Software)

[0110] Regardless of whether the software is called as software, firmware, middleware, a microcode, or a hardware description language or by another name, the software should be broadly interpreted to mean an instruction, an instruction set, a code, a code segment, a program code, a program, a subprogram, a software module, an application, a software application, a software package, a routine, a subroutine, an object, an executable file, an execution thread, a procedure, a function, and the like.

[0111] The software, the instruction, the information, and the like may be transmitted and received through a transmission medium. For example, when the software is transmitted from a website, a server, or another remote source by using at least one of a wired technique (e.g., a coaxial cable, an optical fiber cable, a twisted pair, and a digital subscriber line (DSL)) and a wireless technique (e.g., an infrared ray and a microwave), the at least one of the wired technique and the wireless technique is included in the definition of the transmission medium.

(Information and Signals)

[0112] The information, the signals, and the like described in the present disclosure may be expressed by using any of various different techniques. For example, data, instructions, commands, information, signals, bits, symbols, chips, and the like that may be mentioned throughout the entire description may be expressed by one or an arbitrary combination of voltage, current, electromagnetic waves, magnetic fields, magnetic particles, optical fields, and photons.

[0113] Note that the terms described in the present disclosure and the terms necessary to understand the present disclosure may be replaced with terms with the same or similar meaning. For example, at least one of the channel and the symbol may be a signal (signaling). The signal may be a message. The component carrier (CC) may be called a carrier frequency, a cell, a frequency carrier, or the like.

("System" and "Network")

[0114] The terms "system" and "network" used in the present disclosure can be interchangeably used.

(Names of Parameters and Channels)

[0115] The information, the parameters, and the like described in the present disclosure may be expressed using absolute values, using values relative to predetermined values, or using other corresponding information. For example, radio resources may be indicated by indices.

[0116] The names used for the parameters are not limitative in any respect. Furthermore, the numerical formulas and the like using the parameters may be different from the ones explicitly disclosed in the present disclosure. Various channels (for example, PUCCH and PDCCH) and information elements, can be identified by any suitable names, and various names assigned to these various channels and information elements are not limitative in any respect.

(Base Station (Radio Base Station))

[0117] The terms "Base Station (BS)," "radio base station ," "fixed station," "NodeB," "eNodeB (eNB)," "gNodeB (gNB)," "access point," "transmission point," "reception point, "transmission/reception point," "cell," "sector," "cell group," "carrier," "component carrier," and the like may be used interchangeably in the present disclosure. The base station may be called a macro cell, a small cell, a femtocell, or a pico cell.

[0118] The base station can accommodate one cell or a plurality of (for example, three) cells. When the base station accommodates a plurality of cells, the entire coverage area of the base station can be divided into a plurality of smaller areas, and each of the smaller areas can provide a communication service based on a base station subsystem (for example, small base station for indoor remote radio head (RRH)). The term "cell" or "sector" denotes part or all of the coverage area of at least one of the base station and the base station subsystem that perform the communication service in the coverage.

(Terminal)

[0119] The terms "Mobile Station (MS)," "user terminal," "User Equipment (UE)," and "terminal" may be used interchangeably in the present disclosure.

[0120] The mobile station may be called, by a person skilled in the art, a subscriber station, a mobile unit, a subscriber unit, a wireless unit, a remote unit, a mobile device, a wireless device, a wireless communication device, a remote device, a mobile subscriber station, an access terminal, a mobile terminal, a wireless terminal, a remote terminal, a handset, a user agent, a mobile client, a client, or by some other appropriate terms.

(Base Station/Mobile Station)

[0121] At least one of the base station and the mobile station may be called a transmission apparatus, a reception apparatus, a communication apparatus, or the like. Note that, at least one of the base station and the mobile station may be a device mounted in a mobile entity, the mobile entity itself, or the like. The mobile entity may be a vehicle (e.g., an automobile or an airplane), an unmanned mobile entity (e.g., a drone or an autonomous vehicle), or a robot (a manned-type or unmanned-type robot). Note that, at least one of the base station and the mobile station also includes an apparatus that does not necessarily move during communication operation. For example, at least one of the base station and the mobile station may be Internet-of-Things (IoT) equipment such as a sensor.

[0122] The base station in the present disclosure may also be replaced with the user terminal. For example, the aspects and the embodiments of the present disclosure may find application in a configuration that results from replacing communication between the base station and the user terminal with communication between multiple user terminals (such communication may, e.g., be referred to as device-to-device (D2D), vehicle-to-everything (V2X), or the like). In this case terminal 200 may be configured to have the functions that the above-described base station has. The wordings "uplink" and "downlink" may be replaced with a corresponding wording for inter-equipment communication (for example, "side"). For example, an uplink channel, a downlink channel, and the like may be replaced with a side channel.

[0123] Similarly, the terminal in the present disclosure may be replaced with the base station . In this case, the base station is configured to have the functions that the above-described terminal 200 has.

(Meaning and Interpretation of Terms)

[0124] As used herein, the term "determining" may encompass a wide variety of actions. For example, "determining" may be regarded as judging, calculating, computing, processing, deriving, investigating, looking up, searching (or, search or inquiry)(e.g., looking up in a table, a database or another data structure), ascertaining and the like. Furthermore, "determining" may be regarded as receiving (for example, receiving information), transmitting (for example, transmitting information), inputting, outputting, accessing (for example, accessing data in a memory) and the like. Also, "determining" may be regarded as resolving, selecting, choosing, establishing, comparing and the like. That is, "determining" may be regarded as a certain type of action related to determining. Also, "determining" may be replaced with "assuming," "expecting," "considering," and the like.

[0125] The terms "connected" and "coupled" as well as any modifications of the terms mean any direct or indirect connection and coupling between two or more elements, and the terms can include cases in which one or more intermediate elements exist between two "connected" or "coupled" elements. The coupling or the connection between elements may be physical or logical coupling or connection or may be a combination of physical and logical coupling or connection. For example, "connected" may be replaced with "accessed." When the terms are used in the present disclosure, two elements can be considered to be "connected" or "coupled" to each other using at least one of one or more electrical wires, cables, and printed electrical connections or using electromagnetic energy with a wavelength of a radio frequency domain, a microwave domain, an optical (both visible and invisible) domain, or the like hat are non-limiting and non-inclusive examples.

[0126] The reference signal can also be abbreviated as an RS and may also be called as a pilot depending on the applied standard.

[0127] The description "based on" used in the present disclosure does not mean "based only on," unless otherwise specified. In other words, the description "based on" means both of "based only on" and "based at least on."

[0128] Any reference to elements by using the terms "first," "second," and the like does not generally limit the quantities of or the order of these elements. The terms can be used as a convenient method of distinguishing between two or more elements in the present disclosure. Therefore, reference to first and second elements does not mean that only two elements can be employed, or that the first element has to precede the second element somehow.

[0129] The "section" in the configuration of each apparatus may be replaced with "means," "circuit," "device," or the like.

[0130] In a case where terms "include," "including," and their modifications are used in the present disclosure, these terms are intended to be inclusive like the term "comprising." Further, the term "or" used in the present disclosure is not intended to be an exclusive or.

[0131] The radio frame may be constituted by one frame or a plurality of frames in the time domain. The one frame or each of the plurality of frames may be called a subframe in the time domain. The subframe may be further constituted by one slot or a plurality of slots in the time domain. The subframe may have a fixed time length (e.g., 1 ms) independent of numerology.

[0132] The numerology may be a communication parameter that is applied to at least one of transmission and reception of a certain signal or channel. The numerology, for example, indicates at least one of SubCarrier Spacing (SCS), a bandwidth, a symbol length, a cyclic prefix length, Transmission Time Interval (TTI), the number of symbols per TTI, a radio frame configuration, specific filtering processing that is performed by a transmission and reception apparatus in the frequency domain, specific windowing processing that is performed by the transmission and reception apparatus in the time domain, and the like.

[0133] The slot may be constituted by one symbol or a plurality of symbols (e.g., Orthogonal Frequency Division Multiplexing (OFDM)) symbol, Single Carrier-Frequency Division Multiple Access (SC-FDMA) symbol, or the like) in the time domain. The slot may also be a time unit based on the numerology.

[0134] The slot may include a plurality of mini-slots. Each of the mini-slots may be constituted by one or more symbols in the time domain. Furthermore, the mini-slot may be referred to as a subslot. The mini-slot may be constituted by a smaller number of symbols than the slot. A PDSCH (or a PUSCH) that is transmitted in the time unit that is greater than the mini-slot may be referred to as a PDSCH (or a PUSCH) mapping type A. The PDSCH (or the PUSCH) that is transmitted using the mini-slot may be referred to as a PDSCH (or PUSCH) mapping type B.

[0135] The radio frame, the subframe, the slot, the mini slot, and the symbol indicate time units in transmitting signals. The radio frame, the subframe, the slot, the mini slot, and the symbol may be called by other corresponding names.

[0136] For example, one subframe, a plurality of continuous subframes, one slot, or one mini-slot may be called a Transmission Time Interval (TTI). That is, at least one of the subframe and the TTI may be a subframe (1 ms) in the existing LTE, a duration (for example, 1 to 13 symbols) that is shorter than 1 ms, or a duration that is longer than 1 ms. Note that, a unit that represents the TTI may be referred to as a slot, a mini-slot, or the like instead of a subframe.

[0137] Here, the TTI, for example, refers to a minimum time unit for scheduling in radio communication. For example, in an LTE system, the base station performs scheduling for allocating a radio resource (a frequency bandwidth, a transmit power, and the like that are used in each user terminal) on a TTI-by-TTI basis to each user terminal. Note that, the definition of TTI is not limited to this.

[0138] The TTI may be a time unit for transmitting a channel-coded data packet (a transport block), a code block, or a codeword, or may be a unit for processing such as scheduling and link adaptation. Note that, when the TTI is assigned, a time section (for example, the number of symbols) to which the transport block, the code block, the codeword, or the like is actually mapped may be shorter than the TTI.

[0139] Note that, in a case where one slot or one mini-slot is referred to as the TTI, one or more TTIs (that is, one or more slots, or one or more mini-slots) may be a minimum time unit for the scheduling. Furthermore, the number of slots (the number of mini-slots) that make up the minimum time unit for the scheduling may be controlled.

[0140] A TTI that has a time length of 1 ms may be referred to as a usual TTI (a TTI in LTE Rel. 8 to LTE Rel. 12), a normal TTI, a long TTI, a usual subframe, a normal subframe, a long subframe, a slot, or the like. A TTI that is shorter than the usual TTI may be referred to as a shortened TTI, a short TTI, a partial TTI (or a fractional TTI), a shortened subframe, a short subframe, a mini-slot, a subslot, a slot, or the like.

[0141] Note that the long TTI (for example, the usual TTI, the subframe, or the like) may be replaced with the TTI that has a time length which exceeds 1 ms, and the short TTI (for example, the shortened TTI or the like) may be replaced with a TTI that has a TTI length which is less than a TTI length of the long TTI and is equal to or longer than 1 ms.

[0142] A resource block (RB) is a resource allocation unit in the time domain and the frequency domain, and may include one or more contiguous subcarriers in the frequency domain. The number of subcarriers that are included in the RB may be identical regardless of the numerology, and may be 12, for example. The number of subcarriers that are included in the RB may be determined based on the numerology.

[0143] In addition, the RB may include one symbol or a plurality of symbols in the time domain, and may have a length of one slot, one mini slot, one subframe, or one TTI. One TTI and one subframe may be constituted by one resource block or a plurality of resource blocks.

[0144] Note that one or more RBs may be referred to as a Physical Resource Block (PRB), a Sub-Carrier Group (SCG), a Resource Element Group (REG), a PRB pair, an RB pair, or the like.

[0145] In addition, the resource block may be constituted by one or more Resource Elements (REs). For example, one RE may be a radio resource region that is one subcarrier and one symbol.

[0146] A bandwidth part (BWP) (which may be referred to as a partial bandwidth or the like) may represent a subset of contiguous common resource blocks (RB) for certain numerology in a certain carrier. Here, the common RBs may be identified by RB indices that use a common reference point of the carrier as a reference. The PRB may be defined by a certain BWP and may be numbered within the BWP.

[0147] The BWP may include a UL BWP and a DL BWP. An UE may be configured with one or more BWPs within one carrier.

[0148] At least one of the configured BWPs may be active, and the LTE does not have to assume transmission/reception of a predetermined signal or channel outside the active BWP. Note that, "cell," "carrier," and the like in the present disclosure may be replaced with "BWP."

[0149] Structures of the radio frame, the subframe, the slot, the mini-slot, the symbol, and the like are described merely as examples. For example, the configuration such as the number of subframes that are included in the radio frame, the number of slots per subframe or radio frame, the number of mini-slots that are included within the slot, the numbers of symbols and RBs that are included in the slot or the mini-slot, the number of subcarriers that are included in the RB, the number of symbols within the TTI, the symbol length, the Cyclic Prefix (CP) length, and the like can be changed in various ways.

[0150] In a case where articles, such as "a," "an," and "the" in English, for example, are added in the present disclosure by translation, nouns following these articles may have the same meaning as used in the plural.

[0151] In the present disclosure, the expression "A and B are different" may mean that "A and B are different from each other." Note that, the expression may also mean that "A and B are different from C." The expressions "separated" and "coupled" may also be interpreted in the same manner as the expression "A and B are different."

(Variations and the like of Aspects)

[0152] The aspects and embodiments described in the present disclosure may be independently used, may be used in combination, or may be switched and used along the execution. Furthermore, notification of predetermined information (for example, notification indicating "it is X") is not limited to explicit notification, and may be performed implicitly (for example, by not notifying the predetermined information).

[0153] While the present disclosure has been described in detail, it is obvious to a person skilled in the art that the present disclosure is not limited to the embodiments described in the present disclosure. Modifications and variations of the aspects of the present disclosure can be made without departing from the spirit and the scope of the present disclosure defined by the description of the appended claims. Therefore, the description of the present disclosure is intended for exemplary description and does not limit the present disclosure in any sense.

[0154] This present application claims its priority under Japanese Patent Application No. 2020-058849, filed on March 27, 2020, and the entire contents of Japanese Patent Application No. 2020-058849 are incorporated herein by reference.

Industrial Applicability

[0155] One aspect of the present disclosure is useful, for example, in a radio communication system.

Reference Signs List

[0156]

200 Terminal
201 Reception section
202 Sending section
203 Control section
204 Antenna
204a Large antenna
205, 205a Transmittance direction limiting section
20,20a Metasurface Unit
21 Dielectric substrate
22 Metasurface substrate
22a Unit cell
31 Connecting member
32 Adjusting section
41 Connecting member
42 Adjusting section

Claims

1. A terminal, comprising:

a control section that determines a direction of transmitting a radio wave based on an arrival direction of a desired wave or an arrival direction of an interference wave; and a transmittance direction limiting section that limits the direction of transmitting a radio wave in accordance with the determination of the control section.

2. The terminal according to claim 1, wherein

the transmittance direction limiting section includes a plurality of metasurface units that each include a metasurface substrate and a dielectric substrate disposed so as to face the metasurface substrate, and
the control section adjusts a distance between the metasurface substrate and the dielectric substrate in each of the plurality of metasurface units.

3. The terminal according to claim 2, wherein
a resonant frequency of a transmittance of a radio wave of the metasurface substrate changes based on the distance.

4. The terminal according to claim 2 or 3, wherein
the metasurface substrate and the dielectric substrate are in a parallel state or a non-parallel state to each other based on the adjustment of the distance.

5. The terminal according to any one of claims 2 to 4, wherein
a permittivity of the dielectric substrate is larger than a permittivity of the metasurface substrate.

6. The terminal according to any one of claims 1 to 5, wherein
the control section predicts the arrival direction of the desired wave based on an amount of change in an arrival direction of a past desired wave.

7. A communication method for a terminal, comprising:

determining a direction of transmitting a radio wave based on an arrival direction of a desired wave or an arrival direction of an interference wave; and
limiting a direction of transmitting a radio wave in accordance with the determination.

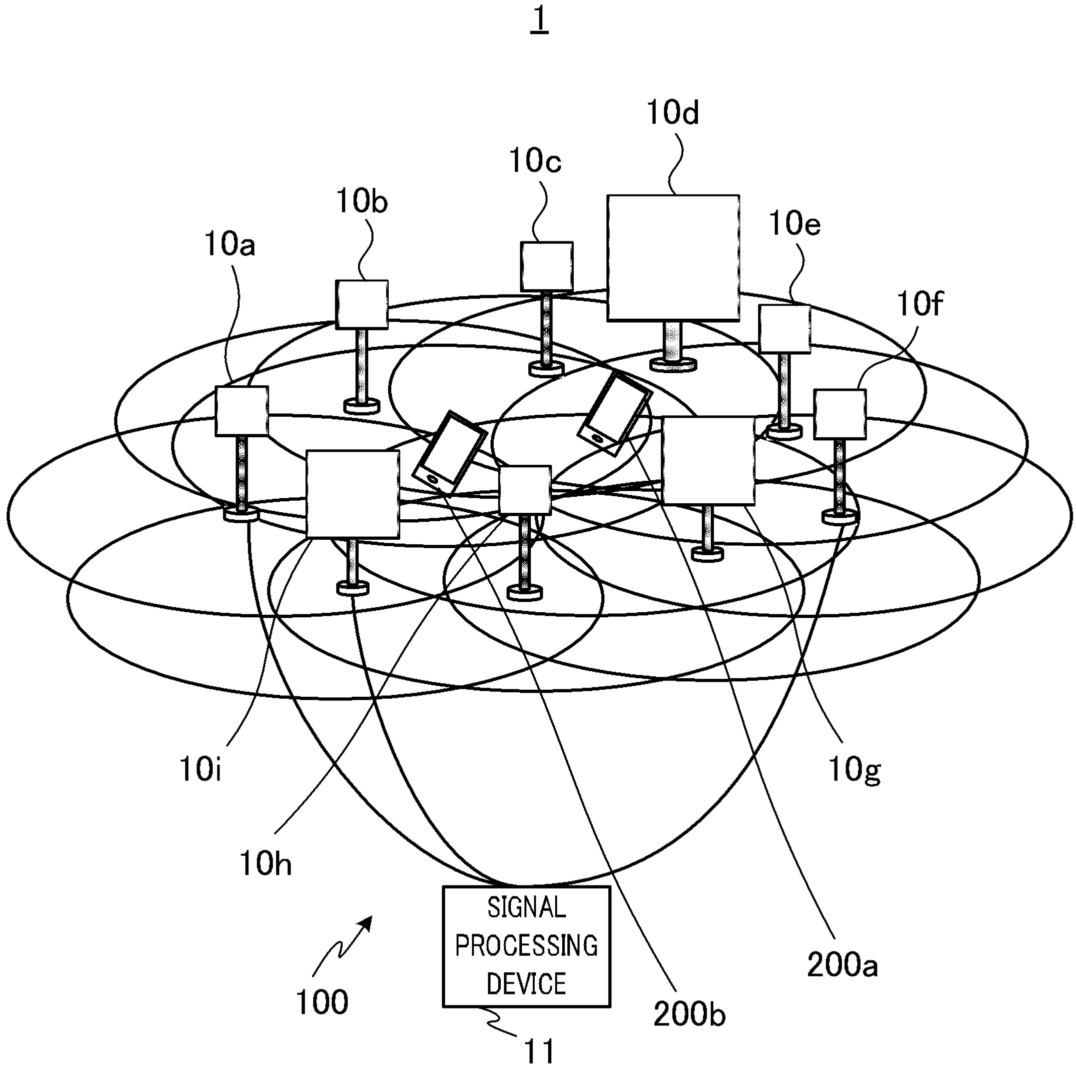
1
10a
10b
10c
10d
10e
10f
10g
10h
10i
200a
200b
100
SIGNAL PROCESSING DEVICE
11

FIG. 1

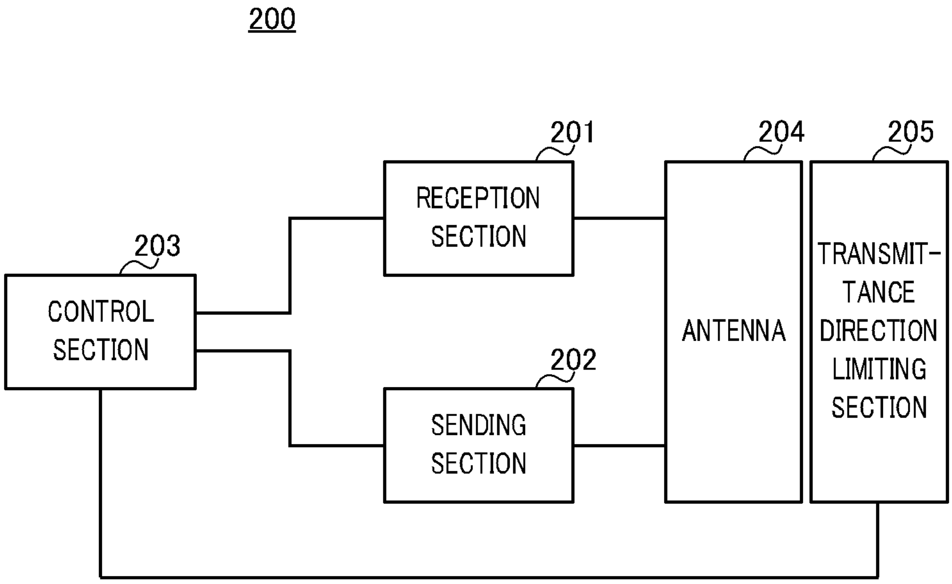
200
201
204
205
RECEPTION SECTION
203
CONTROL SECTION
TRANSMIT-TANCE DIRECTION LIMITING SECTION
ANTENNA
202
SENDING SECTION

FIG. 2

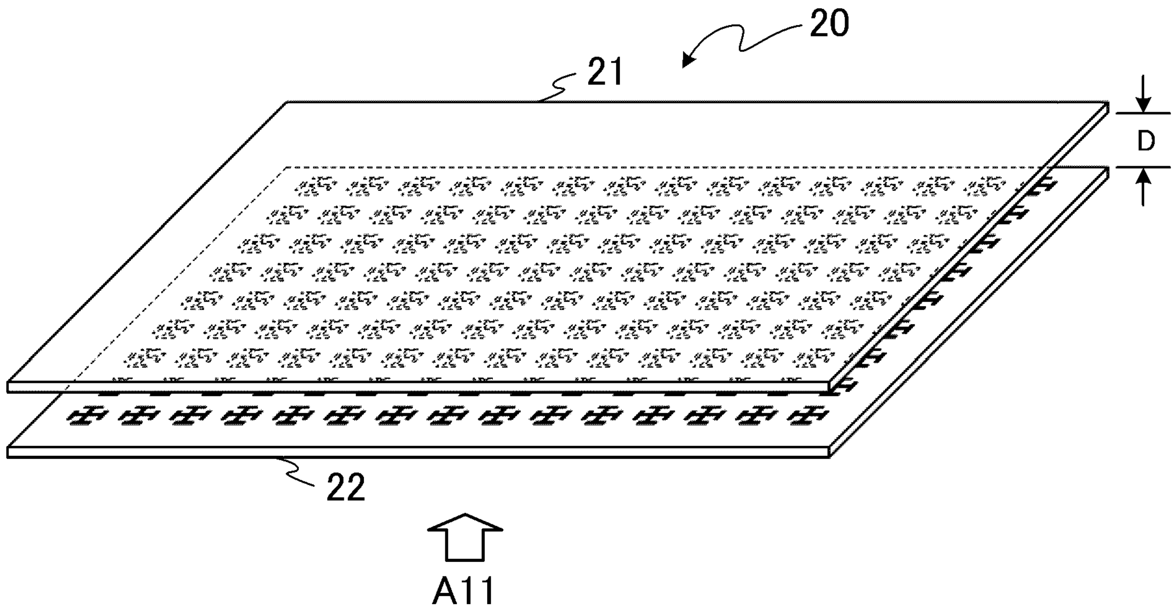

FIG. 3A

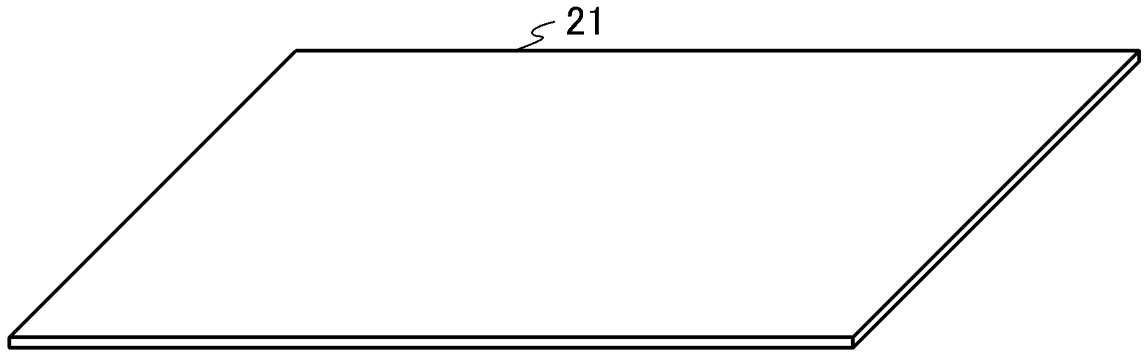

FIG. 3B

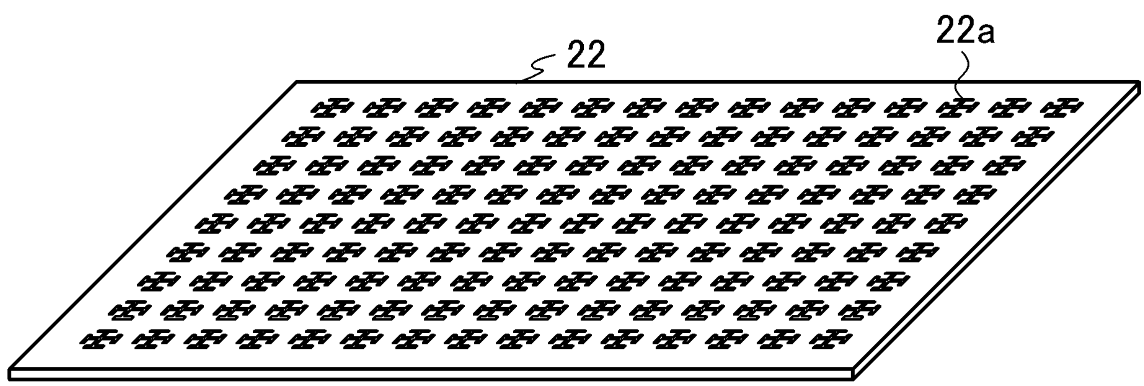

FIG. 3C

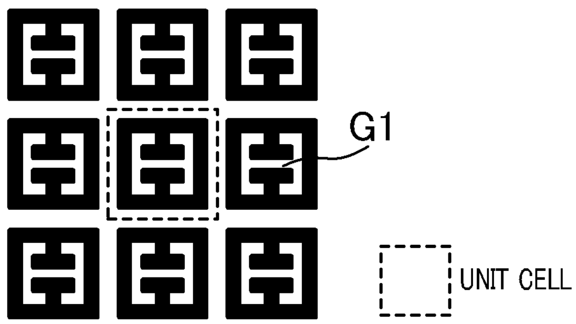

FIG. 4A

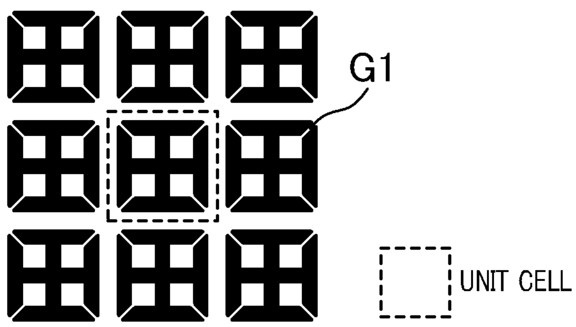

FIG. 4B

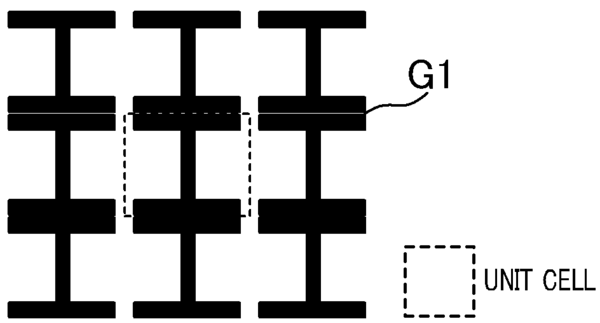

FIG. 4C

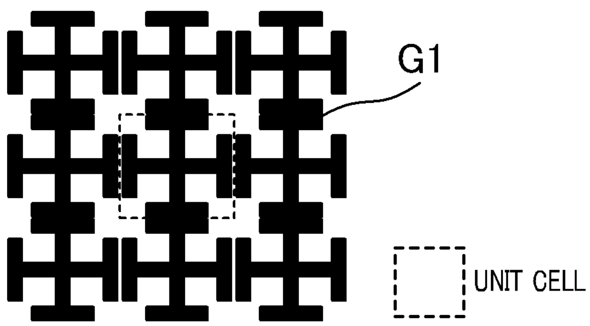

FIG. 4D

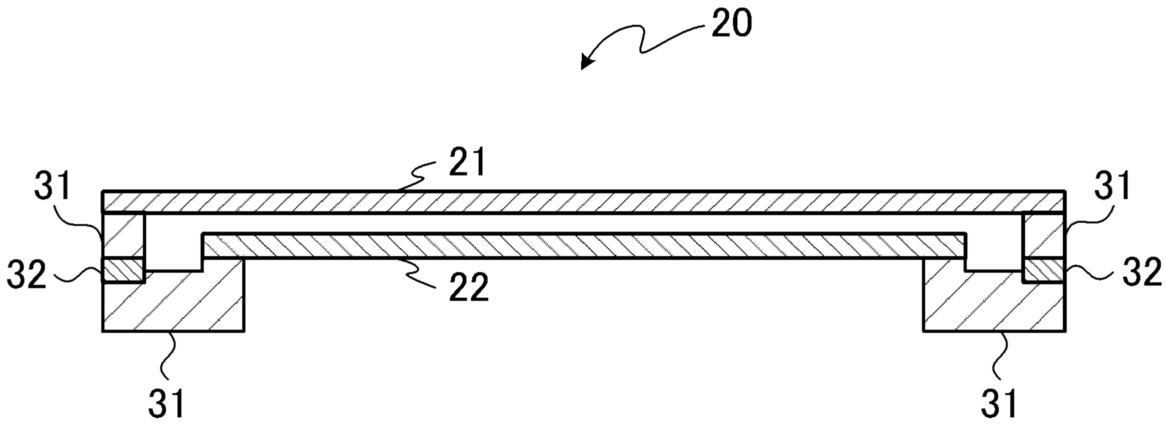

FIG. 5

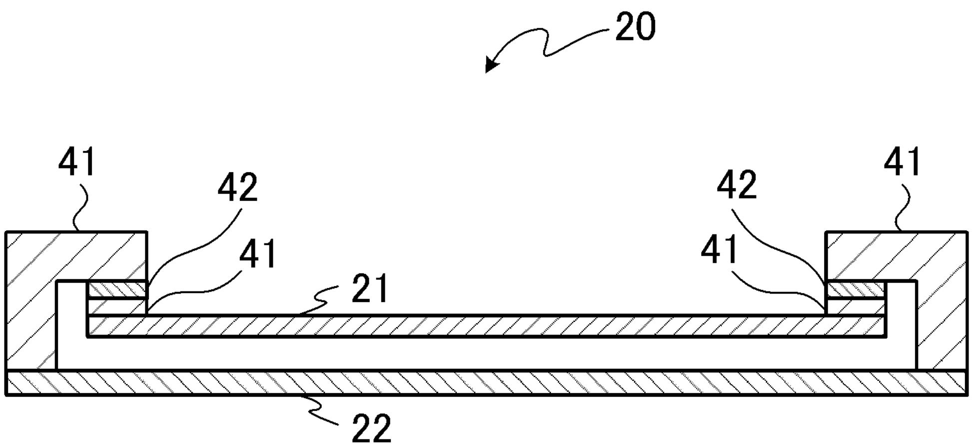

FIG. 6

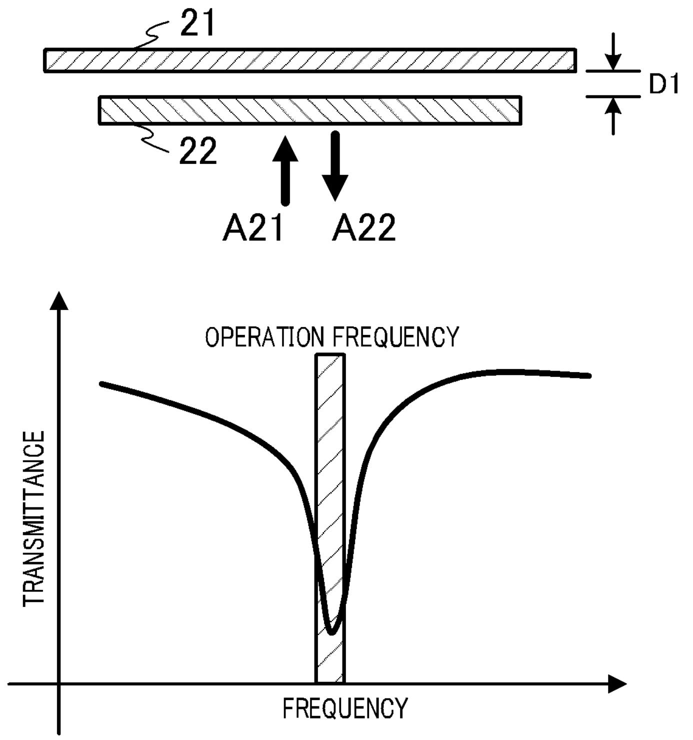
21
D1
22
A21
A22
OPERATION FREQUENCY
TRANSMITTANCE
FREQUENCY

FIG. 7A

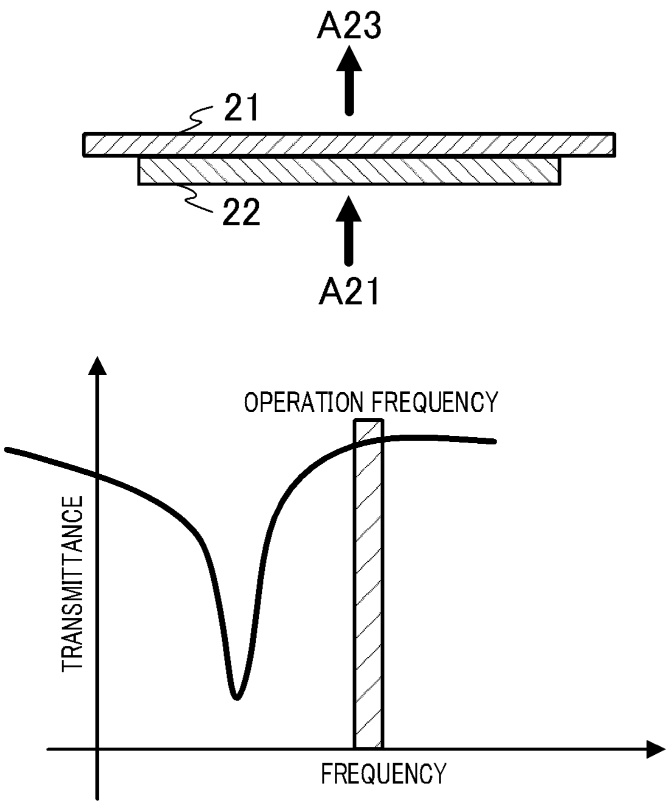
A23
21
22
A21
OPERATION FREQUENCY
TRANSMITTANCE
FREQUENCY

FIG. 7B

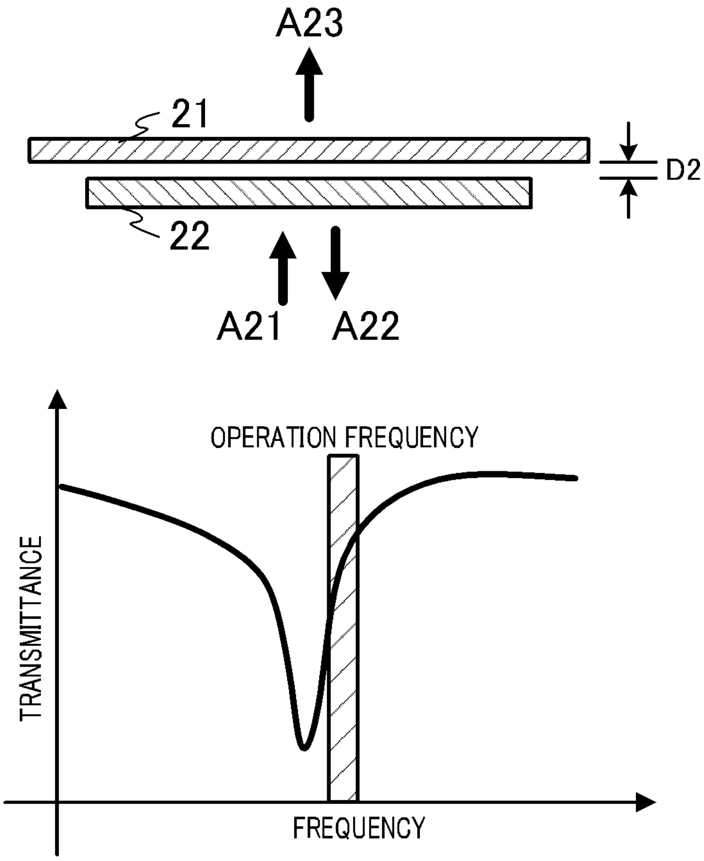
A23
21
D2
22
A21
A22
OPERATION FREQUENCY
TRANSMITTANCE
FREQUENCY

FIG. 7C

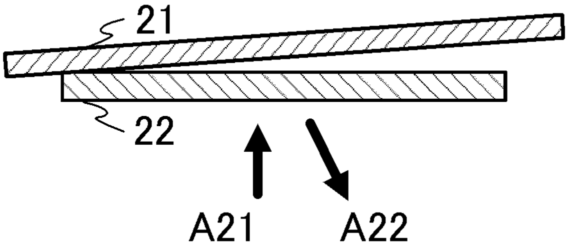
21
22
A21
A22

FIG. 7D

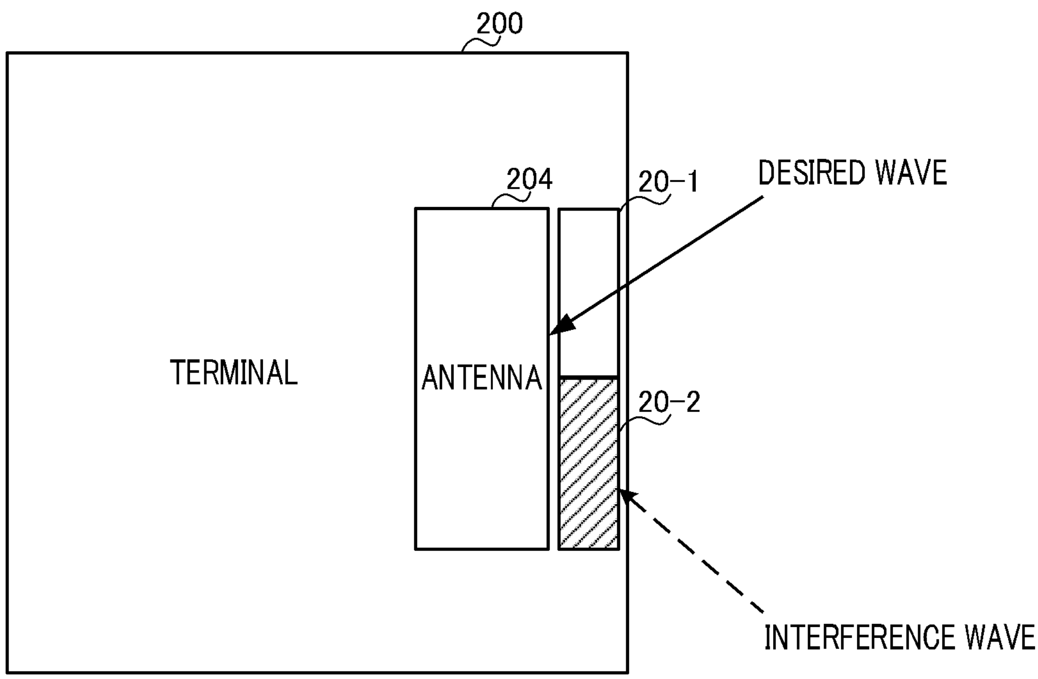
200
204
20-1
DESIRED WAVE
TERMINAL
ANTENNA
20-2
INTERFERENCE WAVE

FIG. 8

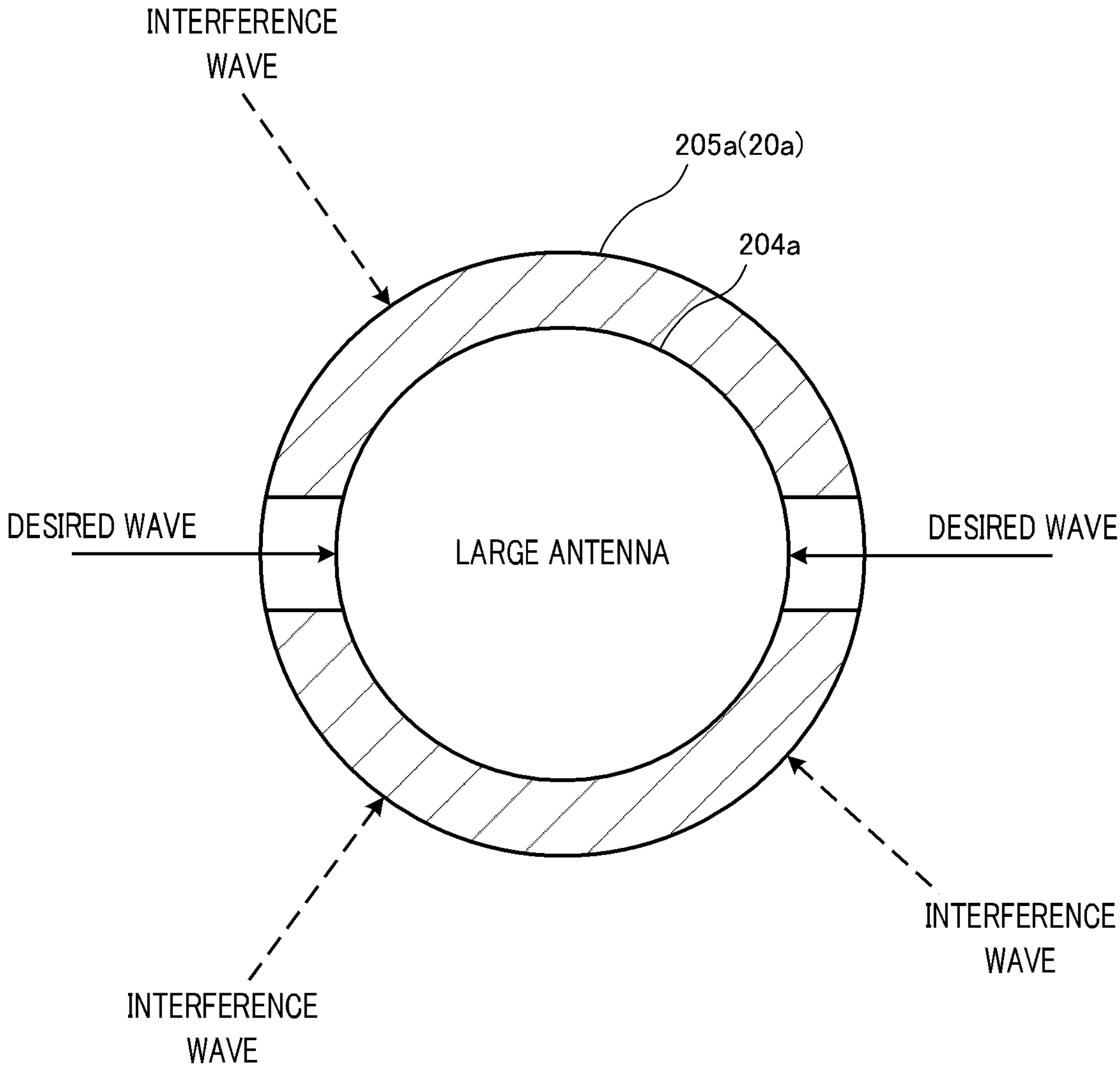
INTERFERENCE
WAVE
205a(20a)
204a
DESIRED WAVE
LARGE ANTENNA
DESIRED WAVE
INTERFERENCE
WAVE
INTERFERENCE
WAVE

FIG. 9

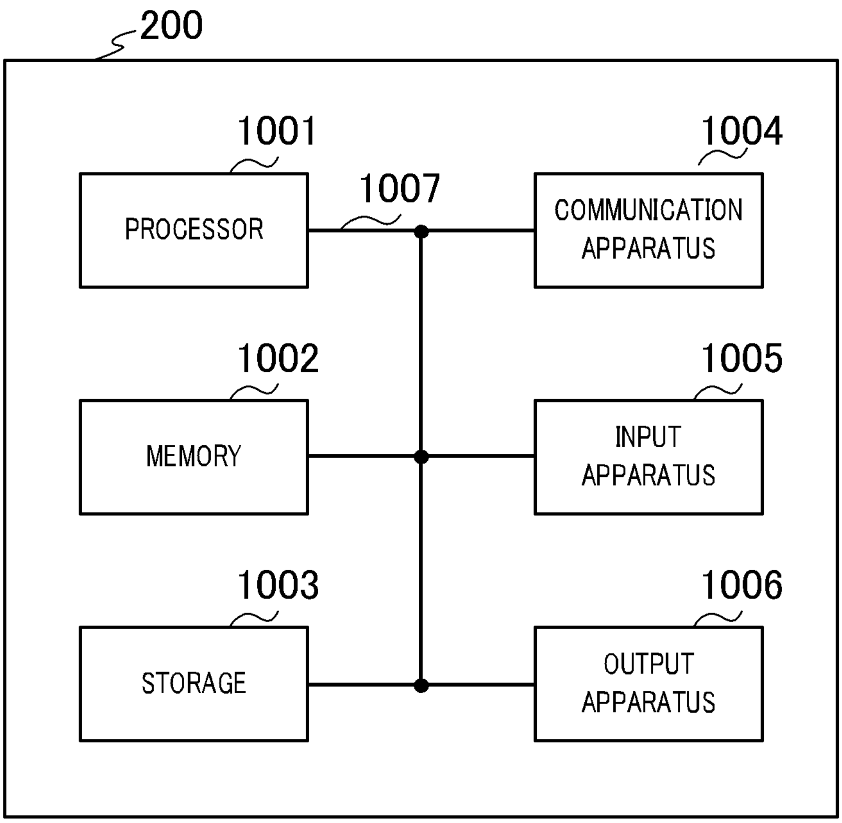
200
1001
PROCESSOR
1007
1004
COMMUNICATION APPARATUS
1002
MEMORY
1005
INPUT APPARATUS
1003
STORAGE
1006
OUTPUT APPARATUS

FIG. 10

INTERNATIONAL SEARCH REPORT	International application No. PCT/JP2021/005055

A. CLASSIFICATION OF SUBJECT MATTER
Int. Cl. H01Q15/02(2006.01)i, H01Q19/06(2006.01)i
FI: H01Q19/06, H01Q15/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int. Cl. H01Q15/02, H01Q19/06

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

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2021
Registered utility model specifications of Japan	1996-2021
Published registered utility model applications of Japan	1994-2021

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2018/096740 A1 (NEC CORP.) 31 May 2018	1-7
A	JP 2007-5614 A (MITSUBISHI ELECTRIC CORP.) 11 January 2007	1-7

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22.03.2021	30.03.2021

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2021/005055

Patent Documents referred to in the Report	Publication Date	Patent Family	Publication Date
WO 2018/096740 A1	31.05.2018	(Family: none)	
JP 2007-5614 A	11.01.2007	(Family: none)	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2020058849 A **[0154]**

Non-patent literature cited in the description

- Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2 (Release 8). *3GPP TS 36.300 V8.12.0,* April 2010 **[0006]**