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(54) **AUTONOMOUS MOVING APPARATUS AND COMPOSITE UNIT OF SPEAKER-MICROPHONE FOR AUTONOMOUS MOVING APPARATUS**

(71) Applicant: **ROHM CO., LTD.**, Kyoto (JP)

(72) Inventor: **Hiroshi YAGUMA**, Kyoto (JP)

(73) Assignee: **ROHM CO., LTD.**, Kyoto (JP)

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(30) **Foreign Application Priority Data**

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G01S 7/521 (2006.01)
H04R 1/02 (2006.01)
H04R 1/08 (2006.01)

(52) **U.S. Cl.**
CPC ***G01S 15/931*** (2013.01); ***G01S 7/521*** (2013.01); ***H04R 1/025*** (2013.01); ***H04R 1/08*** (2013.01); *G01S 2015/937* (2013.01)

(57) **ABSTRACT**

An autonomous moving apparatus includes: a first speaker that is attached to the vehicle body and transmits an acoustic wave toward an area including a front direction of the vehicle body; a first microphone and a second microphone that is attached to the vehicle body, receives an acoustic wave reflected by an object. When viewed from a vertical direction, the first speaker, the first microphone, and the second microphone are located on an outside or an outer periphery of the vehicle body. The first speaker is interposed between the first microphone and the second microphone in a left-right direction perpendicular to the front direction. Distances from the first speaker or a center of gravity of a plurality of speakers including the first speaker, to each of the first microphone and the second microphone in the left-right direction are equal.

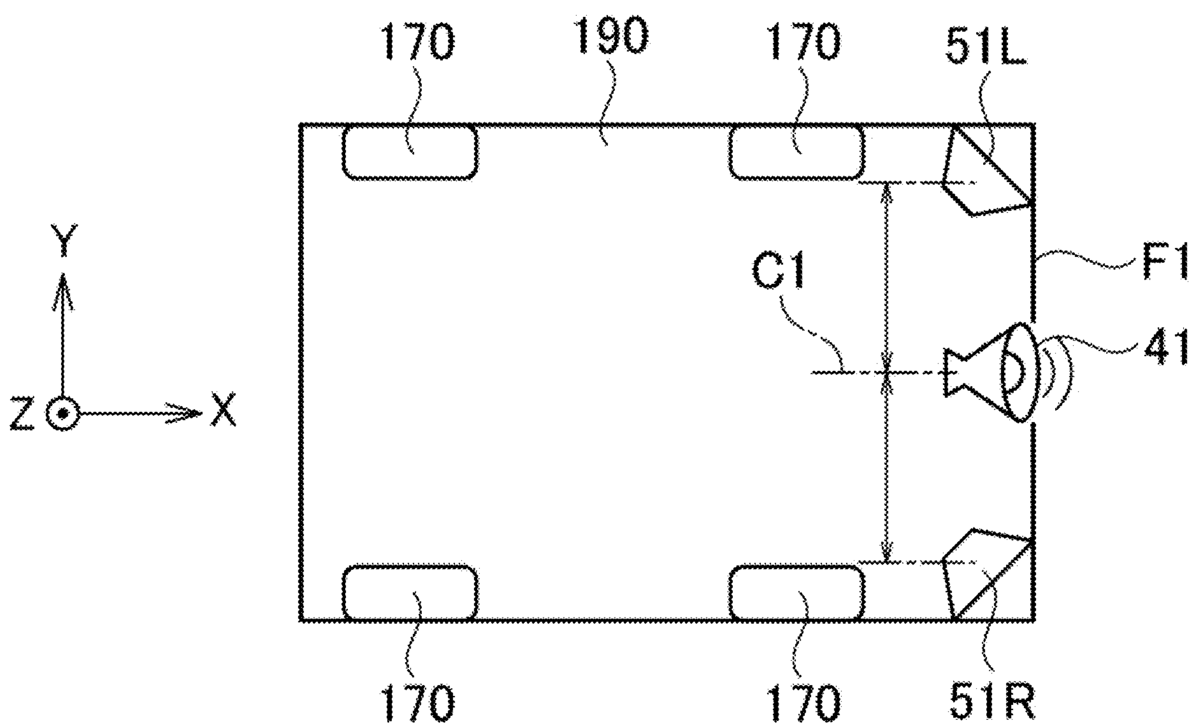


FIG. 1

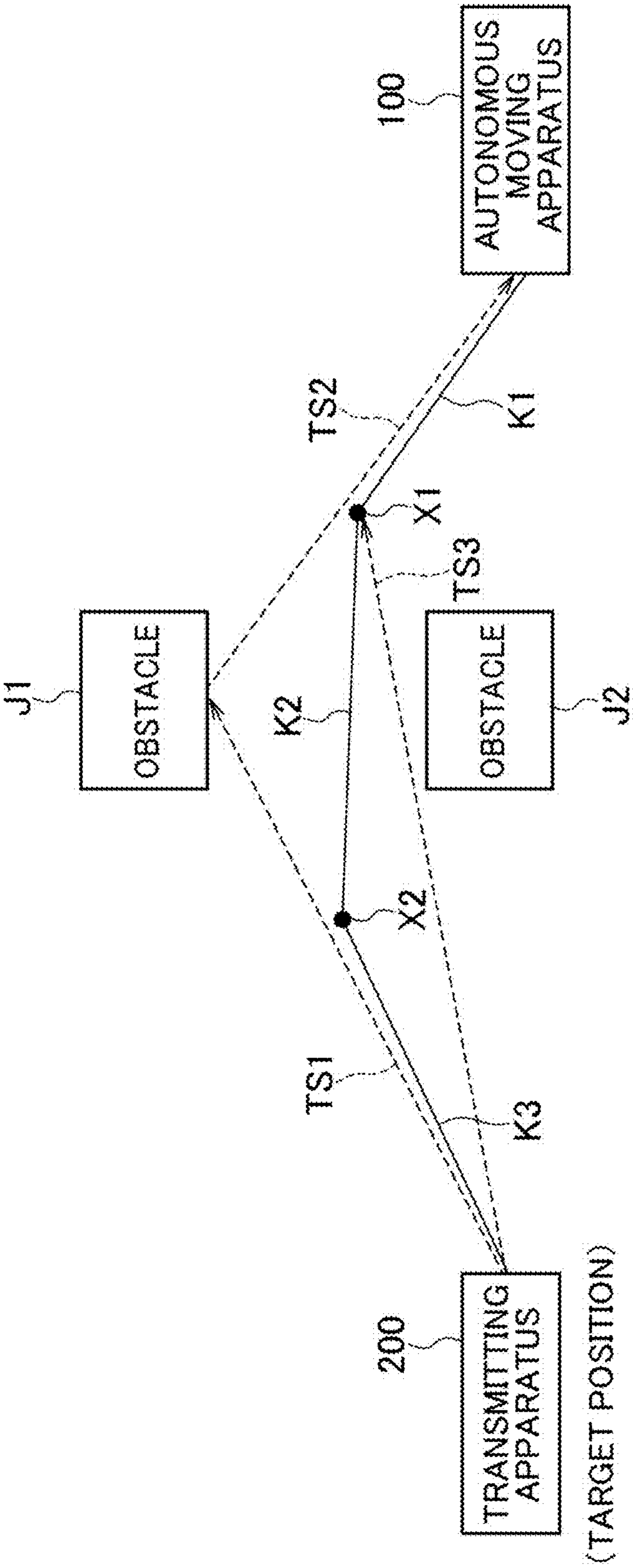

100
AUTONOMOUS MOVING APPARATUS
TS2
K1
X1
TS3
J1
OBSTACLE
K2
OBSTACLE
J2
X2
TS1
K3
200
TRANSMITTING APPARATUS
(TARGET POSITION)

FIG. 2

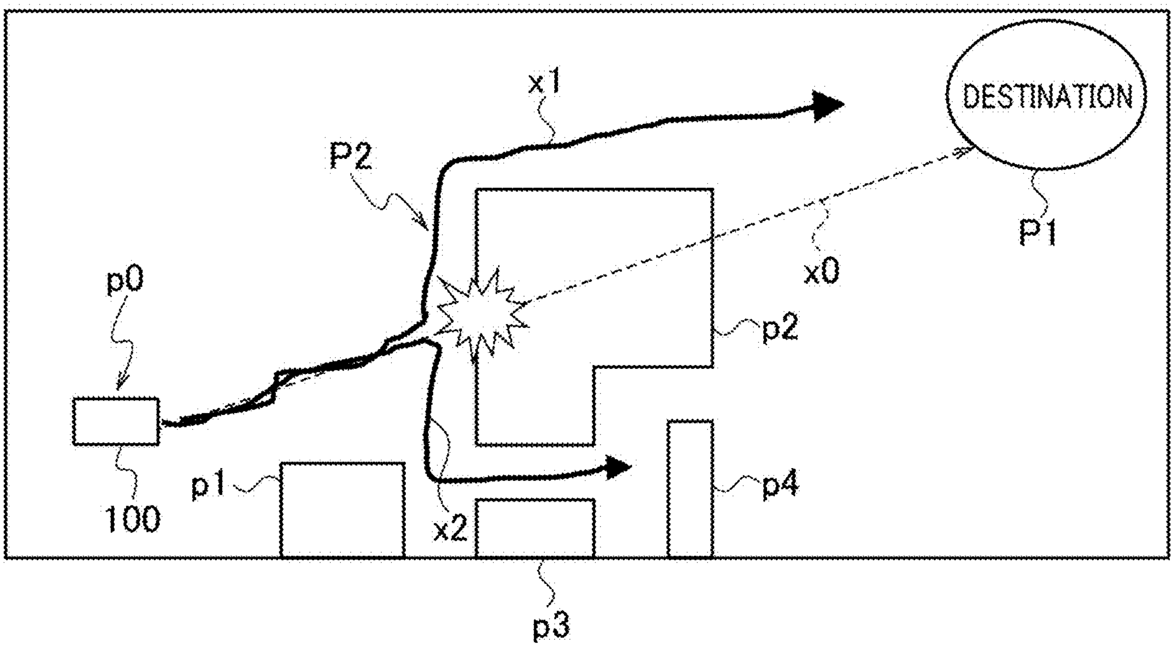


FIG. 3

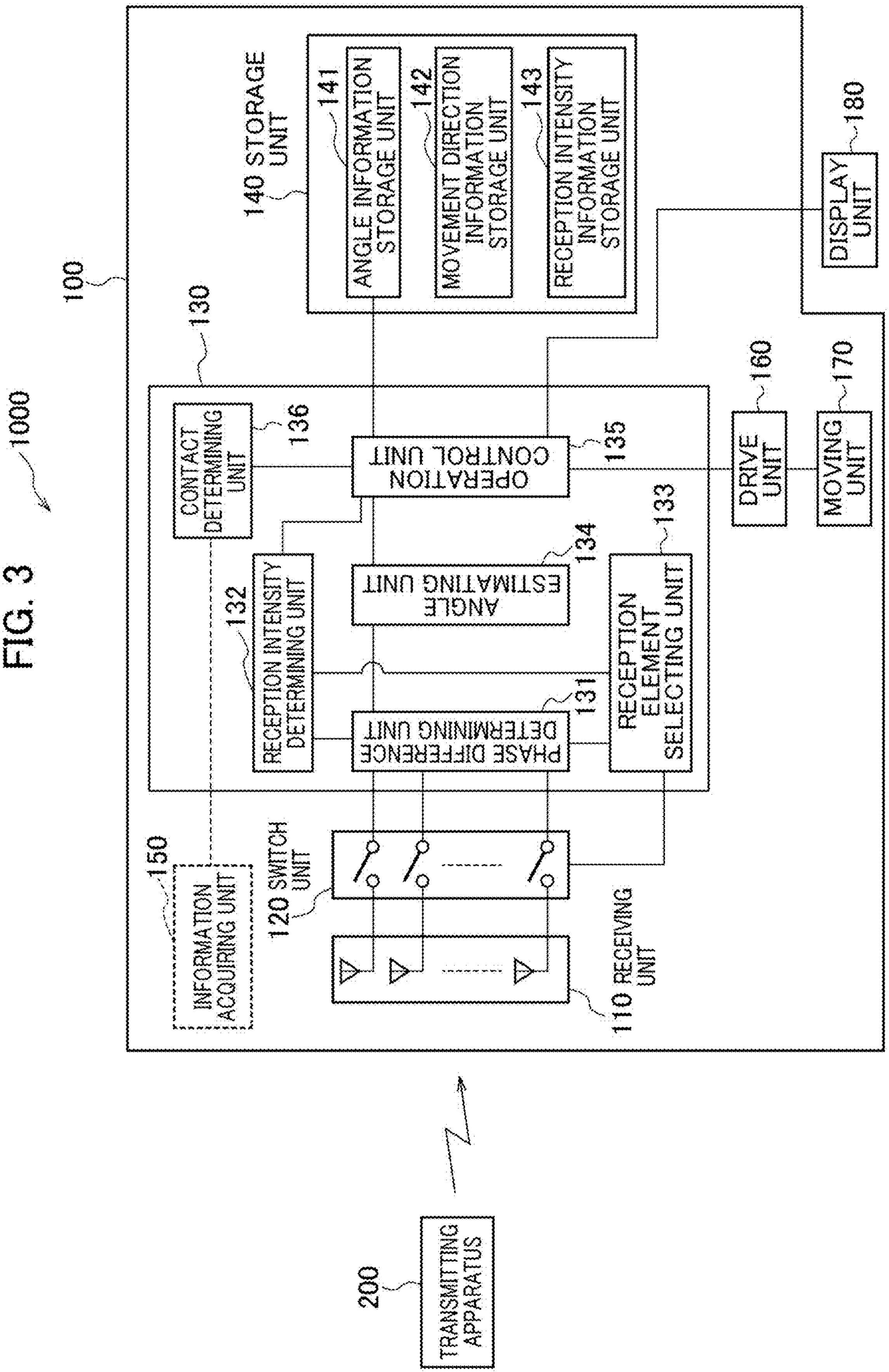

1000
100
130
140 STORAGE UNIT
141
ANGLE INFORMATION STORAGE UNIT
142
MOVEMENT DIRECTION INFORMATION STORAGE UNIT
143
RECEPTION INTENSITY INFORMATION STORAGE UNIT
180
DISPLAY UNIT
136
CONTACT DETERMINING UNIT
135
OPERATION CONTROL UNIT
160
DRIVE UNIT
170
MOVING UNIT
132
RECEPTION INTENSITY DETERMINING UNIT
134
ANGLE ESTIMATING UNIT
133
RECEPTION ELEMENT SELECTING UNIT
131
PHASE DIFFERENCE DETERMINING UNIT
150
INFORMATION ACQUIRING UNIT
120 SWITCH UNIT
110 RECEIVING UNIT
200
TRANSMITTING APPARATUS

FIG. 4

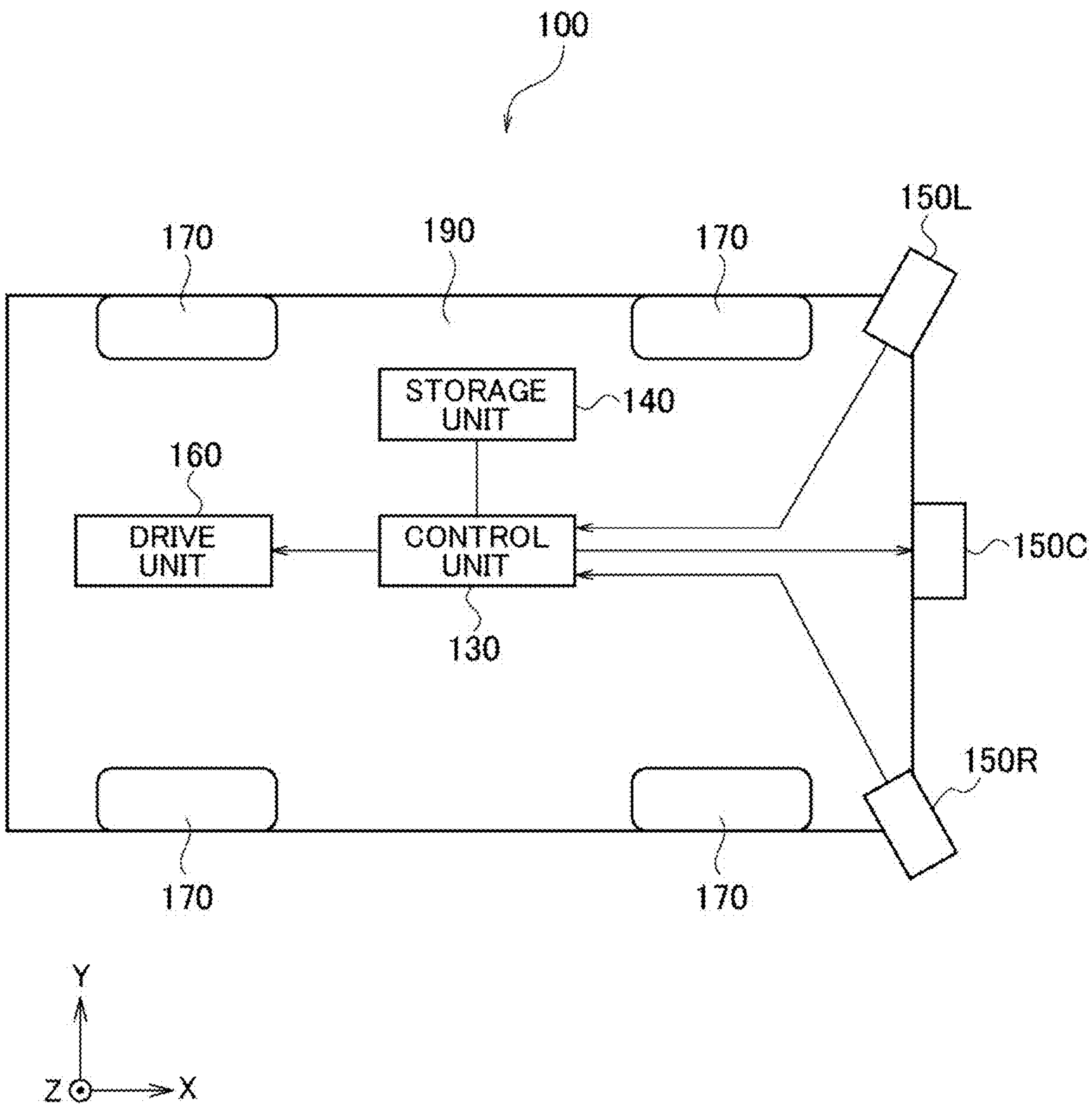

100
170
190
170
150L
STORAGE UNIT
140
160
DRIVE UNIT
CONTROL UNIT
150C
130
150R
170
170
Y
Z
X

FIG. 5

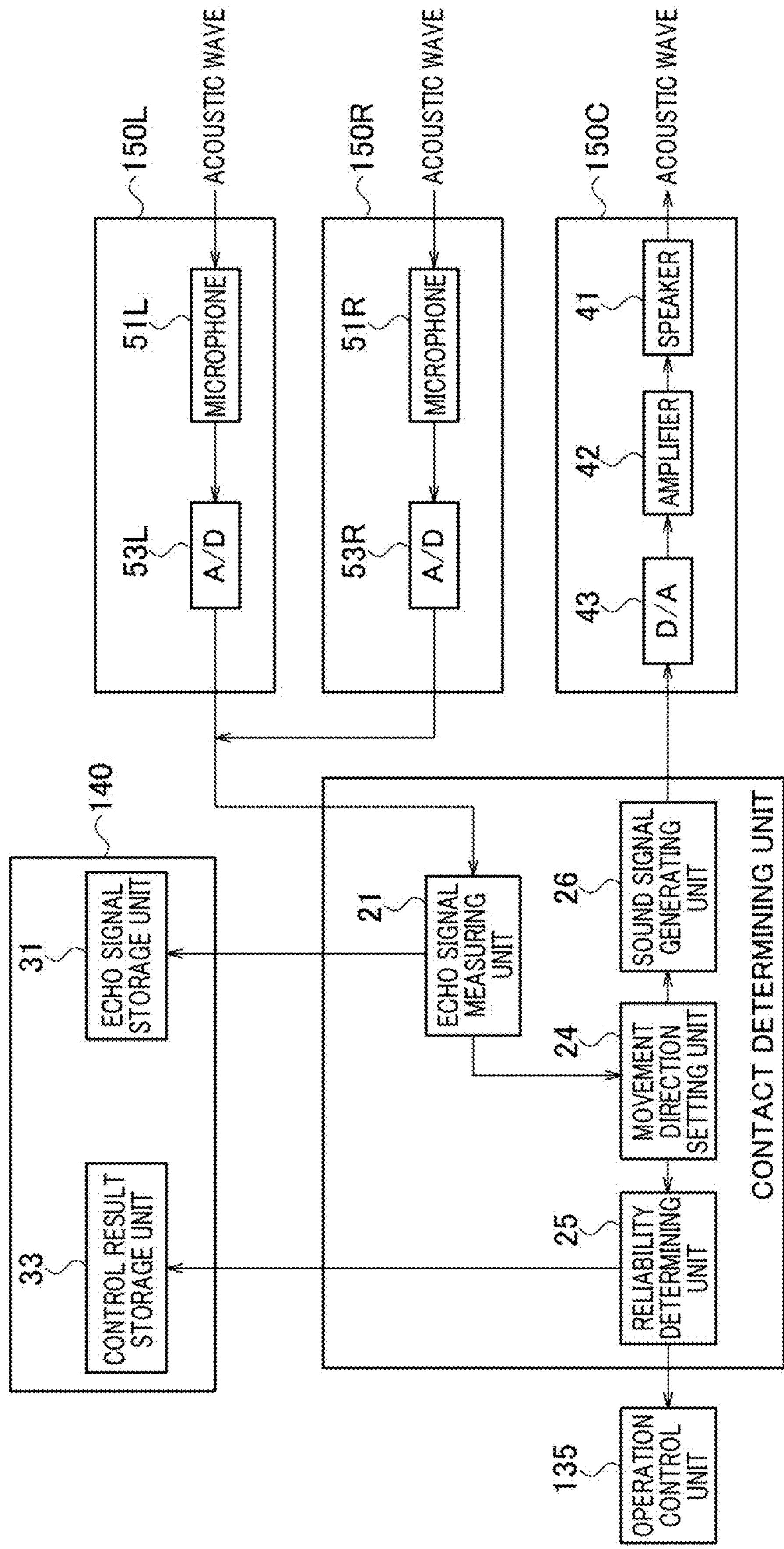

150L
ACOUSTIC WAVE
51L
MICROPHONE
53L
A/D
150R
ACOUSTIC WAVE
51R
MICROPHONE
53R
A/D
150C
ACOUSTIC WAVE
41
SPEAKER
42
AMPLIFIER
43
D/A
140
31
ECHO SIGNAL STORAGE UNIT
33
CONTROL RESULT STORAGE UNIT
136
CONTACT DETERMINING UNIT
21
ECHO SIGNAL MEASURING UNIT
24
MOVEMENT DIRECTION SETTING UNIT
25
RELIABILITY DETERMINING UNIT
26
SOUND SIGNAL GENERATING UNIT
135
OPERATION CONTROL UNIT

FIG. 6A

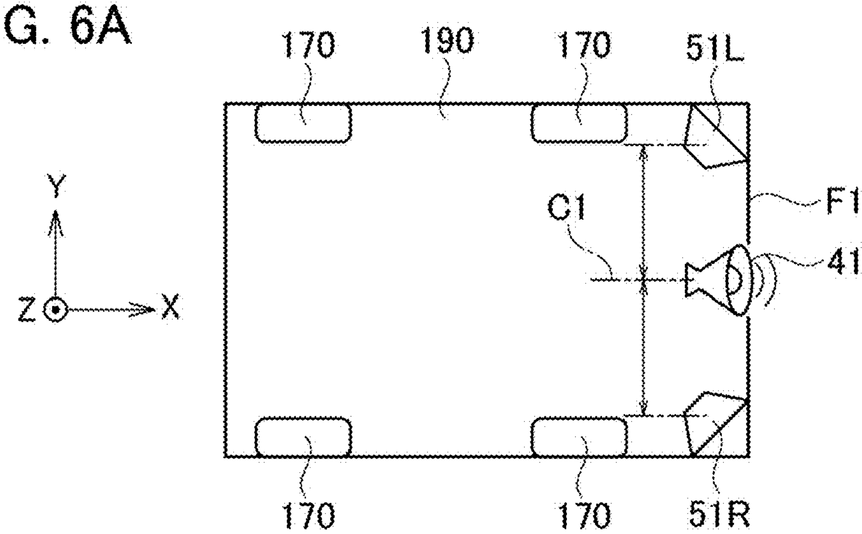


FIG. 6B

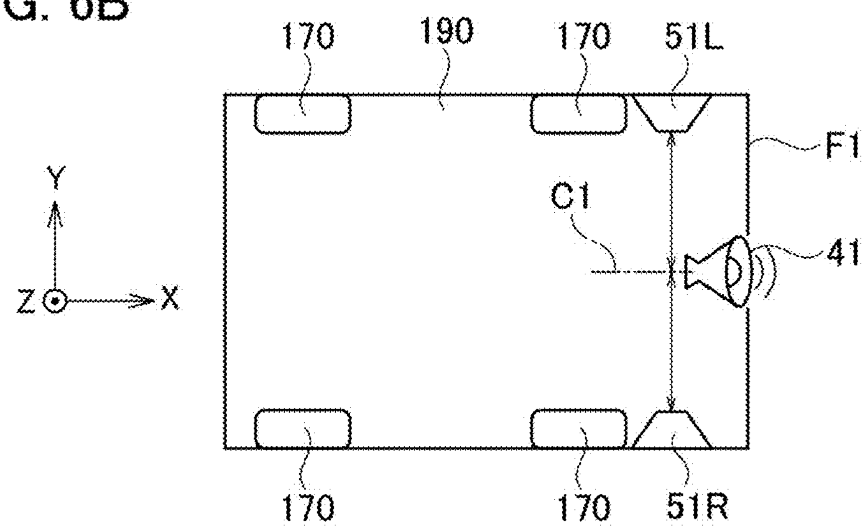


FIG. 6C

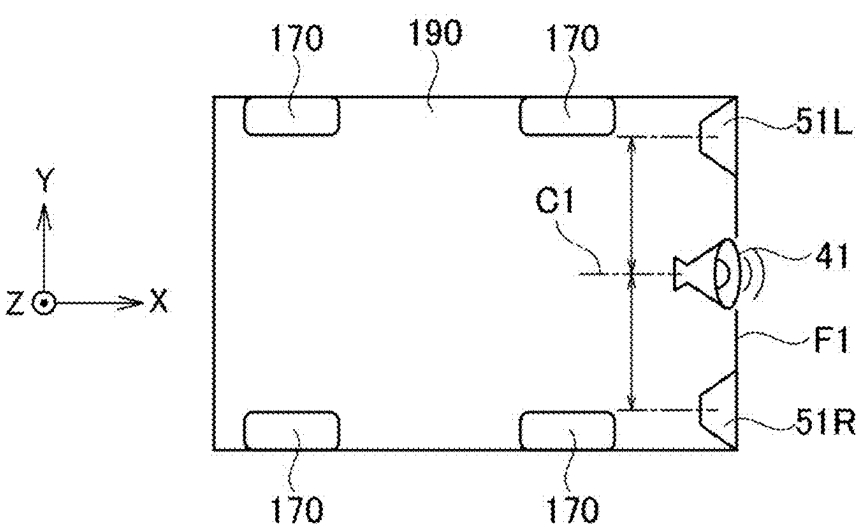


FIG. 7A

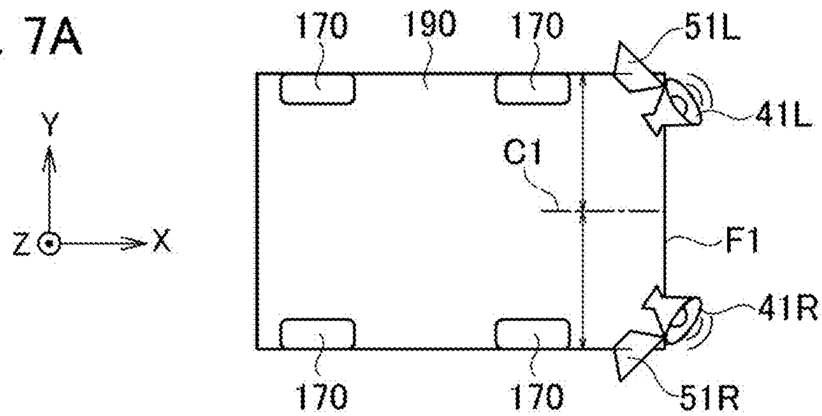


FIG. 7B

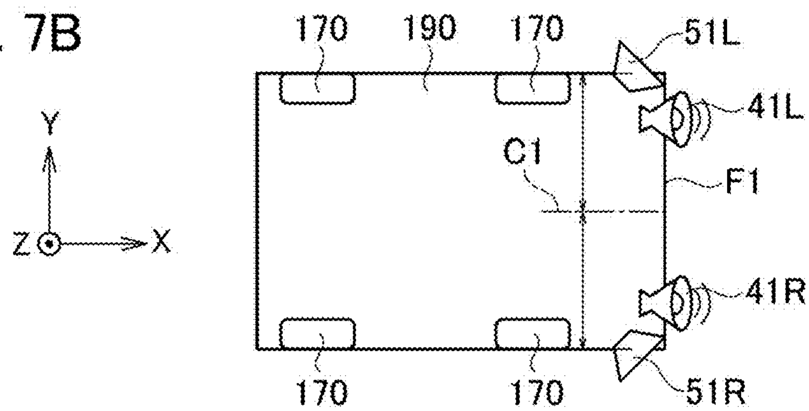


FIG. 7C

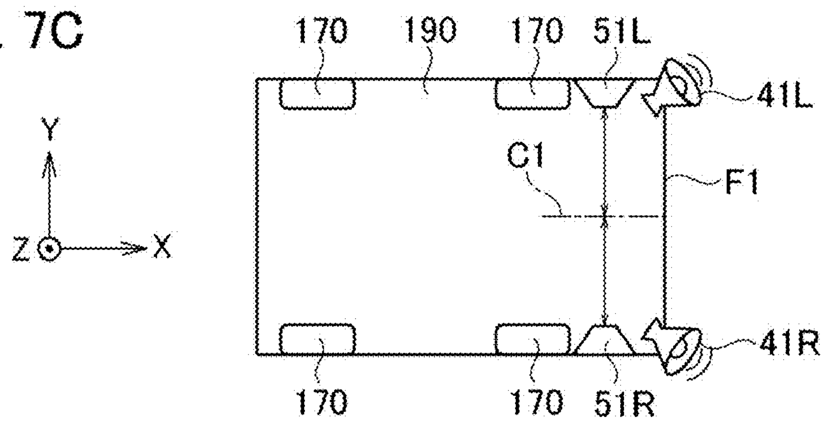


FIG. 7D

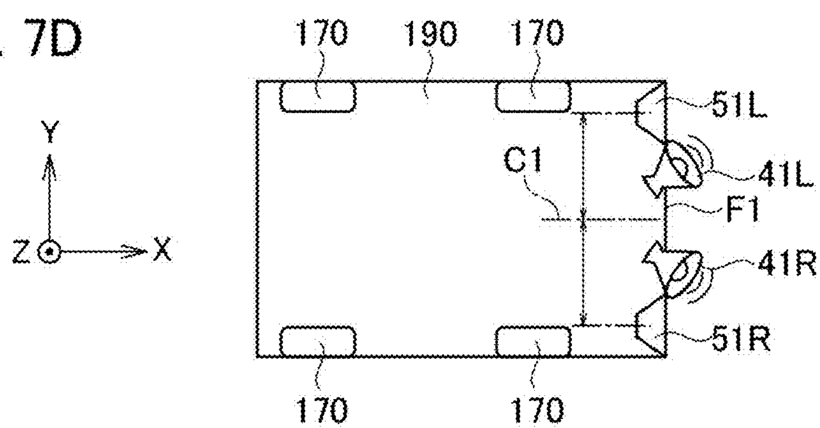


FIG. 7E

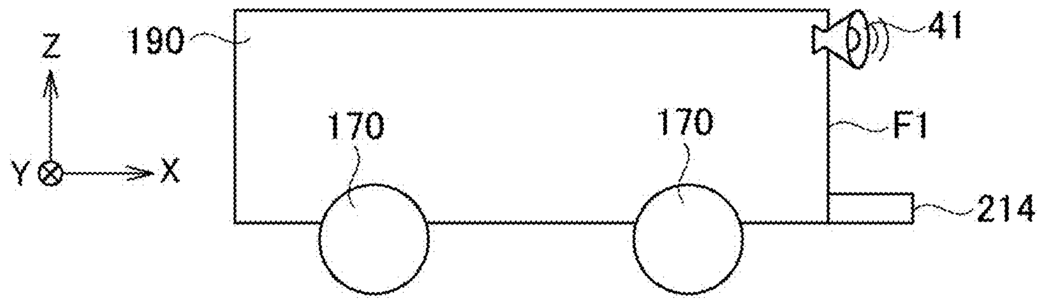


FIG. 7F

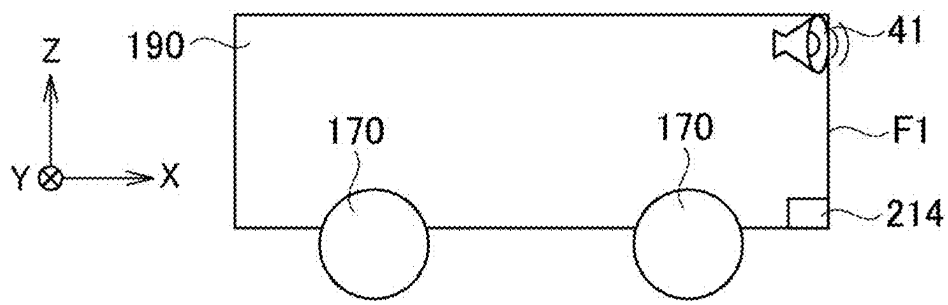


FIG. 7G

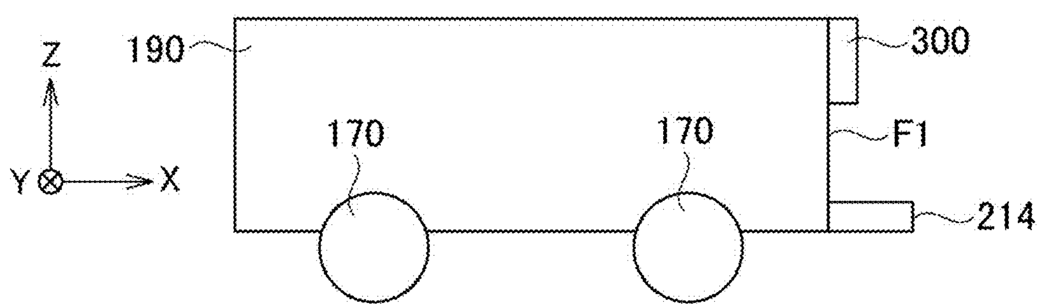


FIG. 7H

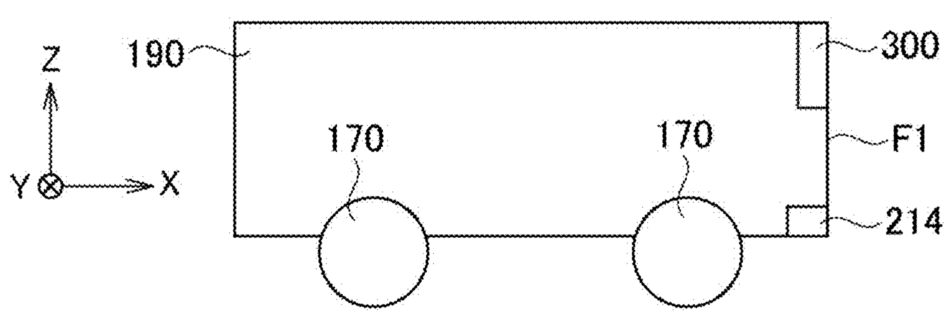


FIG. 8

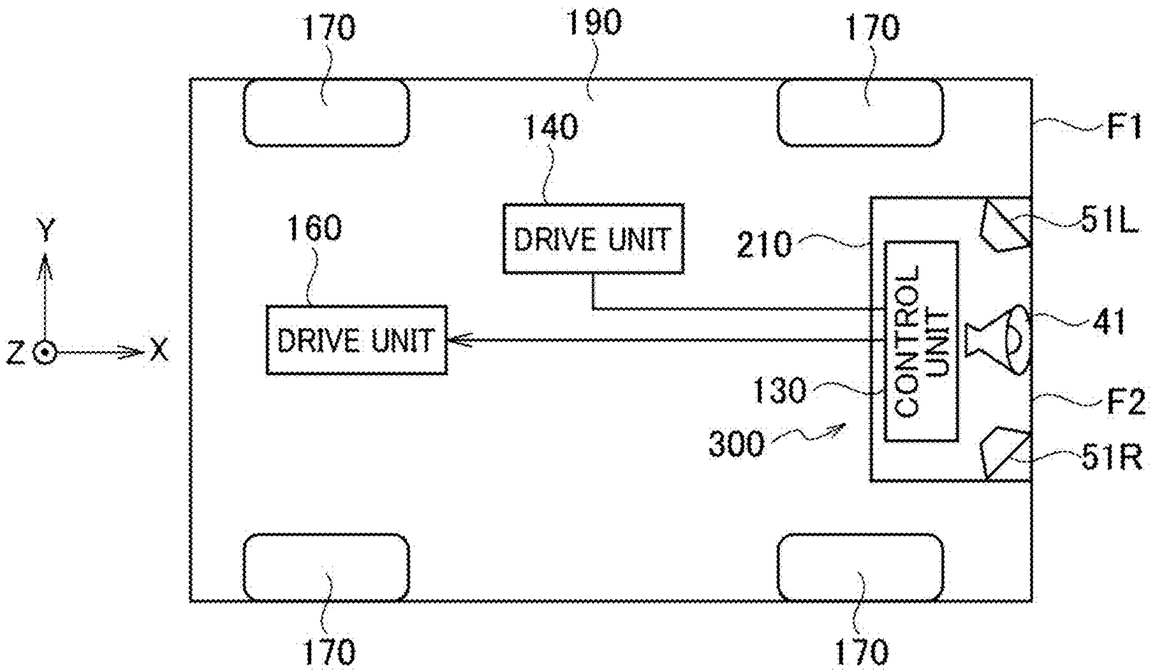

170
190
170
F1
140
DRIVE UNIT
160
210
51L
DRIVE UNIT
CONTROL UNIT
41
Y
Z
X
130
F2
300
51R
170
170

FIG. 9

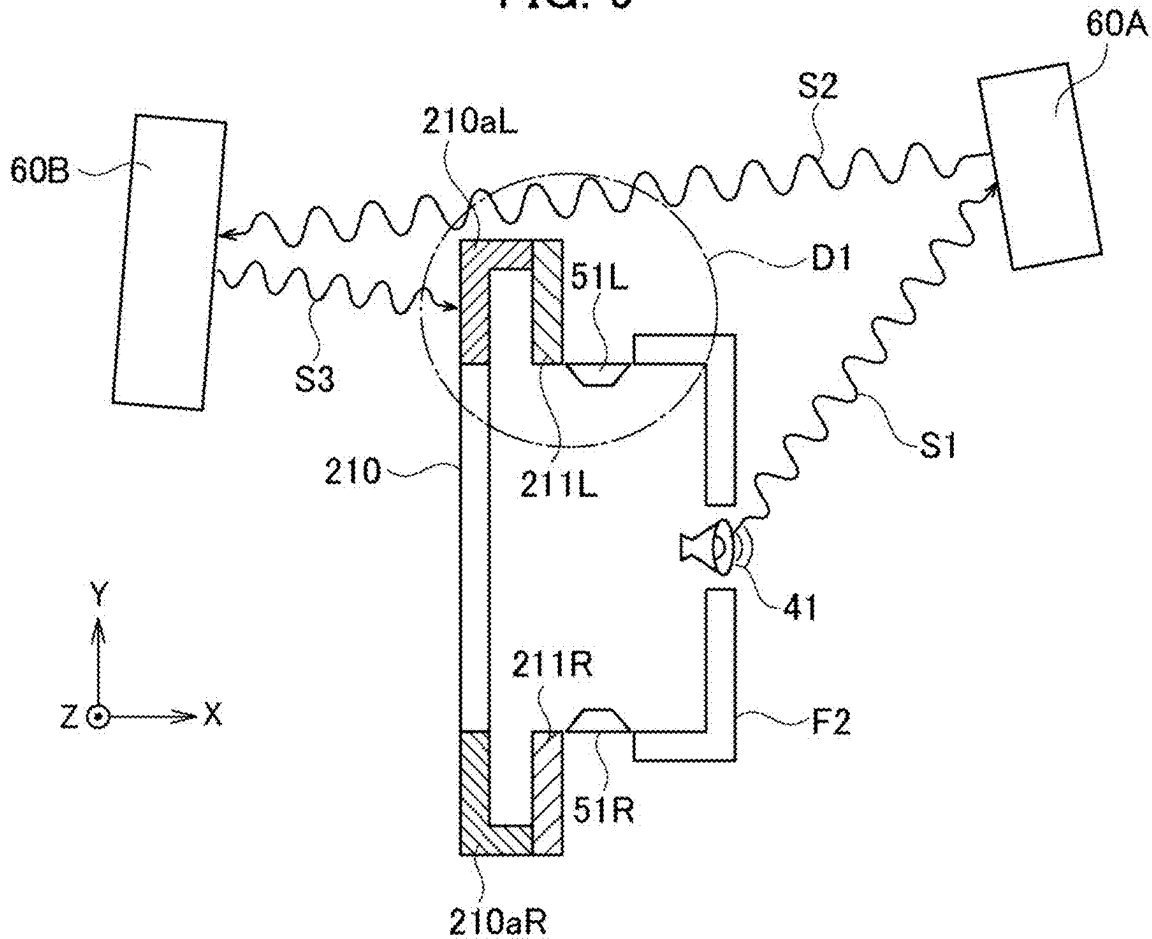

60A
S2
210aL
60B
D1
51L
S3
S1
210
211L
41
Y
211R
Z
X
F2
51R
210aR

FIG. 10A

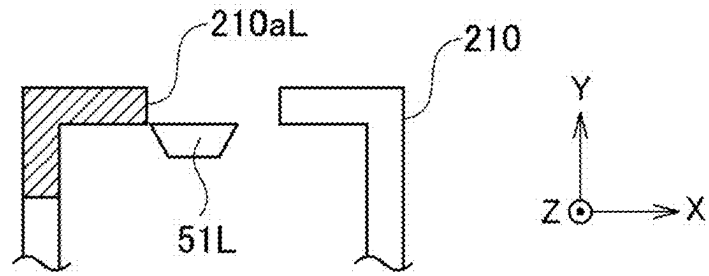


FIG. 10B

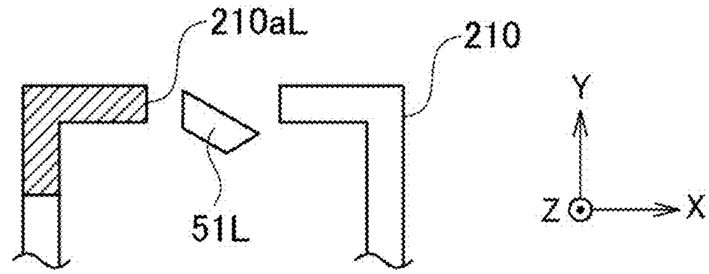


FIG. 10C

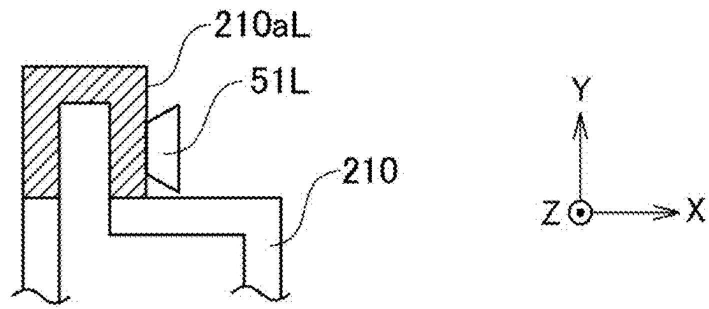


FIG. 10D

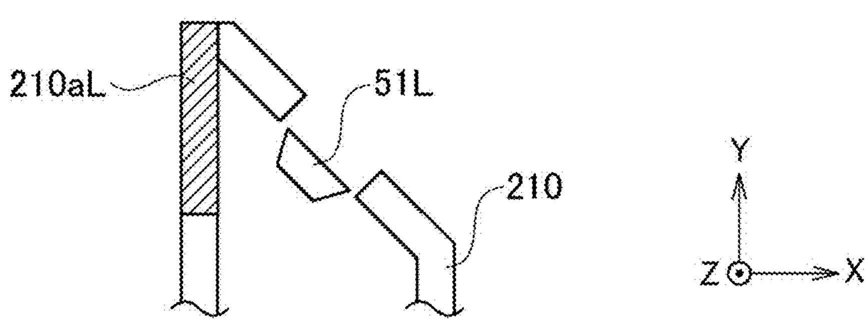


FIG. 11

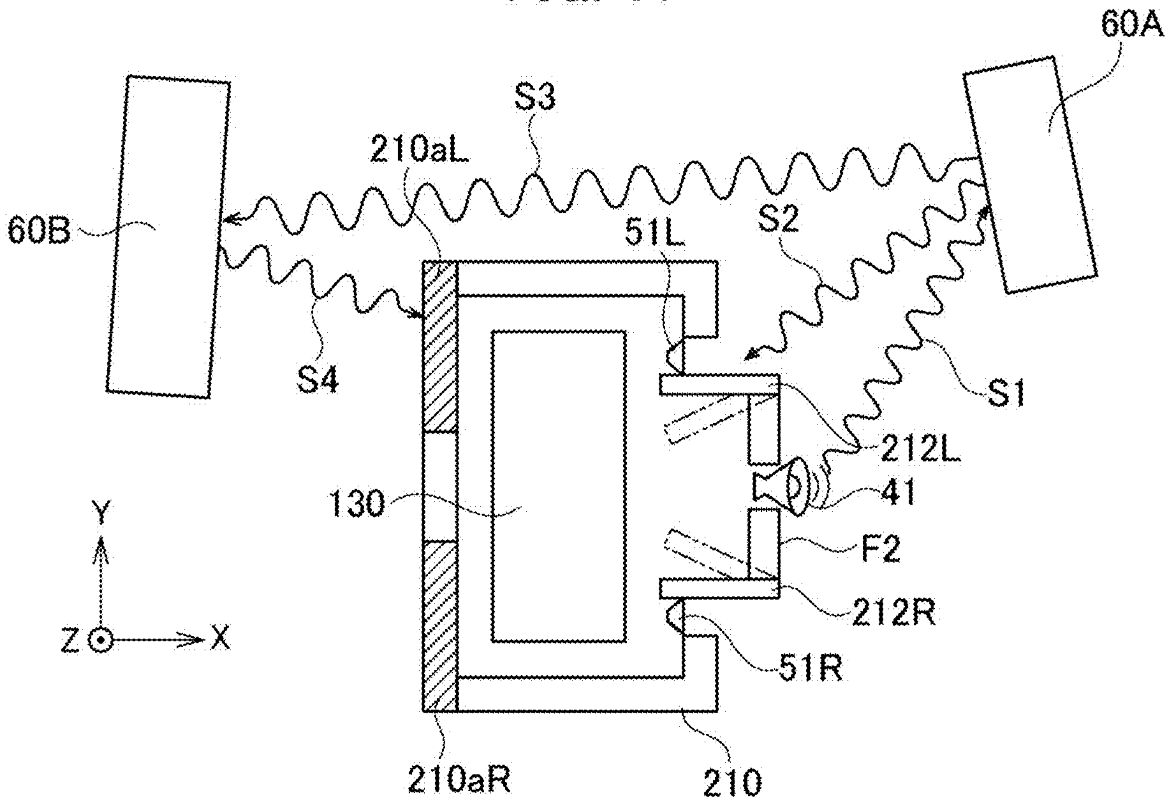

60A
S3
210aL
60B
51L
S2
S4
S1
212L
41
130
Y
F2
212R
Z
X
51R
210aR
210

FIG. 12

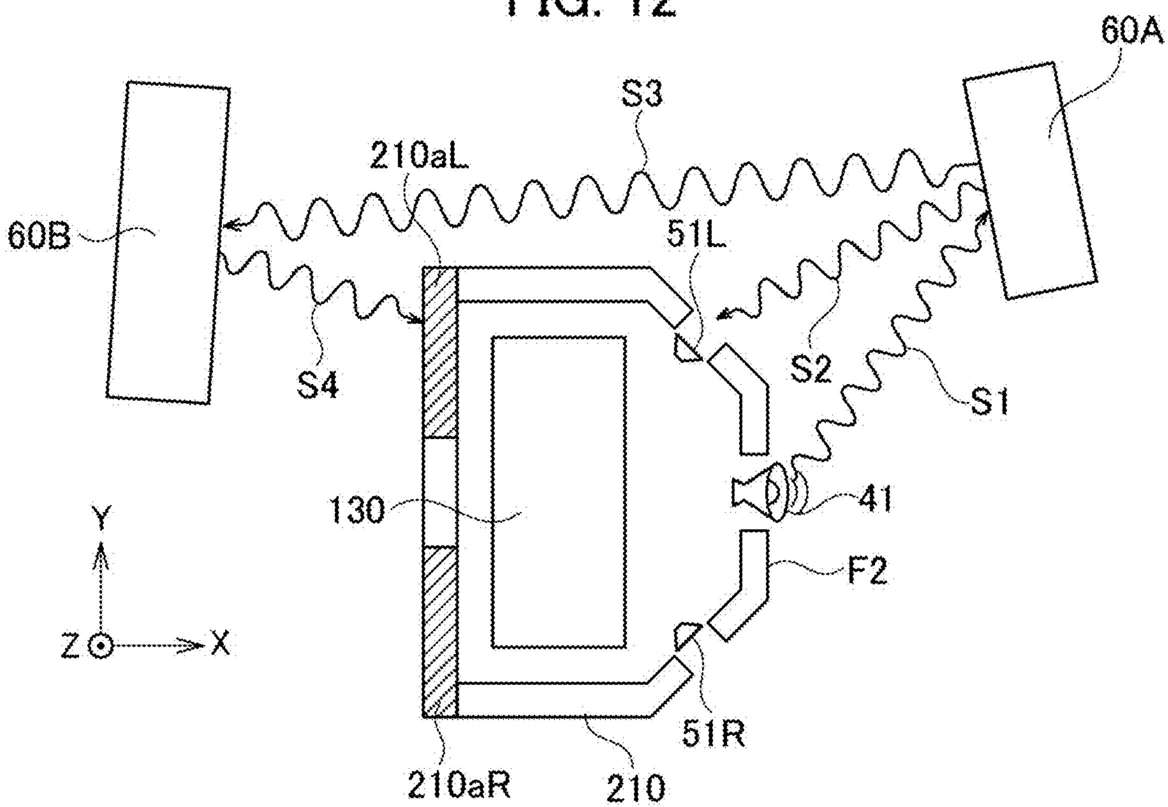

60A
S3
210aL
60B
51L
S4
S2
S1
41
130
Y
F2
Z
X
51R
210aR
210

FIG. 13

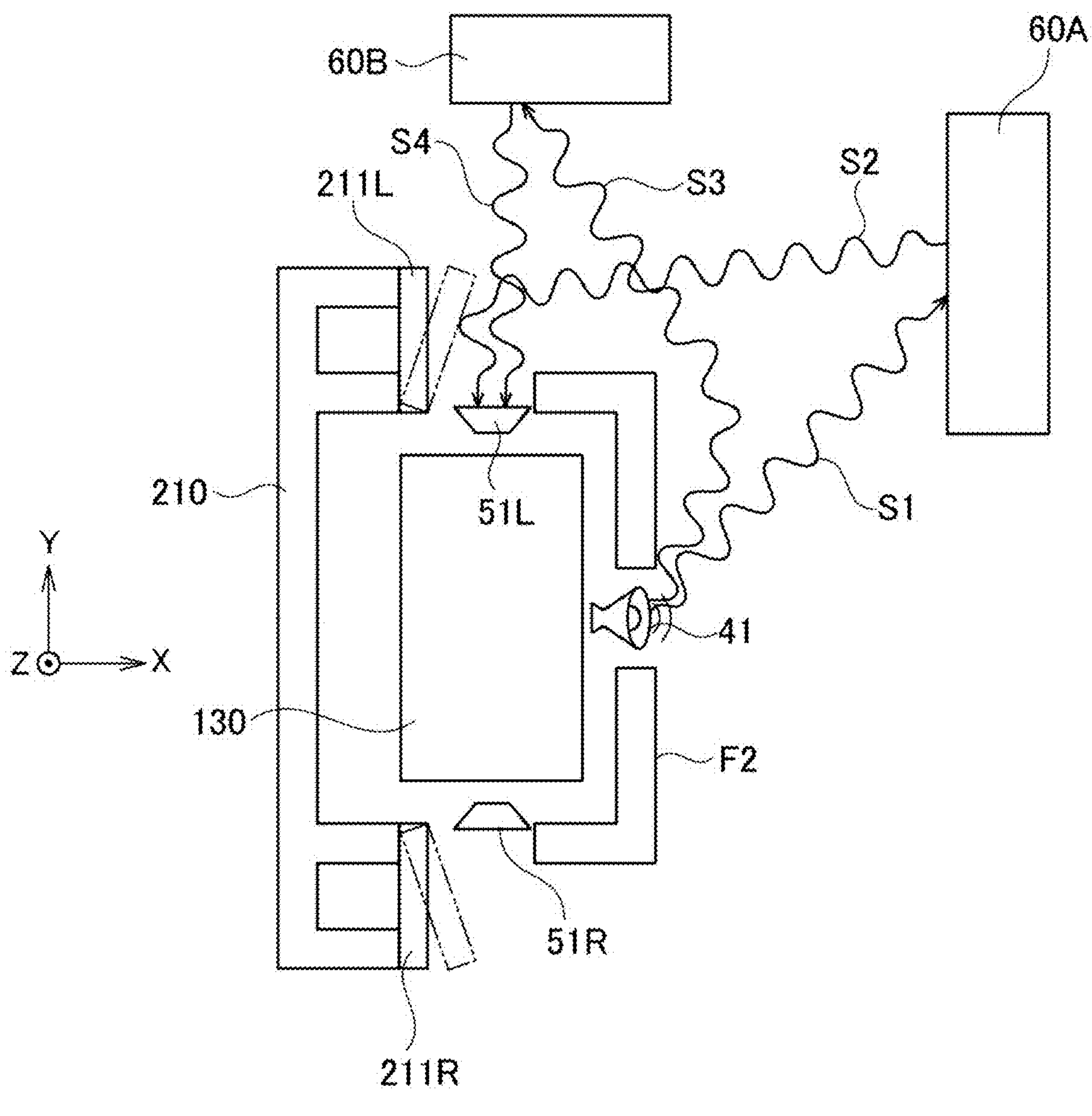


FIG. 14A

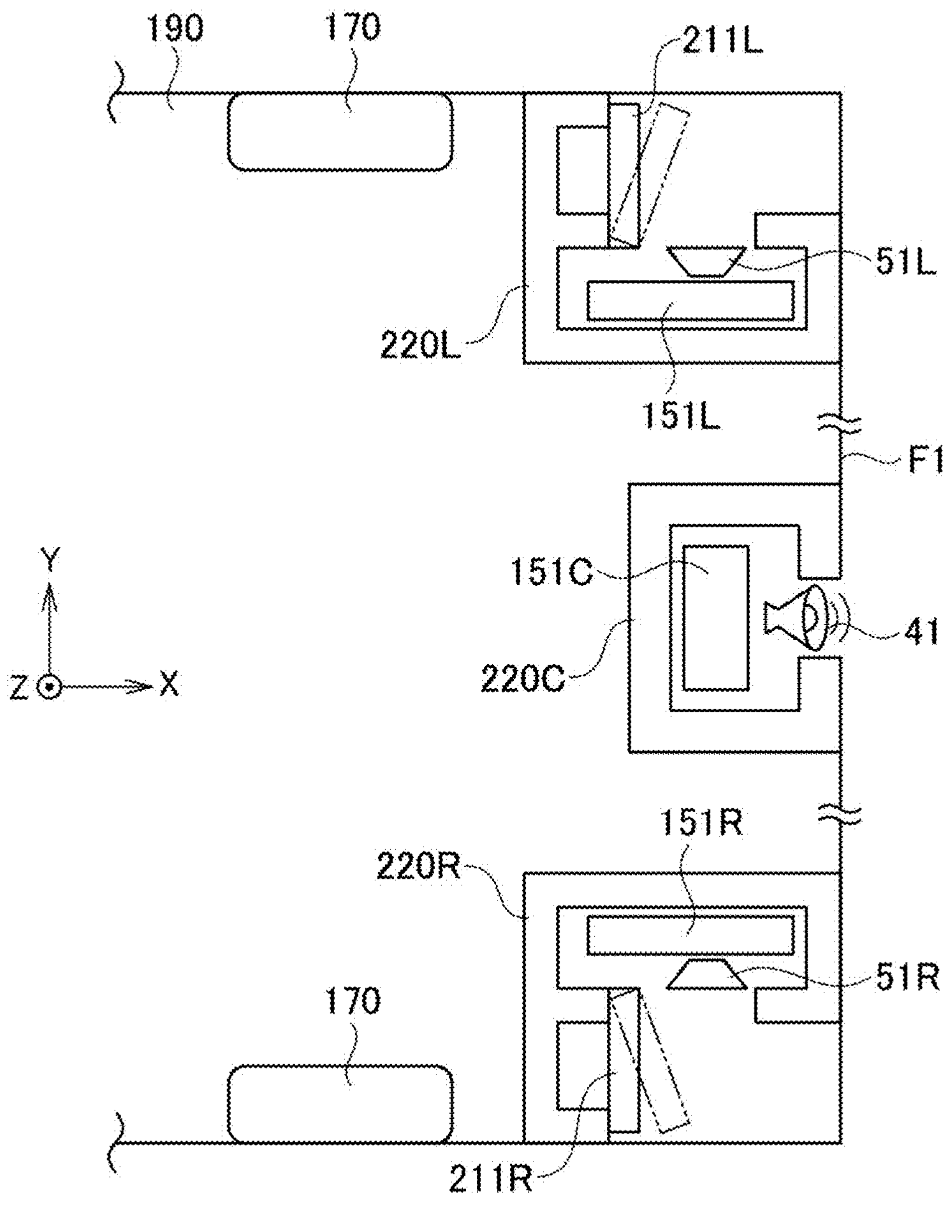

190
170
211L
51L
220L
151L
F1
Y
151C
41
220C
Z
X
151R
220R
51R
170
211R

FIG. 14B

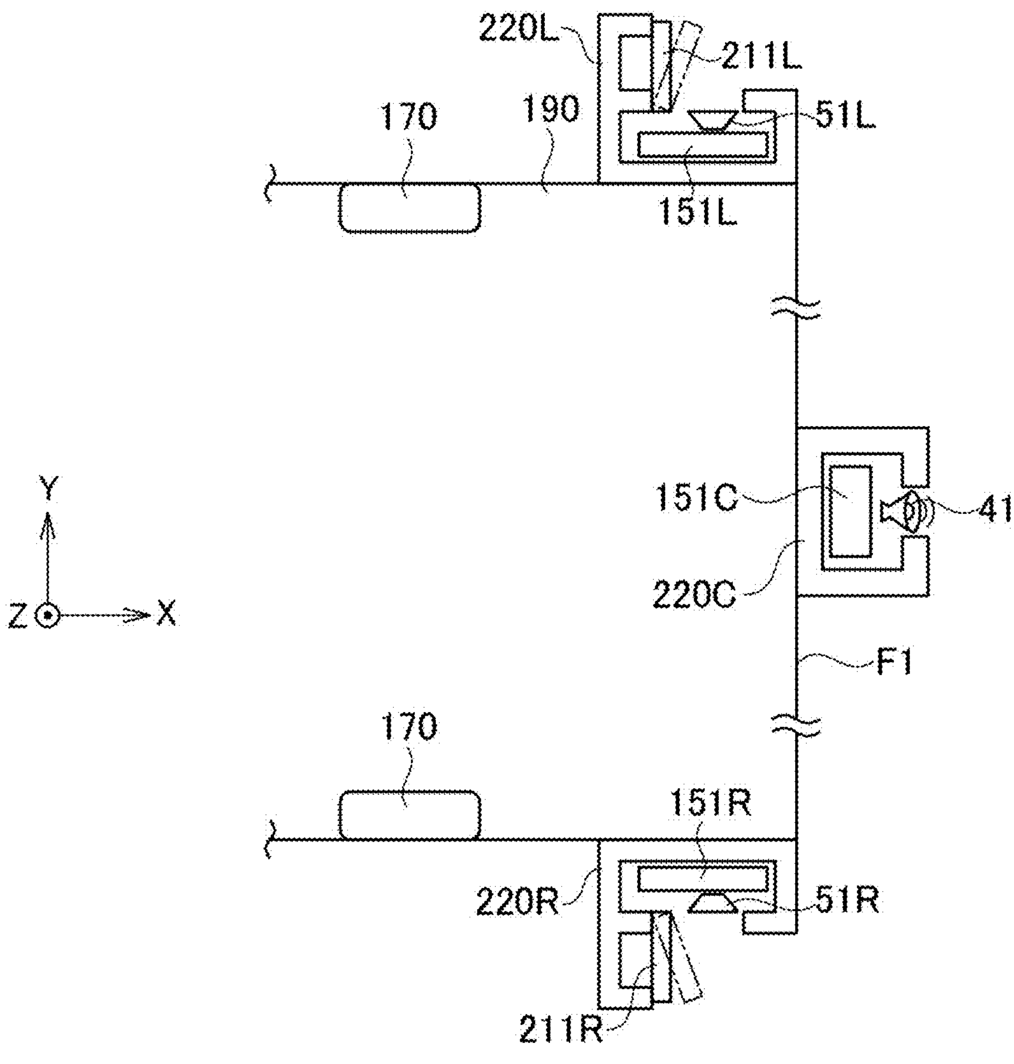

220L
211L
170
190
51L
151L
151C
41
220C
Y
Z
X
F1
170
151R
220R
51R
211R

FIG. 15A

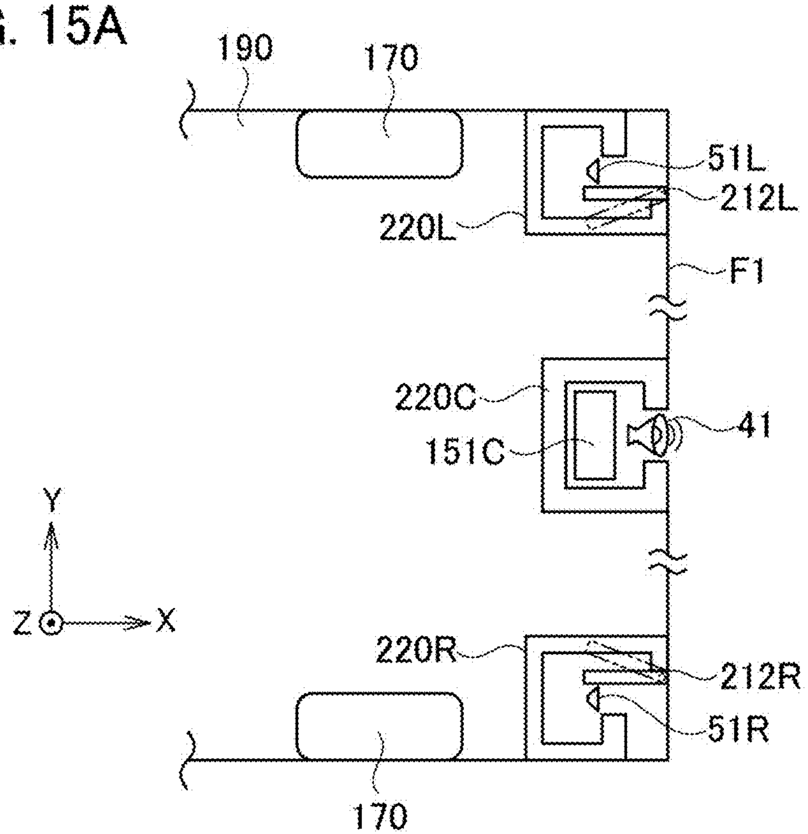


FIG. 15B

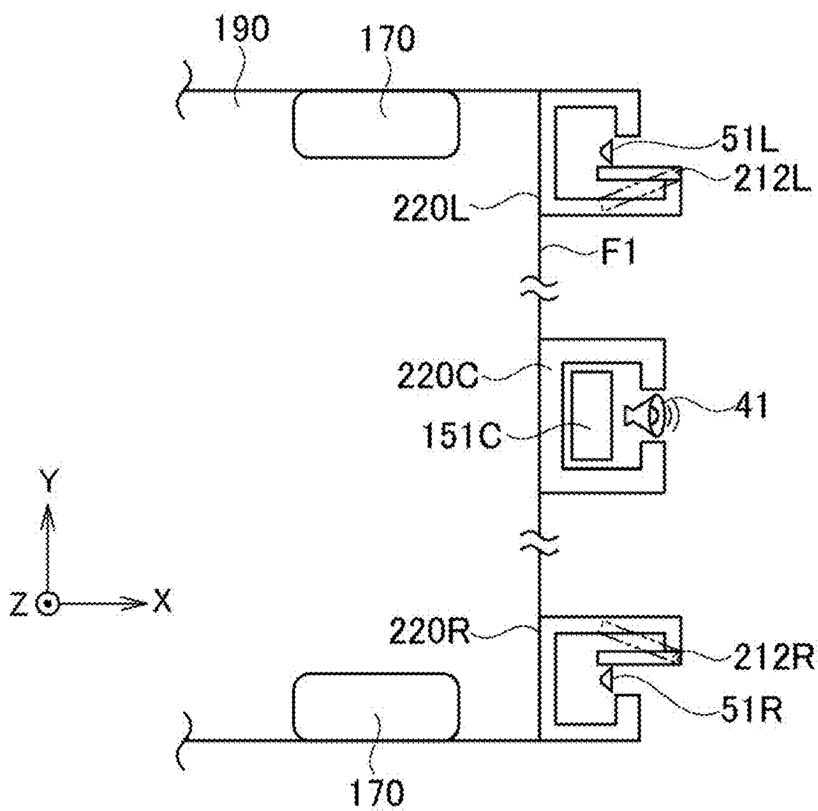


FIG. 16

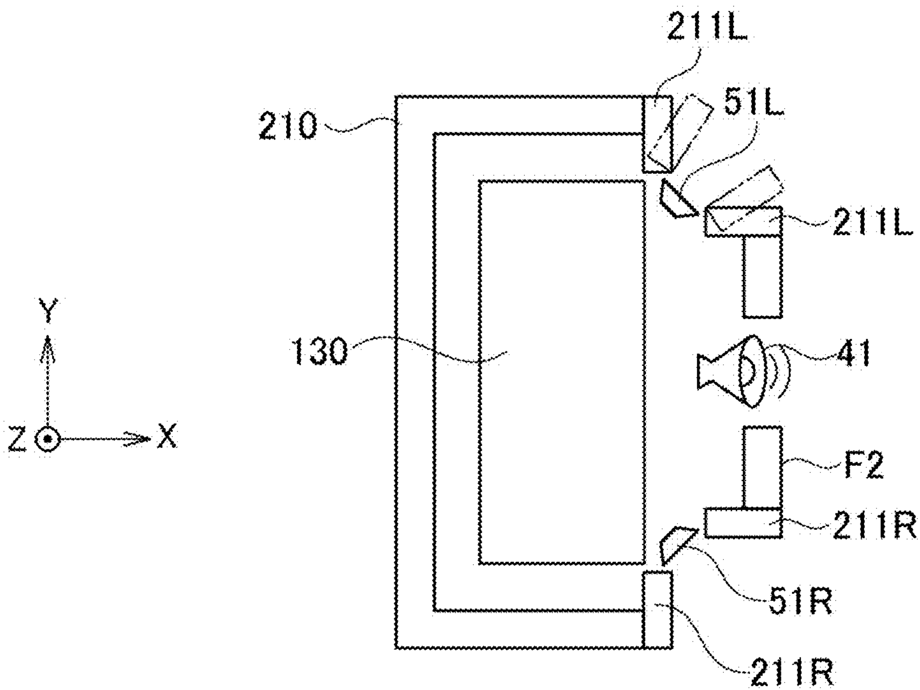


FIG. 17A

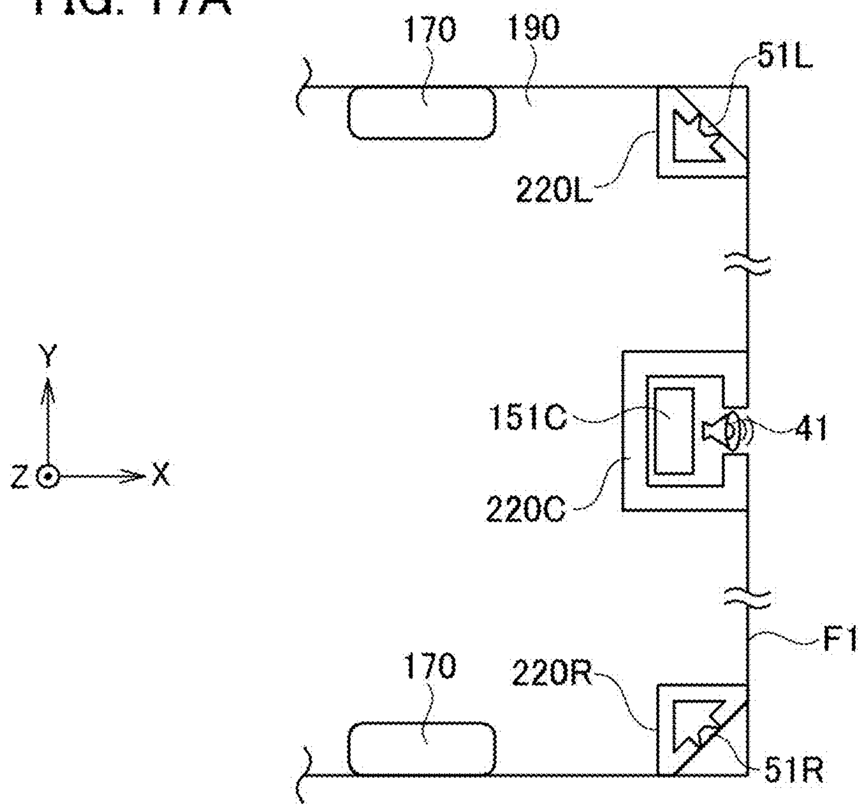


FIG. 17B

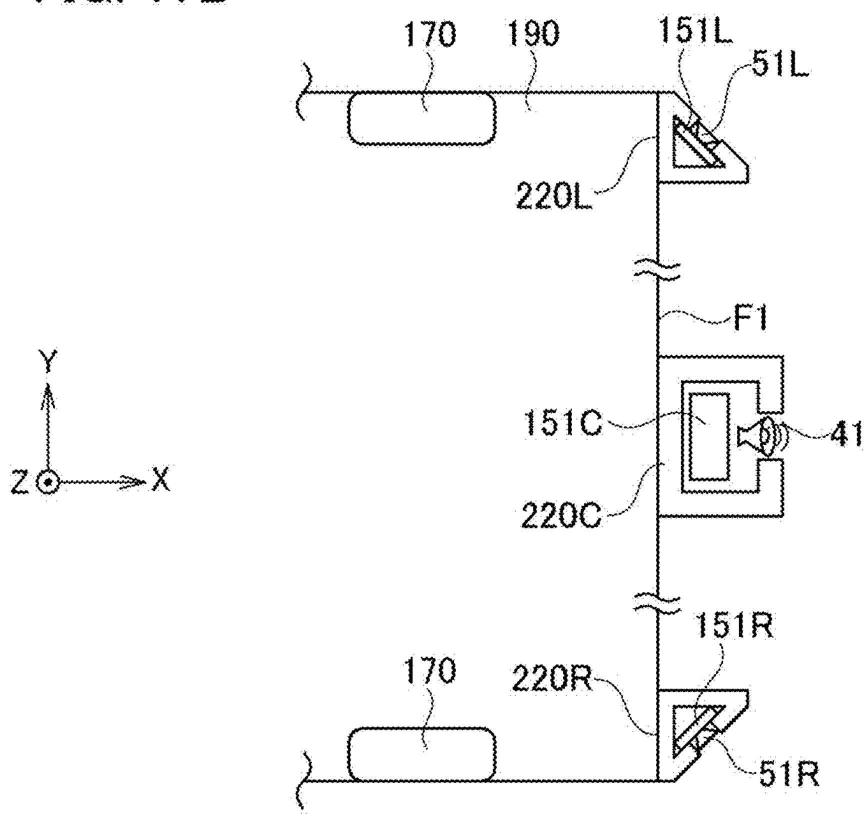


FIG. 18A

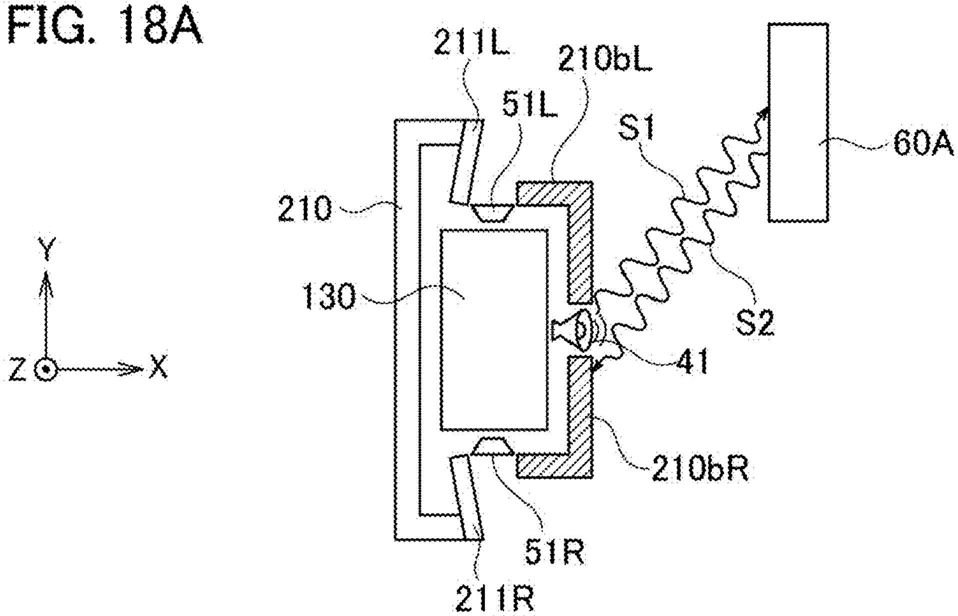


FIG. 18B

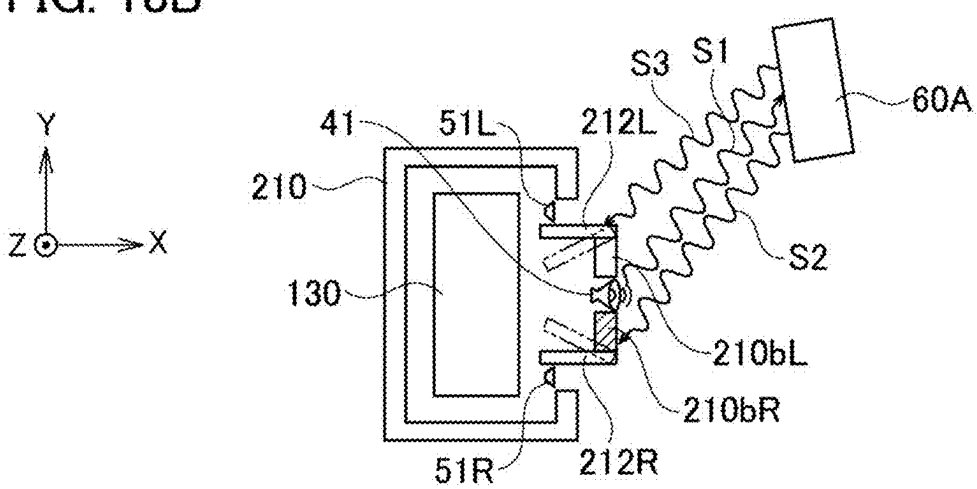


FIG. 18C

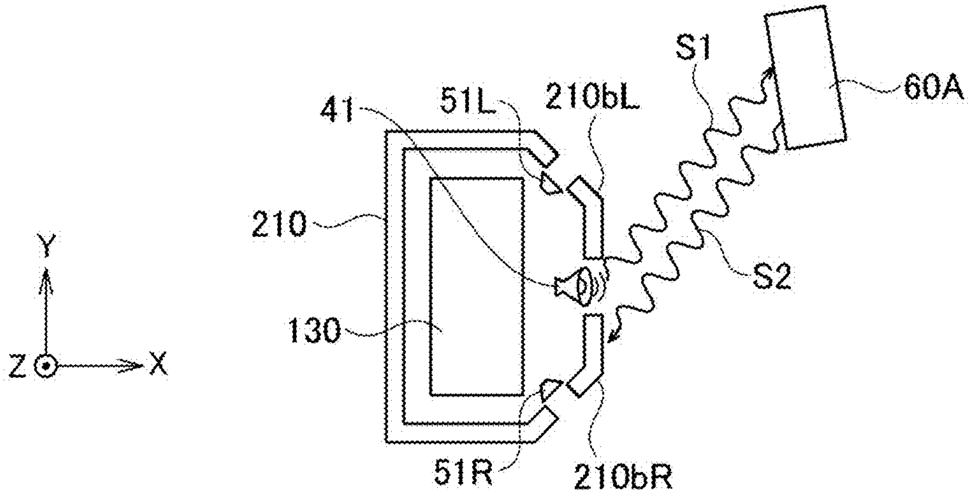


FIG. 19

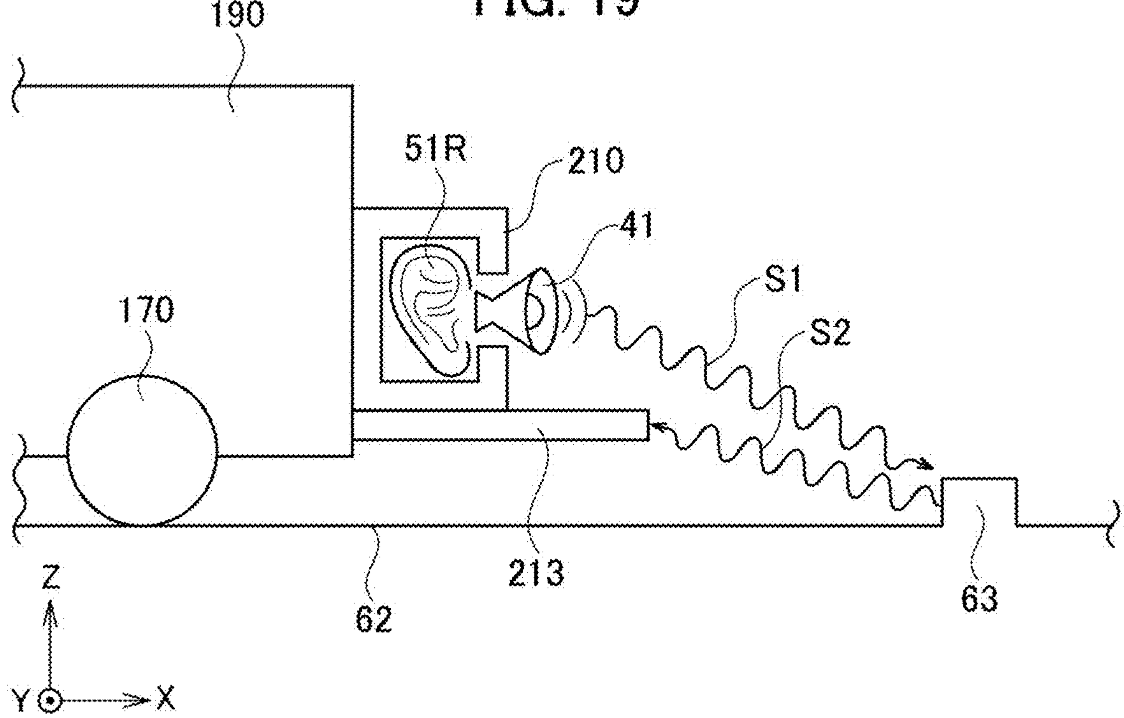

190
51R
210
41
S1
S2
170
213
62
63
Z
Y
X

FIG. 20

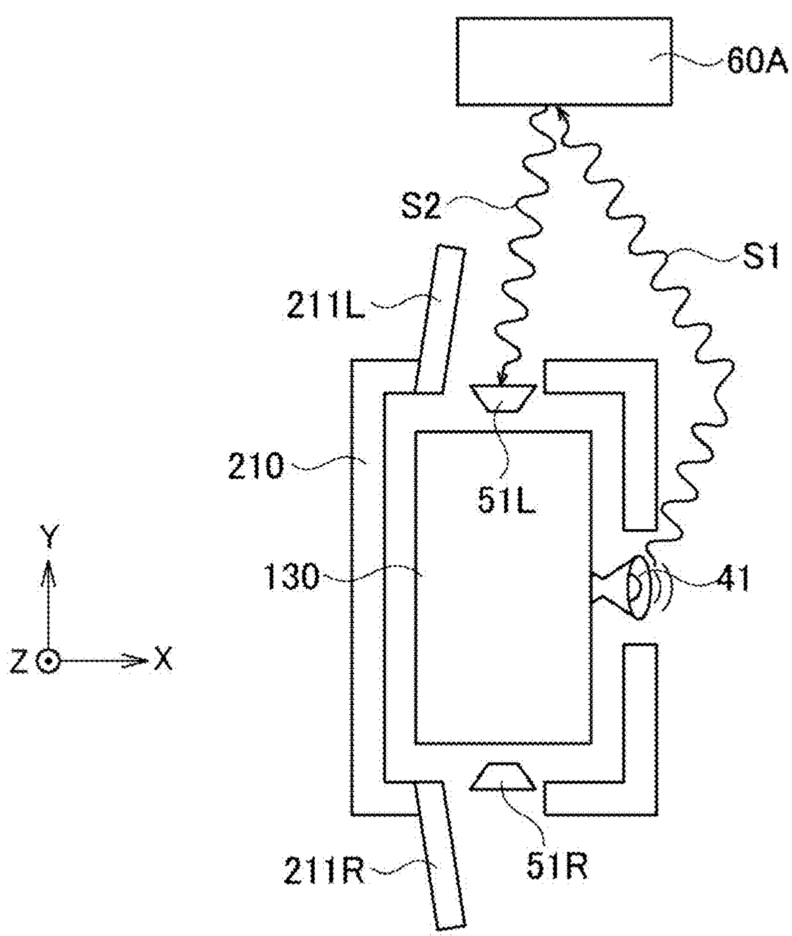

60A
S2
S1
211L
210
51L
130
41
Y
Z
X
211R
51R

FIG. 21

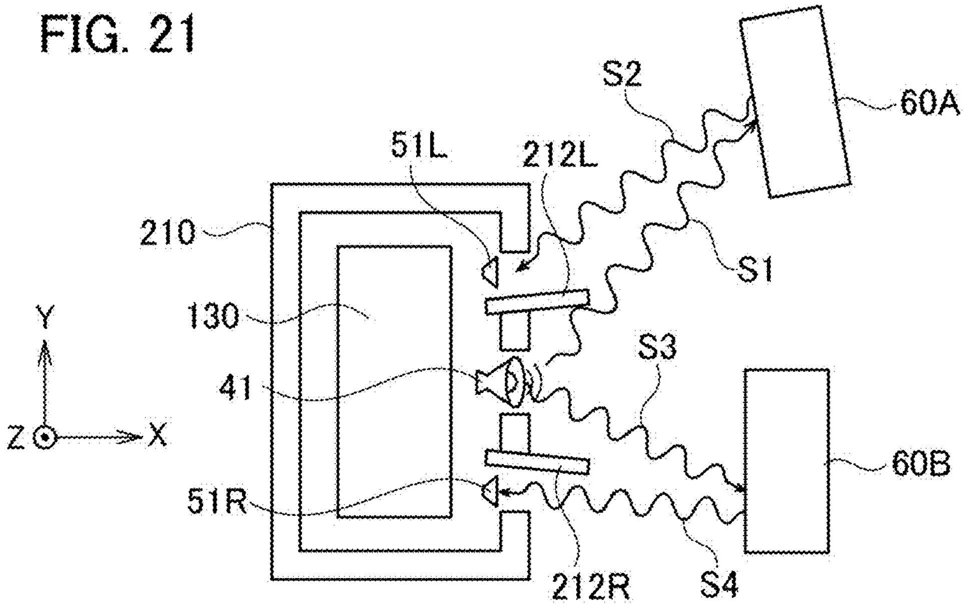


FIG. 22A

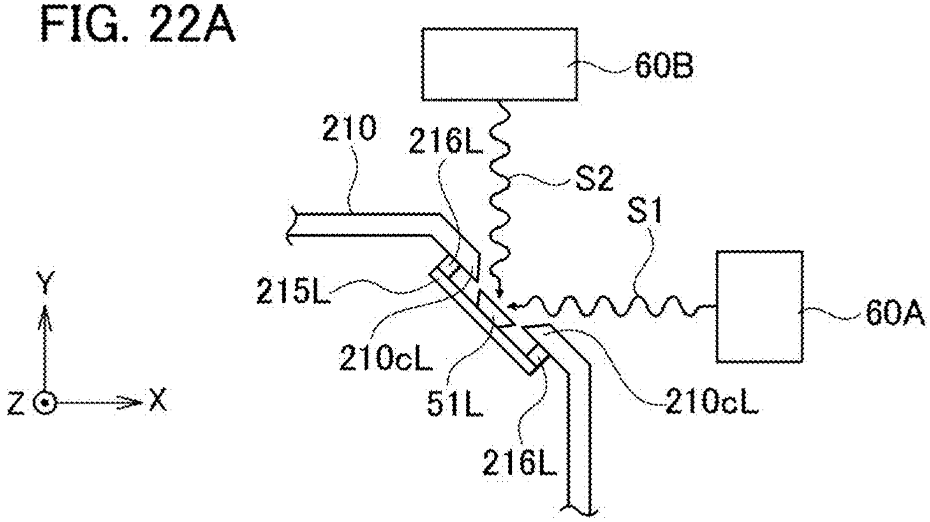


FIG. 22B

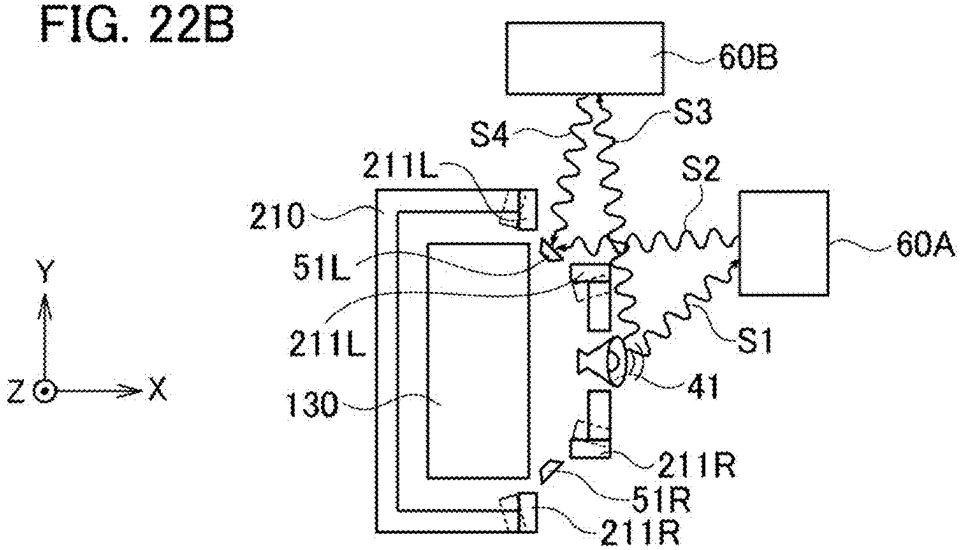


FIG. 23A

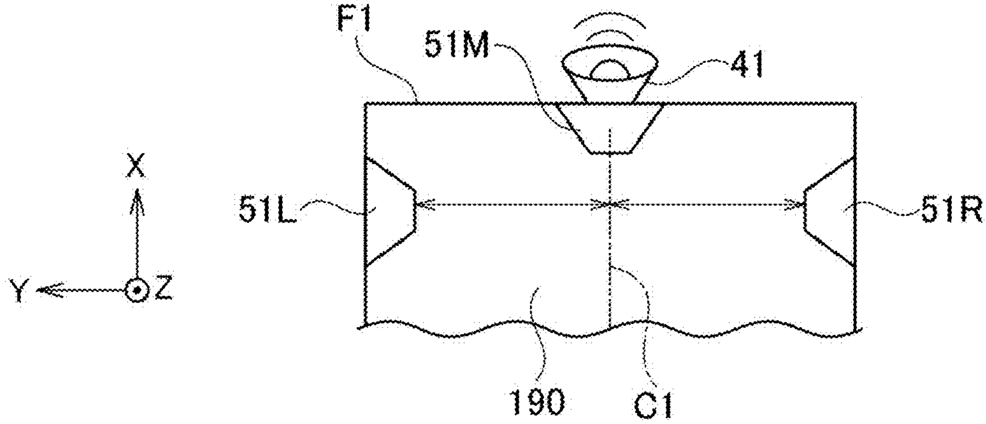


FIG. 23B

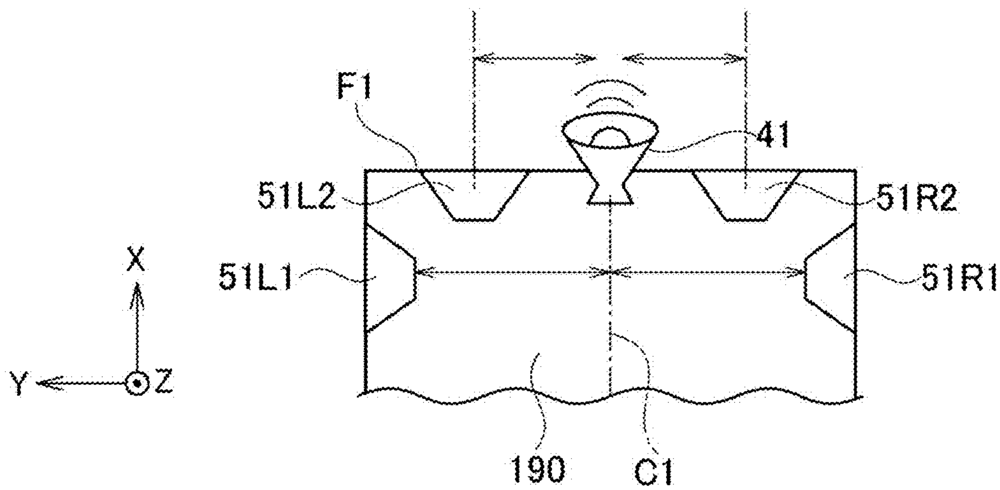


FIG. 23C

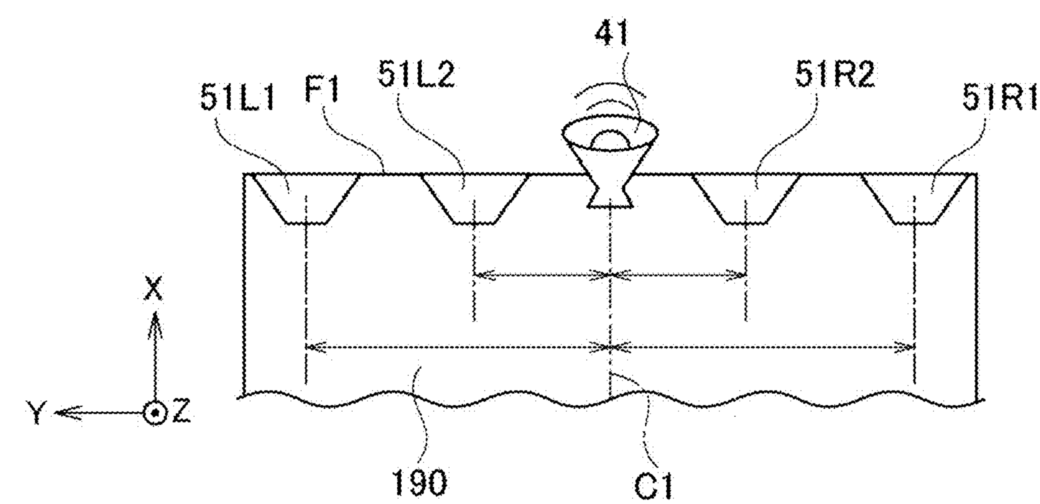


FIG. 23D

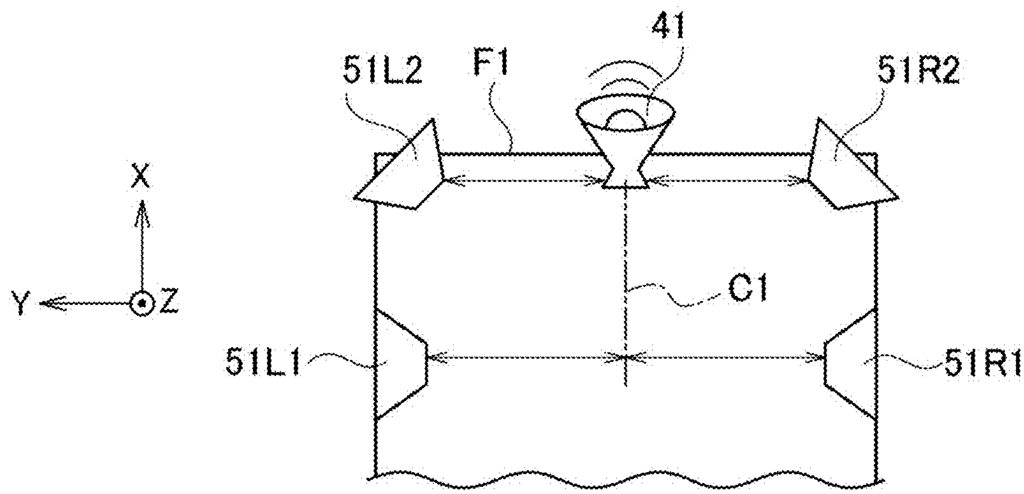
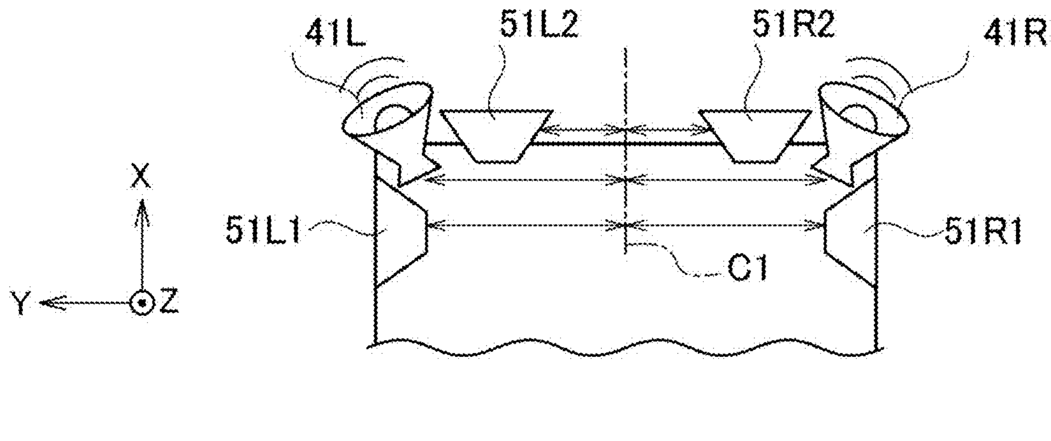


FIG. 23E



AUTONOMOUS MOVING APPARATUS AND COMPOSITE UNIT OF SPEAKER-MICROPHONE FOR AUTONOMOUS MOVING APPARATUS

CROSS REFERENCE TO RELATED APPLICATIONS AND INCORPORATION BY REFERENCE

[0001] This is a continuation application (CA) of PCT Application No. PCT/JP2023/039925, filed on Nov. 6, 2023, which claims priority to Japan Patent Application No. P2022-181345 filed on Nov. 11, 2022 and is based upon and claims the benefit of priority from prior Japanese Patent Application No. P2022-181345 filed on Nov. 11, 2022 and PCT Application No. PCT/JP2023/039925, filed on Nov. 6, 2023; the entire contents of each of which are incorporated herein by reference.

TECHNICAL FIELD

[0002] The present disclosure relates to an autonomous moving apparatus and a composite unit of a speaker-microphone for an autonomous moving apparatus.

BACKGROUND

[0003] There are conventionally known autonomous traveling vehicles adopting Simultaneous Localization And Mapping (SLAM). By using an external sensor such as a camera or a laser sensor and an internal sensor such as an encoder or a gyroscope in combination for each autonomous traveling vehicle, each autonomous traveling vehicle estimates a position thereof and automatically generates a travel path, and this enables automatic avoidance of an obstacle without being limited by a fixed route, for example. The autonomous traveling vehicles eliminate the necessity for infrastructure such as wires embedded in the floor or markings on the floor. SLAM using a camera may be referred to as Visual SLAM, and SLAM using a laser sensor may be referred to as Light Detection And Ranging (LIDAR) SLAM.

[0004] Patent Literature 1: JP 2020-181485 A

BRIEF DESCRIPTION OF DRAWINGS

[0005] FIG. **1** is a schematic diagram for explaining an operation summary of an autonomous movement system including an autonomous moving apparatus according to a plurality of embodiments.

[0006] FIG. **2** is an explanatory diagram showing a situation in which the autonomous moving apparatus travels on a planar travel path where a plurality of obstacles **p1** to **p4** are present, and travels toward a destination P**1**.

[0007] FIG. **3** is a block diagram showing an example of a configuration of the autonomous moving apparatus according to the plurality of embodiments.

[0008] FIG. **4** is a block diagram showing an example of an echolocation configuration of one speaker and two microphones in an autonomous moving apparatus **100** according to the present embodiment.

[0009] FIG. **5** is a block diagram showing details of each component in the echolocation configuration shown in FIG. **4**.

[0010] FIG. **6**A is a plan view showing the autonomous moving apparatus **100** having layouts of a speaker and microphones for increasing the difference in sound pressures of acoustic waves received by a pair of left and right first microphone **51**L and second microphone **51**R (part 1).

[0011] FIG. **6**B is a plan view showing the autonomous moving apparatus **100** having layouts of a speaker and microphones for increasing the difference in sound pressures of acoustic waves received by the pair of left and right first microphone **51**L and second microphone **51**R (part 2).

[0012] FIG. **6**C is a plan view showing the autonomous moving apparatus **100** having layouts of a speaker and microphones for increasing the difference in sound pressures of acoustic waves received by the pair of left and right first microphone **51**L and second microphone **51**R (part 3).

[0013] FIG. **7**A is a plan view showing the autonomous moving apparatus **100** having layouts of speakers and microphones for increasing the difference in sound pressures of acoustic waves received by the pair of left and right first microphone **51**L and second microphone **51**R (part 4).

[0014] FIG. **7**B is a plan view showing the autonomous moving apparatus **100** having layouts of speakers and microphones for increasing the difference in sound pressures of acoustic waves received by the pair of left and right first microphone **51**L and second microphone **51**R (part 5).

[0015] FIG. **7**C is a plan view showing the autonomous moving apparatus **100** having layouts of speakers and microphones for increasing the difference in sound pressures of acoustic waves received by the pair of left and right microphones **51**L and **51**R (part 6).

[0016] FIG. **7**D is a plan view showing the autonomous moving apparatus **100** having layouts of speakers and microphones for increasing the difference in sound pressures of acoustic waves received by the pair of left and right microphones **51**L and **51**R (part 7).

[0017] FIG. **7**E is a side view showing a layout of the autonomous moving apparatus **100** for increasing sound pressures of acoustic waves received by the first microphone **51**L and the second microphone **51**R from a front direction or an oblique front direction (part 1).

[0018] FIG. **7**F is a side view showing a layout of the autonomous moving apparatus **100** for increasing sound pressures of acoustic waves received by the first microphone **51**L and the second microphone **51**R from the front direction or the oblique front direction (part 2).

[0019] FIG. **7**G is a side view showing a layout of a composite unit **300** for increasing sound pressures of acoustic waves received by the first microphone **51**L and the second microphone **51**R from the front direction or the oblique front direction (part 1).

[0020] FIG. **7**H is a side view showing a layout of the composite unit **300** for increasing sound pressures of acoustic waves received by the first microphone **51**L and the second microphone **51**R from the front direction or the oblique front direction (part 2).

[0021] FIG. **8** is a plan view showing the autonomous moving apparatus having the composite unit **300** for an autonomous moving apparatus, with layouts of a speaker and microphones for increasing the difference in sound pressures of acoustic waves received by the pair of left and right microphones **51**L and **51**R.

[0022] FIG. **9** is a plan view showing a structure of a casing **210** for reducing a sound pressure of an acoustic wave (noise) coming from a rear direction.

[0023] FIG. **10**A is a plan view showing a modified example of an embodiment for reducing a sound pressure of an acoustic wave (noise) coming from the rear direction (part 1).

[0024] FIG. **10**B is a plan view showing a modified example of the embodiment for reducing a sound pressure of an acoustic wave (noise) coming from the rear direction (part 2).

[0025] FIG. **10**C is a plan view showing a modified example of the embodiment for reducing a sound pressure of an acoustic wave (noise) coming from the rear direction (part 3).

[0026] FIG. **10**D is a plan view sowing a modified example of the embodiment for reducing a sound pressure of an acoustic wave (noise) coming from the rear direction (part 4).

[0027] FIG. **11** is a plan view showing a modified example of the embodiment for reducing a sound pressure of an acoustic wave (noise) coming from the rear direction (part 5).

[0028] FIG. **12** is a plan view showing a modified example of the embodiment for reducing a sound pressure of an acoustic wave (noise) coming from the rear direction (part 6).

[0029] FIG. **13** is a plan view showing an example of a structure of the composite unit for increasing sound pressures of acoustic waves coming from oblique front directions, among acoustic waves received by the first microphone **51**L and the second microphone **51**R.

[0030] FIG. **14**A is a plan view showing a modified example of an embodiment for increasing sound pressures of acoustic waves coming from the oblique front directions, among acoustic waves received by the first microphone **51**L and the second microphone **51**R (part 1).

[0031] FIG. **14**B is a plan view showing a modified example of the embodiment for increasing sound pressures of acoustic waves coming from the oblique front directions, among acoustic waves received by the first microphone **51**L and the second microphone **51**R (part 2).

[0032] FIG. **15**A is a plan view showing a modified example of the embodiment for increasing sound pressures of acoustic waves coming from the oblique front directions, among acoustic waves received by the first microphone **51**L and the second microphone **51**R (part 3).

[0033] FIG. **15**B is a plan view showing a modified example of the embodiment for increasing sound pressures of acoustic waves coming from the oblique front directions, among acoustic waves received by the first microphone **51**L and the second microphone **51**R (part 4).

[0034] FIG. **16** is a plan view showing a modified example of the embodiment for increasing sound pressures of acoustic waves coming from the oblique front directions, among acoustic waves received by the first microphone **51**L and the second microphone **51**R (part 5).

[0035] FIG. **17**A is a plan view showing a modified example of the embodiment for increasing sound pressures of acoustic waves coming from the oblique front directions, among acoustic waves received by the first microphone **51**L and the second microphone **51**R (part 6).

[0036] FIG. **17**B is a plan view showing a modified example of the embodiment for increasing sound pressures of acoustic waves coming from the oblique front directions, among acoustic waves received by the first microphone **51**L and the second microphone **51**R (part 7).

[0037] FIG. **18**A is a plan view showing an example of a structure of the composite unit **300** for reducing sound pressures of acoustic waves coming from right and left opposite sides, among acoustic waves received by the first microphone **51**L and the second microphone **51**R.

[0038] FIG. **18**B is a plan view showing another example of a structure of the composite unit **300** for reducing sound pressures of acoustic waves coming from the right and left opposite sides, among acoustic waves received by the first microphone **51**L and the second microphone **51**R (part 1).

[0039] FIG. **18**C is a plan view showing another example of a structure of the composite unit **300** for reducing sound pressures of the acoustic waves coming from the right and left opposite sides, among acoustic waves received by the first microphone **51**L and the second microphone **51**R (part 2).

[0040] FIG. **19** is a side view showing an example of a structure of the composite unit **300** for reducing sound pressures of acoustic waves reflected by an unevenness **63** on a ground **62**, among acoustic waves received by the first microphone **51**L and the second microphone **51**R.

[0041] FIG. **20** is a plan view showing an example of a structure of the composite unit **300** for increasing sound pressures of acoustic waves coming from a lateral direction of the composite unit **300** to prevent an object **60**A in the lateral direction from being entangled.

[0042] FIG. **21** is a plan view showing an example of a structure of the composite unit **300** for increasing sound pressures of acoustic waves coming from a front direction of the autonomous moving apparatus **100** to prevent collision with the object **60**A in the front direction.

[0043] FIG. **22**A is a plan view showing an example of a structure of the composite unit **300** for increasing sound pressures of acoustic waves coming from at least one of a front direction and a lateral direction, while increasing sound pressures of acoustic waves coming from oblique front directions to the pair of left and right microphones **51**L and **51**R.

[0044] FIG. **22**B is a plan view showing another example of a structure of the composite unit **300** for increasing sound pressures of acoustic waves coming from at least one of a front direction and a lateral direction, while increasing sound pressures of acoustic waves coming from the oblique front directions to the pair of left and right microphones **51**L and **51**R.

[0045] FIG. **23**A is a plan view showing another modified example of the number and arrangement of microphones and speakers of the autonomous moving apparatus **100** (part 1).

[0046] FIG. **23**B is a plan view showing another modified example of the number and arrangement of microphones and speakers of the autonomous moving apparatus **100** (part 2).

[0047] FIG. **23**C is a plan view showing another modified example of the number and arrangement of microphones and speakers of the autonomous moving apparatus **100** (part 3).

[0048] FIG. **23**D is a plan view showing another modified example of the number and arrangement of microphones and speakers of the autonomous moving apparatus **100** (part 4).

[0049] FIG. **23**E is a plan view showing another modified example of the number and arrangement of microphones and speakers of the autonomous moving apparatus **100** (part 5).

DETAILED DESCRIPTION

[0050] An autonomous moving apparatus, an autonomous movement system, and a composite unit of a speaker-microphone for an autonomous moving apparatus according to a plurality of embodiments will be described below in detail with reference to the drawings. It should be noted that embodiments described below shows exhaustive or specific examples. Numerical values, shapes, materials, constituent elements, and installation positions and connection forms of constituent elements described in the following embodiments are examples and are not intended to be limited to those of the present disclosure. Further, among constituent elements in the following embodiments, constituent elements not recited in independent claims indicating the most significant concept are described as optional constituent elements. Still further, the dimensional ratios in the drawings are exaggerated for illustrative purposes and may differ from the actual ratios.

[0051] In addition, the following embodiments and modified examples thereof may include similar constituent elements, and therefore the similar constituent elements are denoted with a common reference numeral to omit duplicated descriptions thereof.

(Outline of Autonomous Moving Apparatus)

[0052] The autonomous moving apparatus according to the plurality of embodiments can be used in the internal space or, in some cases, in the external space of buildings such as houses and offices and structures such as factories, and has a configuration of autonomously reaching a target object, for example. Further, by using a propeller or the like which enables aerial movement for a moving mechanism, a flying object such as what is referred to as a drone can autonomously reach a target object, for example. The autonomous moving apparatus can be used for moving objects such as vehicles including passenger cars and buses, aircraft, spacecraft, ships, and submersibles.

[0053] The autonomous moving apparatus does not use an imaging device such as a camera, LiDAR, and radar, but reaches the target object while avoiding an obstacle using information output by the target object. Although there are no particular limitations, example of the information output by the target object include radio waves or high-frequency electromagnetic waves. Hereafter, a description will be given by taking radio waves as examples. The autonomous moving apparatus receives radio waves such as beacons using a plurality of antennas thereof, uses a technology for estimating an incoming direction of radio waves to estimate a direction of the target object which emits the radio waves, and moves in the estimated direction. When an obstacle is present outside a line-of-sight between the target object and the autonomous moving apparatus, the autonomous moving apparatus may move in an incoming direction of radio waves reflected by the obstacle. However, the autonomous moving apparatus may receive radio waves directly received from the target object during movement. In this case, the autonomous moving apparatus can change a movement direction thereof in a direction of the target object on the way to move toward the obstacle. As a result, the autonomous moving apparatus can move toward the target object while avoiding the obstacle. In addition, when the obstacle is present on the line-of-sight between the target object and the autonomous moving apparatus, the autonomous moving apparatus can detect the presence of the obstacle, because the reception intensity of the radio waves oscillates as the autonomous moving apparatus moves toward the obstacle. In this way, the autonomous moving apparatus can reach the target object, while avoiding the obstacle, by continuously moving in a direction where the reception intensity of the radio waves is high, while estimating the incoming direction of the radio waves.

[0054] As described above, it is not necessary for the autonomous moving apparatus to have an imaging device such as a CCD camera, LiDAR, and radar for route search which have been employed in a conventional technology. In other words, the autonomous moving apparatus of the present disclosure can reach the target object which outputs the information by having the plurality of antennas and a control unit and a drive unit for the autonomous moving apparatus to move in an incoming direction of information, while measuring the intensity of the information. In addition, acoustic waves emitted from a speaker mounted in the autonomous moving apparatus are reflected by objects in the periphery of the autonomous moving apparatus, and based on the acoustic waves received by a plurality of microphones, the movement direction of the autonomous moving apparatus can be set. Therefore, the movement direction of the autonomous moving apparatus can be set by avoiding a narrow travel path or an intricate and complicated travel path. As a result, the autonomous moving apparatus can reach the target object while selecting a suitable travel path that is less affected by objects (including obstacles) in the periphery of the autonomous moving apparatus.

[0055] Next, with reference to FIGS. **1** and **2**, a general description will be given regarding an operation principle of an autonomous moving apparatus **100** according to a plurality of embodiments and an autonomous movement system **1000** including the autonomous moving apparatus **100**.

(Outline of Digital Pheromone)

[0056] First, with reference to FIG. **1**, a mechanism (digital pheromone) will be described in which the autonomous moving apparatus **100** continuously moves in a direction where the reception intensity of a radio wave such as a beacon is high, while estimating an incoming direction of the radio wave, and as a result the autonomous moving apparatus **100** reaches a target object (transmitting apparatus **200**), while avoiding obstacles J**1** and J**2**. The autonomous moving apparatus **100** receives a radio wave transmitted from the transmitting apparatus **200** (corresponding to target object) arranged at a target position. Since a line-of-sight between the autonomous moving apparatus **100** and the transmitting apparatus **200** is blocked by the obstacle J**2**, the autonomous moving apparatus **100** receives the radio wave via a path K**3**→a path K**2**→a path K**1**. There is a possibility that the autonomous moving apparatus **100** receives a radio wave from the line-of-sight direction depending on the size of the obstacle J**2** and a frequency of a beacon. However it is assumed that a radio wave received via the path K**1** has the highest intensity. The autonomous moving apparatus **100** estimates an incoming direction of a radio wave with the highest intensity using a plurality of antennas mounted on the autonomous moving apparatus **100**, and moves based on the estimated incoming direction.

[0057] The autonomous moving apparatus **100** moving on the path K**1** toward the obstacle J**1** continuously moves on the path K**1** toward the obstacle J**1**, because the reception intensity of the radio wave increases as the autonomous moving apparatus **100** approaches the obstacle J**1**. However, when the autonomous moving apparatus **100** reaches a position x**1**, the transmitting apparatus **200** appears ahead of the line-of-sight of the autonomous moving apparatus **100**, and therefore the autonomous moving apparatus **100** can directly receive a radio wave TS**3**. Since the reception intensity of the radio wave TS**3** is higher than that of a radio wave TS**2** at the position x**1**, the autonomous moving apparatus **100** attempts to change a movement direction to an incoming direction of the radio wave TS**3**. The autonomous moving apparatus **100** can move on the line of the incoming direction of the radio wave TS**3**, but in that case, there is a possibility that the autonomous moving apparatus **100** collides with the obstacle J**2**. Therefore, from a fact that the autonomous moving apparatus **100** could not receive the radio wave TS**3** until the autonomous moving apparatus **100** reaches the position x**1** on the path K**1**, and from the estimated incoming direction of the radio wave TS**3** with a high intensity received when the autonomous moving apparatus **100** is at the position x**1**, the autonomous moving apparatus **100** recognizes the presence of the obstacle J**2** and moves in a direction of the path K**2**. From a fact that an incoming direction of a radio wave output from the transmitting apparatus **200** is gradually widened, and from the change in the movement direction at the position x**1**, the autonomous moving apparatus **100** moving in a direction of the path K**2** can recognize the presence of the obstacle J**1** and can estimate the path K**3**. Therefore, the autonomous moving apparatus **100** can change a traveling direction toward the transmitting apparatus **200** at a position x**2** and can reach the transmitting apparatus **200**.

(Outline of Echolocation)

[0058] Next, with reference to FIG. **2**, a description will be given regarding a mechanism (echolocation) in which the autonomous moving apparatus **100** reaches a target object P**1** while selecting a suitable travel path which is less affected by obstacles p**1** to p**4**. FIG. **2** is an explanatory diagram showing a situation in which the autonomous moving apparatus **100** travels on a planar travel path where the plurality of obstacles p**1** to p**4** are present, and travels toward a destination P**1**.

[0059] When the autonomous moving apparatus **100** autonomously travels from a position P**0** to the destination P**1**, the obstacle p**2** is present on a travel path x**0** which is the shortest path. In this case, the autonomous moving apparatus **100** outputs an acoustic wave in the traveling direction and receives the acoustic wave reflected by a surface of the obstacle p**2**. The autonomous moving apparatus **100** detects the obstacle p**2** from the received acoustic wave, and changes the movement direction at a position P**2** which is closer to the autonomous moving apparatus **100** than the obstacle p**2** to avoid collision with the obstacle p**2**.

[0060] At this time, it is desirable that the autonomous moving apparatus **100** changes the movement direction to a left direction to avoid the obstacle p**2**. That is, a travel path x**1** on the left side of the obstacle p**2** as viewed from the autonomous moving apparatus **100** is an open space. Therefore, the autonomous moving apparatus **100** can travel without being regulated by the obstacle. However, a travel path x**2** on the right side of the obstacle p**2** extends in a complicated space. Therefore, when the autonomous moving apparatus **100** travels, the autonomous moving apparatus **100** is more regulated by the obstacle. Therefore, it is preferable to change the movement direction of the autonomous moving apparatus **100** to the left direction.

[0061] Meanwhile, the travel path x**2** on the right side of the obstacle p**2** extends in the complicated space, and when the autonomous moving apparatus **100** travels, the autonomous moving apparatus **100** is more regulated by the obstacle. More specifically, there are following problems. a) When there are obstacles in the immediate vicinity of an antenna, the phase shift occurs, and the accuracy of direction detection remarkably deteriorates. Further, b) when the autonomous moving apparatus **100** enters a complicated space with many obstacles, the reflection of a radio wave becomes complicated and the autonomous moving apparatus is not able to escape from the space.

[0062] The autonomous moving apparatus **100** receives sound reflected by peripheral objects (obstacles p**1** to p**4**) using a pair of left and right microphones. By comparing left and right sound signals, it is possible for the autonomous moving apparatus **100** to avoid an intricate and complicated space with many obstacles p**1** to p**4**, and travel in an open space without being regulated by peripheral objects to reach the destination P**1**. More specific methods will be described later.

(Details of Autonomous Moving Apparatus)

[0063] With reference to FIG. **3**, the detailed configuration of the autonomous moving apparatus **100** according to the plurality of embodiments will be described. The autonomous moving apparatus **100** includes a receiving unit **110** with a plurality of antennas, a switch unit **120** for selecting reception elements of the receiving unit **110**, a control unit **130**, a storage unit **140**, an information acquiring unit **150**, a drive unit **160**, and a moving unit **170**. The autonomous moving apparatus **100** may also include a display unit **180**. In addition, basically the moving unit **170** such as a wheel, a belt, a caterpillar, or a propeller is driven by means of drive information output from the drive unit **160** shown in FIG. **3**, so that the autonomous moving apparatus **100** moves. The receiving unit **110** has a plurality of reception elements.

[0064] The receiving unit **110** is an antenna which receives a radio wave (including high-frequency electromagnetic wave) output from the transmitting apparatus **200**. The receiving unit **110** may be an array antenna constituted by a plurality of antenna elements, for example. If the receiving unit **110** is the array antenna, an array of the antenna elements constituting the array antenna may be an arbitrary array. The antenna elements may be arranged in a line in the traveling direction of the autonomous moving apparatus **100** or in a direction intersecting the traveling direction such as a direction orthogonal to the traveling direction, for example. It is also possible to arrange the antenna elements so as to form a rectangular shape or an annular shape on a plane not intersecting the traveling direction or on a plane intersecting the traveling direction of the autonomous moving apparatus **100**. Further, it is also possible to array the antenna elements in a curved shape. Still further, it is not necessary that the number of the array antenna is one, but the number of array antennas arranged may be more than one to enhance the accuracy of estimation of an incoming direction of a radio wave and the like. In addition, the receiving unit **110** may be constituted by a plurality of antennas having directivities in different directions. In this case, the plurality of antennas may be arranged in the same manner as the antenna elements of the array antenna. In addition, partition plates made of metal or the like may be disposed to at least one non-directional antenna so as to be able to detect the intensity of a radio wave or a high-frequency electromagnetic wave in a direction surrounded by the partition plates.

[0065] The switch unit **120** is a switch configured to select any one of reception elements of the receiving unit **110** and output information on a radio wave or the like received by the reception element. Therefore, the number of switches of the switch unit **120** is equal to the number of the reception elements of the receiving unit **110**, and one switch may correspond to one reception element. If the receiving unit **110** is the array antenna, a plurality of antenna elements are selected, and information on the intensity and phase of radio waves received by the plurality of antenna elements is output to a phase difference determining unit **131** and a reception intensity determining unit **132**, which will be described later, for example. Further, the switch unit **120** is preferably, but is not limited to, a semiconductor switch, and it is possible to employ a switch which can open and close an electrical connection of any configuration.

[0066] The control unit **130** can be implemented using a microcomputer having a Central Processing Unit (CPU) or the like. A computer program (autonomous movement program) for causing the microcomputer to function as the control unit **130** is installed in the microcomputer and is executed. As a result, the microcomputer functions as a plurality of information processing units of the control unit **130**.

[0067] The control unit **130** includes, as the plurality of information processing units, the phase difference determining unit **131**, the reception intensity determining unit **132**, a reception element selecting unit **133**, an angle estimating unit **134**, an operation control unit **135**, and a contact determining unit **136**.

[0068] The phase difference determining unit **131** analyzes received signals from the plurality of reception elements of the receiving unit **110** selected by the reception element selecting unit **133**, and determines phase differences between the received signals from the differences in arrival times between the received signals. The determined phase differences are output to the angle estimating unit **134**. Further, if the autonomous moving apparatus **100** stops or moves, the phase difference determining unit **131** can also determine one angle from the plurality of phase differences between the plurality of received signals.

[0069] The reception intensity determining unit **132** determines the reception intensity from the plurality of reception elements of the receiving unit **110** selected by the reception element selecting unit **133**. The estimated reception intensity is output to the operation control unit **135**. Further, the estimated reception intensity may be output to the reception element selecting unit **133**. The reception intensity may be expressed in an arbitrary unit related to the reception intensity, and may be expressed as relative information. The reception intensity may be output to the operation control unit **135** and the reception element selecting unit **133** as reception intensity information in any format.

[0070] The reception element selecting unit **133** selects elements for receiving radio waves and the like from the plurality of reception elements of the receiving unit **110**. It is preferable that the number of reception elements selected is one or more. In order that the phase difference determining unit **131** determines the phase difference, the reception element selecting unit **133** selects a plurality of reception elements. Further, it is possible that the reception element selecting unit **133** selects the reception elements in order, and selects one or more reception elements in which the reception intensity is determined to be high by the reception intensity determining unit **132**, and the angle estimating unit **134** estimates an incoming direction of a radio wave and the like via the phase difference determining unit **131**.

[0071] The angle estimating unit **134** can adopt any incoming direction estimation method, such as an estimation method in which a complex reception response to an incoming wave is obtained in advance from the phase difference of several sets of antenna elements, an evaluation function is introduced, and an angle at which an evaluation function value is maximum is set as an incoming direction of a radio wave. Further, the angle estimating unit **134** can estimate an incoming direction of a radio wave from the phase difference of a plurality of antenna elements. A Multiple Signal Classification (MUSIC) and Root-MUSIC method using eigenvalues and eigenvectors of a correlation matrix can be adopted, for example. Further, an Estimation of Signal Parameters via Rotational Invariance Techniques (ESPRIT) method can be adopted. The angle estimated in this way is stored in an angle information storage unit **141** of the storage unit **140** as arbitrary angle information from a reference axis. Still further, the estimated angle information may be stored in the angle information storage unit **141** in association with the reception intensity determined by the reception intensity determining unit **132**. Furthermore, the estimated angle information may also be stored in the angle information storage unit **141** in association with the determined reception intensity and time information. The time information may be received by the receiving unit **110** from the outside of the autonomous moving apparatus **100**, and the autonomous moving apparatus **100** can perform timing using a timing unit (not shown).

[0072] In addition, there may be a plurality of angles estimated by the angle estimating unit **134**. If there are a plurality of angles estimated, it is also possible that the angle estimating unit **134** receives the reception intensity at each angle from the reception intensity determining unit **132**, associates each angle with the reception intensity, and stores the information in the angle estimating unit **134**. If there is an obstacle, a radio wave reflected by the obstacle and a radio wave propagated on a line-of-sight may be received by the autonomous moving apparatus **100** at different angles, for example. In addition, the radio wave reflected by the obstacle may be further reflected by another obstacle and received by the autonomous moving apparatus **100** at a further different angle. In this way, the reflected wave from the obstacle may reach the autonomous moving apparatus **100** after being reflected multiple times. Basically, the autonomous moving apparatus **100** moves in a direction where the reception intensity is high. However, there is a possibility that an obstacle prevents the autonomous moving apparatus from moving in the direction where the reception intensity is high, or that a path is wrong. In this way, there is also a possibility that the autonomous moving apparatus **100** may not avoid moving in a direction of another reflected wave. Therefore, if a plurality of angles are estimated, the autonomous moving apparatus **100** can associate each angle with the reception intensity and store the information in the angle information storage unit **141**.

[0073] The operation control unit **135** generates movement direction information including a movement direction for moving the autonomous moving apparatus **100** in response to the magnitude or change of the reception intensity determined by the reception intensity determining unit **132** and an incoming direction of a radio wave estimated by the angle estimating unit **134**. In the embodiments, suppose that the operation control unit **135** determines that there is an obstacle or a complicated space in the periphery of the autonomous moving apparatus **100** based on information from the information acquiring unit **150**, which will be described later, for example. In the above case, the operation control unit **135** generates movement direction information, assuming that the reliability of an estimation result by the angle estimating unit **134** and/or a determination result by the reception intensity determining unit **132** is lower than a predetermined reference value. That is, basically, when a reliability index (**1**) is lower than the predetermined reference value, the operation control unit **135** performs movement control so as to avoid the vicinity thereof.

[0074] The operation control unit **135** may generate movement direction information by performing weighting on an estimated incoming direction of a radio waves according to the reliability. More specifically, the operation control unit **135** may multiply the reception intensity (R) of a plurality of estimated incoming directions of radio waves by the degree of reliability (reliability degree: I) to obtain a product (R*I), and may control the autonomous moving apparatus to move in an incoming direction where the product (R*I) is large. A case is not limited to a case where a plurality of incoming directions of radio waves can be estimated at the same time, but a plurality of incoming directions of radio waves may be compared in the past history. That is, the operation control unit **135** may generate movement direction information by weighting an incoming direction of a radio wave stored in the storage unit **140** by an index according to the reliability. In addition, if the reliability deteriorates, the operation control unit **135** may control the autonomous moving apparatus to move in a space or direction where the reliability is high.

[0075] There are various methods for a method in which the operation control unit **135** determines that the reliability is low due to the presence of an obstacle or a complicated space in the periphery of the autonomous moving apparatus **100**. The operation control unit **135** may determine the reliability based on at least one of the magnitude, the change, the number of reception times, the left-right comparison, and the comparison with the past history of received output information, as well as an estimated distance to an obstacle, the shape of a space, the reception intensity, the amount of noise, and the stability of an incoming direction angle, for example. If the reception intensity determined by the reception intensity determining unit **132** oscillates periodically in an estimated direction, the operation control unit **135** may determine that an obstacle is present in the estimated direction and lower the reliability, for example. This is because, when the reception intensity oscillates periodically, there is a possibility an obstacle is present in the periphery of the autonomous moving apparatus **100** or between the autonomous moving apparatus **100** and a target object, and a diffracted wave is received.

[0076] In addition, in order for the operation control unit **135** to determine a peripheral obstacle or an intricate and complicated space, the autonomous moving apparatus **100** may include an obstacle measuring unit for measuring a distance to an obstacle. In the preset embodiment, units from the information acquiring unit **150** to the contact determining unit **136**, which will be described later, function as obstacle measuring units. The information acquiring unit **150** may be an infrared sensor, an ultrasonic sensor, or a depth sensor. Further, when the operation control unit **135** receives contact prediction information or contact information from the contact determining unit **136**, the operation control unit **135** can determine that the reliability is low and change a movement direction so as to avoid the obstacle or intricate complicated space. In this case, the changed direction may be maintained temporarily or for a predetermined period of time.

[0077] In this way, the operation control unit **135** can associate an index according to the reliability, an incoming direction and the reception intensity of a radio wave, and the history of control contents of the autonomous moving apparatus **100** and store the information in the storage unit **140**. The operation control unit **135** can generate movement direction information in consideration of the time transition of the histories. The operation control unit **135** can associate a movement direction, a movement time or a movement distance in the movement direction, reliability, and the like and store the information in a movement direction information storage unit **142**. As described above, from the above described information stored in the movement direction information storage unit **142**, the operation control unit **135** can calculate the past movement history and generate map information. This enables the autonomous moving apparatus to move by avoiding the periphery of an obstacle or a complicated space with low reliability.

[0078] Further, if the radio wave intensity is very low, and if an incoming direction of a radio wave may not be estimated by the angle estimating unit **134**, the autonomous moving apparatus including the operation control unit **135** may move while maintaining the current movement direction. This is because if a null point occurs due to interference between an emitted radio wave and a reflected radio wave, it may be possible to estimate an incoming direction of a radio wave again by the autonomous moving apparatus **100** moving to another point, for example.

[0079] Further, the operation control unit **135** can perform machine learning or deep learning using information such as movement history information, angle information, information on an estimated direction of a radio wave, and reliability, and store machine learning result information or deep learning result information in the storage unit **140**. Therefore, the operation control unit **135** causes the storage unit **140** to store the reliability history according to the reliability and movement direction information as teaching data. Still further, the machine learning result information or deep learning result information can be stored in the storage unit **140** in association with the information such as the movement direction information, angle information, information on an estimated direction of a radio wave, and reliability.

[0080] The contact determining unit **136** determines whether there is a possibility that the autonomous moving apparatus **100** contacts an obstacle, based on information acquired by the information acquiring unit **150**. After the information acquiring unit **150** detects the obstacle, the information acquiring unit **150** transmits information on the detected obstacle to the contact determining unit **136**. The contact determining unit **136** transmits contact prediction information to the operation control unit **135**, if the contact determining unit **136** expects that the autonomous moving apparatus **100** contacts the obstacle, based on a movement direction and size of the autonomous moving apparatus **100**

and the obtained information on the obstacle. Further, the contact determining unit **136** transmits contact information to the operation control unit **135**, if the contact determining unit **136** determines that the autonomous moving apparatus **100** contacts the obstacle.

[0081] The storage unit **140** is a computer-readable storage medium. The storage unit **140** may be a Read Only Memory (ROM) or an Erasable Programmable ROM (EPROM), for example. Further, the storage unit **140** may be an Electrically Erasable Programmable ROM (EEPROM), a Random Access Memory (RAM), a hard disk, or the like.

[0082] The storage unit **140** includes the angle information storage unit **141**, the movement direction information storage unit **142**, and a reception intensity information storage unit **143**.

[0083] The angle information storage unit **141** stores angle information of a radio wave of which an incoming direction is estimated by the angle estimating unit **134**. The angle information may be information from a predetermined reference axis, which may be based on a physical outline of the autonomous moving apparatus **100**. The outline may be expressed in two-dimensional relative coordinates other than a space in which the autonomous moving apparatus **100** moves, and a line represented by the relative coordinates may be used as the reference axis, for example. The angle information may be stored in association with estimated radio wave reception intensity information and time information at which the angle information is estimated. This is because, in the predetermined case described above, angle information other than angle information in which the reception intensity is the highest may be used, and it may be necessary to compare the information with the past angle information. In addition, the angle information may represent an angle changed from a first determined angle and may be stored in such a way that it is easy to create map information.

[0084] The movement direction information storage unit **142** can store information on a movement direction which is determined by the operation control unit **135** and in which the autonomous moving apparatus **100** actually moves, in association with time information at which movement of the autonomous moving apparatus in the movement direction starts, and time information at which the movement of the autonomous moving apparatus in the movement direction ends. In addition, the time information at which the movement of the autonomous moving apparatus in the movement direction starts, or the time information at which the movement of the autonomous moving apparatus in the movement direction ends, and timing information at which the autonomous moving apparatus is moving in the movement direction may be stored in the movement direction information storage unit **142**, in association with the movement direction information. The operation control unit **135** may reproduce the past movement path of the autonomous moving apparatus **100** based on the pieces of information. In order that the autonomous moving apparatus may reach a target object, the operation control unit **135** can select a path which prevents the autonomous moving apparatus from travelling along the same movement path, with reference to the past movement path. Further, the contact determining unit **136** may also estimate a position of an obstacle with reference to the past movement path. In addition, the control unit **130** may perform machine learning or deep learning, and the storage unit **140** including the movement direction information storage unit **142** may store machine learning result information or deep learning result information. Further, the machine learning result information or deep learning result information may be stored in association with the information such as the movement direction information, angle information, information on an estimated direction of a radio wave, and reliability.

[0085] The reception intensity information storage unit **143** stores reception intensity information of radio waves received by a plurality of reception elements, the information being determined by the reception intensity determining unit **132**. Further, the reception intensity information storage unit **143** stores the reception intensity of the radio waves from the plurality of reception elements in an estimated radio wave incoming direction. Still further, the reception intensity information may be stored in the reception intensity information storage unit **143** in association with time information at which the reception intensity is determined.

[0086] The drive unit **160** includes a mechanism for driving the moving unit **170** to move the autonomous moving apparatus **100** in a movement direction determined by the operation control unit **135**. The drive unit **160** includes a mechanism for rotating a wheel if the moving unit **170** is the wheel, a mechanism for turning a caterpillar if the moving unit **170** is the caterpillar, and a mechanism for rotating a propeller if the moving unit **170** is the propeller, for example. The drive unit **160** is not limited to the above aspects, but the drive unit can have any driving configuration that drives a configuration of the moving unit **170**.

[0087] The moving unit **170** is a portion constituting means for moving the autonomous moving apparatus **100**. If the autonomous moving apparatus **100** is a vehicle, the moving unit **170** may be a wheel including a tire, a caterpillar, or the like. Further, if the autonomous moving apparatus **100** is a flying object such as a drone or a helicopter, the moving unit **170** may be a propeller. The moving unit **170** is not limited to the above aspects, but the moving unit can have any moving mechanism capable of moving the autonomous moving apparatus **100**.

[0088] The display unit **180** can optionally be attached to the autonomous moving apparatus **100**, or installed in a monitor space separated from the autonomous moving apparatus **100** to enable a user to confirm image information in a movement direction of the autonomous moving apparatus **100**. As described above, it is also possible for the user to confirm whether the autonomous moving apparatus **100** is moving normally by confirming the image information output to the display unit **180**.

[0089] The transmitting apparatus **200** shown in FIG. **1** can be arranged in the periphery of a target object or attached to the target object. Further, the transmitting apparatus **200** may be the target object. Information output by the transmitting apparatus **200** needs to be information that can be received by the receiving unit **110** of the autonomous moving apparatus **100**. Examples of the information output by the transmitting apparatus **200** include, but are not limited to, radio waves and high-frequency electromagnetic waves, as described above, but may also include electromagnetic waves, vibration waves, and the like of any frequency. Still further, it is not necessary that the frequency of radio waves, vibration waves, and the like is fixed, and the frequency can be changed periodically or randomly. In addition, the transmitting apparatus **200** may be configured to repeatedly sweep the frequency in a predetermined frequency range.

The frequency fluctuation may make it easier for the autonomous moving apparatus **100** to determine the presence of an obstacle, even if the autonomous moving apparatus **100** does not include the information acquiring unit **150**. In addition, the transmitting apparatus **200** may be an electronic device used by the user such as a mobile phone, PHS telephone, smartphone, or personal digital assistant carried by the user, or another autonomous moving apparatus.

[0090] The autonomous moving apparatus **100** according to the embodiments may further include a transmitting unit (not shown) that transmits, to the outside, arrival information to the target object or abnormality information during movement in a wired or wireless manner. The transmitting unit can wirelessly transmit the arrival information and abnormality information to an external electronic device by means of what is referred to as mobile communication. Further, the transmitting unit may perform wireless communication which is based on a near-field communication standard of at least one of wireless LAN and Bluetooth (registered trademark). Still further, the transmitting unit may communicate with the outside by means of connection using a cable (for example, USB cable, optical cable). According to this kind of a configuration, it is possible for another device to perform the following processing in response to reception of the arrival information or abnormality information.

[0091] A transmission destination of the transmitting unit may be an electronic device used by the user such as a computer arranged on the cloud, or a mobile phone, PHS telephone, smartphone, or personal digital assistant carried by the user, for example.

(Details of Echolocation)

[0092] The information acquiring unit **150** may be a device having one or more speakers and two or more microphones. As an example, a device having one speaker and two microphones will be described with reference to FIG. **4**. FIG. **4** is a block diagram showing an example of an echolocation configuration of one speaker and two microphones in the autonomous moving apparatus **100** according to the present embodiment. FIG. **5** is a block diagram showing details of each component in the echolocation configuration shown in FIG. **4**.

[0093] As shown in FIG. **4**, the autonomous moving apparatus **100** includes the control unit **130**, the storage unit **140**, the drive unit **160**, four wheels as the moving unit **170**, and one sound transmitting unit **150**C and two sound receiving units **150**L and **150**R as the form of the information acquiring unit **150**.

[0094] The sound transmitting unit **150**C is attached to a vehicle body **190** of the autonomous moving apparatus **100**, and transmits an acoustic wave toward an area including a front direction of the vehicle body **190** (positive direction of X axis). As shown in FIG. **5**, the sound transmitting unit **150**C includes a speaker **41**, an amplifier **42**, and a D/A conversion unit **43**. With reference to FIGS. **4** and **5**, an example of the autonomous moving apparatus having one sound transmitting unit **150**C is described, but as will be described later, the autonomous moving apparatus may have a plurality of sound transmitting units **150**C. If sound emitted from the sound transmitting unit **150**C does not reach the entire periphery of the autonomous moving apparatus **100**, two sound transmitting units **150**C may be disposed on the left and right sides of the autonomous moving apparatus **100**, for example.

[0095] The sound transmitting unit **150**C outputs an ultrasonic wave or an acoustic wave of a frequency in a human audible band. The sound transmitting unit **150**C may be configured to output an acoustic wave other than an ultrasonic wave or an acoustic wave of a frequency in an audible band. The term "acoustic wave" is a general term for an elastic wave that propagates regardless of gas, liquid, or solid.

[0096] The sound transmitting unit **150**C outputs an acoustic wave at predetermined intervals or at irregular intervals. The sound transmitting unit **150**C also has a function of changing a frequency of an acoustic wave to be transmitted. That is, when a frequency of an acoustic wave generated by a sound signal generating unit **26** described later is changed, the acoustic wave of the changed frequency is transmitted. When the autonomous moving apparatus has a plurality of sound transmitting units **150**C, timings at which the sound transmitting units **150**C output acoustic waves can be synchronized.

[0097] The D/A conversion unit **43** converts a digital sound signal generated by the control unit **130**, which will be described later, into an analog signal. The sound includes a human audible frequency sound, an ultrasonic wave sound higher than the audible frequency, and ultra-low frequency sound lower than the audible frequency. The sound is an example of an acoustic wave.

[0098] The amplifier **42** amplifies the analog sound signal which has been converted from the digital sound signal. When an ultrasonic speaker is used as the speaker **41**, a rectangular wave of a digital output can be output without any changes. That is, a logic output may be used instead of an analog output, and a buffer circuit may be disposed instead of the D/A conversion unit **43** and amplifier **42**.

[0099] The speaker **41** outputs the analog sound signal amplified by the amplifier **42** as an acoustic wave. The speaker **41** is disposed so as to face a straight-travelling direction of the autonomous moving apparatus **100**, and outputs an acoustic wave toward the straight-travelling direction of the autonomous moving apparatus **100**, for example. In other words, the sound transmitting unit **150**C outputs an acoustic wave toward one direction that serves as a reference of the autonomous moving apparatus **100** (for example, straight-travelling direction). It is sufficient if the straight-travelling direction of the autonomous moving apparatus **100** is included in a range where the speaker **41** outputs the acoustic wave. A center axis of the speaker **41** may be different from the straight-travelling direction of the autonomous moving apparatus **100** (front direction). Hereinafter, the "straight-travelling direction" may be referred to as a "front direction".

[0100] The sound receiving unit **150**L and the sound receiving unit **150**R are attached to the vehicle body **190** of the autonomous moving apparatus **100**, receive acoustic waves reflected by objects in the periphery of the autonomous moving apparatus **100**, and convert the acoustic waves into electric signals. The sound receiving unit **150**L (acoustic wave receiving unit) is disposed on the left side from the front direction of the autonomous moving apparatus **100**. The sound receiving unit **150**R (acoustic wave receiving unit) is disposed on the right side from the front direction of the autonomous moving apparatus **100**. In other words, two sound receiving units are symmetrically arranged relative to one direction that serves as a reference of the autonomous moving apparatus **100** (for example, front direction).

[0101] One sound receiving unit **150**L receives an acoustic wave on the left side relative to the front direction of the autonomous moving apparatus **100**. The other sound receiving unit **150**R receives an acoustic wave on the right side relative to the front direction of the autonomous moving apparatus **100**. The two sound receiving units **150**L and **150**R are a plurality of acoustic wave receiving units of which acoustic wave input directions are different from each other. The sound receiving units **150**L and **150**R include microphones **51**L and **51**R and A/D conversion units **53**L and **53**R, respectively.

[0102] The microphones **51**L and **51**R receive acoustic waves reflected by objects and convert the acoustic waves into sound signals as electric signals. The microphone **51**L on the left side is disposed so as to face a left direction by 30 degrees, relative to the front direction of the autonomous moving apparatus **100**, for example. The microphone **51**R on the right side is disposed so as to face a right direction by 30 degrees, relative to the front direction of the autonomous moving apparatus **100**, for example.

[0103] The microphones **51**L and **51**R may be arranged with the speaker **41** therebetween in a left-right direction perpendicular to the front direction of the autonomous moving apparatus **100**. In other words, the speaker **41** may be interposed between the microphones **51**L and **51**R in a vehicle width direction. The orientations of the microphones **51**L and **51**R are not limited to the angles as long as the microphones are disposed between the front direction of the autonomous moving apparatus **100** and the left-right direction. The two microphones **51**L and **51**R may face different directions. If the autonomous moving apparatus **100** is a drone and moves in a three-dimensional space, sound receiving units may be disposed at four positions, that are a left position, a right position, a top position, and a bottom position of the autonomous moving apparatus **100**. In this case, microphones may be disposed at four positions, that are a top position, a bottom position, a left position, and a right position on the front side of the autonomous moving apparatus **100**.

[0104] The A/D conversion units **53**L and **53**R convert analog sound signals output from the microphones **51**L and **51**R into digital signals and output the digital signals to the control unit **130**.

[0105] The storage unit **140** may include an echo signal storage unit **31** and a control result storage unit **33**.

[0106] The echo signal storage unit **31** stores an echo signal measured by an echo signal measuring unit **21**, which will be described later. Here, the term "echo signal" indicates a phenomenon in which sound is reflected by a certain target plane and is heard again. The term "echo signal" is a concept including "reverberation" which indicates a phenomenon in which even after a sound source stops vibrating, the reflection from a ceiling or a wall is repeated, and the sound is continuously heard.

[0107] The control result storage unit **33** stores a control result by a reliability determining unit **25**, which will be described later.

[0108] The contact determining unit **136** includes the echo signal measuring unit **21**, a movement direction setting unit **24**, the reliability determining unit **25**, and the sound signal generating unit **26**.

[0109] The sound signal generating unit **26** generates a sound signal of a predetermined frequency, and outputs the generated sound signal to the sound transmitting unit **150**C at a predetermined time interval (for example, one second interval).

[0110] The sound signal generating unit **26** changes a frequency of a sound signal as necessary. Suppose that, in addition to the autonomous moving apparatus **100**, another moving apparatus transmits a sound signal, and a frequency of the sound signal approximates or matches a frequency of a sound signal transmitted by the sound transmitting unit **150**C of the autonomous moving apparatus **100**, for example. In the above case, the frequency of the sound signal transmitted from the sound transmitting unit **150**C is changed such that the frequency is different from the frequency of the sound signal transmitted from another moving apparatus.

[0111] The echo signal measuring unit **21** receives sound signals output from the A/D conversion units **53**L and **53**R and transfers the sound signals to the echo signal storage unit **31** and the movement direction setting unit **24** individually.

[0112] When an obstacle is present in a travelling direction of the autonomous moving apparatus **100**, the movement direction setting unit **24** analyzes a sound signal transferred from the echo signal measuring unit **21** and pieces of data stored in the echo signal storage unit **31** and the control result storage unit **33**, and sets a movement direction of the autonomous moving apparatus **100**. Further, the movement direction setting unit **24** calculates travel information such as a turning direction, turning angle, and traveling speed of the autonomous moving apparatus **100**. When there are a plurality of incoming directions of output information, the movement direction setting unit **24** does not set a travelling direction, but provides various pieces of information such as the plurality of incoming directions to the reliability determining unit **25**.

[0113] The reliability determining unit **25** determines the reliability degree based on the various pieces of information obtained from the movement direction setting unit **24**, and outputs various drive signals such as the reliability degree to the operation control unit **135**. The drive signals include information related to driving such as a movement direction, turning direction, turning angle, and travelling speed, in addition to the reliability degree.

[0114] The reliability determining unit **25** outputs a control signal output to the drive unit **160** to the control result storage unit **33**. The control result storage unit **33** stores the control signal output from the reliability determining unit **25**.

[0115] Next, a description will be given regarding a setting method of a movement direction by the movement direction setting unit **24**, when the autonomous moving apparatus **100** avoids an obstacle.

(First Setting Method)

[0116] The movement direction setting unit **24** sets a movement direction of the autonomous moving apparatus **100** based on a received echo signal. The movement direction setting unit **24** outputs information on the set movement direction to the reliability determining unit **25**.

[0117] Suppose that, when the autonomous moving apparatus **100** autonomously travels from the position P**0** to the destination P**1** shown in FIG. **2**, the obstacle p**2** is present on the travel path x**0** which is the shortest path, for example. In the above case, the autonomous moving apparatus **100** changes a movement direction at the position P**2** which is closer to the autonomous moving apparatus **100** than the obstacle p**2** to avoid the obstacle p**2**. At this time, the travel path x**2** on the right side of the obstacle p**2** extends in an intricate and complicated space, and when the autonomous moving apparatus travels, the autonomous moving apparatus is more regulated by obstacles. Therefore, it is preferable to change the movement direction of the autonomous moving apparatus **100** to a left direction. Therefore, the contact determining unit **136** shown in FIG. **5** determines a peripheral obstacle and complicated space to calculate the reliability degree, and provides a drive signal including the reliability degree to the operation control unit **135**.

(Second Setting Method)

[0118] The movement direction setting unit **24** acquires an echo signal received in the past which is stored in the echo signal storage unit **31** and the past control signal stored in the control result storage unit **33**.

[0119] The movement direction setting unit **24** performs machine learning based on the past control signal output by the reliability determining unit **25** using the sound receiving units **150**L and **150**R on left and right sides. By performing machine learning, the movement direction setting unit **24** acquires a correlation between an echo signal and a movement direction when the autonomous moving apparatus **100** avoids an obstacle. The machine learning is a well-known technology, and therefore a detailed description thereof will be omitted.

[0120] The movement direction setting unit **24** sets an optimum movement direction of the autonomous moving apparatus **100** based on the acquired correlation, and the reliability determining unit **25** determines the reliability degree based on a machine learning result.

[0121] The reliability determining unit **25** sets travel information such as a movement direction, turning direction, turning angle, and travelling speed of the autonomous moving apparatus **100** using a machine learning result based on the past control result, and outputs a drive command to the drive unit **160** together with the reliability degree. As a result, when the autonomous moving apparatus **100** travels by avoiding an obstacle, the autonomous moving apparatus **100** can travel by selecting a more open travel path.

[0122] According to the above configuration, in the autonomous moving apparatus **100** such as an unmanned transport vehicle, SLAM eliminates the necessity of expensive equipment such as a camera or LiDAR, and the manufacturing cost can be reduced by adopting a simple configuration. Further, when the autonomous moving apparatus **100** is introduced to a new location, and each time a layout of a previous location is changed, it is not necessary to create a map of the location or layout, and this can also reduce the introduction cost. It is also not necessary to determine a plan of a travel path in advance. It is not necessary to lay a magnetic tape, a magnetic rod, or a two-dimensional cord on the floor for guiding a vehicle such as an Automatic Guided Vehicle (AGV). Further, it is not necessary to perform computational processing of a large amount of data which is required by a robot such as an Autonomous Mobile Robot (AMR), and an expensive computer associated with this becomes unnecessary. This can also reduce the power consumption.

[0123] The autonomous moving apparatus **100** may also have a short distance measuring sensor, a depth camera, or a stereo camera for preventing contact with an obstacle that appears in the immediate vicinity (for example, within 50 cm), and a bumper sensor or a contact sensor for detecting collision with an obstacle. When the autonomous moving apparatus **100** is applied to an unmanned transport vehicle, it is needless to say that the autonomous moving apparatus **100** has a function that satisfies the provision related to ISO3691-4/JIS D 6802 "Automatic guided vehicles and systems-Safety requirements and verification" related to the safety of an unmanned transport vehicle.

(Embodiment of Speaker and Microphone)

[0124] As described above, there are various embodiments for the number of speakers and microphones for echolocation, orientations of a speaker and a microphone relative to the vehicle body **190**, and a layout on the vehicle body **190**. Further, as another embodiment for a speaker and a microphone, there is a composite unit for the autonomous moving apparatus **100** in which microphones and a speaker are arranged in one casing (package). The composite unit of a speaker-microphone as one component of the autonomous moving apparatus **100** is fixed on the vehicle body **190** of the autonomous moving apparatus **100**, and wiring such as a signal line and a power line is used to electrically connect between the composite unit and another component such as the control unit **130**, the storage unit **140**, or the drive unit **160** of the autonomous moving apparatus **100**. As a result, the autonomous moving apparatus **100** can be manufactured using the composite unit of a speaker-microphone as a component. The autonomous moving apparatus **100** and a composite unit **300** of a speaker-microphone will be described below as embodiments of a speaker and a microphone for echolocation. Other configurations of the autonomous moving apparatus **100** except for speakers and microphones in the following embodiments are the same as those of the autonomous moving apparatus **100** already described with reference to FIGS. **3** and **5**, and therefore duplicated descriptions thereof will be omitted.

First Embodiment

[0125] In a first embodiment, with reference to FIGS. **6**A to **7**D and **8**, a description will be given regarding layouts of a speaker and microphones for increasing the difference in sound pressures of acoustic waves received by the pair of left and right microphones **51**L and **51**R. FIGS. **6**A to **7**D show an embodiment of the autonomous moving apparatus **100**, and FIG. **8** shows an embodiment of the composite unit **300** of a speaker-microphone for the autonomous moving apparatus.

[0126] As shown in FIGS. **6**A to **6**C, the autonomous moving apparatus **100** includes the vehicle body **190**, a first speaker **41** which is attached to the vehicle body **190** and transmits an acoustic wave toward an area including the front direction of the vehicle body **190** (positive direction of X axis), and a first microphone **51**L and a second microphone **51**R which are attached to the vehicle body **190**, receive acoustic waves reflected by objects in the periphery of the autonomous moving apparatus **100**, and convert the acoustic waves into electric signals. The first speaker **41** corresponds to the speaker **41** shown in FIG. **5**. The first microphone **51**L and the second microphone **51**R correspond to the microphone **51**L and the microphone **51**R shown in FIG. **5**, respectively. A vehicle having four wheels is exemplified as the moving unit **170**. It is sufficient if the front direction of the autonomous moving apparatus **100** (positive direction of X axis) is included in the area to which the acoustic wave is output by the first speaker **41**, and a center axis of the first speaker **41** may be different from the front direction of the autonomous moving apparatus **100**.

[0127] A front-rear direction that is the front direction of the autonomous moving apparatus **100** (straight-travelling direction) and a rear direction which is an opposite direction thereof is defined as an X axis direction. A vehicle width direction (left-right direction) which is perpendicular to the front-rear direction in a horizontal plane is defined as a Y axis direction. An up-down direction (vertical direction) which is perpendicular to both the front-rear direction (X axis direction) and the vehicle width direction (Y axis direction) is defined as a Z axis direction.

[0128] When viewed from the vertical direction, the first speaker **41**, the first microphone **51**L, and the second microphone **51**R are located on the outside or outer periphery of the vehicle body **190**. When an entirety of the vehicle body **190** when viewed from the vertical direction is divided into an outside area including an outer edge of the vehicle body **190** and an inside area surrounded by the outside area, the expression "the outside of the vehicle body **190**" means the outside area of the vehicle body **190**. The expression "the outer periphery of the vehicle body **190**" means an area other than the vehicle body **190**, surrounding the outside of the outer edge of the vehicle body **190**, when viewed from the vertical direction. All of FIGS. **6**A to **6**C show examples in which the first speaker **41**, the first microphone **51**L, and the second microphone **51**R are arranged on the outside of the vehicle body **190**. All of FIGS. **7**A to **7**D show examples in which parts of a first speaker **41**L and a second speaker **41**R are arranged on the outer periphery of the vehicle body **190**.

[0129] The first speaker **41**, the first microphone **51**L, and the second microphone **51**R may be arranged on the front side of the vehicle body **190** in the front-rear direction. This reduces a distance to an object located in the front direction (positive direction of X axis), and can increase sound pressures of acoustic waves received by the first microphone **51**L and the second microphone **51**R. It is sufficient if a direction in which the first speaker **41** outputs an acoustic wave, and a direction in which the first microphone **51**L and the second microphone **51**R receive acoustic waves, are within a range from the front direction of the autonomous moving apparatus **100** to the left-right direction, and are toward the outside of the vehicle body **190**. As a result, it is possible to receive acoustic waves coming from right and left oblique directions and the right and left sides, in addition to an acoustic wave coming from the front direction. This can avoid collision with peripheral objects when the autonomous moving apparatus **100** turns.

[0130] The first speaker **41** is interposed between the first microphone **51**L and the second microphone **51**R in the left-right direction (Y axis direction). In other words, the first microphone **51**L and the second microphone **51**R are arranged to have the first speaker **41** therebetween in the left-right direction (Y axis direction). As a result, the first microphone **51**L and the second microphone **51**R can be moved away from the first speaker **41** in the left-right direction. This can increase the sound pressure difference of acoustic waves received by the first microphone **51**L and the second microphone **51**R.

[0131] Distances from the first speaker **41** to each of the microphones **51**L and **51**R in the left-right direction are equal. This can reduce the left-right deviation of sound pressures of acoustic waves received by the microphones **51**L and **51**R. The autonomous moving apparatus **100** may have two or more speakers. In this case, distances from a center of gravity of a plurality of speakers including the first speaker **41** to each of the microphones **51**L and **51**R in the left-right direction are equal. As shown in FIGS. **7**A to **7**D, the autonomous moving apparatus **100** may have the second speaker **41**R in addition to the first speaker **41**L, for example. In this case, distances from a center of gravity C**1** of the first speaker **41**L and the second speaker **41**R to each of the microphones **51**L and **51**R in the left-right direction are equal.

[0132] As described above, the first speaker **41**, the first microphone **51**L, and the second microphone **51**R are located on the outside or outer periphery of the vehicle body **190**, when viewed from an upper side in the vertical direction, the first speaker **41** is interposed between the first microphone **51**L and the second microphone **51**R in the left-right direction (Y axis direction), and distances from the first speaker **41** to each of the first microphone **51**L and the second microphone **51**R in the left-right direction are equal. This can increase the difference in sound pressures of acoustic waves received by the pair of left and right first microphone **51**L and the second microphone **51**R.

[0133] In the first embodiment, as shown in FIGS. **6**A to **6**C, the first speaker **41** faces the front direction of the autonomous moving apparatus **100** (positive direction of X axis). The first speaker **41**L and the second speaker **41**R may face a left oblique front direction and a right oblique front direction, respectively (FIG. **6**A), may face the left side and right side, respectively (FIG. **6**B), or may face the front direction (FIG. **6**C). In order to eliminate the left-right deviation of sound pressures, orientations of the first microphone **51**L and the second microphone **51**R may be symmetrical, relative to a center C**1** in the left-right direction of the vehicle body **190**.

[0134] Further, in the first embodiment, as shown in FIGS. **7**A to **7**D, the autonomous moving apparatus **100** may further have the second speaker **41**R which is attached to the vehicle body **190** and transmits an acoustic wave in the front direction (positive direction of X axis). In this case, the center of gravity C**1** of the first speaker **41**L and the second speaker **41**R may be located between the first microphone **51**L and the second microphone **51**R in the left-right direction (Y axis direction). Distances from the center of gravity of the first speaker **41**L and the second speaker **41**R to each of the first microphone **51**L and the second microphone **51**R in the left-right direction are equal. This can reduce the left-right deviation of sound pressures of acoustic waves received by the first microphone **51**L and the second microphone **51**R. The first speaker **41**L and the second speaker **41**R may be arranged plane symmetrically, relative to a center plane (target plane) C**1** in the left-right direction of the vehicle body **190**. Further, orientations of the first speaker **41**L and the second speaker **41**R may be plane symmetrical, relative to the center plane C**1** in the left-right direction of the vehicle body **190**. The first speaker **41**L and the first microphone **51**L shown in FIG. **7**A are attached at the same position and face the same front direction. In this case, the first speaker **41**L and the first microphone **51**L can be configured as one module (sensor for both transmission and reception). The same applies to the second speaker **41**R and the second microphone **51**R.

[0135] As shown in FIGS. **7**A to **7**D, at least parts of the first speaker **41**L and the second speaker **41**R are disposed on "the outer periphery of the vehicle body **190**". At least parts of the first speaker **41**L and the second speaker **41**R project in a front direction of a front end F**1** of the vehicle body **19**. This reduces a distance to a peripheral object, and can increase sound pressures of acoustic waves received by the first microphone **51**L and the second microphone **51**R. In addition, if the first speaker **41**L and the second speaker **41**R are arranged inside the vehicle body **190**, instead of the outer periphery of the vehicle body **190**, an output acoustic waves may be reflected by a surface of the vehicle body **190**. In this case, the first microphone **51**L and the second microphone **51**R receive acoustic waves that are not reflected by obstacles, and the autonomous moving apparatus **100** causes malfunction or misrecognition. By arranging at least parts of the first speaker **41**L and the second speaker **41**R on "the outer periphery of the vehicle body **190**", it is possible to reduce a sound pressure of an acoustic wave which is reflected by the vehicle body **190** itself, which becomes noise.

[0136] Magnetic speakers or piezoelectric speakers can be used as the first speaker **41**L and the second speaker **41**R. Condenser microphones or piezoelectric type sensors can be used as the first microphone **51**L and the second microphone **51**R. As shown in FIG. **7**A, when a speaker and a microphone are arranged at the same position and face the same direction, a pair of the speaker and microphone may form one module. The first speaker **41**L and the second speaker **41**R may be controlled to output ultrasonic waves at the same time period. The size of the first speaker **41**L and second speaker **41**R, and the first microphone **51**L and second microphone **51**R is assumed to be approximately 1 mm to 30 mm. Meanwhile, the width of the vehicle body **190** (length in left-right direction) is assumed to be approximately 20 cm to 1 m. In FIG. **7**A, the size of the first speaker **41**L and second speaker **41**R, and the first microphone **51**L and second microphone **51**R, relative to the size of the vehicle body **190**, is expressed to be larger than the real size. In FIGS. **6**A to **6**C, each of the first microphone **51**L and the second microphone **51**R is separated from the first speaker **41** by 2.5 cm or more in the left-right direction (Y axis direction), for example. The first microphone **51**L and the second microphone **51**R are separated from each other by 5 cm or more in the left-right direction (Y axis direction). Signals received by the first microphone **51**L and the second microphone **51**R are processed in the same control unit **130** as shown in FIGS. **3** to **5**.

[0137] As shown in FIG. **8**, the autonomous moving apparatus **100** may include the vehicle body **190**, wheels **170**, storage unit **140**, drive unit **160**, and composite unit **300** of a speaker-microphone for an autonomous moving apparatus. The vehicle body **190**, wheels **170**, storage unit **140**, and drive unit **160** have already been described with reference to FIGS. **3** and **5**, and therefore duplicated descriptions thereof will be omitted. The composite unit **300** is attached to an end F**1** in the front direction of the vehicle body **190**.

[0138] The composite unit **300** of a speaker-microphone for an autonomous moving apparatus is the composite unit **300** including a speaker and microphones used in the autonomous moving apparatus **100** described above. The composite unit **300** includes a casing **210** forming an outer shape of the composite unit **300**, the first speaker **41** which is attached in the casing **210** and transmits an acoustic wave in a front direction of the composite unit **300** (positive direction of X axis), and the first microphone **51**L and the second microphone **51**R which are attached in the casing **210**, receive acoustic waves reflected by objects in the periphery of the composite unit **300**, and convert the acoustic waves into electric signals. The first speaker **41**, and the first microphone **51**L, and the second microphone **51**R are located on the outside or outer periphery of the casing **210**, when the composite unit **300** is viewed from the vertical direction. The first speaker **41** is interposed between the first microphone **51**L and the second microphone **51**R in the left-right direction (Y axis direction) perpendicular to the front direction (positive direction of X axis). Distances from the first speaker **41** or a center of gravity of a plurality of speakers including the first speaker **41**, to each of the first microphone **51**L and the second microphone **51**R in the left-right direction (Y axis direction) are equal.

[0139] The first speaker **41** may be located at a front end F**2** of the casing **210**. The composite unit **300** may be fixed to the vehicle body **190** such that the front end F**2** of the casing **210** is aligned with the front end F**1** of the vehicle body **190**. The casing **210** may be made of a metal or resin, for example.

[0140] By replacing the "vehicle body **190**" shown in FIGS. **6**A to **7**D with the "casing **210**" shown in FIG. **8**, the composite unit shown in FIG. **8** may have a layout of the same speakers and microphones shown in FIGS. **6**A to **7**D. In this way, it is possible to apply, to the composite unit **300**, the embodiment described with reference to FIGS. **6**A to **7**D, and an embodiment of the autonomous moving apparatus **100**, which will be described later. Conversely, by replacing the "casing **210**" with the "vehicle body **190**", the embodiment of the composite unit **300**, which will be described later, can be applied to the autonomous moving apparatus **100**. In other words, the embodiments of the autonomous moving apparatus **100** and the composite unit **300** can be applied to each other by mutually replacing the "vehicle body **190**" and the "casing **210**".

[0141] Although FIG. **8** shows an example in which the control unit **130** is disposed in the casing **210** of the composite unit **300** (see FIGS. **3** to **5**), the control unit **130** may be mounted on the vehicle body **190** instead being mounted in the composite unit **300**.

Second Embodiment

[0142] In a second embodiment, with reference to FIGS. **7**E to **7**H, a description will be given regarding the layout of the first speaker **41** and the composite unit **300** for increasing sound pressures of acoustic waves received by the first microphone **51**L and the second microphone **51**R from front directions or oblique front directions. FIGS. **7**E and **7**F show an embodiment of the autonomous moving apparatus **100**, and FIGS. **7**G and **7**H show an embodiment of the composite unit **300**. As shown in FIGS. **7**E to **7**H, the composite unit **300** is disposed at the front end F**1** of the vehicle body **190**. The first speaker **41** or the composite unit **300** is disposed at the end F**1** of the vehicle body **190** in the front direction (positive direction of X axis), which is the straight-travelling direction of the autonomous moving apparatus. This reduces a distance to an object located in the front direction or oblique front direction, and increases a sound pressure of an acoustic wave reflected by the object. In addition, it is also possible to reduce an echo signal by the vehicle body **190** itself, which becomes noise, instead of an echo signal by an obstacle.

[0143] As shown in FIGS. **6**A to **6**C, the first speaker **41** may be disposed at the front end F**1** of the vehicle body **190**. Further, the first microphone **51**L and the second microphone **51**R may be disposed in a rear direction of the first speaker **41**, or at the same position in the front-rear direction as the first speaker **41**. This can reduce sound pressures of acoustic waves directly received by the first microphone **51**L and the second microphone **51**R from the first speaker **41**.

[0144] As shown in FIGS. **7**E to **7**H, in order to avoid collision between an object and the first speaker **41** or composite unit **300**, the autonomous moving apparatus **100** may further include a contact detection sensor **214** for detecting contact with an object. The contact detection sensor **214** is disposed in a front direction of the first speaker **41** or composite unit **300** (positive direction of X axis). The vehicle body **190** and the first speaker **41** are not disposed in a front direction of the contact detection sensor **214**. The contact detection sensor **214**, the first speaker **41** or composite unit **300**, and the vehicle body **190** are disposed in this order from the front side. A contact point of the contact detection sensor **214** is arranged in a front direction of the first speaker **41** or composite unit **300**. When the contact detection sensor **214** detects contact with an object, the autonomous moving apparatus **100** immediately stops. Collision between the object and the first speaker **41** or composite unit **300** can be avoided by stopping the autonomous moving apparatus **100** before collision between the object and the first speaker **41** or composite unit **300** occurs. Any kind of contact detection sensor **214** may be used, and a contact type detection sensor may be used therefor, for example. The contact detection sensor **214** may be arranged at the same position in the front-rear direction (X axis direction) as the first speaker **41** or composite unit **300**. The can slightly prevent collision between the object and the first speaker **41** or composite unit **300**.

[0145] As shown in FIGS. **7**E and **7**G, a part the first speaker **41** or an entirety of the composite unit **300** may project from the front end F**1** of the vehicle body **190**. The first speaker **41** is arranged at the front end F**1** of the vehicle body **190**. When viewed from the vertical direction, the first speaker **41** or composite unit **300** may be arranged on the outer periphery of the vehicle body **190** (FIG. **7**E, FIG. **7**G). Alternatively, as shown in FIGS. **7**F and **7**H, an entirety of the first speaker **41** or an entirety of the composite unit **300** may be disposed inside the vehicle body **190** instead of the front end F**1** of the vehicle body **190**.

[0146] When viewed from the vertical direction, the first speaker **41** or composite unit **300** may be disposed on the outside the vehicle body **190** (FIG. **7**F, FIG. **7**H). A position of the contact detection sensor **214** relative to the vehicle body **190** also changes according to a position of the first speaker **41** or composite unit **300** relative to the vehicle body **190**. The second embodiment may be implemented in combination with one or more other embodiments.

Third Embodiment

[0147] In a third embodiment, with reference to FIGS. **9** to **12**, a description will be given regarding a structure of the vehicle body **190** or casing **210** for reducing a sound pressure of an acoustic wave (noise) coming from a rear direction. FIG. **9** is a plan view which shows an example of the composite unit **300** and shows a structure of the casing **210** for reducing a sound pressure of an acoustic wave (noise) coming from the rear direction, among acoustic waves received by the first microphone **51**L and the second microphone **51**R. The casing **210** includes sound pressure reducing units **210***a*L and **210***a*R which are disposed in the rear direction of the first microphone **51**L and the second microphone **51**R, and reduce sound pressures of a transmitted acoustic wave and a diffracted acoustic wave.

[0148] As shown in FIG. **9**, the casing **210** has a convex planar shape in which a center portion in the left-right direction (Y axis direction) projects in the front direction (positive direction of X axis). The first microphone **51**L and the second microphone **51**R are arranged at openings of the casing **210** formed in side wall portions of the convex portion. The first microphone **51**L and the second microphone **51**R are attached such that they face the outside of the casing **210** in the left-right direction. In rear directions of the first microphone **51**L and the second microphone **51**R, the sound pressure reducing units **210***a*L and **210***a*R are arranged, respectively, which are parts of the casing **210**, and prevent an acoustic wave S**3** coming from a rear direction from directly entering the microphones, or reduce sound pressures thereof. A part of an acoustic wave S**1** output from the first speaker **41** is reflected by an object **60**A and is directed toward a rear direction as an acoustic wave S**2**. A part of the acoustic wave S**2** is reflected by an object **60**B arranged in a rear direction of the composite unit **300**, and is directed toward the composite unit **300** (first microphone **51**L) located in a front direction of the object **60**B as the acoustic wave S**3**. The sound pressure reducing unit **210***a*L arranged in a rear direction of the first microphone **51**L prevents the acoustic wave S**3** from directly entering the microphone or reduces sound pressures thereof. Among acoustic waves received by the first microphone **51**L and the second microphone **51**R, an acoustic wave coming from a rear direction is unnecessary for the autonomous moving apparatus **100** to travel. The sound pressure reducing unit **210***a*L can reduce a sound pressure of an acoustic wave (noise) coming from a rear direction, among acoustic waves received by the first microphone **51**L. The casing **210** has a symmetrical shape relative to the center in the left-right direction. Therefore, the sound pressure reducing unit **210***a*R can reduce a sound pressure of an acoustic wave (noise) coming from a rear direction, among acoustic waves received by the second microphone **51**R.

[0149] FIGS. **10**A to **10**D are plan views showing a modified example for reducing a sound pressure of an acoustic wave (noise) coming from a rear direction. As shown in FIG. **10**A, the first microphone **51**L facing a lateral direction (Y direction) is arranged inside the casing **210**, instead of the openings in the casing **210**. As a result, a part of the casing **210** located in a rear direction of the first microphone **51**L functions as the sound pressure reducing unit **210***a*L. As shown in FIG. **10**B, the first microphone **51**L is located at the same position as the first microphone **51**L in FIG. **10**A, but an orientation of the first microphone **51**L in FIG. **10**B is caused to face an oblique front direction. This can reduce a sound pressure of an acoustic wave (noise) coming from a rear direction. Further, as shown in FIG. **10**C, even if the casing **210** has no opening, a part of the casing

210 having a convex shape can function as the sound pressure reducing unit **210***a*L. Still further, as shown in FIG. **10**D, when the casing **210** has an opening facing an oblique front direction, the first microphone **51**L facing an oblique front direction is attached at the opening. As a result, a part of the casing **210** located in a rear direction of the first microphone **51**L can function as the sound pressure reducing unit **210***a*L. With reference to FIGS. **10**A to **10**D, a left side portion of the casing **210** and the first microphone **51**L have been described. However, a right side portion of the casing **210** and the second microphone **51**R have the same configuration as the left side portion, because the composite unit **300** has a symmetrical planar shape.

[0150] FIG. **11** is a plan view showing a modified example of the embodiment for reducing a sound pressure of an acoustic wave (noise) coming from a rear direction. In an example shown in FIG. **11**, orientations of the first microphone **51**L and the second microphone **51**R face a front direction. As in FIG. **9**, the first microphone **51**L and the second microphone **51**R receive acoustic waves from openings in the casing **210**. Parts of the casing **210** disposed in a rear direction of the first microphone **51**L and the second microphone **51**R function as the sound pressure reducing units **210***a*L and **210***a*R.

[0151] FIG. **12** is a plan view showing a modified example of the embodiment for reducing a sound pressure of an acoustic wave (noise) coming from a rear direction. In an example shown in FIG. **12**, openings in the casing **210** face oblique front directions. The first microphone **51**L and the second microphone **51**R are attached at the openings and face oblique front directions. As in FIG. **9**, the first microphone **51**L and the second microphone **51**R receive acoustic waves from the openings in the casing **210**. Part of the casing **210** arranged in a rear direction of the first microphone **51**L and the second microphone **51**R function as the sound pressure reducing units **210***a*L and **210***a*R. Although FIGS. **11** and **12** show the composite unit **300** with the casing **210** having the control unit **130** therein, the composite unit **300** may not have the control unit **130**.

[0152] In the third embodiment, the example of the composite unit **300** has been described with reference to FIGS. **9** to **12**, but it is also possible to implement the example by replacing the casing **210** of the composite unit **300** with the vehicle body **190** of the autonomous moving apparatus **100**. As a result, it is possible to provide the autonomous moving apparatus **100** which achieves the same effect as the above-described composite unit **300**. The third embodiment can be implemented in combination with one or more other embodiments.

Fourth Embodiment

[0153] In a fourth embodiment, with reference to FIGS. **13** to **17**B, a description will be given regarding structures of the composite unit **300** and autonomous moving apparatus **100** for increasing sound pressures of acoustic waves coming from oblique front directions to the pair of left and right first microphone **51**L and the second microphone **51**R, among acoustic waves received by the first microphone **51**L and the second microphone **51**R.

[0154] FIG. **13** is a plan view showing an example of a structure of the composite unit **300** for increasing sound pressures of acoustic waves coming from oblique front directions, among acoustic waves received by the first microphone **51**L and the second microphone **51**R. The composite unit **300** further includes a first reflecting member **211**L which reflects an acoustic wave and is at least partially disposed in a rear direction of the first microphone **51**L, and a second reflecting member **211**R which reflects an acoustic wave and is at least partially disposed in a rear direction of the second microphone **51**R. The reflecting members are a plate-like members (reflecting plates) having reflecting surfaces, for example.

[0155] The first microphone **51**L and the second microphone **51**R face the left-right direction and the outside of the casing **210**. This enables the first microphone **51**L and the second microphone **51**R to receive acoustic waves coming from the outside of the casing **210**.

[0156] Reflecting surfaces of the first reflecting member **211**L and the second reflecting member **211**R face the front direction (positive direction of X axis). As a result, the first reflecting member **211**L and the second reflecting member **211**R can reflect acoustic waves coming from oblique front directions toward the first microphone **51**L and the second microphone **51**R. This can increase sound pressures of acoustic waves coming from the oblique front directions which are received by the first microphone **51**L and the second microphone **51**R. The reflecting surfaces of the first reflecting member **211**L and the second reflecting member **211**R are formed on surfaces facing the first microphone **51**L and the second microphone **51**R. The reflecting surfaces may have a planar shape as shown in FIG. **13**, or may have a spherical shape such as a hemispherical shape. If the reflecting surfaces have a planar shape, orientations of the reflecting surfaces are set at angles at which acoustic waves coming from oblique front directions are reflected toward the microphones **51**L and **51**R. If the reflecting surfaces have a spherical shape, positions and orientations of the reflecting surfaces are set such that reflected acoustic waves converge at positions of the microphones **51**L and **51**R.

[0157] A part of the acoustic wave S**1** output from the first speaker **41** is reflected by the object **60**A and is directed toward the first reflecting member **211**L as the acoustic wave S**2**. The acoustic wave S**2** is reflected by the first reflecting member **211**L and is directed toward the first microphone **51**L in a front direction. This can increase a sound pressure of the acoustic wave S**2** coming from an oblique front direction to the first microphone **51**L. It is also possible to increase a sound pressure of an acoustic wave coming from an oblique front direction to the second microphone **51**R, because the composite unit **300** has a symmetrical planar shape.

[0158] The reflecting surfaces of the first reflecting member **211**L and the second reflecting member **211**R do not have to directly face the front direction (positive direction of X axis). In other words, the reflecting surfaces do not have to be accurately perpendicular to the front direction (positive direction of X axis). As shown in FIG. **13**, the reflecting surfaces of the first reflecting member **211**L and the second reflecting member **211**R may be inclined toward the center side of the casing **210** in the left-right direction. As a result, as shown in FIG. **13**, the first reflecting member **211**L can reflect the acoustic wave S**2**, which has been reflected by the object **60**A located in an oblique front direction, toward the first microphone **51**L.

[0159] FIG. **14**A shows an example of a structure of the autonomous moving apparatus **100** for increasing a sound pressure of an acoustic wave coming from an oblique front direction, among acoustic waves received by the first microphone **51**L and the second microphone **51**R. While FIG. **13** shows the example of the composite unit **300**, FIG. **14**A shows an example of the autonomous moving apparatus **100** with the vehicle body **190** on which the speaker **41** and the microphones **51**L and **51**R are individually attached.

[0160] The first speaker **41** is arranged in a speaker casing **220**C, the first microphone **51**L is arranged in a first microphone casing **220**L, and the second microphone **51**R is arranged in a second microphone casing **220**R. The speaker casing **220**C, the first microphone casing **220**L, and the second microphone casing **220**R are mounted on the vehicle body **190**. A circuit **151**C including the amplifier **42** and the D/A conversion unit **43** may be arranged in the casing **220**C. A circuit **151**L having the A/D conversion unit **53**L and a circuit **151**R having the A/D conversion unit **53**R may be arranged in the casing **220**L and the casing **220**R, respectively.

[0161] Positions and orientations of the first microphone **51**L and the second microphone **51**R relative to the vehicle body **190** in FIG. **14**A are the same as the positions and orientations of the first microphone **51**L and the second microphone **51**R relative to the casing **210** in FIG. **13**. Positions and orientations of the first reflecting member **211**L and the second reflecting member **211**R relative to the first microphone **51**L and the second microphone **51**R in FIG. **14**A are the same as those in FIG. **13**.

[0162] FIG. **14**A shows an example in which the casings **220**C, **220**L, and **220**R are arranged on the outside of the vehicle body **190**, and the first speaker **41**, the first microphone **51**L, and the second microphone **51**R are arranged on the outside of the vehicle body **190**. That is, the first speaker **41**, the first microphone **51**L, and the second microphone **51**R are arranged inside of the outer edge of the vehicle body **190**. However, the speaker and microphones are not limited thereto, and as shown in FIG. **14**B, the casings **220**C, **220**L, and **220**R, the first speaker **41**, the first microphone **51**L, and the second microphone **51**R may be arranged on the outer periphery of the vehicle body **190**, that is, may be arranged on the outside of the outer edge of the vehicle body **190**. In this case, the first speaker **41** is located in a front direction of the front end F**1** of the vehicle body **190**. This reduces a distance between the first speaker **41** and an object in a front direction, and can increase a sound pressure of an acoustic wave reflected by the object. In addition, it is possible to reduce an echo signal of the vehicle body **190** itself, which becomes noise, instead of an echo signal by an obstacle (object in front direction). The first microphone **51**L and the second microphone **51**R are arranged on the outer periphery of the vehicle body **190** in the left-right direction. This further increases a distance between the first microphone **51**L and the second microphone **51**R, compared to that in FIG. **14**A. Therefore, as described in the first embodiment, it is possible to further increase the difference in sound pressures of left and right acoustic waves. The autonomous moving apparatus **100** shown in FIGS. **14**A and **14**B may have the contact detection sensor **214** shown in FIGS. **7**E to **7**H.

[0163] FIG. **15**A shows another example of a structure of the autonomous moving apparatus **100** for increasing a sound pressure of an acoustic wave coming from an oblique front direction, among acoustic waves received by the first microphone **51**L and the second microphone **51**R. FIGS. **15**A and **15**B show examples in which the first microphone **51**L and the second microphone **51**R face the front direction (positive direction of X axis).

[0164] The autonomous moving apparatus **100** further includes a first reflecting member **212**L which reflects an acoustic wave and is at least partially disposed inside of the vehicle body **190** in the left-right direction (Y axis direction) of the first microphone **51**L, and a second reflecting member **212**R which reflects an acoustic wave and is at least partially disposed inside of the vehicle body **190** in the left-right direction of the second microphone **51**R. Reflecting surfaces of the first reflecting member **212**L and the second reflecting member **212**R face the outside in the left-right direction. The reflecting surfaces of the first reflecting member **212**L and the second reflecting member **212**R are formed on surfaces facing the first microphone **51**L and the second microphone **51**R. As a result, the first reflecting member **212**L and the second reflecting member **212**R can reflect acoustic waves coming from oblique front directions toward the first microphone **51**L and the second microphone **51**R. This can increase sound pressures of the acoustic waves coming from the oblique front directions, which are received by the first microphone **51**L and the second microphone **51**R. The reflecting surfaces may have a planar shape as shown in FIGS. **15**A and **15**B, or may have a spherical shape such as a hemispherical shape. If the reflecting surfaces have a planar shape, orientations of the reflecting surfaces are set at angles at which the acoustic waves coming from the oblique front directions are reflected toward the microphones **51**L and **51**R. If the reflecting surfaces have a spherical shape, positions and orientations of the reflecting surfaces are set such that the reflected acoustic waves converge at positions of the microphones **51**L and **51**R.

[0165] The reflecting surfaces of the first reflecting member **212**L and the second reflecting member **212**R do not have to directly face the outside in the left-right direction (Y axis direction). In other words, the reflecting surfaces do not have to be accurately perpendicular to the outside in the left-right direction (Y axis direction). As shown in FIGS. **15**A and **15**B, the reflecting surfaces of the first reflecting member **212**L and the second reflecting member **212**R may be inclined toward a rear direction (negative direction of X axis). As a result, the first reflecting member **212**L and the second reflecting member **212**R can reflect acoustic waves, which have been reflected by objects located in oblique front directions, toward the first microphone **51**L and the second microphone **51**R.

[0166] As in FIG. **14**A, the first speaker **41**, the first microphone **51**L, and the second microphone **51**R shown in FIG. **15**A are housed in the casing **220**C, the casing **220**L, and the casing **220**R, respectively. The casings **220**C, **220**L, and **220**R are disposed on the outside of the vehicle body **190**, and the first speaker **41**, the first microphone **51**L, and the second microphone **51**R are disposed on the outside of the vehicle body **190**. In addition, as shown in FIG. **15**B, the casings **220**C, **220**L, and **220**R, the first speaker **41**, the first microphone **51**L, and the second microphone **51**R may be disposed on the outer periphery of the vehicle body **190**. In this case, the first speaker **41**, the first microphone **51**L, and the second microphone **51**R are located in the front direction of the front end F**1** of the vehicle body **190**. This reduces a distance to an object located in a front direction, and can increase a sound pressure of an acoustic wave reflected by the object. Further, it is also possible to reduce an echo signal of the vehicle body **190** itself, which becomes noise.

[0167] FIG. **16** shows another example of a structure of the composite unit **300** for increasing a sound pressure of an acoustic wave coming from an oblique front direction, among acoustic waves received by the first microphone **51**L and the second microphone **51**R. FIGS. **16** to **17**B show examples in which the first microphone **51**L and the second microphone **51**R face oblique front directions.

[0168] In the composite unit **300** shown in FIG. **16**, orientations of the first microphone **51**L and the second microphone **51**R are inclined to the outside of the casing **210** in the left-right direction (Y axis direction) from the front direction (positive direction of X axis). Specifically, the first microphone **51**L is inclined on the left side from the front direction. The second microphone **51**R is inclined on the right side from the front direction. As a result, it is possible to increase sound pressures of acoustic waves coming from oblique front directions, among acoustic waves received by the first microphone **51**L and the second microphone **51**R. An angle of inclination is larger than 0 degrees and 90 degrees or less, for example. The composite unit **300** shown in FIG. **16** further includes the first reflecting member **211**L and the second reflecting member **211**R arranged in the periphery of the first microphone **51**L and the second microphone **51**R. Reflecting surfaces of the first reflecting member **211**L and the second reflecting member **211**R are formed on surfaces of the first microphone **51**L and the second microphone **51**R. As a result, the first reflecting member **211**L and the second reflecting member **211**R can reflect acoustic waves coming from oblique front directions toward the first microphone **51**L and the second microphone **51**R. Due to the first microphone **51**L and the second microphone **51**R facing oblique front directions, it is possible to increase sound pressures of acoustic waves coming from the oblique front directions. The composite unit **300**, which does not have the first reflecting member **211**L and the second reflecting member **211**R shown in FIG. **12**, has the first microphone **51**L and the second microphone **51**R facing the oblique front directions in FIG. **16**. Therefore it is possible to increase sound pressures of acoustic waves coming from oblique front directions. Therefore, the composite unit **300** shown in FIG. **12** is also included in the fourth embodiment.

[0169] FIGS. **17**A and **17**B show another example of a structure of the autonomous moving apparatus **100** for increasing a sound pressure of an acoustic wave coming from an oblique front direction, among acoustic waves received by the first microphone **51**L and the second microphone **51**R. FIGS. **17**A and **17**B show examples in which the first microphone **51**L and the second microphone **51**R face oblique front directions. As in FIG. **14**A, the first speaker **41**, the first microphone **51**L, and the second microphone **51**R shown in FIGS. **17**A and **17**B are housed in the casing **220**C, the casing **220**L, and the casing **220**R, respectively. The circuit **151**C having the amplifier **42** and the D/A conversion unit **43** may be arranged in the casing **220**C. The circuit **151**L having the A/D conversion unit **53**L and the circuit **151**R having the A/D conversion unit **53**R may be arranged in the casing **220**L and the casing **220**R, respectively.

[0170] As shown in FIG. **17**A, each of the casings **220**C, **220**L, and **220**R may be arranged on the outside the vehicle body **190** and may be in contact with the front end F**1** of the vehicle body **190**. This can increase a sound pressure of an acoustic wave coming from a front direction. In addition, it is possible to reduce an echo signal of the vehicle body **190** itself, which becomes noise. In addition, the casings **220**L and **220**R are in contact with ends of the vehicle body **190** in the left-right direction. This can separate the first microphone **51**L and the second microphone **51**R in the left-right direction. Therefore, it is possible to increase the difference in sound pressures of acoustic waves received by the pair of left and right first microphone **51**L and second microphone **51**R. Parts of the casings **220**L and **220**R located in a rear direction of the first microphone **51**L and the second microphone **51**R function as sound pressure reducing units.

[0171] As shown in FIG. **17**B, each of the casings **220**C, **220**L, and **220**R may be disposed on the outer periphery of the vehicle body **190**, and may be in contact with the front end F1 of the vehicle body **190**. The casings **220**C, **220**L, and **220**R are attached in a further front direction of the vehicle body **19**, compared to those in FIG. **17**A. This can increase sound pressures of acoustic waves coming from front directions which are received by the first microphone **51**L and the second microphone **51**R. In addition, it is possible to reduce an echo signal of the vehicle body **190** itself, which becomes noise. The autonomous moving apparatus **100** shown in FIGS. **17**A and **17**B may have the contact detection sensor **214** shown in FIGS. **7**E to **7**H.

Fifth Embodiment

[0172] In a fifth embodiment, with reference to FIGS. **18**A to **18**C, a description will be given regarding a structure of the composite unit **300** for reducing sound pressures of acoustic waves coming from right and left opposite sides, among acoustic waves received by the first microphone **51**L and the second microphone **51**R. The pair of left and right first microphone **51**L and second microphone **51**R increase a sound pressure of an acoustic wave coming from the same side, left or right, and reduce sound pressures of acoustic waves coming from the right and left opposite sides. This can increase the difference in sound pressures of acoustic waves received by the pair of left and right first first microphone **51**L and second microphone **51**R.

[0173] FIG. **18**A is a plan view showing an example of a structure of the composite unit **300** for reducing sound pressures of acoustic waves coming from the right and left opposite sides, among acoustic waves received by the first microphone **51**L and the second microphone **51**R. FIGS. **18**B and **18**C are plan views, each showing another example of a structure of the composite unit **300** for reducing sound pressures of acoustic waves coming from the right and left opposite sides, among acoustic waves received by the first microphone **51**L and the second microphone **51**R. As shown in FIGS. **18**A to **18**C, the casing **210** of the composite unit **300** has a first sound pressure reducing unit **210***b*L and a second sound pressure reducing unit **210***b*R. The first sound pressure reducing unit **210***b*L is a portion of the casing **210** which reduces a sound pressure of a transmitted acoustic wave, and which is located on the outside of the casing **210** and on the outside of a first line segment connecting the first speaker **41** and the first microphone **51**L, when viewed from the vertical direction (Z axis direction). The second sound pressure reducing unit **210***b*R is a portion of the casing **210** which reduces a sound pressure of a transmitted acoustic wave, and which is located on outside of the casing **210** and on the outside of a second line segment connecting the first speaker **41** and the second microphone **51**R, when viewed from the vertical direction. The first sound pressure reducing unit **210***b*L and the second sound pressure reducing unit

210*b*R may be made of the same material as the casing **210**, or may be made of a material different from that of the casing **210**, such as a material that absorbs an acoustic wave, for example. Members that reflect acoustic waves may be disposed on surfaces of the first sound pressure reducing unit **210***b*L and the second sound pressure reducing unit **210***b*R.

[0174] The acoustic wave S**1** output from the first speaker **41** is reflected by the object **60**A located in a left oblique front direction. The acoustic wave S**2** directed toward the second microphone **51**R, of the reflected acoustic wave, is prevented from directly entering the second microphone **51**R by the second sound pressure reducing unit **210***b*R, or a sound pressure thereof is reduced. In this way, it is possible to reduce sound pressures of acoustic waves coming from the right and left opposite sides, among acoustic waves received by the first microphone **51**L and the second microphone **51**R.

[0175] The first sound pressure reducing unit **210***b*L and the second sound pressure reducing unit **210***b*R are also implemented in the casings **210**, **220**C, **220**L, and **220**R shown in FIGS. **9**, **11**, **12**, **13**, **14**A, **14**B, **15**A, **15**B, **16**, **17**A, and **17**B. The fifth embodiment can be implemented in combination with one or more other embodiments. The structure of the composite unit **300** shown in FIGS. **18**A to **18**C shows an example obtained by combining the second embodiment for increasing a sound pressure of an acoustic wave received from a front direction or an oblique front direction, the third embodiment for reducing a sound pressure of an acoustic wave (noise) coming from a rear direction, and the fourth embodiment for increasing sound pressures of acoustic waves coming from an oblique front direction to the pair of left and right microphones **51**L and **51**R, for example.

Sixth Embodiment

[0176] In a sixth embodiment, with reference to FIG. **19**, a description will be given regarding structures of the composite unit **300** and the autonomous moving apparatus **100** for reducing a sound pressure of an acoustic wave (noise) reflected by an unevenness **63** on a ground **62**, among acoustic waves received by the first microphone **51**L and the second microphone **51**R. The composite unit **300** further includes a projecting member **213** which reduces a sound pressure of a transmitted acoustic wave and which projects in a traveling direction of an acoustic wave from a lower portion of at least one of the first speaker **41**, the first microphone **51**L, and the second microphone **51**R.

[0177] An expression "a traveling direction of an acoustic wave" is a concept including a direction in which an acoustic wave is output from the first speaker **41**, and a direction in which the first microphone **51**L and the second microphone **51**R receive acoustic waves. FIG. **19** shows the composite unit **300** having one casing **210** on which the first speaker **41**, first microphone **51**L, and second microphone **51**R are attached, and shows an example in which the projecting member **213** projects in the front direction (positive direction of X axis) from lower surfaces of the first microphone **51**L and the second microphone **51**R. Meanwhile, the first speaker **41**, the first microphone **51**L, and the second microphone **51**R may be individually attached directly on the vehicle body **190**, unlike those in the composite unit **300**. In this case, the projecting member **213** projects in the front direction (positive direction of X axis) from a lower surface of each of the first speaker **41**, the first microphone **51**L, and the second microphone **51**R. The projection amount is in a range from 2 cm to 10 cm, for example. A material of the projecting member **213** may be the same as that of the casing **210** or the vehicle body **190**, or the projecting member **213** may be made of a material different from that of the casing **210** or the vehicle body **190**, such as a material which absorbs an acoustic wave or a material which reflects an acoustic wave, for example.

[0178] The acoustic wave S**1** output from the first speaker **41** is reflected by the unevenness **63** on the ground **62** on which the autonomous moving apparatus **100** travels, and when the acoustic wave S**2** reflected toward the first microphone **51**L or the second microphone **51**R passes through the projecting member **213**, a sound pressure thereof is reduced. As a result, it is possible to reduce a sound pressure of an acoustic wave (noise) reflected by the unevenness **63** on the ground **62**, among acoustic waves received by the first microphone **51**L and the second microphone **51**R. Although not shown in FIG. **19**, if the projecting member **213** projects in a front direction from a lower surface of the first speaker **41**, and when the acoustic wave S**1** output from the first speaker **41** passes through the projecting member **213**, a sound pressure thereof is reduced. The acoustic wave S**1** may be reflected by the projecting member **213**.

Seventh Embodiment

[0179] In a seventh embodiment, with reference to FIG. **20**, a description will be given regarding structures of the composite unit **300** and the autonomous moving apparatus **100** for preventing the object **60**A in a lateral direction from being entangled by increasing a sound pressure of an acoustic waves coming from a lateral direction of the autonomous moving apparatus **100**. As shown in FIG. **20**, the entire first reflecting member **211**L is disposed in a rear direction of the first microphone **51**L. Similarly, the entire second reflecting member **211**R is disposed in a rear direction of the second microphone **51**R. That is, when the first microphone **51**L is viewed from the outside in the left-right direction (left side), the entire first microphone **51**L is visible without being shielded by the first reflecting member **211**L. Similarly, when the second microphone **51**R is viewed from the outside in the left-right direction (right side), the entire second microphone **51**R is visible without being shielded by the second reflecting member **211**R.

[0180] The acoustic wave S**1** output from the first speaker **41** is reflected by a surface of the object **60**A located on the left side of the autonomous moving apparatus **100**, and the acoustic wave S**2** reflected toward the first microphone **51**L can reach the first microphone **51**L without being shielded by the first reflecting member **211**L. Therefore, it is possible to detect the object **60**A in the lateral directing by increasing a sound pressure of an acoustic wave coming from the lateral direction of the autonomous moving apparatus **100** having the composite unit **300** shown in FIG. **20**, and this can prevent the autonomous moving apparatus **100** from entangling the object **60**A when turning left. It is possible to enhance the sensitivity of the first microphone **51**L and the second microphone **51**R to an acoustic wave coming from the lateral direction of the autonomous moving apparatus **100**.

[0181] In the examples shown in FIGS. **13**, **14**A, and **14**B, the first reflecting member **211**L and the second reflecting member **211**R are inclined largely to the inside of the composite unit **300** in order to increase sound pressures of acoustic waves coming from oblique front directions to the pair of left and right microphones **51**L and **51**R. Therefore, when the first microphone **51**L and the second microphone **51**R are viewed from the outside in the left-right direction, parts of the first microphone **51**L and the second microphone **51**R are not visible due to the presence of the first reflecting member **211**L and the second reflecting member **211**R. Meanwhile, in the example shown in FIG. **20**, an inclination angle is set to be small so that the entire first microphone **51**L and the entire second microphone **51**R are visible. The inclination angle is not limited thereto, and even if inclination angles of the first reflecting member **211**L and the second reflecting member **211**R remain large, if positions thereof are moved in a further rear direction (negative direction of X axis), the entire first microphone **51**L and the entire second microphone **51**R become visible. The seventh embodiment can also be applied to the structure of the autonomous moving apparatus **100** by replacing the casing **210** shown in FIG. **20** with the vehicle body **190**.

[0182] The seventh embodiment can be implemented in combination with one or more other embodiments. Due to the presence of the first reflecting member **211**L and the second reflecting member **211**R shown in FIG. **20**, it is possible to obtain an effect of reducing a sound pressure of an acoustic wave (noise) coming from a rear direction (third embodiment), and an effect of increasing sound pressures of acoustic waves coming from oblique front directions to the pair of left and right microphones **51**L and **51**R (fourth embodiment). Since parts of the casing **210** located on the outside of the line segment connecting the microphone **51**L and the first speaker **41** and the line segment connecting the microphone **51**R and the first speaker **41** function as sound pressure reducing units, it is possible to obtain an effect of reducing sound pressures of acoustic waves coming from right and left opposite sides (fifth embodiment). That is, the example shown in FIG. **20** is an example obtained by combining the third to fifth embodiments.

Eighth Embodiment

[0183] In an eighth embodiment, with reference to FIG. **21**, a description will be given regarding structures of the composite unit **300** and the autonomous moving apparatus **100** for preventing collisions with the objects **60**A and **60**B in a front direction of the autonomous moving apparatus **100** by increasing a sound pressure of an acoustic wave coming from the front direction. As shown in FIG. **21**, the entire first reflecting member **212**L is disposed in the inner side of the casing **210** in the left-right direction of the first microphone **51**L. Similarly, the entire second reflecting member **212**R is disposed in the inner side of the casing **210** in the left-right direction of the second microphone **51**R. That is, when the first microphone **51**L is viewed from the front direction, the entire first microphone **51**L is visible without being shielded by the first reflecting member **212**L. Similarly, when the second microphone **51**R is viewed from the front direction, the entire second microphone **51**R is visible without being shielded by the second reflecting member **212**R.

[0184] The acoustic wave S**1** output from the first speaker **41** is reflected by a surface of the object **60**A located in the front direction of the autonomous moving apparatus **100**, and the acoustic wave S**2** reflected toward the first microphone **51**L can reach the first microphone **51**L without being shielded by the first reflecting member **212**L. Therefore, it is possible to detect the object **60**A in the front direction of the autonomous moving apparatus **100** by increasing a sound pressure of an acoustic wave coming from the front direction, and this can prevent collision with the object **60**A. Similarly, the acoustic wave S**3** output from the first speaker **41** is reflected by a surface of the object **60**B located in the front direction of the autonomous moving apparatus **100**, and an acoustic wave S**4** reflected toward the second microphone **51**R can reach the second microphone **51**R without being shielded by the second reflecting member **212**R. Therefore, it is possible to detect the object **60**B in the front direction of the autonomous moving apparatus **100** by increasing a sound pressure of an acoustic wave coming from the front direction, and this can prevent collision with the object **60**A. It is possible to enhance the sensitivity of the first microphone **51**L and the second microphone **51**R to an acoustic wave coming from the front direction of the autonomous moving apparatus **100**.

[0185] Due to the presence of the first reflecting member **212**L and the second reflecting member **212**R in FIG. **21**, it is possible to obtain an effect of increasing sound pressures of acoustic waves coming from oblique front directions to the pair of left and right microphones **51**L and **51**R (fourth embodiment), and an effect of reducing sound pressures of acoustic waves coming from right and left opposite sides (fifth embodiment). That is, the example shown in FIG. **20** is an example obtained by combining the fourth and fifth embodiments. It is needless to say that parts of the casing **210** located in a rear direction of the first microphone **51**L and the second microphone **51**R form sound pressure reducing units for reducing sound pressures of acoustic waves (noise) coming from a rear direction (third embodiment).

Ninth Embodiment

[0186] In a ninth embodiment, with reference to FIGS. **22**A and **22**B, a description will be given regarding structures of the composite unit **300** and the autonomous moving apparatus **100** for increasing a sound pressure of an acoustic waves coming from at least one of a front direction and a lateral direction, while increasing sound pressures of acoustic waves coming from oblique front directions to the pair of left and right microphones **51**L and **51**R. FIG. **22**A shows a modified example of the composite unit **300** shown in FIGS. **12** and **18**C, and is a plan view showing an enlarged view of parts of the first microphone **51**L and the casing **210** in the periphery thereof.

[0187] As shown in FIG. **22**A, portions of the first microphone **51**L and the second microphone **51**R that receive acoustic waves may be visible from the outside of the casing **210** in at least one of a front direction and a left-right direction. Entire tips of acoustic horns of the first microphone **51**L and the second microphone **51**R may be visible from the outside of the casing **210** in at least one of the front direction (X axis direction) and the left-right direction (Y axis direction), for example. Orientations of the first microphone **51**L and the second microphone **51**R are inclined to the outside of the casing **210** in the left-right direction (Y axis direction) from the front direction (positive direction of X axis).

[0188] In FIGS. **12** and **18**C, portions of the first microphone **51**L and the second microphone **51**R are shielded by the casing **210**. Specifically, edge portions of an opening in the casing **210** hide the portions of the first microphone **51**L and the second microphone **51**R. In the example of FIG. **22**A, the side of an opening of the casing **210** in which the first microphone **51**L and the second microphone **51**R are arranged is inclined such that the opening becomes wide toward the outside of the casing **210**. As a result, the portions of the first microphone **51**L and the second microphone **51**R that receive acoustic waves are visible from the outside of the casing **210** in at least one of the front direction and the left-right direction. Therefore, while increasing sound pressures of acoustic waves coming from oblique front directions to the pair of left and right microphones **51**L and **51**R, it is also possible to increase a sound pressure of an acoustic wave coming from at least one of a front direction and a lateral direction.

[0189] FIG. **22**B is a plan view showing another example of a structure of the composite unit **300** for increasing a sound pressure of an acoustic wave coming from at least one of a front direction and a lateral direction, while increasing sound pressures of acoustic waves coming from oblique front directions to the pair of left and right microphones **51**L and **51**R. The composite unit **300** further includes the first reflecting member **211**L that is arranged in the periphery of the first microphone **51**L and reflects an acoustic wave toward a portion of the first microphone **51**L which receives an acoustic wave, and the second reflecting member **211**R that is arranged in the periphery of the second microphone **51**R and reflects an acoustic wave toward a portion of the second microphone **51**R which receives an acoustic wave. As in FIG. **22**A, portions of the first microphone **51**L and the second microphone **51**R which receive acoustic waves are visible from the outside of the casing **210** in at least one of a front direction (positive direction of X axis) and a left-right direction (Y axis direction). Due to the composite unit **300** having the first reflecting member **211**L and the second reflecting member **211**R, while increasing sound pressures of acoustic waves coming from oblique front directions to the pair of left and right microphones **51**L and **51**R, it is also possible to further increase a sound pressure of an acoustic wave coming from at least one of a front direction and a lateral direction. Reflecting surfaces of the first reflecting member **211**L and the second reflecting member **211**R may directly face outside of the casing **210** in a front direction or a left-right direction (Y axis direction), or may be inclined.

[0190] Further, as a modified example of FIGS. **9**, **11**, **13**, **14**A, **14**B, **15**A, **15**B, **16**, **18**A, **20**, and **22**B, a convex casing **210** may be formed by reducing a portion of a rectangular casing, and portions of the casing **210** may function as the first reflecting member **211**L and the second reflecting member **211**R or the first reflecting member **212**L and the second reflecting member **212**R. Alternatively, as a modified example of FIG. **21**, a concave casing **210** may be formed, and side surfaces of the concave portion which is a part of the casing **210** may function as the first reflecting member **212**L and the second reflecting member **212**R.

[0191] Although the example of the composite unit **300** has been described in the ninth embodiment, the example can be implemented by replacing the casing **210** of the composite unit **300** with the vehicle body **190** of the autonomous moving apparatus **100**. As a result, it is possible to provide the autonomous moving apparatus **100** which achieves the same effect as the composite unit **300** described above. The ninth embodiment may be implemented in combination with one or more other embodiments.

Tenth Embodiment

[0192] In a tenth embodiment, with reference to FIGS. **23**A to **23**E, another modified example of the number and arrangement of microphones and speakers of the autonomous moving apparatus **100** will be described. FIGS. **6**A to **6**C show configuration examples in which the number of speaker is one and the number of microphones is two, and FIGS. **7**A to **7**D show configuration examples in which the number of speakers is two and the number of microphones is two. In the tenth embodiment, an example in which the number of microphones is three or four will be described.

[0193] As shown in FIG. **23**A, the autonomous moving apparatus **100** may further include a third microphone **51**M which is attached to the vehicle body **190**, receives an acoustic wave reflected by an object, and converts the acoustic wave into an electric signal. The first speaker **41**, the first microphone **51**L, the second microphone **51**R, and the third microphone **51**M are arranged plane symmetrically, relative a single target plane C**1**. The third microphone **51**M is attached to the front end F**1** of the vehicle body **190** and to the center of the vehicle body **190** in a left-right direction, to face an area including a front direction. The single target plane C**1** is the center plane C**1** which is parallel to a plane including a front-rear direction and an up-down direction of the autonomous moving apparatus **100** (X Z plane) and includes the center of the vehicle body **190** in the left-right direction. Positions and orientations of the first speaker **41**, the first microphone **51**L, the second microphone **51**R, and the third microphone **51**M are plane symmetrical, relative to the center plane C**1**. The first speaker **41** and the third microphone **51**M are located at the same position and face the same front direction. In this case, the first speaker **41** and the third microphone **51**M can be configured as one module (sensor for both transmission and reception).

[0194] As shown in FIGS. **23**B to **23**E, the autonomous moving apparatus **100** may include a first microphone **51**L**1**, a second microphone **51**L**2**, a third microphone **51**R**1**, and a fourth microphone **51**R**2**, each of which is attached to the vehicle body **190**, receives an acoustic wave reflected by an object, and converts the acoustic wave into an electric signal. Positions and orientations of the first speaker **41**, the first microphone **51**L**1**, the second microphone **51**L**2**, the third microphone **51**R**1**, and the fourth microphone **51**R**2** are plane symmetrical, relative to the center plane C**1** as a single target plane. The first microphone **51**L**1**, the second microphone **51**L**2**, the third microphone **51**R**1**, and the fourth microphone **51**R**2** may be attached to the front end F**1** of the vehicle body **190** to face a front direction (FIG. **23**C). The two microphones **51**L**1** and **51**R**1** may be attached to face the outside of the vehicle body **190** in the left-right direction, and the other two microphones **51**L**2** and **51**R**2** may be attached to face an oblique front direction or a front direction (FIGS. **23**D and **23**E).

[0195] As shown in FIGS. **23**A to **23**E, even if the number of speakers or microphones attached to the vehicle body **190** increases, all of speakers and microphones are attached plane symmetrically, relative to the single target plane C**1**. This can reduce the left-right deviation of sound pressures of acoustic waves received by the first microphone **51**L**1**, the second microphone **51**L**2**, the third microphone **51**R**1**, and the fourth microphone **51**R**2**.

[0196] The above-described embodiments are examples of the present invention. Therefore, the present invention is not limited to the above-described embodiments, and it is needless to say that, even in forms other than the embodiments, various modifications are possible according to a design or the like without deviating from a technical concept according to the present invention.

[0197] Acoustic waves which have entered through openings of the vehicle body **190** or the casing **210** are reflected inside the vehicle body **190** or the casing **210**, and can be received by the first microphone **51**L and the second microphone **51**R as echo signals (noise). Therefore, as shown in FIG. **12** or **17**A, only openings for the first microphone **51**L and the second microphone **51**R to receive acoustic waves, and an opening for the first speaker **41** to output an acoustic wave may be formed in the casings **210**, **220**L, and **220**R as the openings, for example. This can reduce the number of openings which allow acoustic waves to enter the interior of the casing **210**, and therefore it is possible to reduce acoustic waves entering the interior of the casing **210**. Further, FIG. **12** shows an example in which an opening for outputting an acoustic wave is formed in the casing **210**, because the first speaker **41** is disposed on the outside of the casing **210**, that is, inside of the outer edge of the casing **210**. However, the speaker is not limited thereto, and the entire first speaker **41** may be disposed on the outer periphery of the casing **210**, that is, inside of the outer edge of the casing **210**. This eliminates the necessity of an opening for the first speaker **41**, and it is possible to further reduce the number of openings which allow acoustic waves to enter the interior of the casing **210**. Further, if there is a gap between the outer periphery of the first microphone **51**L and the second microphone **51**R and the inner periphery of an opening, an acoustic wave enters through the gap, and this causes an increase in noise. Therefore, as shown in FIG. **22**B, the composite unit **300** may further include a microphone mounted substrate **215**L on which the first microphone **51**L is mounted, and a sealing member **216**L which is made of a rubber packing or the like and closes a gap between the casing **210** and the microphone mounted substrate **215**L. The sealing member **216**L is arranged to surround the periphery of the first microphone **51**L including a left-right direction and an up-down direction of the first microphone **51**L. The gap between the outer periphery of the first microphone **51**L and the second microphone **51**R and the inner periphery of the opening is closed due to the configuration. This can reduce noise entering through the gap. The gap may be made smaller or closed by reducing or eliminating the difference between the outer diameter of the first microphone **51**L and the second microphone **51**R and the inner diameter of the opening. It is needless to say that the composite unit **300** can be implemented as the autonomous moving apparatus **100** by replacing the casing **210** with the vehicle body **190**.

Supplementary Notes

Supplementary Note 1: First Embodiment, FIGS. 6A to 8: Increasing Difference in Left and Right Sound Pressures

[0198] The autonomous moving apparatus **100** includes: the vehicle body **190**; the first speaker **41** that is attached to the vehicle body **190** and transmits an acoustic wave toward an area including a front direction of the vehicle body **190**; and the first microphone **51**L and the second microphone **51**R that are attached to the vehicle body **190**, receive acoustic waves reflected by an object, and convert the acoustic waves into electric signals. When viewed from a vertical direction, the first speaker **41**, the first microphone **51**L, and the second microphone **51**R are located on an outside or outer periphery of the vehicle body **190**. The first speaker **41** is interposed between the first microphone **51**L and the second microphone **51**R in a left-right direction perpendicular to a front direction. Distances from the first speaker **41** or a center of gravity of a plurality of speakers including the first speaker **41**, to each of the first microphone **51**L and the second microphone **51**R in a left-right direction are equal.

Supplementary Note 2: Second Embodiment, FIGS. 7E to 7H: Increasing Sound Pressure in Front Direction

[0199] In the autonomous moving apparatus **100** according to Supplementary note 1, the first speaker **41** is disposed at the front end F**1** of the vehicle body **190**.

Supplementary Note 3: Second Embodiment, FIGS. 7E to 7H: Contact Detection Sensor

[0200] The autonomous moving apparatus **100** according to Supplementary note 2 further includes: the contact detection sensor **214** that detects contact with an object and is disposed in a front direction of the first speaker **41** or disposed at the same position in a front-rear direction as the first speaker **41**.

Supplementary Note 4: Third Embodiment, FIGS. 9 to 12: Reducing Noise in Rear Direction

[0201] In the autonomous moving apparatus **100** according to any one of Supplementary notes 1 to 3, the vehicle body **190** includes the sound pressure reducing units **210***a*L and **210***a*R that are disposed in a rear direction of the first microphone **51**L and the second microphone **51**R and reduce sound pressures of transmitted acoustic waves.

Supplementary Note 5: Fourth Embodiment, FIGS. 13 to 14B: Increasing Sound Pressure in Oblique Front Direction

[0202] The autonomous moving apparatus **100** according to any one of Supplementary notes 1 to 4 further includes: the first reflecting member **211**L that reflects an acoustic wave and is at least partially disposed in a rear direction of the first microphone **51**L; and the second reflecting member **211**R that reflects an acoustic wave and is at least partially disposed in a rear direction of the second microphone **51**R. The first microphone **51**L and the second microphone **51**R face a left-right direction and an outside of the vehicle body **190**, and reflecting surfaces of the first reflecting member **211**L and the second reflecting member **211**R face a front direction.

Supplementary Note 6: Fourth Embodiment, FIGS. 15A and 15B: Increasing Sound Pressure in Oblique Front Direction

[0203] The autonomous moving apparatus **100** according to any one of Supplementary notes 1 to 4 further includes: the first reflecting member **212**L that reflects an acoustic wave and is at least partially disposed in an inner side of the vehicle body **190** in a left-right direction of the first microphone **51**L; and the second reflecting member **212**R that reflects an acoustic wave and is at least partially disposed in an inner side of vehicle body **190** in a left-right direction of the second microphone **51**R. The first microphone **51**L and the second microphone **51**R face a front direction, and reflecting surfaces of the first reflecting member **212**L and the second reflecting member **212**R face an outside in a left-right direction.

Supplementary Note 7: Fourth Embodiment, FIGS. **16** to **17**B: Increasing Sound Pressure in Oblique Front Direction

[0204] In the autonomous moving apparatus **100** according to any one of Supplementary notes 1 to 4, orientations of the first microphone **51**L and the second microphone **51**R are inclined from a front direction to an outside of the vehicle body **190** in a left-right direction.

Supplementary Note 8: Fifth Embodiment, FIGS. **18**A to **18**C: Reducing Sound Pressures from Right and Left Opposite Sides

[0205] In the autonomous moving apparatus **100** according to any one of Supplementary notes 1 to 7, the vehicle body **190** includes: the first sound pressure reducing unit **210***b*L that reduces a sound pressure of a transmitted acoustic wave, and that is located on an outside of the vehicle body **190** and on an outside of the first line segment connecting the first speaker **41** and the first microphone **51**L, when viewed from the vertical direction; and the second sound pressure reducing unit **210***b*R that reduces a sound pressure of a transmitted acoustic wave, and that is located on an outside the vehicle body **190** and on an outside of the second line segment connecting the first speaker **41** and the second microphone **51**R, when viewed from the vertical direction.

Supplementary Note 9: Sixth Embodiment, FIG. **19**: Reducing Sound Pressure Reflected by Unevenness on Ground

[0206] The autonomous moving apparatus **100** according to any one of Supplementary notes 1 to 8 further includes: the projecting member **213** that reduces a sound pressure of a transmitted acoustic wave, and that projects in a traveling direction of an acoustic wave from a lower portion of at least one of the first speaker **41**, the first microphone **51**L, and the second microphone **51**R.

Supplementary Note 10: Seventh Embodiment, FIG. **20**: Increasing Sound Pressure in Lateral Direction

[0207] In the autonomous moving apparatus **100** according to Supplementary note 5, an entirety of the first reflecting member **211**L is disposed in a rear direction of the first microphone **51**L, and an entirety of the second reflecting member **211**R is disposed in a rear direction of the second microphone **51**R.

Supplementary Note 11: Eighth Embodiment, FIG. **21**: Increasing Sound Pressure in Front Direction

[0208] In the autonomous moving apparatus **100** according to Supplementary note 6, an entirety of the first reflecting member **212**L is disposed in the inner side of the vehicle body **190** in a left-right direction of the first microphone **51**L, and an entirety of the second reflecting member **212**R is disposed in the inner side of the vehicle body **190** in a left-right direction of the second microphone **51**R.

Supplementary Note 12: Ninth Embodiment, FIGS. **22**A and **22**B: Increasing Sound Pressure in Lateral Direction, Front Direction/Lateral Direction

[0209] In the autonomous moving apparatus **100** according to Supplementary note 7, a portion of the first microphone **51**L that receives an acoustic wave and a portion of the second microphone **51**R that receives an acoustic wave are visible from an outside of the vehicle body **190** in at least one of a front direction and a left-right direction.

Supplementary Note 13: Ninth Embodiment, FIG. **22**B: Increasing Sound Pressure in Lateral Direction, Front Direction/Lateral Direction

[0210] The autonomous moving apparatus **100** according to Supplementary note 12 further includes: the first reflecting member **211**L that is disposed in the periphery of the first microphone **51**L and reflects an acoustic wave toward the portion of the first microphone **51**L which receives the acoustic wave; and the second reflecting member **211**R that is disposed in the periphery of the second microphone **51**R and reflects an acoustic wave toward the portion of the second microphone **51**R which receives the acoustic wave.

Supplementary Note 14: Tenth Embodiment, FIGS. **23**A to **23**E

[0211] The autonomous moving apparatus **100** according to any one of Supplementary notes 1 to 13 further includes: the second speaker **41**R that is attached to the vehicle body **190** and transmits an acoustic wave in a front direction; and the third microphone **51**M that is attached to the vehicle body **190**, receives an acoustic wave reflected by an object, and converts the acoustic wave into an electric signal. The first speaker **41**L, the second speaker **41**R, the first microphone **51**L, the second microphone **51**R, and the third microphone **51**M are disposed plane symmetrically, relative to the single target plane C**1**.

Supplementary Note 15: Structure for Closing Gap

[0212] The autonomous moving apparatus **100** according to any one of Supplementary notes 1 to 14 further includes: a first microphone mounted substrate **215**L on which the first microphone **51**L is mounted; a first sealing member **216**L that closes a gap between the vehicle body **190** and the first microphone mounted substrate **215**L; a second microphone mounted substrate on which the second microphone **51**R is mounted; and a second sealing member that closes a gap between the vehicle body **190** and the second microphone mounted substrate.

Supplementary Note 16: Composite Unit Used in Autonomous Moving Apparatus

[0213] The composite unit **300** used in the autonomous moving apparatus **100** includes: the casing **210**; the first speaker **41** that is attached in the casing **210** and transmits an acoustic wave toward an area including a front direction of the casing **210**; and the first microphone **51**L and the second microphone **51**R that are attached in the casing **210**, receive acoustic waves reflected by an object, and convert the acoustic waves into electric signals. When the composite unit **300** is viewed from the vertical direction, the first speaker **41**, the first microphone **51**L, and the second microphone **51**R are located on an outside or outer periphery of the casing **210**. The first speaker **41** is interposed between the first microphone **51**L and the second microphone **51**R in a left-right direction perpendicular to the front direction. Distances from the first speaker **41** or a center of gravity of a plurality of speakers including the first speaker **41**, to each of the first microphone **51**L and the second microphone **51**R in a left-right direction are equal.

Supplementary Note 17: Composite Unit Used in Autonomous Moving Apparatus

[0214] The autonomous moving apparatus **100** includes the composite unit **300** according to Supplementary note 16.

Supplementary Note 18

[0215] The autonomous moving apparatus **100** according to Supplementary note 17 further includes: a structure surrounding a bottom surface and a top surface of the composite unit **300**. Due to the presence of the structure, it is possible to reduce a sound pressure of an acoustic wave that comes from a rear direction of the autonomous moving apparatus **100**, comes around the bottom surface and the top surface of the composite unit **300**, and enters the first microphone **51**L and the second microphone **51**R.

Supplementary Note 19: Digital Pheromone+Echolocation

[0216] The autonomous moving apparatus **100** autonomously moves using a radio wave and an acoustic wave. The autonomous moving apparatus includes: the receiving unit **110** that receives a radio wave; the angle estimating unit **134** that estimates an incoming direction of a radio wave; the first speaker **41** that transmits an acoustic wave toward a straight-travelling direction of the autonomous moving apparatus **100**; the first microphone **51**L and the second microphone **51**R that receive acoustic waves reflected by an object and convert the acoustic waves into a first sound signal and a second sound signal; and the operation control unit **135** that controls a movement direction of the autonomous moving apparatus **100** based on the first sound signal, the second sound signal, and the incoming direction of the radio wave.

Supplementary Note 20

[0217] In the autonomous moving apparatus **100** according to Supplementary note 18, the operation control unit **135** controls a movement direction of the autonomous moving apparatus **100** based on echo signals included in a first sound signal and a second sound signal and an incoming direction of a radio wave.

[0218] The entire contents of Japanese Patent Application No. 2022-181345 (filed on Nov. 11, 2022 in Japan) are incorporated herein by reference, to thereby take some protection against translation errors or omitted portions.

REFERENCE SIGNS LIST

[0219] **41**, **41**L First speaker
[0220] **41**R Second speaker
[0221] **51**L, **51**L**1** First microphone
[0222] **51**M Third microphone
[0223] **51**R, **51**R**1** Second microphone
[0224] **60**A, **60**B Object
[0225] **100** Autonomous moving apparatus
[0226] **190** Vehicle body
[0227] **214** Contact detection sensor
[0228] **210** Casing
[0229] **210***a*L, **210***a*R Sound pressure reducing unit
[0230] **210***b*L First sound pressure reducing unit
[0231] **210***b*R Second sound pressure reducing unit
[0232] **211**L, **212**L First reflecting member
[0233] **211**R, **212**R Second reflecting member
[0234] **213** Projecting member
[0235] **300** Composite unit
[0236] C**1** Single target plane
[0237] F**1** Front end of vehicle body
[0238] F**2** Front end of casing

1. An autonomous moving apparatus comprising:
a vehicle body;
a first speaker that is attached to the vehicle body and transmits an acoustic wave toward an area including a front direction of the vehicle body;
a first microphone that is attached to the vehicle body, receives an acoustic wave reflected by an object, and converts the acoustic wave into an electric signal; and
a second microphone that is attached to the vehicle body, receives an acoustic wave reflected by the object, and converts the acoustic wave into an electric signal, wherein
when viewed from a vertical direction, the first speaker, the first microphone, and the second microphone are located on an outside or an outer periphery of the vehicle body,
the first speaker is interposed between the first microphone and the second microphone in a left-right direction perpendicular to the front direction, and
distances from the first speaker or a center of gravity of a plurality of speakers including the first speaker, to each of the first microphone and the second microphone in the left-right direction are equal.

2. The autonomous moving apparatus according to claim **1**, wherein
the first speaker is disposed at a front end of the vehicle body.

3. The autonomous moving apparatus according to claim **2** further comprising:
a contact detection sensor that detects contact with the object and is disposed in a front direction of the first speaker or disposed at the same position in a front-rear direction as the first speaker.

4. The autonomous moving apparatus according to claim **1**, wherein
the vehicle body includes a sound pressure reducing unit that is disposed in a rear direction of the first microphone and in a rear direction of the second microphone, and reduces a sound pressure of a transmitted acoustic wave.

5. The autonomous moving apparatus according to claim **1** further comprising:
a first reflecting member that reflects an acoustic wave and is at least partially disposed in the rear direction of the first microphone; and
a second reflecting member that reflects an acoustic wave and is at least partially disposed in the rear direction of the second microphone, wherein

the first microphone and the second microphone face the left-right direction and an outside of the vehicle body, and

reflecting surfaces of the first reflecting member and the second reflecting member face the front direction.

6. The autonomous moving apparatus according to claim **1** further comprising:

a first reflecting member that reflects an acoustic wave and is at least partially disposed in an inner side of the vehicle body in the left-right direction of the first microphone; and

a second reflecting member that reflects an acoustic wave and is at least partially disposed in an inner side of the vehicle body in the left-right direction of the second microphone, wherein

the first microphone and the second microphone face the front direction, and

reflecting surfaces of the first reflecting member and the second reflecting member face an outside in the left-right direction.

7. The autonomous moving apparatus according to claim **1**, wherein

orientations of the first microphone and the second microphone are inclined from the front direction to an outside of the vehicle body in the left-right direction.

8. The autonomous moving apparatus according to claim **1**, wherein

the vehicle body includes:

a first sound pressure reducing unit that reduces a sound pressure of a transmitted acoustic wave, and that is located on an outside of the vehicle body and on an outside of a first line segment connecting the first speaker and the first microphone, when viewed from the vertical direction; and

a second sound pressure reducing unit that reduces a sound pressure of a transmitted acoustic wave, and that is located on the outside the vehicle body and on an outside of a second line segment connecting the first speaker and the second microphone, when viewed from the vertical direction.

9. The autonomous moving apparatus according to claim **1** further comprising:

a projecting member that reduces the sound pressure of the transmitted acoustic wave, and that projects in a traveling direction of the acoustic wave from a lower portion of at least one of the first speaker, the first microphone, and the second microphone.

10. The autonomous moving apparatus according to claim **5**, wherein

an entirety of the first reflecting member is disposed in the rear direction of the first microphone, and

an entirety of the second reflecting member is disposed in the rear direction of the second microphone.

11. The autonomous moving apparatus according to claim **6**, wherein

an entirety of the first reflecting member is disposed in the inner side of the vehicle body in the left-right direction of the first microphone, and

an entirety of the second reflecting member is disposed in the inner side of the vehicle body in the left-right direction of the second microphone.

12. The autonomous moving apparatus according to claim **7**, wherein

a portion of the first microphone that receives an acoustic wave and a portion of the second microphone that receives an acoustic wave are visible from the outside of the vehicle body in at least one of the front direction and the left-right direction.

13. The autonomous moving apparatus according to claim **12** further comprising:

a first reflecting member that is disposed in the periphery of the first microphone and reflects the acoustic wave toward the portion of the first microphone which receives the acoustic wave; and

a second reflecting member that is disposed in the periphery of the second microphone and reflects the acoustic wave toward the portion of the second microphone which receives the acoustic wave.

14. The autonomous moving apparatus according to claim **1** further comprising:

a second speaker that is attached to the vehicle body and transmits an acoustic wave in the front direction; and

a third microphone that is attached to the vehicle body, receives an acoustic wave reflected by the object, and converts the acoustic wave into an electric signal, wherein

the first speaker, the second speaker, the first microphone, the second microphone, and the third microphone are disposed plane symmetrically relative to a single target plane.

15. The autonomous moving apparatus according to claim **1** further comprising:

a first microphone mounted substrate on which the first microphone is mounted;

a first sealing member that closes a gap between the vehicle body and the first microphone mounted substrate;

a second microphone mounted substrate on which the second microphone is mounted; and

a second sealing member that closes a gap between the vehicle body and the second microphone mounted substrate.

16. A composite unit of a speaker-microphone for an autonomous moving apparatus that is a composite unit used in an autonomous moving apparatus, the composite unit comprising:

a casing;

a first speaker that is attached in the casing and transmits an acoustic wave toward an area including a front direction of the casing;

a first microphone that is attached in the casing, receives an acoustic wave reflected by an object, and converts the acoustic wave into an electric signal; and

a second microphone that is attached in the casing, receives an acoustic wave reflected by the object, and converts the acoustic wave into an electric signal, wherein

when viewed from a vertical direction, the first speaker, the first microphone, and the second microphone are located on an outside or an outer periphery of the casing,

the first speaker is interposed between the first microphone and the second microphone in a left-right direction perpendicular to the front direction, and

distances from the first speaker or a center of gravity of a plurality of speakers including the first speaker, to each of the first microphone and the second microphone in the left-right direction are equal.

17. An autonomous moving apparatus comprising:

the composite unit according to claim **16**.

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