

MILLIMETER WAVE IMAGING APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This international application claims the benefit of Japanese Patent Application No. 2010-091486 filed April 12, 2010 in the Japan Patent Office, and the entire disclosure of which is incorporated herein by reference.

TECHNICAL FIELD

[0002] The present invention relates to a millimeter wave imaging apparatus that images a subject by receiving millimeter waveband thermal noise radiated from the subject.

BACKGROUND ART

[0003] Conventionally, it has been proposed to image a subject such as a human body by receiving millimeter waveband thermal noise radiated from the subject, and detect weapons, smuggled goods, and others concealed in the subject from the captured image (see, for example, Patent Documents 1 and 2).

PRIOR ART DOCUMENTS

PATENT DOCUMENTS

[0004] Patent Document 1: Japanese Unexamined Patent Application Publication No. 2003-177175

Patent Document 2: Japanese Unexamined Patent Application Publication No. 2008-241352

SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0005] Because the proposed apparatus is a so-called passive imaging apparatus that images a subject by receiving millimeter waveband thermal noise radiated from the subject, the apparatus configuration can be simplified as compared with an active imaging apparatus that irradiates millimeter waves to a subject and images the subject from the reflected waves.

[0006] However, such passive imaging apparatus receives weak thermal noise (millimeter waves) radiated from a subject and then generates a captured image of the subject based on the received weak signals. Thus, when external thermal noise enters a subject location region in which the subject to be imaged is located, the passive imaging apparatus is influenced by the external thermal noise, and is unable to successfully image the subject.

[0007] The present invention was made in view of the above problem. One object of the present invention is, in a millimeter wave imaging apparatus that images a

subject such as a human body by receiving millimeter waveband thermal noise radiated from the subject, to be able to obtain a sharp subject image without being influenced by external thermal noise that enters a location region of the subject.

MEANS FOR SOLVING THE PROBLEMS

[0008] A first aspect of the present invention which was made to achieve the above object provides a millimeter wave imaging apparatus comprising:

a lens antenna that transmits millimeter waveband thermal noise radiated from a subject to form a subject image generated based on the thermal noise at a predetermined image forming position; and

an image data generating unit that includes a receiving antenna for receiving the thermal noise of each portion of the subject image formed by the lens antenna, and generates image data of the subject based on a level of the thermal noise received by the receiving antenna,

wherein a blocking plate that blocks passage of the thermal noise at least in an image capturable range in which the subject image can be captured by the antenna elements as viewed from the lens antenna is provided on a side opposite to the lens antenna across a subject

location region in which the subject is located upon imaging the subject.

[0009] According to a second aspect of the present invention, in the millimeter wave imaging apparatus in the first aspect, the blocking plate is made of metal which can reflect the thermal noise.

According to a third aspect of the present invention, in the millimeter wave imaging apparatus in the first aspect, the blocking plate is made of wave absorber which can absorb the millimeter waveband thermal noise.

[0010] According to a fourth aspect of the present invention, in the millimeter wave imaging apparatus in the third aspect, a temperature adjusting unit is provided which keeps a temperature of the wave absorber constituting the blocking plate at constant temperature.

[0011] According to a fifth aspect of the present invention, in the millimeter wave imaging apparatus in one of the first to fourth aspects of the present invention, a bent portion that is bent such that a plate surface of the blocking plate faces the lens antenna is formed at an upper portion of the blocking plate.

[0012] According to a sixth aspect of the present invention, in the millimeter wave imaging apparatus in one of the first to fifth aspect, at least part of a floor between the

blocking plate and the lens antenna has a corrugated shape.

[0013] According to a seventh aspect of the present invention, in the millimeter wave imaging apparatus in one of the first to sixth aspects, the image data generating unit includes:

a reflector that is disposed in a vicinity of the image forming position of the subject image formed by the lens antenna, and reflects the thermal noise forming the subject image toward the antenna elements;

a scanning unit that, by oscillating the reflector, makes the thermal noise at each position of the subject image enter the antenna elements; and

a control unit that, while oscillating the reflector via the scanning unit, captures received signals from the antenna elements and generates the image data representing the subject image.

EFFECT OF THE INVENTION

[0014] In the millimeter wave imaging apparatus of the first aspect, the blocking plate that blocks passage of the thermal noise is provided on the side opposite to the lens antenna across the subject location region in which the subject is located upon imaging the subject.

[0015] The blocking plate is configured to be large enough to block the passage of the thermal noise at least in the image capturable range in which the subject image can be captured by the antenna elements as viewed from the lens antenna. Thus, it is possible to control entrance, to the antenna elements via the lens antenna, of external thermal noise (millimeter waves) which enters the subject location region.

[0016] Therefore, according to the millimeter wave imaging apparatus of the present invention, it becomes possible to shut off unnecessary thermal noise which enters the image capturable range from the rear of the subject by the blocking plate. Without influence of unnecessary thermal noise, the subject can be imaged.

[0017] Therefore, if a subject is imaged by means of a millimeter wave imaging apparatus of the present invention, a clear subject image can be obtained. Further, detection accuracy upon detecting weapons and smuggled goods, and others concealed in the subject from the captured image can be increased.

[0018] Here, the blocking plate should be able to block unwanted thermal noise (millimeter waves). The blocking plate, as in the invention of the second aspect, may be made of metal which can reflect the thermal noise, or, as the invention of the third aspect, may be

made of wave absorber which can absorb the thermal noise.

[0019] The wave absorber has low transmittance and reflectance and high emissivity of thermal noise. Moreover, the higher the ambient temperature is, the stronger the radiation of the thermal noise (millimeter waves) is. Thus, when the blocking plate is made of wave absorber, it is necessary to limit use conditions of the millimeter wave imaging apparatus, for example, to use under conditions of low ambient temperature and small temperature change.

[0020] Therefore, when the blocking plate is made of wave absorber, as in the invention of the fourth aspect, it is desirable to provide a temperature adjusting unit that keeps a temperature of the wave absorber constituting the blocking plate at constant temperature. Moreover, it is desirable to adjust the temperature to be set to a temperature that is largely different from human body temperature.

[0021] On the other hand, a metal plate has high reflectivity and low transmittance and emissivity of thermal noise. Moreover, a metal plate is hardly affected by temperature. Thus, when the blocking plate is made of metal, the millimeter wave imaging apparatus can be used without limitation of use conditions.

[0022] When the blocking plate is made of metal, it is only necessary to block millimeter waveband thermal noise received by the antenna elements. Thus, the blocking plate does not necessarily have to be a metal plate. A metal mesh may be used as the blocking plate. Alternatively, a conductive film produced by making a metal foil or a metal mesh adhere to a synthetic resin film may be used as the blocking plate.

[0023] On the other hand, as in the fifth aspect of the invention, a bent portion that is bent such that a plate surface of the blocking plate faces the lens antenna may be formed at an upper portion of the blocking plate.

In this case, if a blockable range of the thermal noise (millimeter waves) by the blocking plate is not varied, it is possible to lower a height of the blocking plate.

[0024] Accordingly, the fifth aspect of the invention is very effective when the blocking plate is installed in a location where there is a height limit.

In the meantime, when the image capturable range contains a floor, it is conceivable that the captured image may be distorted by the thermal noise (millimeter waves) reflected from the floor.

[0025] In such cases, as in the sixth aspect of the invention, at least part of the floor between the blocking plate and

the lens antenna may be formed into a corrugated shape. Thereby, reflection at a surface of the floor is controlled, and transparency of the thermal noise (millimeter waves) is improved so that the reflected waves are inhibited from entering the receiving antenna from the lens antenna.

[0026] In this way, a sharper captured image can be obtained without being affected by the reflected waves from the floor.

The image data generating unit may two-dimensionally arrange a plurality of antenna elements in an image region of the subject image to be formed by the lens antenna, and sequentially capture an output from each antenna element thereby to generate image data.

[0027] However, for this purpose, a planar antenna having a plurality of two-dimensionally arranged antenna elements that can receive millimeter waveband thermal noise, and a plurality of signal processing circuits to process each received signal from each antenna element, are required. Thereby, there is an increase in cost of the millimeter wave imaging apparatus.

[0028] Therefore, as in the seventh aspect of the present invention, the image data generating unit may be constituted by a reflector, a scanning unit, and a control

unit. The control unit, while oscillating the reflector via the scanning unit, may capture the received signals from the antenna elements, and generate image data.

[0029] In other words, in this way, the antenna elements and the signal processing circuits (such as a detection circuit and an amplifier circuit described later) can be reduced in number, as compared with use of a planar antenna. Thereby, costs of the millimeter wave imaging apparatus can be reduced.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030] FIG. 1 is a schematic diagram showing an overall configuration of a millimeter wave imaging apparatus of an embodiment.

FIG. 2 is an explanatory diagram showing a configuration of the imaging apparatus shown in FIG. 1.

FIG. 3 is a cross-sectional view showing a variation of a floor of the millimeter wave imaging apparatus.

FIG. 4 is an explanatory view showing a configuration example of a blocking plate using a wave absorber.

EXPLANATION OF REFERENCE NUMERALS

[0031] 2...subject, 4...blocking plate, 6...sheet material (wave absorber), 8...floor material, 10...imaging apparatus body, 12...lens antenna, 14...reflector,

16...actuator, 20...receiving portion, 20a...antenna element, 22...drive unit, 24...input device, 26...output device, 30...image processing apparatus, 32...face plate, 34...back plate, 35, 36...inner space, 38...blocking portion, 39...floor, 40...blocking plate body, 42...air conditioner, 44...circulation pipe.

MODE FOR CARRYING OUT THE INVENTION

[0032] Hereinafter, an embodiment of the present invention will be described with reference to the drawings.

FIG. 1 is a schematic diagram showing a configuration of an entire millimeter wave imaging apparatus to which the present invention is applied.

The millimeter wave imaging apparatus of the present embodiment is used to check whether or not a passenger carries hazardous materials in a concealed manner, for example, at an airport. A passenger located in an inspection target region, that is a target region to dispose a subject, is referred to as a subject 2. The millimeter wave imaging apparatus of the present embodiment has an imaging apparatus body 10 and a blocking plate 4.

[0033] The imaging apparatus body 10 images the subject 2 by receiving millimeter waveband thermal noise radiated from the subject 2.

The blocking plate 4 is provided on a side opposite to the imaging apparatus body 10 across the inspection target region.

[0034] As shown in FIG. 2, the imaging apparatus body 10 is provided with a lens antenna 12, a reflector 14, a receiving portion 20 and an actuator 16.

The lens antenna 12 captures millimeter waveband thermal noise radiated from the subject 2 located in the inspection target region into the apparatus and forms a subject image generated based on the thermal noise.

[0035] The reflector 14 is disposed near an image forming position of the subject image formed by the lens antenna 12.

The receiving portion 20 receives the millimeter waveband thermal noise reflected by the reflector 14 and detects a signal level of the thermal noise.

[0036] The actuator 16 bidirectionally oscillates the reflector 14 on its central axis, so that the thermal noise in each position of the subject image enters the receiving portion 20.

The receiving portion 20 is constituted as a line sensor. The line sensor is configured by arranging in a horizontal direction a plurality of antenna elements 20a which can receive millimeter waveband thermal noise.

[0037] The reflector 14 oscillates about the central axis disposed in the horizontal direction thereby to scan in a vertical direction an image formed by the lens antenna 12, and make the thermal noise (millimeter waves) for one horizontal line enter the line sensor in sequence.

[0038] In addition, a plurality of amplifier circuits (not shown) and a plurality of detection circuits (diodes for detection; not shown) are included in the receiving portion 20. The plurality of amplifier circuits respectively amplify received signals from the plurality of antenna elements 20a. The plurality of detection circuits respectively detect the received signals from the plurality of antenna elements 20a. The detection signals for one line detected by the respective detection circuits are outputted from the receiving portion 20.

[0039] Then, the detection signals are inputted to an image processing apparatus 30 via an input device 24.

The image processing apparatus 30 is configured by a microcomputer or the like. The image processing apparatus 30, while driving the actuator 16 via a drive 22 to oscillate the reflector 14 and vertically scanning the image formed by the lens antenna 12, outputs a synchronization signal periodically to the receiving portion 20. In addition, the image processing apparatus 30, by outputting the detection signals for one horizontal

line of the formed image sequentially from the receiving portion 20, and sequentially capturing the detection signals for one horizontal line, generates image data corresponding to the formed image.

[0040] Then, the image processing apparatus 30 outputs the generated image data to an external display or storage device via the output device 26. Thereby, the captured image which images the inspection target region is displayed on the display, or the image data is stored in the storage device.

[0041] Therefore, a user of the millimeter wave imaging apparatus according to the present embodiment, by looking at the captured image displayed on the display, can detect that there is a person to be the subject 2 in the inspection target region, or detect from the displayed image that the person who is the subject 2 carries a weapon in a concealed manner.

[0042] Further, by displaying the captured image on the display using the image data stored in the storage device, the user can confirm the person who has been in the inspection target region or verify an object the person carries.

[0043] The blocking plate 4 is intended to inhibit millimeter waveband thermal noise that can be received by the receiving portion 20 of the imaging apparatus

body 10 from entering the inspection target region from outside the inspection target region, and inhibit the thermal noise from entering the imaging apparatus body 10. In the present embodiment, the blocking plate 4 is made by a metal plate which can reflect the thermal noise.

[0044] The blocking plate 4, when viewed from the lens antenna 12, is set to be large enough to cover an image capturable range (region indicated by a dashed line in FIG. 1) in which the subject image can be captured by the receiving portion 20.

[0045] In addition, in the millimeter wave imaging apparatus of the present embodiment, a distance L1 between the imaging apparatus body 10 and the blocking plate 4 (i.e., a width of the inspection target region) is set to be a few meters (for example, about 2.4 m).

When imaging the subject 2 by the imaging apparatus body 10, the user makes the person who is the subject 2 either stand near the blocking plate 4 or walk in a vicinity of the blocking plate 4, in order to inhibit the millimeter waveband thermal noise radiated from the subject 2 toward the blocking plate 4 from being reflected from the blocking plate 4 and entering the imaging apparatus body 10.

[0046] As above, according to the millimeter wave imaging apparatus of the present embodiment, the blocking plate 4 made by a metal plate that can reflect the millimeter waveband thermal noise is provided on the side opposite to the imaging apparatus body 10 across the inspection target region.

[0047] The blocking plate 4, as viewed from the lens antenna 12 (in other words, imaging apparatus body 10), is large enough to cover the image capturable range (region indicated by a dashed line in FIG. 1) in which the millimeter waveband thermal noise can be received by the receiving portion 20. Thus, it is possible to inhibit unnecessary thermal noise that enters the inspection target region from outside the inspection target region from entering the receiving portion 20 via the lens antenna 12.

[0048] Therefore, according to the present embodiment, the person (subject 2) in the inspection target region can be imaged without being affected by the thermal noise that enters from outside the inspection target region, in the imaging apparatus body 10. A clear captured image can be obtained.

[0049] Then, since the captured image is either displayed on the display or stored in the storage device, the user can accurately detect weapons, smuggled goods and

others concealed in the subject 2, based on the captured image displayed or stored.

[0050] Here, correspondence between the terms will be described. However, it should be noted that the following description is not intended to limit each component to a specific configuration. In the present embodiment, the actuator 16 and the drive unit 22 correspond to an example of the scanning unit of the present invention. The image processing apparatus 30 corresponds to an example of the control unit of the present invention.

[0051] An embodiment of the present invention has been described in the above. However, the present invention is not limited to the above embodiment, and can take various modes within the scope not departing from the gist of the present invention.

For example, as shown in dotted lines in FIG. 1 and the reference numeral 4a, the blocking plate 4 may include a bent portion 4a. The bent portion 4a is formed by bending a plate surface at an upper portion of the blocking plate 4 toward the subject 2.

[0052] In such cases, if a blockable range of the thermal noise (millimeter waves) is not varied, it is possible to lower the height of the blocking plate 4 (the height can be as low as H1 in FIG. 1).

Therefore, this feature is very effective when the blocking plate 4 is installed in a location where there is a height limit.

[0053] Further, in the above embodiment, the blocking plate 4 has been described as being a metal plate. However, since the blocking plate has to be able to block thermal noise (millimeter waves) that enters from outside of the inspection target region, the blocking plate 4 may be configured using a wave absorber which can absorb thermal noise. For example, the blocking plate 4 may be configured by a metal mesh. Alternatively, the blocking plate 4 may be configured by a conductive film.

[0054] Also, if the image capturable range by the imaging apparatus body 10 includes a floor, it is conceivable that the captured image may be distorted by the thermal noise (millimeter waves) reflected from the floor.

Therefore, as shown in FIG. 3, on the floor where the subject 2 is disposed during imaging of the subject 2, a sheet material 6 obtained by mixing ferrite or the like, which is a wave absorber, may be laid, and a floor member 8 for reinforcement may be provided thereon.

[0055] The floor member 8 may be made of synthetic resin which can transmit thermal noise (millimeter waves). Nevertheless, it is desirable that a surface of the floor

member 8 has corrugated unevenness formed by so-called corrugation processing.

[0056] In this way, since reflection of the thermal noise (millimeter waves) from the surface of the floor member 8 is controlled, it is possible to inhibit the reflected waves from entering the imaging apparatus body 10. Such floor can also serve as a slip resistance for the subject.

[0057] When a radio wave absorber is used for the floor and the blocking plate, it is desirable to maintain constant temperature and humidity, because the radio wave absorber changes its characteristics depending on temperature and humidity.

Therefore, as shown in FIG. 4, upon forming the floor and the blocking plate using a radio wave absorber, it is preferable to constitute a blocking plate body 40 having an internal space 36 created by a face plate 32, and a back plate 34, the face plate 32 having stacked sheet materials 6 made of radio wave absorber on a rear surface, so that conditioned air having constant temperature and constant humidity is sent from an air conditioner 42 to the internal space 36.

[0058] In that case, it is preferable that a temperature of the conditioned air is set to be a temperature that is largely different from body temperature.

Here, the blocking plate body 40 includes not only a blocking portion 38 disposed to the rear of the subject but a floor portion 39 on which the subject is disposed, thereby having a L-shaped cross section as shown in FIG. 4. The air conditioner 42 is placed on a floor on which the blocking plate body 40 is installed, and supplies conditioned air to inside the blocking plate body 40 from a rear lower end of the blocking plate body 40. Accordingly, conditioned air is supplied to an internal space 35 of the floor portion 39 and the internal space 36 of the blocking portion 38 of the blocking plate body 40 at the same time.

[0059] Then, conditioned air supplied to the blocking portion 38 of the blocking plate body 40 is returned to the air conditioner 42 via a circulation pipe 44 from an upper end side of the blocking portion 38. After temperature and humidity are readjusted by the air conditioner 42, the returned conditioned air is again sent to the blocking plate body 40.

[0060] In this manner, by constituting the blocking plate by the blocking plate body 40 having the internal space 36 and the air conditioner 42 which supplies conditioned air to the internal space 36, temperature and humidity of the sheet material 6 made of wave absorber and provided in the blocking plate body 40 can be kept constant. As a

result, an image captured by the imaging apparatus body 10 can be obtained in a stable manner.

[0061] In addition, it is preferable to use a plate having high transmittance of millimeter wave for the blocking portion 38 and the face plate 32 of the floor portion 39.

Further, it is desirable that the surface of the face plate 32 of the floor portion 39 has corrugated unevenness formed by so-called corrugation processing, as shown in FIG. 3.

[0062] Further, in the above-described embodiment, it is described that the receiving portion 20 which receives thermal noise is configured as a line sensor having antenna elements arranged in a row, and the reflector 14 is vertically oscillated (scanned) via the actuator 16, thereby to capture an image of the subject 2. However, for example, if the actuator 16 is configured to be able to oscillate the reflector 14 (scan) both horizontally and vertically, the receiving portion 20 can be configured by a single antenna element.

[0063] If the receiving portion 20 is configured as, for example, a two-dimensional sensor (plane antenna, in other words) having a plurality of antenna elements arranged on a flat surface, an image of the subject 2 can be captured without using the reflector 14 and the actuator 16 for scanning.

[0064] As in the above embodiment, a technique of providing the blocking plate 4 to inhibit unnecessary thermal noise from entering the antenna elements for thermal noise detection can be applied to a detection apparatus for human detection.

CLAIMS

1. A millimeter wave imaging apparatus comprising:

a lens antenna that transmits millimeter waveband thermal noise radiated from a subject to form a subject image generated based on the thermal noise at a predetermined image forming position; and

an image data generating unit that includes a receiving antenna for receiving the thermal noise of each portion of the subject image formed by the lens antenna, and generates image data of the subject based on a level of the thermal noise received by the receiving antenna,

wherein a blocking plate that blocks passage of the thermal noise at least in an image capturable range in which the subject image can be captured by the antenna elements as viewed from the lens antenna is provided on a side opposite to the lens antenna across a subject location region in which the subject is located upon imaging the subject.

2. The millimeter wave imaging apparatus according to claim 1, wherein the blocking plate is made of metal which can reflect the thermal noise.

3. The millimeter wave imaging apparatus according to claim 1, wherein the blocking plate is made of wave absorber

which can absorb the millimeter waveband thermal noise.

4. The millimeter wave imaging apparatus according to claim 3, wherein a temperature adjusting unit is provided which keeps a temperature of the wave absorber constituting the blocking plate at constant temperature.

5. The millimeter wave imaging apparatus according to one of claims 1 to 4, wherein a bent portion that is bent such that a plate surface of the blocking plate faces the lens antenna is formed at an upper portion of the blocking plate.

6. The millimeter wave imaging apparatus according to one of claims 1 to 5, wherein at least part of a floor between the blocking plate and the lens antenna has a corrugated shape.

7. The millimeter wave imaging apparatus according to one of claims 1 to 6,

wherein the image data generating unit includes:

a reflector that is disposed in a vicinity of the image forming position of the subject image formed by the lens antenna, and reflects the thermal noise forming the subject image toward the antenna elements;

a scanning unit that, by oscillating the reflector, makes thermal noise at each position of the subject image enter

the antenna elements; and

a control unit that, while oscillating the reflector via the scanning unit, captures received signals from the antenna elements and generates the image data representing the subject image.