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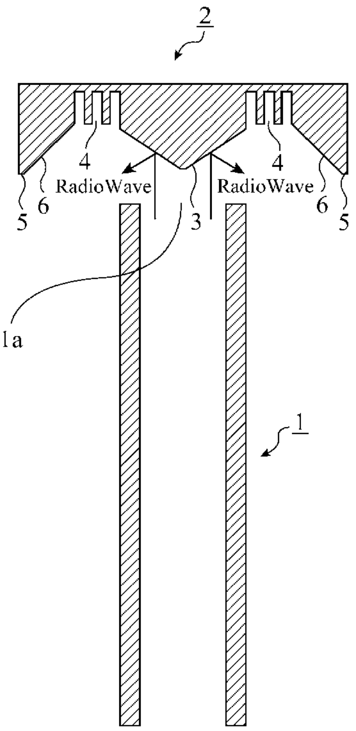
(54) **Primary radiator and antenna apparatus**

(57) Disclosed is a primary radiator in which a central portion (3) of a subreflector (2) is formed in a conical shape, grooves (4) extending, in relation to their depth direction, parallel to an axis of a circular waveguide (1) are formed cylindrically in a surrounding portion of the subreflector (2) surrounding the central portion (3) formed in a conical shape, and a portion extending from the grooves (4) formed in the surrounding portion of the subreflector (2) to a peripheral portion (5) of the subreflector (2) has a sloped structure which is formed in such a way that the peripheral portion (5) projects toward the circular waveguide (1).

FIG.1



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Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a primary radiator equipped with a subreflector for reflecting a radio wave radiated from an opening of a circular waveguide, and an antenna apparatus equipped with a main reflector for reflecting the radio wave radiated from the primary radiator.

Description of Related Art

[0002] In a conventional antenna apparatus, a disc-shaped subreflector for reflecting a radio wave radiated from an opening of a waveguide is located just opposite to the opening of the waveguide, and a main reflector for reflecting the radio wave reflected by the subreflector is located just opposite to the subreflector. The radiation characteristics of the radio wave radiated from the opening of the waveguide have a distortion under the influence of a waveguide wall which is an electric wall. Therefore, in order to provide rotational symmetrical radiation characteristics, the conventional antenna apparatus is constructed in such a way as to have grooves formed in the reflecting surface of the subreflector and having a depth corresponding to one quarter of a wavelength at the frequency of the radio wave.

[0003] Accordingly, because nearly-rotational-symmetrical radiation characteristics are provided, a high gain, a reduction in the cross polarization, and a low sidelobe can be achieved. However, there is a case in which many grooves need to be formed depending upon the frequency of the radio wave in order to provide rotational symmetrical radiation characteristics or suppress the emission of an unnecessary radio wave toward the rear of the subreflector. In this case, the radial size of the subreflector is increased. Because most of the radio wave reflected by the main reflector hits the subreflector when the radial size of the subreflector is increased, this results in an increase in the sidelobe level and a cause of gain degradation.

[0004] To solve this problem, a primary radiator using a small umbrella-shaped subreflector which implements rotational symmetrical radiation characteristics, and which is formed in such a way as to include a peripheral portion which is lowered from a central portion in view of a necessity to suppress the emission of an unnecessary radio wave toward the rear of the subreflector has been developed. Furthermore, a primary radiator in which in addition to grooves extending, in relation to their depth direction, parallel to the axis of a circular waveguide, grooves extending, in relation to their depth direction, perpendicular to the axis are formed in a reflecting surface to achieve a high gain and a low sidelobe has been developed (refer to the following patent reference 1). In any of the above-mentioned conventional primary radiators, each of the grooves formed in the reflecting surface has a depth corresponding to one quarter of a wavelength at the frequency of the radio wave.

[0005] In the former umbrella-shaped subreflector, because the radio wave propagates along the surfaces of the grooves, it is necessary to increase the diameter of the subreflector in order to suppress the leakage of the radio wave toward the rear of the subreflector. In the latter subreflector in which both grooves extending, in relation to their depth direction, parallel to the axis of the circular waveguide and grooves, in relation to their depth direction, perpendicular to the axis are formed in the reflecting surface, although the leakage of the radio wave toward the rear of the subreflector can be suppressed, the rotational symmetry of the radiation characteristics degrades.

[0006] More specifically, in each groove extending, in relation to its depth direction, parallel to the polarization direction of the radio wave, the radio wave is reflected by a top side of the groove, whereas in each groove extending, in relation to its depth direction, perpendicular to the polarization direction of the radio wave, the radio wave is reflected by a bottom side of the groove. The position where a radio wave is reflected by a groove varies in this way according to a relationship between the polarization direction of the radio wave and the direction of the groove. That is, the reflection position where a radio wave is reflected by a groove structure differs between a plane (E plane) parallel to the polarization direction of the radio wave and a plane (H plane) perpendicular to the polarization direction. While the reflection position where a radio wave is reflected by each groove extending, in relation to its depth direction, parallel to the axis of the circular waveguide differs in the axial direction between the E plane and the H plane, the reflection position does not differ in the radial direction between the E plane and the H plane. Therefore, the rotational symmetry of the electromagnetic field distribution in the axial direction is maintained. In contrast, because the reflection position where a radio wave is reflected by a groove extending, in relation to its depth direction, perpendicular to the axis of the circular waveguide differs in the radial direction between the E plane and the H plane, the rotational symmetry in the axial direction collapses and the rotational symmetry of the radiation characteristics degrades.

Related art document

[0007]

Patent reference 1: WO2006/064536 (Fig. 8)

[0008] Because a conventional primary radiator is constructed as above, forming grooves extending, in relation to their depth direction, parallel to the axis of a circular waveguide and grooves extending, in relation to their depth direction, perpendicular to the axis in the reflecting surface of a subreflector can achieve a high gain and a low sidelobe. A problem is, however, that because the reflection position where a radio wave is reflected by each groove, in relation to its depth direction, perpendicular to the axis of the circular waveguide differs in the radial direction between the E plane and the H plane, the rotational symmetry in the axial direction collapses and the rotational symmetry of the radiation characteristics degrades.

SUMMARY OF THE INVENTION

[0009] The present invention is made in order to solve the above-mentioned problem, and it is therefore an object of the present invention to provide a primary radiator and an antenna apparatus which can provide rotational symmetrical radiation characteristics independently upon the frequency of a radio wave emitted thereby without increasing the diameter of a subreflector, and can also suppress the emission of an unnecessary radio wave toward the rear of the subreflector.

[0010] In accordance with the present invention, there is provided a primary radiator for use in antenna apparatus, the primary radiator including a circular waveguide for radiating a radio wave from an opening thereof, and a disc-shaped subreflector located just opposite to the opening of the circular waveguide, for reflecting the radio wave radiated from the opening of the circular waveguide, in which a central portion of the subreflector is formed in a conical shape, grooves extending, in relation to their depth direction, parallel to an axis of the circular waveguide are formed cylindrically in a surrounding portion of the subreflector surrounding the central portion formed in a conical shape, and a portion extending from the grooves formed in the surrounding portion of the subreflector to a peripheral portion of the subreflector has a sloped structure which is formed in such a way that the peripheral portion projects toward the circular waveguide.

[0011] Because the primary radiator in accordance with the present invention is constructed in such a way that the central portion of the subreflector is formed in a conical shape, grooves extending, in relation to their depth direction, parallel to the axis of the circular waveguide are formed cylindrically in the surrounding portion of the subreflector surrounding the central portion formed in a conical shape, and the portion extending from the grooves formed in the surrounding portion of the subreflector to the peripheral portion of the subreflector has a sloped structure which is formed in such a way that the peripheral portion projects toward the circular waveguide, there is provided an advantage of being able to provide rotational symmetrical radiation characteristics independently upon the frequency of a radio wave emitted by the primary radiator without increasing the diameter of the subreflector, and being also able to suppress the emission of an unnecessary radio wave toward the rear of the subreflector.

[0012] Further objects and advantages of the present invention will be apparent from the following description of the preferred embodiments of the invention as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013]

Fig. 1 is a configuration diagram showing a primary radiator of an antenna apparatus in accordance with Embodiment 1 of the present invention;

Fig. 2 is a configuration diagram showing the antenna apparatus in accordance with Embodiment 1 of the present invention;

Fig. 3 is a configuration diagram showing a primary radiator of an antenna apparatus in accordance with Embodiment 2 of the present invention;

Fig. 4 is a configuration diagram showing a primary radiator of an antenna apparatus in accordance with Embodiment 3 of the present invention;

Fig. 5 is a configuration diagram showing a primary radiator of an antenna apparatus in accordance with Embodiment 4 of the present invention;

Fig. 6 is a configuration diagram showing a primary radiator of an antenna apparatus in accordance with Embodiment 5 of the present invention;

Fig. 7 is a configuration diagram showing a primary radiator of an antenna apparatus in accordance with Embodiment 6 of the present invention;

Fig. 8 is a configuration diagram showing the antenna apparatus in accordance with Embodiment 6 of the present invention;

Fig. 9 is a configuration diagram showing a primary radiator of an antenna apparatus in accordance with Embodiment 7 of the present invention;

Fig. 10 is a configuration diagram showing a primary radiator of an antenna apparatus in accordance with Embodiment 8 of the present invention;

Fig. 11 is a configuration diagram showing a primary radiator of an antenna apparatus in accordance with Embodiment 9 of the present invention;

Fig. 12 is a configuration diagram showing a primary radiator of an antenna apparatus in accordance with Embodiment 10 of the present invention;

Fig. 13 is a configuration diagram showing a primary radiator of an antenna apparatus in accordance with Embodiment 11 of the present invention;

Fig. 14 is a partial enlarged configuration diagram showing the primary radiator shown in Fig. 13;

Fig. 15 is a configuration diagram showing a primary radiator of an antenna apparatus in accordance with Embodiment 12 of the present invention;

Fig. 16 is a partial enlarged configuration diagram showing the primary radiator shown in Fig. 15;

Fig. 17 is a configuration diagram showing a primary radiator of an antenna apparatus in accordance with Embodiment 13 of the present invention;

Fig. 18 is a partial enlarged configuration diagram showing the primary radiator shown in Fig. 17;

Fig. 19 is a configuration diagram showing a primary radiator of an antenna apparatus in accordance with Embodiment 14 of the present invention; and

Fig. 20 is a partial enlarged configuration diagram showing the primary radiator shown in Fig. 19.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0014] The preferred embodiments of the present invention will be now described with reference to the accompanying drawings.

Embodiment 1.

[0015] Fig. 1 is a configuration diagram showing a primary radiator of an antenna apparatus in accordance with Embodiment 1 of the present invention. In the structure shown in Fig. 1, a circular waveguide 1 radiates a radio wave from an opening 1a thereof. The subreflector 2 is a disc-shaped reflector located just opposite to the opening 1a of the circular waveguide 1, for reflecting the radio wave radiated from the opening 1a of the circular waveguide 1.

[0016] A central portion 3 of the subreflector 2 is conical in shape, and a radio wave applied to the central portion 3 of the subreflector 2 is reflected radiately (in directions shown by arrows in the figure). Grooves 4 extend, in relation to their depth direction, parallel to the axis of the circular waveguide 1, and are formed cylindrically in a surrounding portion surrounding the central portion 3 which is conical in shape. In the primary radiator shown in Fig. 1, a portion extending from the grooves 4 formed in the surrounding portion surrounding the central portion 3 to a peripheral portion 5 of the subreflector 2 has a sloped structure 6 which is formed in such a way that the peripheral portion 5 projects toward the circular waveguide 1.

[0017] Fig. 2 is a configuration diagram showing the antenna apparatus in accordance with Embodiment 1 of the present invention. In the figure, because the same reference numerals as those shown in Fig. 1 denote the same components or like components, the explanation of the components will be omitted hereafter. A main reflector 7 is a reflector located just opposite to the subreflector 2, for reflecting the radio wave reflected by the subreflector 2. Although the main reflector 7 is illustrated to have a radial size which is not greatly different from that of the subreflector 2 because the drawing of Fig. 2 is deformed, the radial size of the main reflector 7 is actually several times larger than that of the subreflector 2.

[0018] Next, the operation of the antenna apparatus will be explained. A radio wave radiated from the opening 1a of the circular waveguide 1 is reflected by the subreflector 2 located just opposite to the opening 1a of the circular waveguide 1. At this time, although most of the radio wave radiated from the opening 1a of the circular waveguide 1 is reflected by the central portion 3 formed in a conical shape and the radio wave travels toward the main reflector 7, a high gain, a low sidelobe, etc. can be achieved because the grooves 4 each having a depth corresponding to one quarter of a wavelength at the frequency of the radio wave are formed in the surrounding portion surrounding the central portion 3.

[0019] Furthermore, because the grooves 4 formed in the surrounding portion surrounding the central portion 3 extend, in relation to their depth direction, parallel to the axis of the circular waveguide 1, the reflection position where the radio wave is reflected by the plane (E plane) of each groove parallel to the polarization direction of the radio wave differs from that where the radio wave is reflected by the plane (H plane) of each groove perpendicular to the polarization direction in the axial direction of the circular waveguide 1, whereas the reflection position where the radio wave is reflected by the E plane is the same as that where the radio wave is reflected by the H plane in the radial direction of the circular waveguide 1. Therefore, the rotational symmetry of the electromagnetic field distribution in the axial direction is maintained. That is, because the reflection position where the radio wave is reflected by each groove, in relation to its depth direction, perpendicular to the axis of the circular waveguide 1 differs in the radial direction between the E plane and the H plane, the rotational symmetry in the axial direction collapses and the rotational symmetry of the radiation characteristics degrades, whereas in the primary radiator shown in Fig. 1, because only the grooves (the grooves 4) extending, in relation to their depth direction, parallel to the axis of the circular waveguide 1 are formed in the surrounding portion surrounding the central portion 3 while no grooves extending, in relation to their depth direction, perpendicular to the axis of the circular waveguide 1 are formed, the rotational symmetry in the axial direction does not collapse and therefore the rotational symmetry of the radiation characteristics does not degrade.

[0020] In case in which the peripheral portion 5 of the subreflector 2 does not project toward the circular waveguide 1 and the subreflector is shaped like an umbrella, unlike the primary radiator shown in Fig. 1, it is necessary to sufficiently increase the diameter of the subreflector in order to suppress the leakage of the radio wave toward the rear of the subreflector because the radio wave propagates along a surface of each groove. In contrast, because in the primary radiator shown in Fig. 1 the portion extending from the grooves 4 formed in the surrounding portion surrounding the central portion 3 to the peripheral portion 5 has the sloped structure 6 which is formed in such a way that the peripheral portion 5 of the subreflector 2 projects toward the circular waveguide 1, even the subreflector 2 having the small diameter can suppress the emission of an unnecessary radio wave toward the rear of the subreflector 2.

[0021] As can be seen from the above description, the primary radiator in accordance with this Embodiment 1 is constructed in such a way that the central portion 3 of the subreflector 2 is formed in a conical shape, the grooves 4 extending, in relation to their depth direction, parallel to the axis of the circular waveguide 1 are formed cylindrically in the surrounding portion surrounding the central portion 3 formed in a conical shape, and the portion extending from the grooves 4 formed in the surrounding portion surrounding the central portion 3 to the peripheral portion 5 of the subreflector 2 has the sloped structure 6 which is formed in such a way that the peripheral portion 5 projects toward the circular waveguide 1. Therefore, there is provided an advantage of being able to provide rotational symmetrical radiation characteristics independently upon the frequency of the radio wave emitted by the primary radiator without increasing the diameter of the subreflector, and being also able to suppress the emission of an unnecessary radio wave toward the rear of the subreflector.

Embodiment 2.

[0022] Fig. 3 is a configuration diagram showing a primary radiator of an antenna apparatus in accordance with Embodiment 2 of the present invention. In the figure, because the same reference numerals as those shown in Fig. 1 denote the same components or like components, the explanation of the components will be omitted hereafter. A corrugation 8 is projections and depressions concentrically arranged and is formed in a part of an outer wall 1b of a circular waveguide 1. Although no main reflector is shown in Fig. 3, a main reflector 7 as shown in Fig. 2 can be installed in the primary radiator shown in Fig. 3.

[0023] Next, the operation of the primary radiator will be explained. A radio wave radiated from an opening 1a of the circular waveguide 1 is reflected by a subreflector 2 located just opposite to the opening 1a of the circular waveguide 1. At this time, because a part of the radio wave reflected by the subreflector 2 propagates along the outer wall 1b which is a surface of the circular waveguide 1, there is a case in which a multipath reflection occurs between the main reflector 7 and the subreflector 2. In this Embodiment 2, in order to suppress this multipath reflection, the corrugation 8 is formed in a part of the outer wall 1b of the circular waveguide 1.

[0024] The corrugation 8 can be formed into a metallic groove structure in such a way that the depth of each groove is of the order of one quarter of a wavelength at the frequency of the radio wave, like grooves 4 formed in the subreflector 2. In order to suppress the multipath reflection, the corrugation 8 can be formed only in a part of the outer wall of the circular waveguide 1 which is closer to the main reflector 7 (a lower portion in the figure). However, because the corrugation 8 has a depth which is of the order of one quarter of a wavelength at the frequency of the radio wave, it is necessary to make the thick wall portion of the circular waveguide 1 have some thickness in order to form the corrugation 8. Therefore, in case in which a level difference appears between the portion closer to the opening 1a of the circular waveguide 1 in which the corrugation 8 is not formed, and the portion in which the corrugation 8 is formed, and a reflection occurs in the level difference, a multipath reflection occurs between the main reflector 7 and the subreflector 2. To solve this problem, in the primary radiator shown in Fig. 3, the circular waveguide 1 is formed into a tapered shape in such a way as to prevent any level difference from appearing on the outer wall of the circular waveguide.

[0025] As can be seen from the above description, because the primary radiator in accordance with this Embodiment 2 is constructed in such a way that the corrugation 8 is formed in a part of the outer wall 1b of the circular waveguide 1, there is provided an advantage of preventing a multipath reflection from occurring between the main reflector 7 and the subreflector 2, thereby being able to suppress a degradation in the sidelobe due to a multipath reflection.

Embodiment 3.

[0026] Fig. 4 is a configuration diagram showing a primary radiator of an antenna apparatus in accordance with Embodiment 3 of the present invention. In the figure, because the same reference numerals as those shown in Fig. 1 denote the same components or like components, the explanation of the components will be omitted hereafter. A corrugation 9 is projections and depressions concentrically arranged and is formed in the whole of an outer wall 1b of a circular waveguide 1. Although no main reflector is shown in Fig. 4, a main reflector 7 as shown in Fig. 2 can be installed in the primary radiator shown in Fig. 4.

[0027] Next, the operation of the primary radiator will be explained. A radio wave radiated from an opening 1a of the circular waveguide 1 is reflected by a subreflector 2 located just opposite to the opening 1a of the circular waveguide 1. At this time, because a part of the radio wave reflected by the subreflector 2 propagates along the outer wall 1b which is a surface of the circular waveguide 1, there is a case in which a multipath reflection occurs between the main reflector 7 and the subreflector 2. In this Embodiment 3, in order to suppress this multipath reflection, the corrugation 9 is formed in the whole of the outer wall 1b of the circular waveguide 1.

[0028] In the case in which the corrugation 8 is formed in a part of the outer wall 1b of the circular waveguide 1, like in the case of above-mentioned Embodiment 2, it is necessary to form the circular waveguide 1 into a tapered shape to prevent a level difference from appearing between the portion in which the corrugation 8 is not formed and the portion in which the corrugation 8 is formed. In contrast, in accordance with this Embodiment 3, because the corrugation 9 is formed in the whole of the outer wall 1b of the circular waveguide 1, it is not necessary to form the circular waveguide 1 into a tapered shape to prevent a level difference from appearing on the outer wall.

[0029] As can be seen from the above description, because the primary radiator in accordance with this Embodiment 3 is constructed in such a way that the corrugation 9 is formed in the whole of the outer wall 1b of the circular waveguide 1, there is provided an advantage of preventing a multipath reflection from occurring between the main reflector 7 and the subreflector 2, thereby being able to suppress a degradation in the sidelobe due to a multipath reflection.

Embodiment 4.

[0030] Fig. 5 is a configuration diagram showing a primary radiator of an antenna apparatus in accordance with Embodiment 4 of the present invention. In the figure, because the same reference numerals as those shown in Fig. 4 denote the same components or like components, the explanation of the components will be omitted hereafter. A choke structure 10 is grooves extending, in relation to their depth direction, parallel to the axis of a circular waveguide 1, and is formed in a thick wall portion in the vicinity of an opening 1a of the circular waveguide 1. Although no main reflector is shown in Fig. 5, a main reflector 7 as shown in Fig. 2 can be installed in the primary radiator shown in Fig. 5.

[0031] Next, the operation of the primary radiator will be explained. In above-mentioned Embodiments 2 and 3, the corrugations 8 and 9 are formed in a part and the whole of the outer wall 1b of the circular waveguide 1, respectively, in order to prevent a multipath reflection from occurring between the main reflector 7 and the subreflector 2. However, in the case in which the corrugation 8 or 9 is formed, because the corrugation 8 or 9 has a depth of the order of one quarter of a wavelength at the frequency of the radio wave, it is necessary to make the thick wall portion of the circular waveguide 1 have some thickness, as mentioned above.

[0032] As the thickness of the thick wall portion of the circular waveguide 1 increases, the reflection property of the radio wave returning to the circular waveguide 1 degrades. Furthermore, because the radio wave reflected by the subreflector 2 is reflected by the thick wall portion of the circular waveguide 1, the sidelobe characteristics degrade. To solve this problem, in accordance with this Embodiment 4, because the choke structure 10 is formed in the thick wall portion in the vicinity of the opening 1a of the circular waveguide 1, the degradation of the sidelobe characteristics is suppressed.

[0033] As can be seen from the above description, because the primary radiator in accordance with this Embodiment 4 is constructed in such a way that the choke structure 10 is formed in the thick wall portion in the vicinity of the opening 1a of the circular waveguide 1, there is provided an advantage of being able to suppress the degradation of the sidelobe characteristics even if the thick wall portion of the circular waveguide 1 has a large thickness.

Embodiment 5.

[0034] Fig. 6 is a configuration diagram showing a primary radiator of an antenna apparatus in accordance with Embodiment 5 of the present invention. In the figure, because the same reference numerals as those shown in Fig. 5 denote the same components or like components, the explanation of the components will be omitted hereafter. A choke structure 11 is grooves extending, in relation to their depth direction, parallel to the axis of a circular waveguide 1, and is formed in a thick wall portion in the vicinity of an opening 1a of the circular waveguide 1. The choke structure 11 differs from the choke structure 10 shown in Fig. 5 in that the grooves are displaced from one another with respect to the axial direction of the circular waveguide 1. Although no main reflector is shown in Fig. 6, a main reflector 7 as shown in Fig. 2 can be installed in the primary radiator shown in Fig. 6.

[0035] Next, the operation of the primary radiator will be explained. In above-mentioned Embodiments 2 and 3, the corrugations 8 and 9 are formed in a part and the whole of the outer wall 1b of the circular waveguide 1, respectively, in order to prevent a multipath reflection from occurring between the main reflector 7 and the subreflector 2. However, in the case in which the corrugation 8 or 9 is formed, because the corrugation 8 or 9 has a depth of the order of one quarter of a wavelength at the frequency of the radio wave, it is necessary to make the thick wall portion of the circular waveguide 1 have some thickness, as mentioned above.

[0036] As the thickness of the thick wall portion of the circular waveguide 1 is increased, the reflection property of the radio wave returning to the circular waveguide 1 degrades. Furthermore, because the radio wave reflected by the subreflector 2 is reflected by the thick wall portion of the circular waveguide 1, the sidelobe characteristics degrade. To solve this problem, in accordance with this Embodiment 5, because the choke structure 11 is formed in the thick wall portion in the vicinity of the opening 1a of the circular waveguide 1, the degradation of the sidelobe characteristics is suppressed. Furthermore, in accordance with this Embodiment 5, because the grooves in the choke structure 11 are displaced from one another with respect to the axial direction of the circular waveguide 1 (the grooves are arranged at lower positions in the figure with distance from the opening of the circular waveguide 1), the degradation of the sidelobe characteristics due to a reflection by the thick wall portion of the circular waveguide 1 can be reduced.

[0037] As can be seen from the above description, because the primary radiator in accordance with this Embodiment 5 is constructed in such a way that the grooves in the choke structure 11 are displaced from one another with respect to the axial direction of the circular waveguide 1, there is provided an advantage of being able to reduce the degradation of the sidelobe characteristics due to a reflection by the thick wall portion of the circular waveguide 1.

Embodiment 6.

[0038] Fig. 7 is a configuration diagram showing a primary radiator of an antenna apparatus in accordance with Embodiment 6 of the present invention. In the figure, because the same reference numerals as those shown in Fig. 1 denote the same components or like components, the explanation of the components will be omitted hereafter. Grooves 12 extend, in relation to their depth direction, parallel to the axis of a circular waveguide 1, and are formed cylindrically in a peripheral portion 5 of a subreflector 2. In the primary radiator shown in Fig. 7, a portion extending from grooves 4 formed in a surrounding portion surrounding a central portion 3 of the subreflector to the grooves 12 formed in the peripheral portion 5 of the subreflector 2 has a sloped structure 6 which is formed in such a way that the peripheral portion 5 projects toward the circular waveguide 1.

[0039] Fig. 8 is a configuration diagram showing the antenna apparatus in accordance with Embodiment 6 of the present invention. A main reflector 7 is installed for the primary radiator shown in Fig. 7. Although the main reflector 7 is illustrated to have a radial size which is not greatly different from that of the subreflector 2 because the drawing of Fig. 8 is deformed, the radial size of the main reflector 7 is actually several times larger than that of the subreflector 2.

[0040] Next, the operation of the antenna apparatus will be explained. A radio wave radiated from the opening 1a of the circular waveguide 1 is reflected by the subreflector 2 located just opposite to the opening 1a of the circular waveguide 1. At this time, although most of the radio wave radiated from the opening 1a of the circular waveguide 1 is reflected by the central portion 3 formed in a conical shape and the radio wave travels toward the main reflector 7, a high gain, a low sidelobe, etc. can be achieved because the grooves 4 each having a depth corresponding to one quarter of a wavelength at the frequency of the radio wave are formed in the surrounding portion surrounding the central portion 3 and the grooves 12 each having a depth corresponding to one quarter of the wavelength at the frequency of the radio wave are formed in the peripheral portion of the subreflector 2.

[0041] Furthermore, because the grooves 4 formed in the surrounding portion surrounding the central portion 3 and the grooves 12 formed in the peripheral portion of the subreflector 2 extend, in relation to their depth direction, parallel to the axis of the circular waveguide 1, the reflection position where the radio wave is reflected by the plane (E plane) of each groove parallel to the polarization direction of the radio wave differs from that where the radio wave is reflected by the plane (H plane) of each groove perpendicular to the polarization direction in the axial direction of the circular waveguide 1, whereas the reflection position where the radio wave is reflected by the E plane is the same as that where the radio wave is reflected by the H plane in the radial direction of the circular waveguide 1. Therefore, the rotational symmetry of the electromagnetic field distribution in the axial direction is maintained. That is, because the reflection position where the radio wave is reflected by each groove, in relation to its depth direction, perpendicular to the axis of the circular waveguide 1 differs in the radial direction between the E plane and the H plane, the rotational symmetry in the axial direction collapses and the rotational symmetry of the radiation characteristics degrades, whereas in the primary radiator shown in Fig. 7, because only the grooves (the grooves 4 and 12) extending, in relation to their depth direction, parallel to the axis of the circular waveguide 1 are formed in the subreflector 2 while no grooves extending, in relation to their depth direction, perpendicular to the axis of the circular waveguide 1 are formed, the rotational symmetry in the axial direction does not collapse and therefore the rotational symmetry of the radiation characteristics does not degrade.

[0042] In case in which the peripheral portion 5 of the subreflector 2 does not project toward the circular waveguide 1 and the subreflector is shaped like an umbrella, unlike the primary radiator shown in Fig. 7, it is necessary to sufficiently increase the diameter of the subreflector in order to suppress the leakage of the radio wave toward the rear of the subreflector because the radio wave propagates along a surface of each groove. In contrast, because in the primary radiator shown in Fig. 7 the portion extending from the grooves 4 formed in the surrounding portion surrounding the central portion 3 to the grooves 12 formed in the peripheral portion 5 of the subreflector 2 has the sloped structure 6 which is formed in such a way that the peripheral portion 5 projects toward the circular waveguide 1, even the subreflector 2 having the small diameter can suppress the emission of an unnecessary radio wave toward the rear of the subreflector 2.

[0043] Because the grooves 12 formed in the peripheral portion are disposed in order to mainly suppress the emission of an unnecessary radio wave toward the rear of the subreflector 2, and most of the radio wave reflected by the main reflector hits the subreflector 2 when the radial size of the subreflector 2 is increased, this results in an increase in the sidelobe level and a cause of gain degradation. Therefore, it is necessary to reduce the diameter of the subreflector 2 to be as small as possible. Particularly, in a case in which the main reflector 7 is small, the influence becomes remarkable. Although in this Embodiment 6 the grooves 12 are formed in the peripheral portion of the subreflector 2 in order to sufficiently suppress the emission of an unnecessary radio wave toward the rear of the subreflector 2, the diameter of the subreflector 2 can be reduced without forming the grooves 12 in the peripheral portion of the subreflector 2 in a case in which, for example, the main reflector 7 is small (refer to the Fig. 1), like in the case of above-mentioned Embodiment 1.

[0044] As can be seen from the above description, the primary radiator in accordance with this Embodiment 6 is constructed in such a way that the central portion 3 of the subreflector 2 is formed in a conical shape, the grooves 4 extending, in relation to their depth direction, parallel to the axis of the circular waveguide 1 are formed cylindrically in the surrounding portion surrounding the central portion 3 formed in a conical shape, the grooves 12 extending, in relation to their depth direction, parallel to the axis of the circular waveguide 1 are formed in the peripheral portion of the subreflector 2, and the portion extending from the grooves 4 formed in the surrounding portion surrounding the central portion 3 to the grooves 12 formed in the peripheral portion 5 of the subreflector 2 has the sloped structure 6 which is formed in such a way that the peripheral portion 5 projects toward the circular waveguide 1. Therefore, there is provided an advantage of being able to provide rotational symmetrical radiation characteristics independently upon the frequency of a radio wave emitted by the primary radiator without increasing the diameter of the subreflector, and being also able to suppress the emission of an unnecessary radio wave to the rear of the subreflector 2.

Embodiment 7.

[0045] Fig. 9 is a configuration diagram showing a primary radiator of an antenna apparatus in accordance with Embodiment 7 of the present invention. In the figure, because the same reference numerals as those shown in Figs. 7 and 3 denote the same components or like components, the explanation of the components will be omitted hereafter. In the primary radiator shown in Fig. 9, a corrugation 8 is formed in a part of an outer wall 1b of a circular waveguide 1, like in the case of the primary radiator shown in Fig. 3. Although no main reflector is shown in Fig. 9, a main reflector 7 as shown in Fig. 2 can be installed in the primary radiator shown in Fig. 9.

[0046] Next, the operation of the primary radiator will be explained. A radio wave radiated from an opening 1a of the circular waveguide 1 is reflected by a subreflector 2 located just opposite to the opening 1a of the circular waveguide 1. At this time, because a part of the radio wave reflected by the subreflector 2 propagates along the outer wall 1b which is a surface of the circular waveguide 1, there is a case in which a multipath reflection occurs between the main reflector 7 and the subreflector 2. In this Embodiment 7, in order to suppress this multipath reflection, the corrugation 8 is formed in a part of the outer wall 1b of the circular waveguide 1.

[0047] The corrugation 8 can be formed into a metallic groove structure in such a way that the depth of each groove is of the order of one quarter of a wavelength at the frequency of the radio wave, like that in accordance with above-mentioned Embodiment 2. In order to suppress the multipath reflection, the corrugation 8 can be formed only in a part of the outer wall of the circular waveguide 1 which is closer to the main reflector 7 (a lower portion in the figure). However, because the corrugation 8 has a depth which is of the order of one quarter of a wavelength at the frequency of the radio wave, it is necessary to make the thick wall portion of the circular waveguide 1 have some thickness in order to form the corrugation 8. Therefore, in case in which a level difference appears between the portion closer to the opening 1a of the circular waveguide 1 in which the corrugation 8 is not formed, and the portion in which the corrugation 8 is formed, and a reflection occurs in the level difference, a multipath reflection occurs between the main reflector 7 and the subreflector 2. To solve this problem, in the primary radiator shown in Fig. 9, the circular waveguide 1 is formed into a tapered shape in such a way as to prevent any level difference from appearing on the outer wall of the circular waveguide.

[0048] As can be seen from the above description, because the primary radiator in accordance with this Embodiment 7 is constructed in such a way that the corrugation 8 is formed in a part of the outer wall 1b of the circular waveguide 1, there is provided an advantage of preventing a multipath reflection from occurring between the main reflector 7 and the subreflector 2, thereby being able to suppress a degradation in the sidelobe due to a multipath reflection.

Embodiment 8.

[0049] Fig. 10 is a configuration diagram showing a primary radiator of an antenna apparatus in accordance with Embodiment 8 of the present invention. In the figure, because the same reference numerals as those shown in Figs. 7 and 4 denote the same components or like components, the explanation of the components will be omitted hereafter. In the primary radiator shown in Fig. 10, a corrugation 9 is formed in the whole of an outer wall 1b of a circular waveguide 1, like in the case of the primary radiator shown in Fig. 4. Although no main reflector is shown in Fig. 10, a main reflector 7 as shown in Fig. 2 can be installed in the primary radiator shown in Fig. 10.

[0050] Next, the operation of the primary radiator will be explained. A radio wave radiated from an opening 1a of the circular waveguide 1 is reflected by a subreflector 2 located just opposite to the opening 1a of the circular waveguide 1. At this time, because a part of the radio wave reflected by the subreflector 2 propagates along the outer wall 1b which is a surface of the circular waveguide 1, there is a case in which a multipath reflection occurs between the main reflector 7 and the subreflector 2. In this Embodiment 8, in order to suppress this multipath reflection, the corrugation 9 is formed in the whole of the outer wall 1b of the circular waveguide 1, like in the case of above-mentioned Embodiment 3.

[0051] In the case in which the corrugation 8 is formed in a part of the outer wall 1b of the circular waveguide 1, like in the case of above-mentioned Embodiment 7, it is necessary to form the circular waveguide 1 into a tapered shape to prevent a level difference from appearing between the portion in which the corrugation 8 is not formed and the portion in which the corrugation 8 is formed. In contrast, in accordance with this Embodiment 8, because the corrugation 9 is formed in the whole of the outer wall 1b of the circular waveguide 1, it is not necessary to form the circular waveguide 1 into a tapered shape to prevent a level difference from appearing on the outer wall.

[0052] As can be seen from the above description, because the primary radiator in accordance with this Embodiment 8 is constructed in such a way that the corrugation 9 is formed in the whole of the outer wall 1b of the circular waveguide 1, there is provided an advantage of preventing a multipath reflection from occurring between the main reflector 7 and the subreflector 2, thereby being able to suppress a degradation in the sidelobe due to a multipath reflection.

Embodiment 9.

[0053] Fig. 11 is a configuration diagram showing a primary radiator of an antenna apparatus in accordance with Embodiment 9 of the present invention. In the figure, because the same reference numerals as those shown in Figs. 10 and 5 denote the same components or like components, the explanation of the components will be omitted hereafter. Although no main reflector is shown in Fig. 11, a main reflector 7 as shown in Fig. 8 can be installed in the primary radiator shown in Fig. 11.

[0054] Next, the operation of the primary radiator will be explained. In above-mentioned Embodiments 7 and 8, the corrugations 8 and 9 are formed in a part and the whole of the outer wall 1b of the circular waveguide 1, respectively, in order to prevent a multipath reflection from occurring between the main reflector 7 and the subreflector 2. However, in the case in which the corrugation 8 or 9 is formed, because the corrugation 8 or 9 has a depth of the order of one quarter of a wavelength at the frequency of the radio wave, it is necessary to make the thick wall portion of the circular waveguide 1 have some thickness, as mentioned above.

[0055] As the thickness of the thick wall portion of the circular waveguide 1 increases, the reflection property of the radio wave returning to the circular waveguide 1 degrades. Furthermore, because the radio wave reflected by the subreflector 2 is reflected by the thick wall portion of the circular waveguide 1, the sidelobe characteristics degrade. To solve this problem, in accordance with this Embodiment 9, because a choke structure 10 is formed in the thick wall portion in the vicinity of the opening 1a of the circular waveguide 1, the degradation of the sidelobe characteristics is suppressed, like in the case of above-mentioned Embodiment 4.

[0056] As can be seen from the above description, because the primary radiator in accordance with this Embodiment 9 is constructed in such a way that the choke structure 10 is formed in the thick wall portion in the vicinity of the opening 1a of the circular waveguide 1, there is provided an advantage of being able to suppress the degradation of the sidelobe characteristics even if the thick wall portion of the circular waveguide 1 has a large thickness.

Embodiment 10.

[0057] Fig. 12 is a configuration diagram showing a primary radiator of an antenna apparatus in accordance with Embodiment 10 of the present invention. In the figure, because the same reference numerals as those shown in Figs. 10 and 6 denote the same components or like components, the explanation of the components will be omitted hereafter. Although no main reflector is shown in Fig. 12, a main reflector 7 as shown in Fig. 8 can be installed in the primary radiator shown in Fig. 12.

[0058] Next, the operation of the primary radiator will be explained. In above-mentioned Embodiments 7 and 8, the corrugations 8 and 9 are formed in a part and the whole of the outer wall 1b of the circular waveguide 1, respectively, in order to prevent a multipath reflection from occurring between the main reflector 7 and the subreflector 2. However, in the case in which the corrugation 8 or 9 is formed, because the corrugation 8 or 9 has a depth of the order of one quarter of a wavelength at the frequency of the radio wave, it is necessary to make the thick wall portion of the circular waveguide 1 have some thickness, as mentioned above.

[0059] As the thickness of the thick wall portion of the circular waveguide 1 is increased, the reflection property of the radio wave returning to the circular waveguide 1 degrades. Furthermore, because the radio wave reflected by the subreflector 2 is reflected by the thick wall portion of the circular waveguide 1, the sidelobe characteristics degrade. To solve this problem, in accordance with this Embodiment 10, because a choke structure 11 is formed in the thick wall portion in the vicinity of the opening 1a of the circular waveguide 1, the degradation of the sidelobe characteristics is suppressed. Furthermore, in accordance with this Embodiment 10, because the grooves in the choke structure 11 are displaced from one another with respect to the axial direction of the circular waveguide 1 (the grooves are arranged at lower positions in the figure with distance from the opening of the circular waveguide 1), the degradation of the sidelobe characteristics due to a reflection by the thick wall portion of the circular waveguide 1 can be reduced.

[0060] As can be seen from the above description, because the primary radiator in accordance with this Embodiment 10 is constructed in such a way that the grooves in the choke structure 11 are displaced from one another with respect to the axial direction of the circular waveguide 1, there is provided an advantage of being able to reduce the degradation of the sidelobe characteristics due to a reflection by the thick wall portion of the circular waveguide 1.

Embodiment 11.

[0061] In above-mentioned Embodiments 1 to 10, the primary radiator and the antenna apparatus in which the portion extending from the grooves 4 formed in the surrounding portion surrounding the central portion 3 of the subreflector 2 to the peripheral portion 5 of the subreflector 2 has a sloped structure 6 are shown. As an alternative, in the primary radiator and the antenna apparatus, the sloped structure can be formed into a cross-sectional shape in which a quarter circle is rotated around the axis of the circular waveguide 1 in such a way that the sloped structure is recessed toward a direction opposite to the circular waveguide 1. Fig. 13 is a configuration diagram showing a primary radiator of an antenna apparatus in accordance with Embodiment 11 of the present invention. In the figure, because the same reference numerals as those shown in Fig. 12 denote the same components or like components, the explanation of the components will be omitted hereafter. Further, Fig. 14 is a partial enlarged configuration diagram showing the primary radiator shown in Fig. 13.

[0062] In this Embodiment 11, as shown in Figs. 13 and 14, a sloped structure 6a extending from grooves 4 formed in a surrounding portion surrounding a central portion 3 of a subreflector 2 to a peripheral portion 5 of the subreflector 2 is formed into a cross-sectional shape in which a quarter circle is rotated around the axis of a circular waveguide 1 in such a way that the sloped structure is recessed toward a direction opposite to the circular waveguide 1. In Fig. 14, reference numeral 13 denotes the central point of the quarter circle in cross section. In this case, in order to connect the sloped structure 6a to the peripheral portion by using the quarter circle in cross section, the slope angle of the sloped structure 6a is limited to 45 degrees.

[0063] Because the sloped structure 6a is formed in such a way as to have the above-mentioned shape, the electromagnetic field is strongly distributed at a position distant from an opening 1a of the circular waveguide 1. More specifically, because the influence of scattering of the electromagnetic field by the opening 1a of the circular waveguide 1 can be reduced, the on-axis sidelobes in the E plane which are largely influenced by the opening 1a of the circular waveguide 1 can be improved. In this case, because the rotational symmetry of the electromagnetic field degrades, the cross polarization may degrade.

Embodiment 12.

[0064] In above-mentioned Embodiments 1 to 10, the primary radiator and the antenna apparatus in which the portion extending from the grooves 4 formed in the surrounding portion surrounding the central portion 3 of the subreflector 2 to the peripheral portion 5 of the subreflector 2 has a sloped structure 6 are shown. As an alternative, in the primary radiator and the antenna apparatus, the sloped structure can be formed into a cross-sectional shape in which a quarter circle is rotated around the axis of the circular waveguide 1 in such a way that the sloped structure protrudes toward the circular waveguide 1. Fig. 15 is a configuration diagram showing a primary radiator of an antenna apparatus in accordance with Embodiment 12 of the present invention. In the figure, because the same reference numerals as those shown in Fig. 12 denote the same components or like components, the explanation of the components will be omitted hereafter. Further, Fig. 16 is a partial enlarged configuration diagram showing the primary radiator shown in Fig. 15.

[0065] In this Embodiment 12, as shown in Figs. 15 and 16, a sloped structure 6b extending from grooves 4 formed in a surrounding portion surrounding a central portion 3 of a subreflector 2 to a peripheral portion 5 of the subreflector 2 is formed into a cross-sectional shape in which a quarter circle is rotated around the axis of a circular waveguide 1 in such a way that the sloped structure protrudes toward the circular waveguide 1. In this case, in order to connect the sloped structure 6b to the peripheral portion by using the quarter circle in cross section, the slope angle of the sloped structure is limited to 45 degrees.

[0066] Because the sloped structure 6b is formed in such a way as to have the above-mentioned shape, the electromagnetic field is strongly distributed in the vicinity of an opening 1a of the circular waveguide 1. Under the influence of scattering of the electromagnetic field by the circular waveguide 1, the electromagnetic field is weak in the vicinity of a wall 1b of the circular waveguide 1 (in the vicinity of the center of a main reflector 7). Because the sloped structure 6b is formed in such a way as to have the above-mentioned shape, the electromagnetic field intensity in the vicinity of the center of the main reflector 7 can be strengthened, and the on-axis sidelobes can be improved. However, because the electromagnetic field is scattered in the E plane under the influence of the opening of the circular waveguide 1, the on-axis sidelobes in the E plane may degrade. Further, because the rotational symmetry of the electromagnetic field degrades, the cross polarization may degrade.

Embodiment 13.

[0067] In above-mentioned Embodiment 11, the primary radiator in which the sloped structure 6a is formed into a cross-sectional shape in which a quarter circle is rotated around the axis of the circular waveguide 1 in such a way that the sloped structure is recessed toward a direction opposite to the circular waveguide 1. As an alternative, the sloped structure can be formed into a cross-sectional shape in which a partial circle centered on the perpendicular bisector between the start point and the end point of the sloped structure is rotated around the axis of the circular waveguide 1 in such a way that the sloped structure is recessed toward a direction opposite to the circular waveguide 1. Fig. 17 is a configuration diagram showing a primary radiator of an antenna apparatus in accordance with Embodiment 13 of the present invention. In the figure, because the same reference numerals as those shown in Fig. 12 denote the same components or like components, the explanation of the components will be omitted hereafter. Further, Fig. 18 is a partial enlarged configuration diagram showing the primary radiator shown in Fig. 17.

[0068] In this Embodiment 13, as shown in Figs. 17 and 18, a sloped structure 6c extending from grooves 4 formed in a surrounding portion surrounding a central portion 3 of a subreflector 2 to a peripheral portion 5 of the subreflector 2 is formed into a cross-sectional shape in which a partial circle centered on the perpendicular bisector between the start point and the end point of the sloped structure is rotated around the axis of a circular waveguide 1 in such a way that the sloped structure is recessed toward a direction opposite to the circular waveguide 1.

[0069] Because the sloped structure 6c is formed in such a way as to have the above-mentioned shape, the electromagnetic field is strongly distributed at a position distant from an opening 1a of the circular waveguide 1. More specifically, because the influence of scattering of the electromagnetic field by the opening 1a of the circular waveguide 1 can be reduced, the on-axis sidelobes in the E plane which are largely influenced by the opening 1a of the circular waveguide 1 can be improved. In this case, because the rotational symmetry of the electromagnetic field degrades, the cross polarization may degrade. In this Embodiment 13, the slope angle with which the sloped structure connects the grooves 4 formed in the vicinity of the center of the subreflector 2 with the peripheral portion of the subreflector 2 is not limited to 45 degrees, unlike in the case of above-mentioned Embodiment 11. Further, the radius of curvature of the sloped structure can also be set freely. The slope angle and the radius of curvature of the sloped structure can be set according to a required radiation pattern.

Embodiment 14.

[0070] In above-mentioned Embodiment 12, the primary radiator in which the sloped structure 6b is formed into a cross-sectional shape in which a quarter circle is rotated around the axis of the circular waveguide 1 in such a way that the sloped structure protrudes toward the circular waveguide 1. As an alternative, the sloped structure can be formed into a cross-sectional shape in which a partial circle centered on the perpendicular bisector between the start point and the end point of the sloped structure is rotated around the axis of the circular waveguide 1 in such a way that the sloped structure protrudes toward the circular waveguide 1. Fig. 19 is a configuration diagram showing a primary radiator of an antenna apparatus in accordance with Embodiment 14 of the present invention. In the figure, because the same reference numerals as those shown in Fig. 12 denote the same components or like components, the explanation of the components will be omitted hereafter. Further, Fig. 20 is a partial enlarged configuration diagram showing the primary radiator shown in Fig. 19.

[0071] In this Embodiment 14, as shown in Figs. 19 and 20, a sloped structure 6d extending from grooves 4 formed in a surrounding portion surrounding a central portion 3 of a subreflector 2 to a peripheral portion 5 of the subreflector 2 is formed into a cross-sectional shape in which a partial circle centered on the perpendicular bisector between the start point and the end point of the sloped structure is rotated around the axis of a circular waveguide 1 in such a way that the sloped structure protrudes toward the circular waveguide 1.

[0072] Because the sloped structure 6d is formed in such a way as to have the above-mentioned shape, the electromagnetic field is strongly distributed in the vicinity of an opening 1a of the circular waveguide 1. Under the influence of scattering of the electromagnetic field by the circular waveguide 1, the electromagnetic field is weak in the vicinity of a wall 1b of the circular waveguide 1 (in the vicinity of the center of a main reflector 7). Because the sloped structure 6d is formed in such a way as to have the above-mentioned shape, the electromagnetic field intensity in the vicinity of the center of the main reflector 7 can be strengthened, and the on-axis sidelobes can be improved. However, because the electromagnetic field is scattered in the E plane under the influence of the opening of the circular waveguide 1, the on-axis sidelobes in the E plane may degrade. Further, because the rotational symmetry of the electromagnetic field degrades, the cross polarization may degrade. In this Embodiment 14, the slope angle with which the sloped structure connects the grooves 4 formed in the vicinity of the center of the subreflector 2 with the peripheral portion of the subreflector 2 is not limited to 45 degrees, unlike in the case of above-mentioned Embodiment 12. Further, the radius of curvature of the sloped structure can also be set freely. The slope angle and the radius of curvature of the sloped structure can be set according to a required radiation pattern.

[0073] While preferred embodiments have been described, it is to be understood that a combination of freely-selected embodiments, a modification of an arbitrary component in each embodiment, or an omission of an arbitrary component in each embodiment can be made in the invention without departing from the spirit and scope of the invention.

Claims

1. A primary radiator for use in antenna apparatus, said primary radiator including a circular waveguide (1) for radiating a radio wave from an opening (1a) thereof, and a disc-shaped subreflector (2) located just opposite to the opening of said circular waveguide, for reflecting the radio wave radiated from the opening of said circular waveguide, wherein
a central portion (3) of said subreflector is formed in a conical shape, grooves (4) extending, in relation to their depth direction, parallel to an axis of said

circular waveguide are formed cylindrically in a surrounding portion of said subreflector surrounding the central portion formed in a conical shape, and a portion extending from the grooves formed in said surrounding portion of said subreflector to a peripheral portion (5) of said subreflector has a sloped structure (6) which is formed in such a way that said peripheral portion projects toward said circular waveguide.

2. The primary radiator for use in antenna apparatus, according to claim 1, wherein grooves (12) extending, in relation to their depth direction, parallel to the axis of said circular waveguide are formed cylindrically in a peripheral portion (5) of said subreflector.

3. The primary radiator for use in antenna apparatus according to claim 1 or 2, wherein a corrugation (8) which is projections and depressions concentrically arranged is formed in a part of an outer wall (1b) of the circular waveguide.

4. The primary radiator for use in antenna apparatus according to claim 1 or 2, wherein a corrugation (9) which is projections and depressions concentrically arranged is formed in a whole of an outer wall (1b) of the circular waveguide.

5. The primary radiator for use in antenna apparatus according to any of claims 1 to 4, wherein grooves (10) extending, in relation to their depth direction, parallel to the axis of the circular waveguide are formed in a thick wall portion in a vicinity of the opening of said circular waveguide.

6. The primary radiator for use in antenna apparatus according to claim 5, wherein the grooves extending, in relation to their depth direction, parallel to the axis of the circular waveguide are displaced from one another with respect to an axial direction of said circular waveguide.

7. The primary radiator for use in antenna apparatus according to any of claims 1 to 6, wherein the portion extending from the grooves formed in the surrounding portion of the subreflector to the peripheral portion of said subreflector and having the sloped structure which is formed in such a way that said peripheral portion projects toward the circular waveguide is formed into a cross-sectional shape in which a quarter circle is rotated around the axis of said circular waveguide in such a way that the sloped structure is recessed toward a direction opposite to said circular waveguide or protrudes toward said circular waveguide.

8. The primary radiator for use in antenna apparatus according to any of claims 1 to 6, wherein the portion extending from the grooves formed in the surrounding portion of the subreflector to the peripheral portion of said subreflector and having the sloped structure which is formed in such a way that said peripheral portion projects toward the circular waveguide is formed into a cross-sectional shape in which a partial circle centered on a perpendicular bisector between a start point and an end point of said sloped structure is rotated around the axis of said circular waveguide in such a way that the sloped structure is recessed toward a direction opposite to said circular waveguide or protrudes toward said circular waveguide.

9. An antenna apparatus including the primary radiator according to claim 1, and a main reflector (7) located just opposite to said subreflector, for reflecting the radio wave reflected by said subreflector.

10. The antenna apparatus according to claim 9, wherein grooves (12) extending, in relation to their depth direction, parallel to the axis of said circular waveguide are formed cylindrically in a peripheral portion (5) of said subreflector.

11. The antenna apparatus according to claim 9 or 10, wherein the portion extending from the grooves formed in the surrounding portion of the subreflector to the peripheral portion of said subreflector and having the sloped structure which is formed in such a way that said peripheral portion projects toward the circular waveguide is formed into a cross-sectional shape in which a quarter circle is rotated around the axis of said circular waveguide in such a way that the sloped structure is recessed toward a direction opposite to said circular waveguide or protrudes toward said circular waveguide.

12. The antenna apparatus according to claim 9 or 10, wherein the portion extending from the grooves formed in the surrounding portion of the subreflector to the peripheral portion of said subreflector and having the sloped structure which is formed in such a way that said peripheral portion projects toward the circular waveguide is formed into a cross-sectional shape in which a partial circle centered on a perpendicular bisector between a start point and an end point of said sloped structure is rotated around the axis of said circular waveguide in such a way that the sloped structure is recessed toward a direction opposite to said circular waveguide or protrudes toward said circular waveguide.

FIG.1

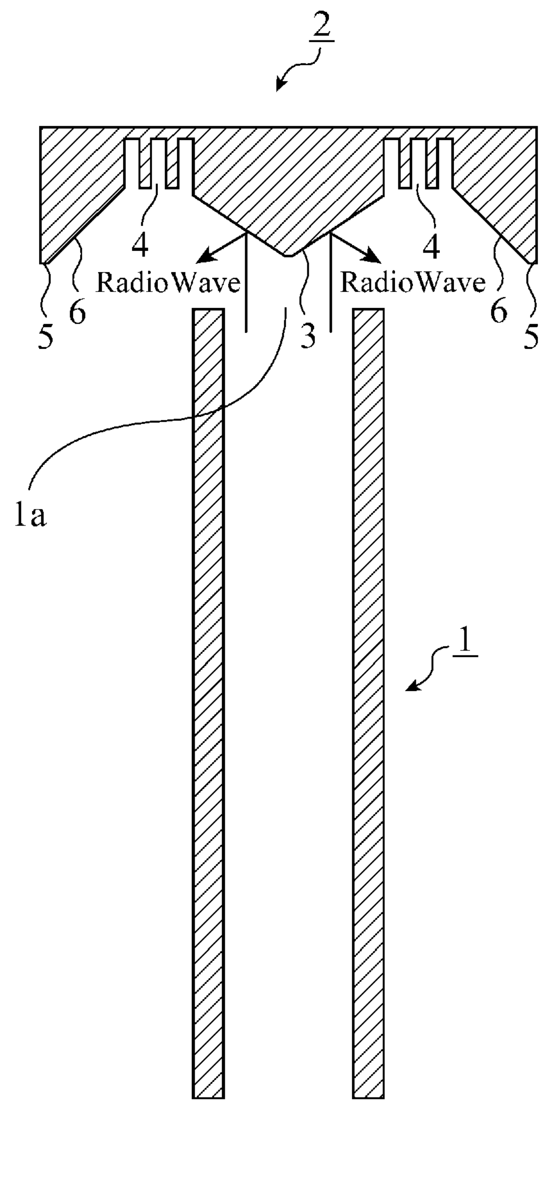


FIG.2

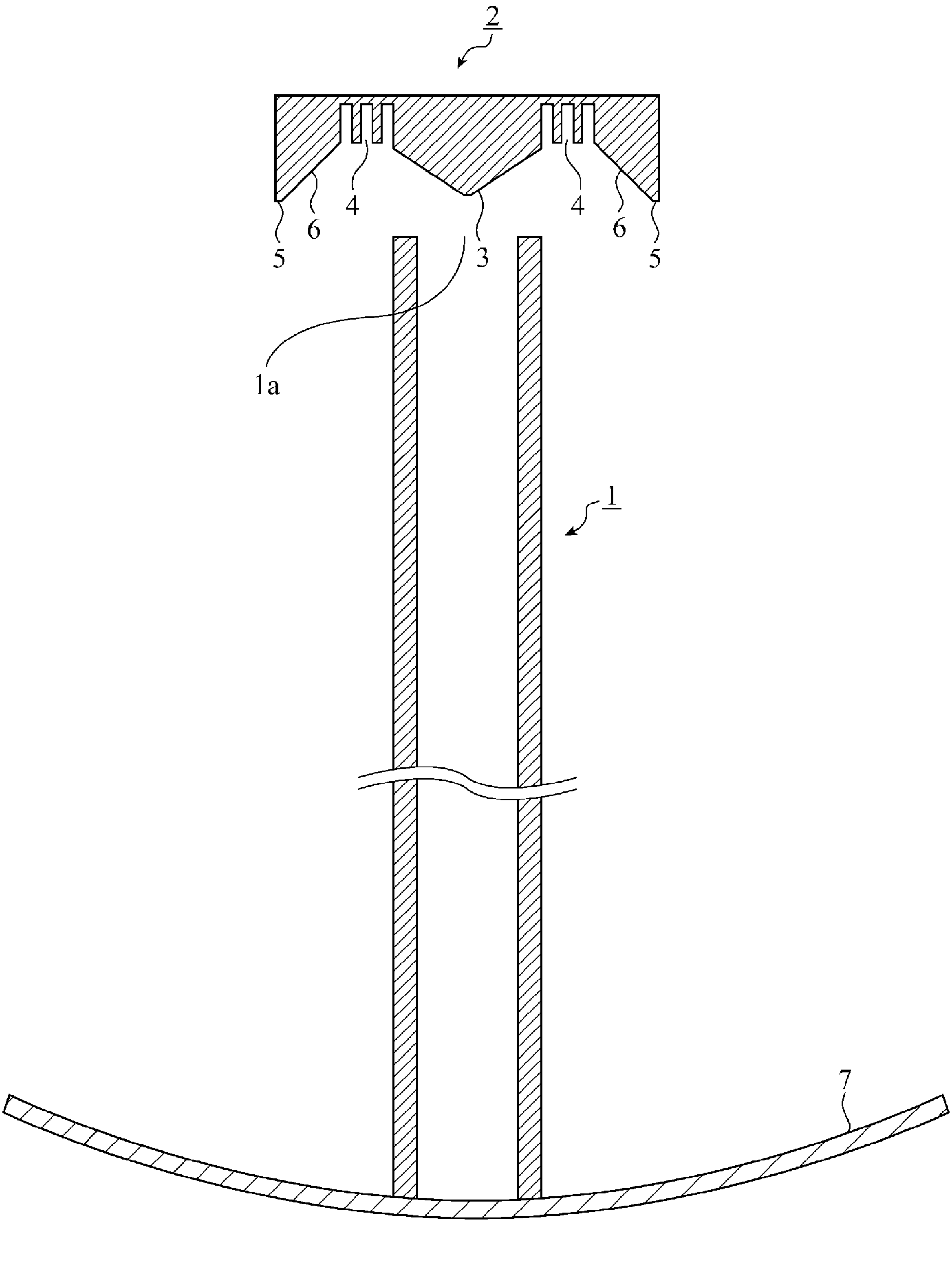


FIG.3

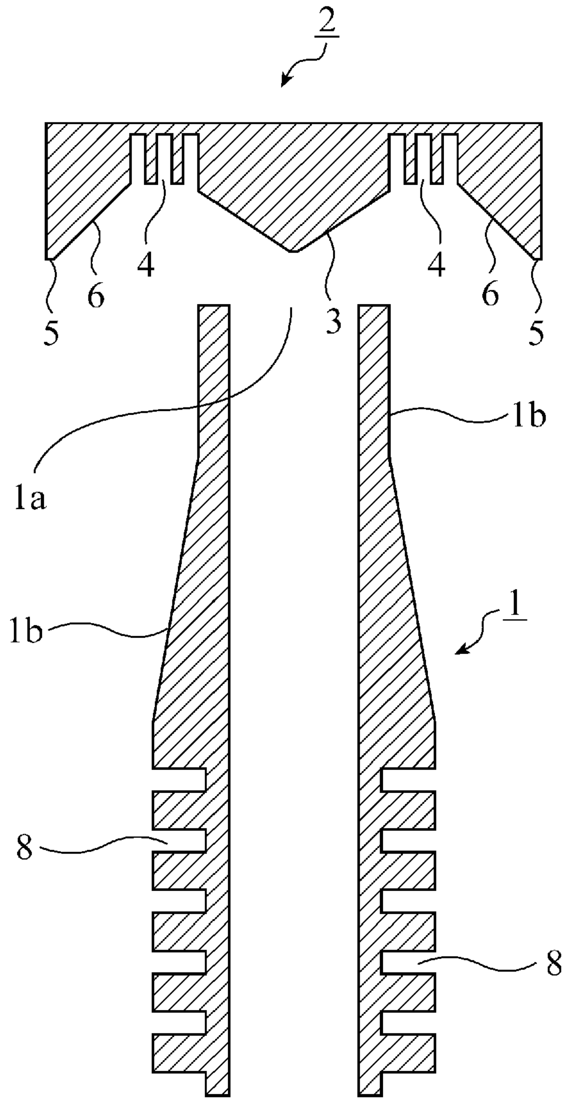


FIG.4

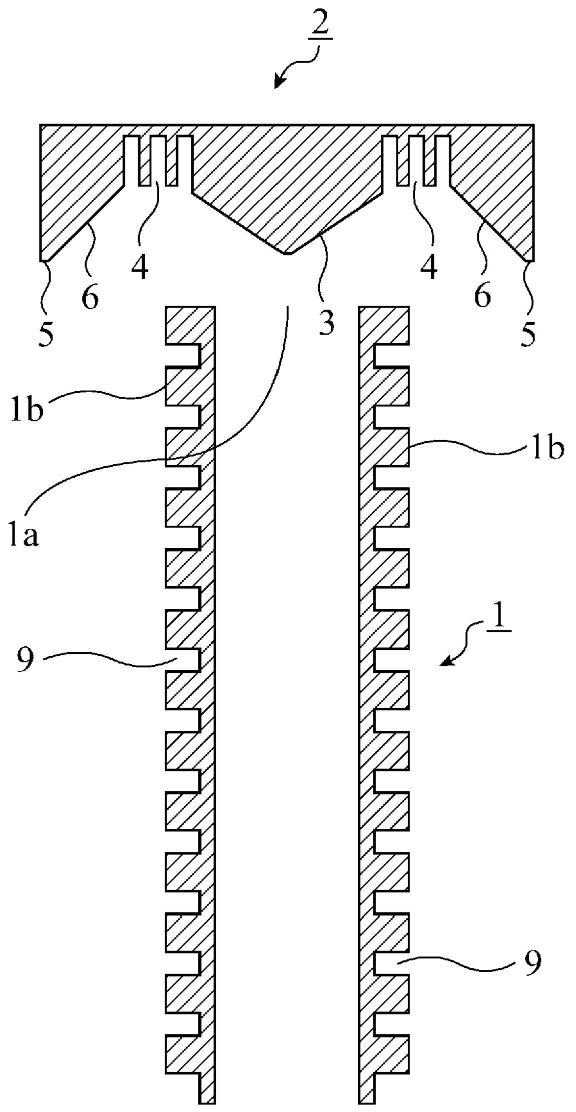


FIG.5

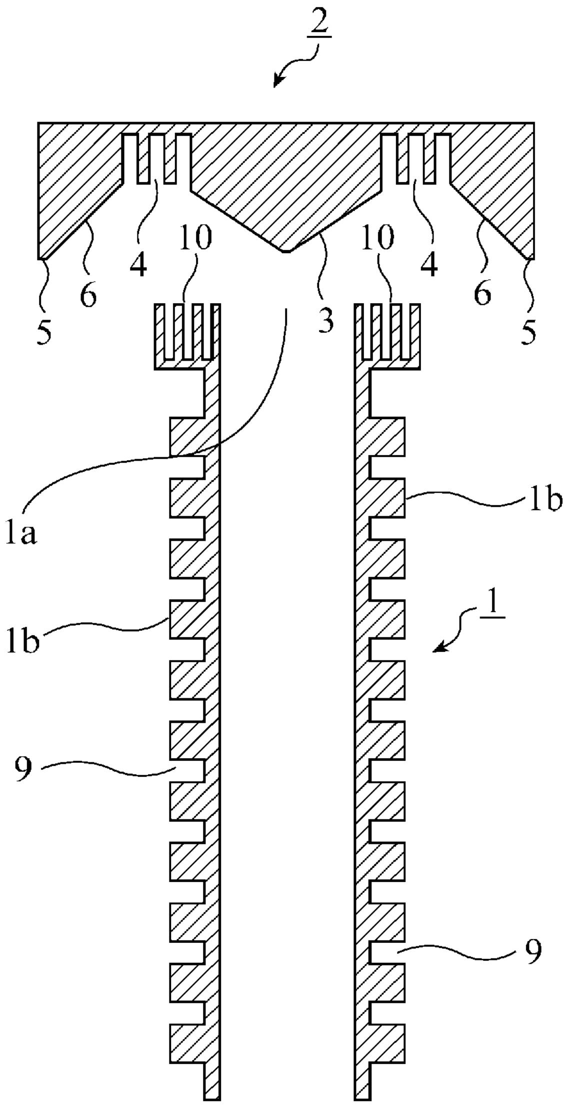


FIG.6

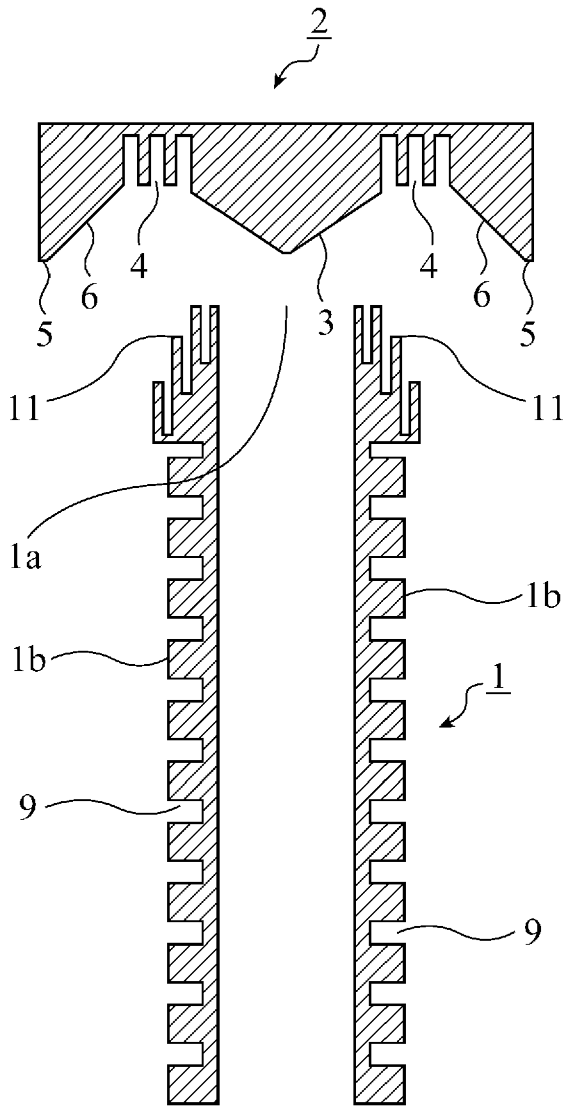


FIG.7

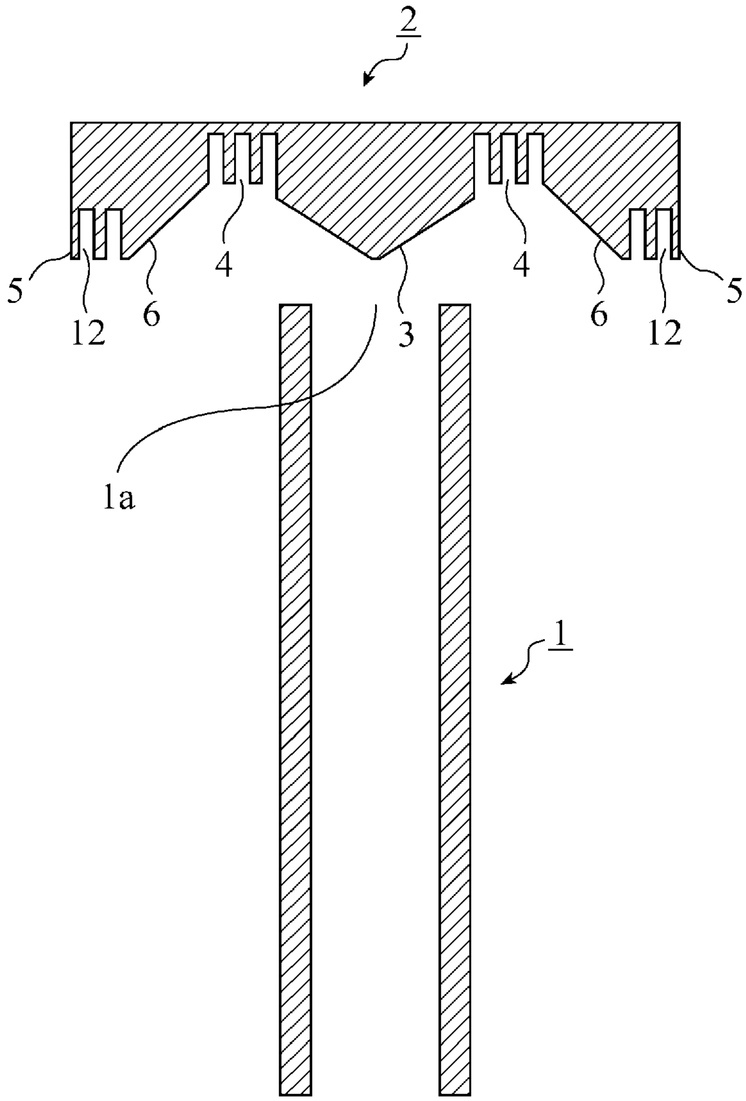


FIG.8

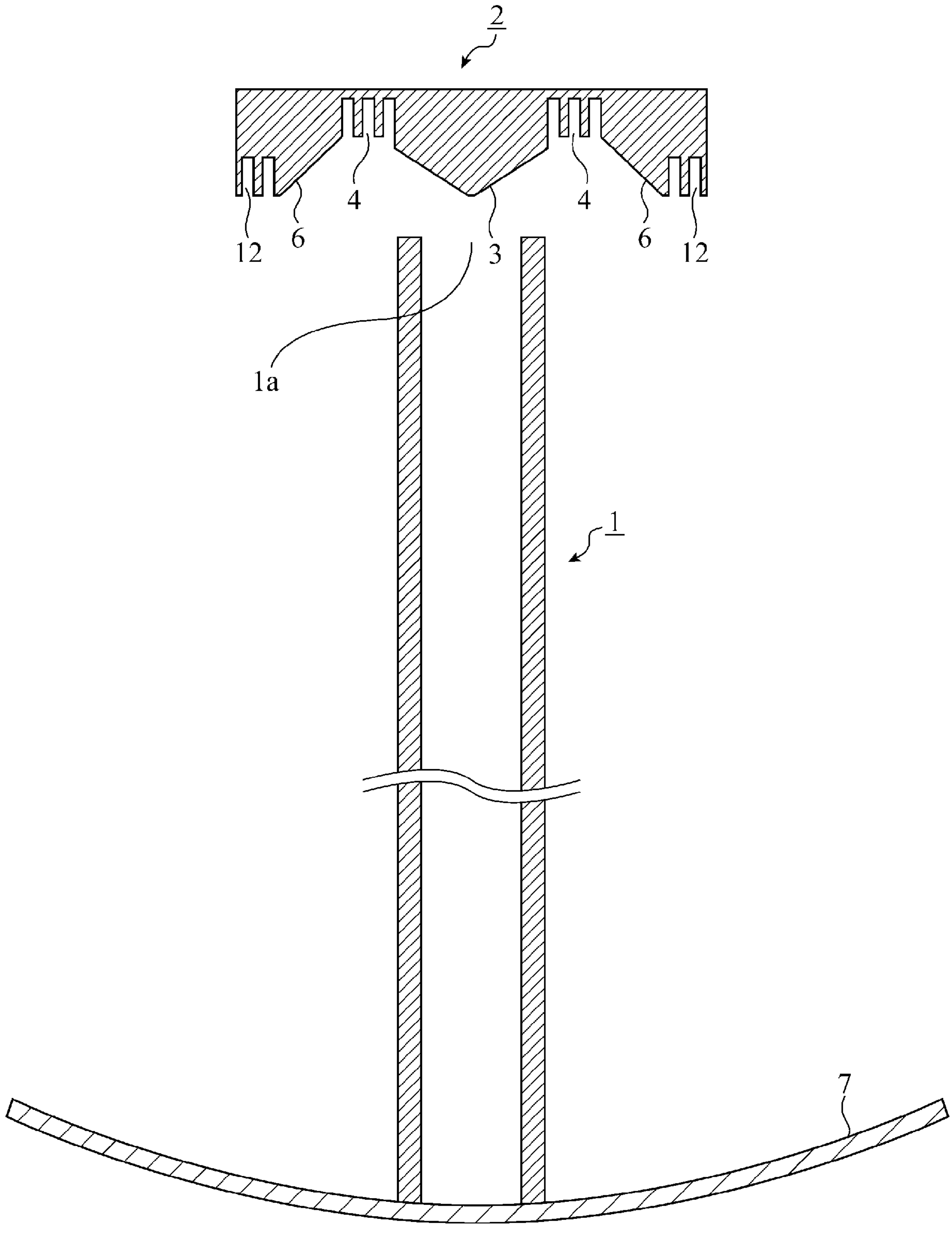


FIG.9

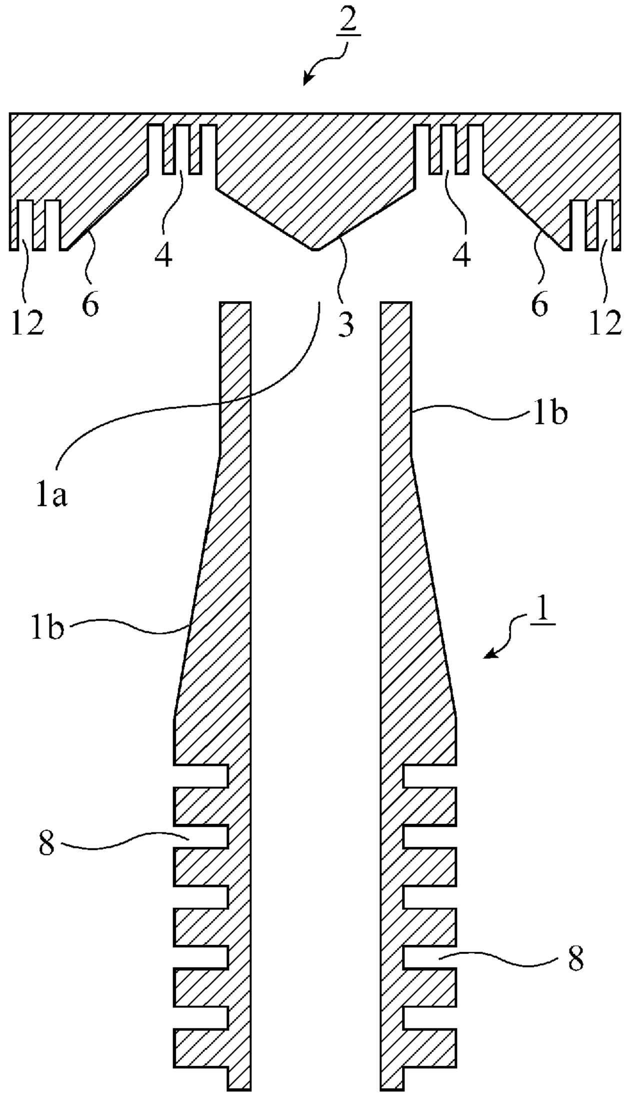


FIG.10

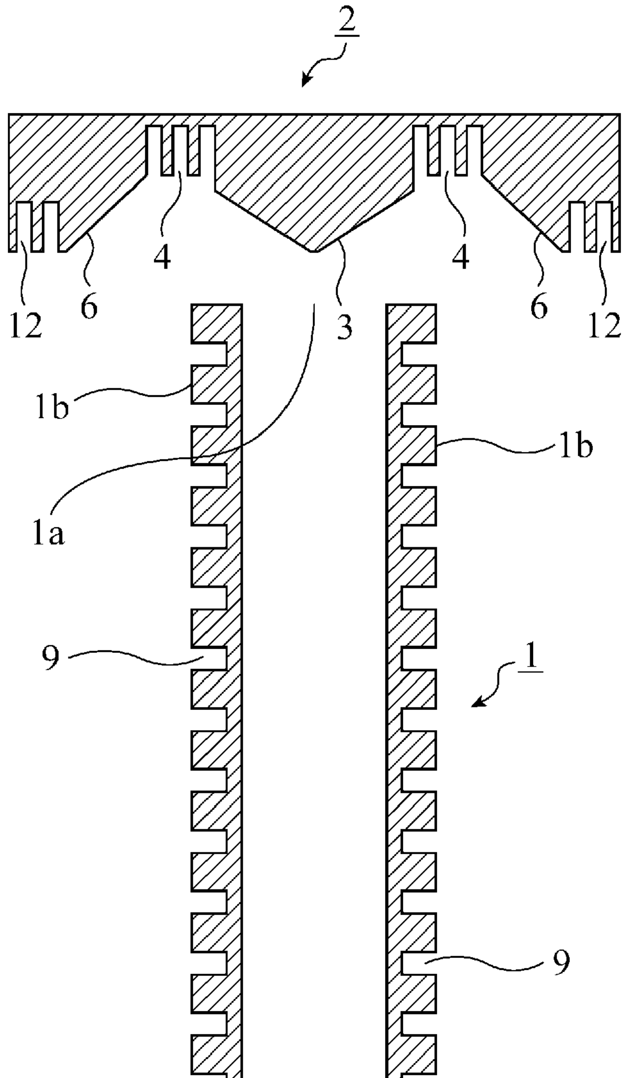


FIG.11

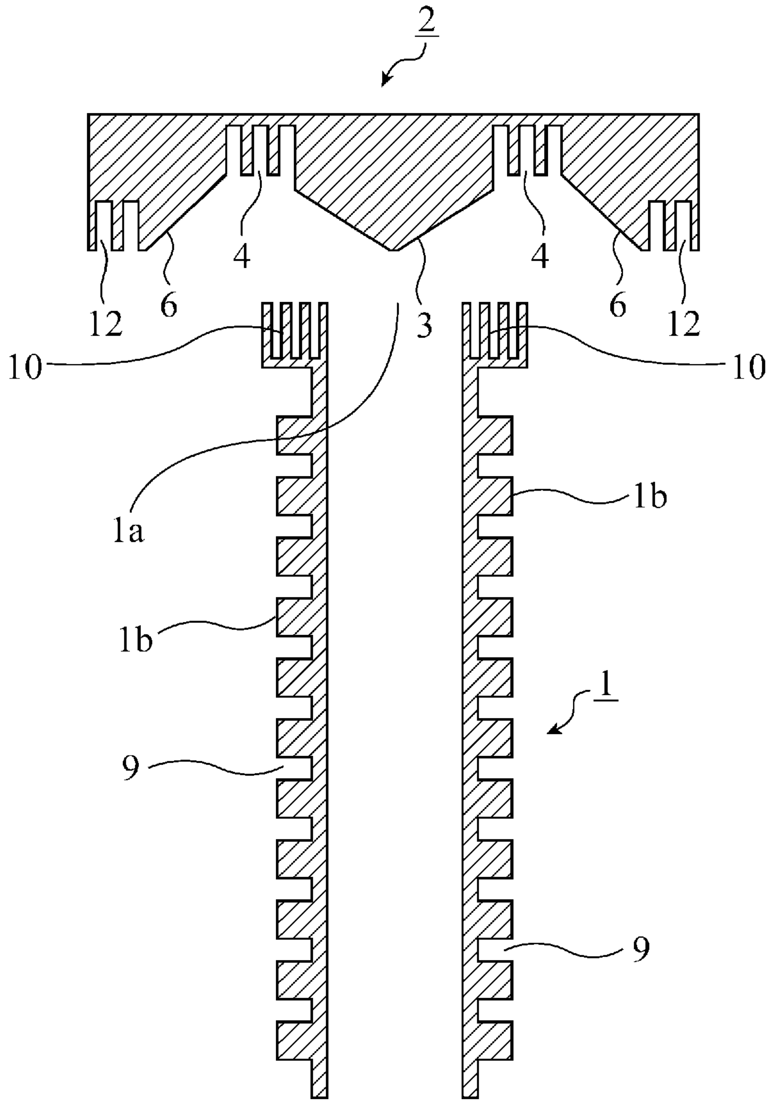


FIG.12

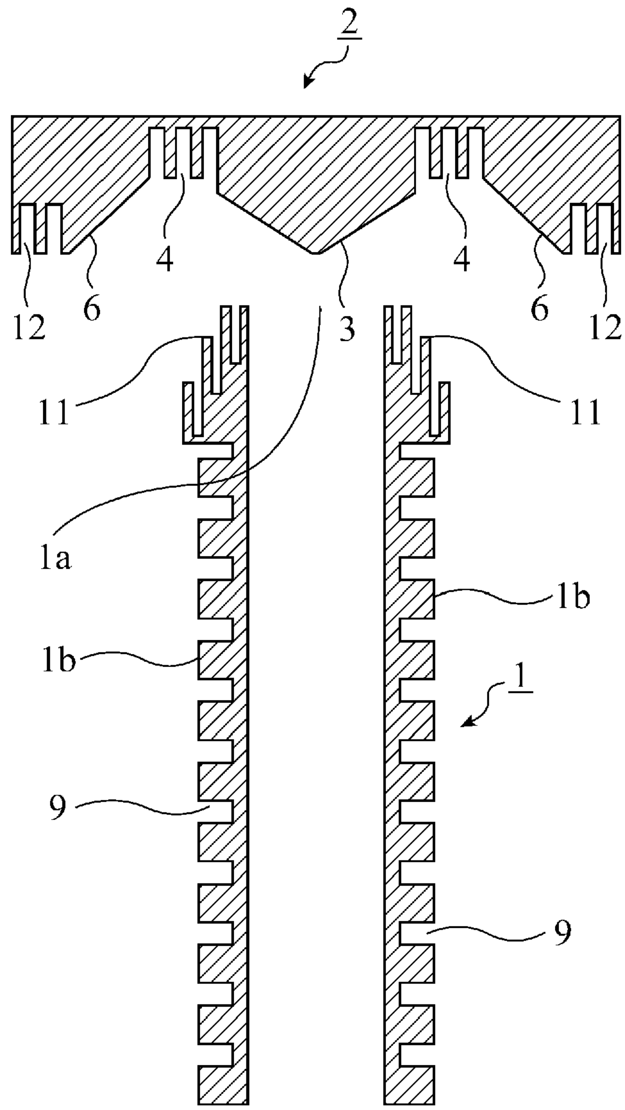


FIG.13

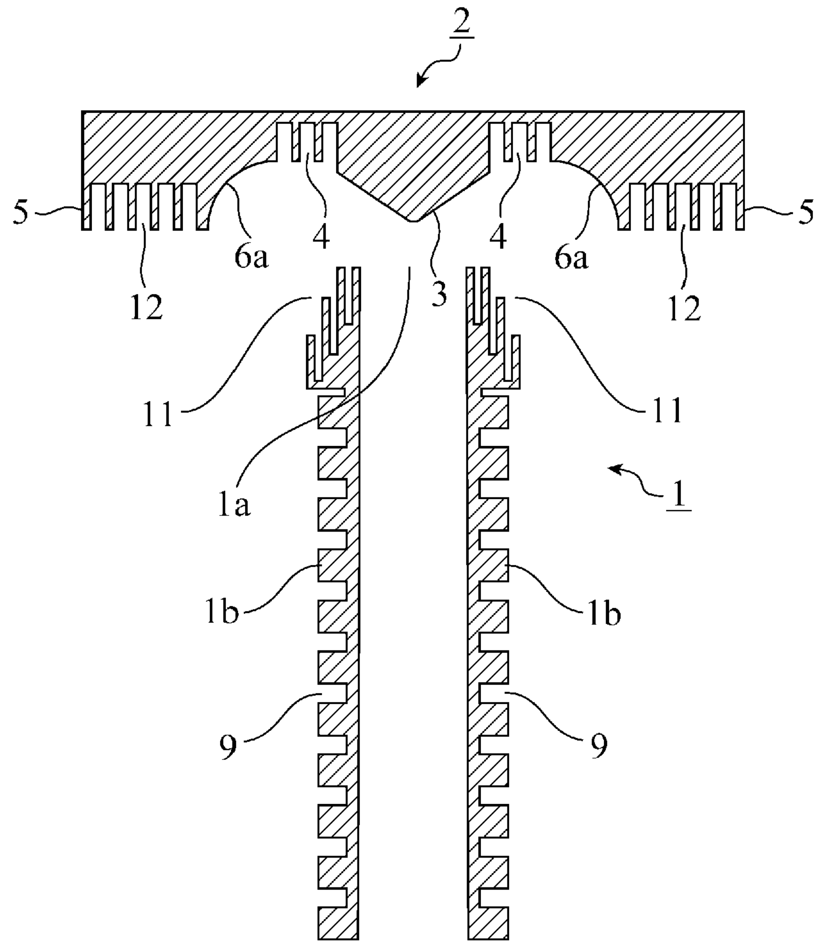


FIG.14

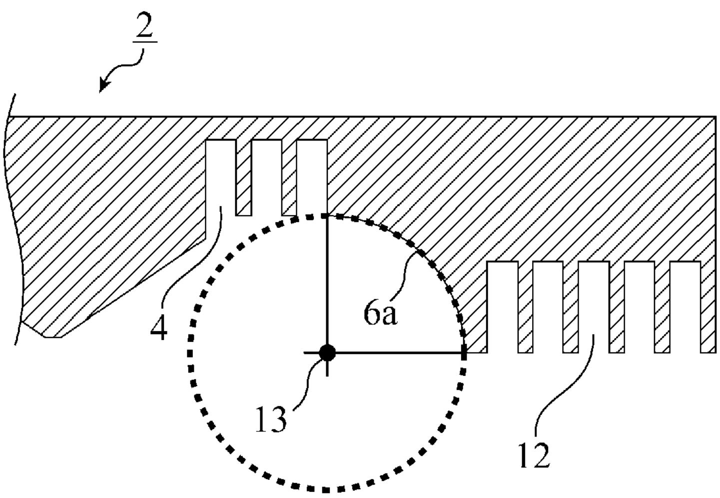


FIG.15

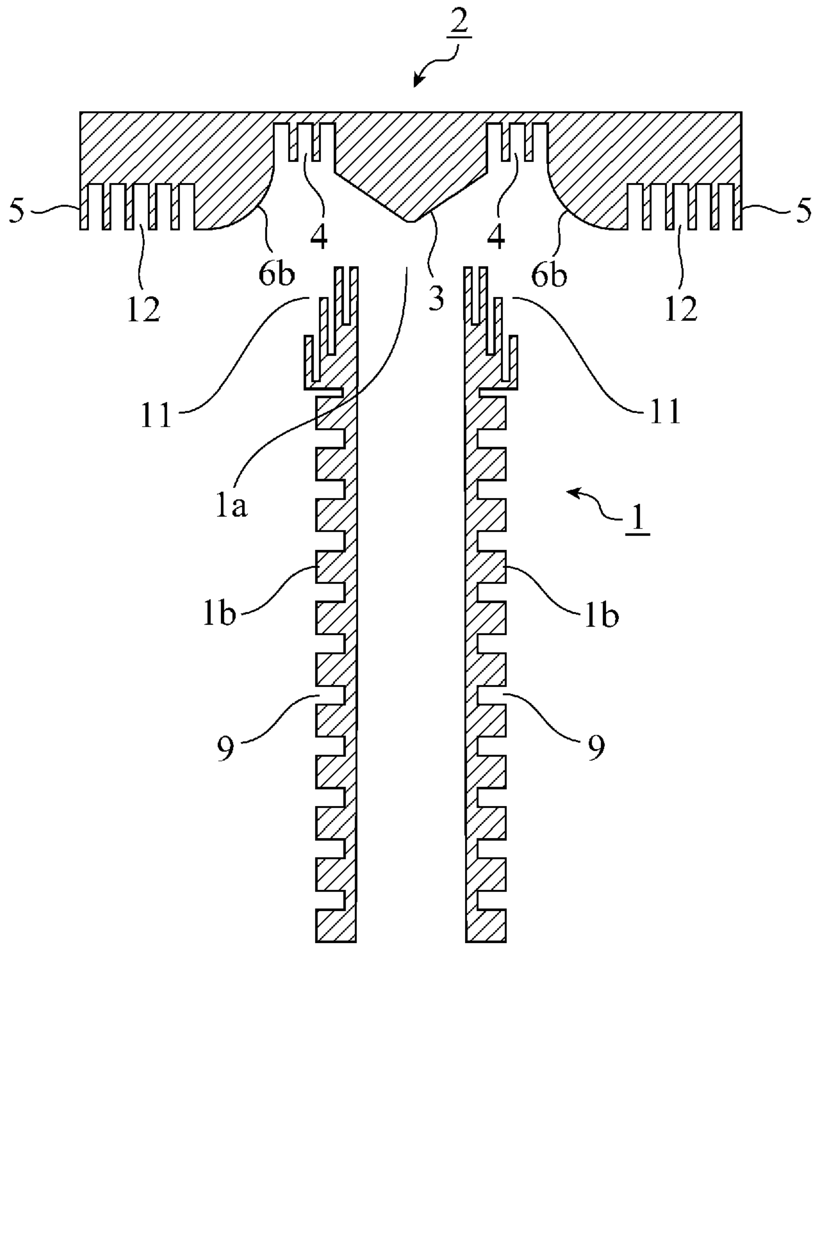


FIG.16

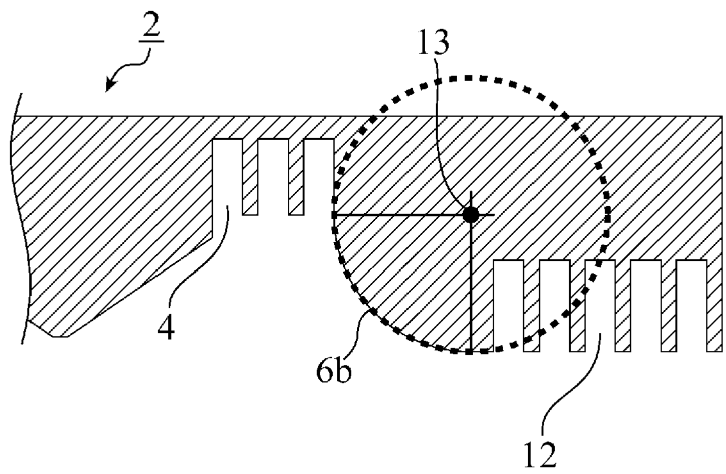


FIG.17

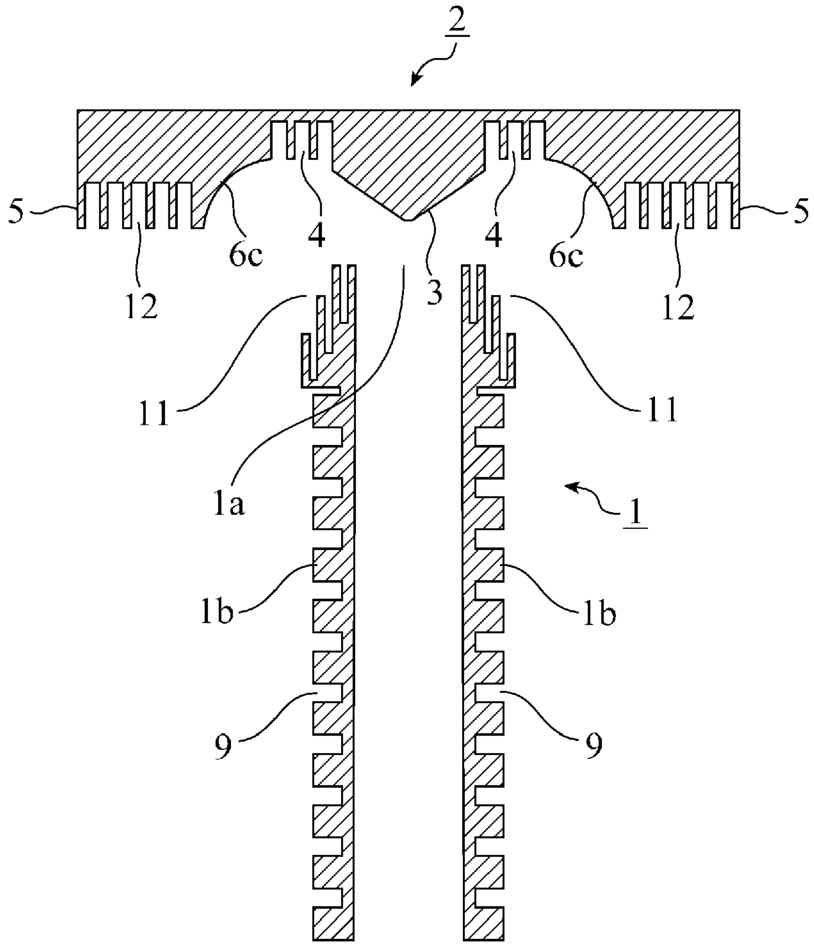


FIG.18

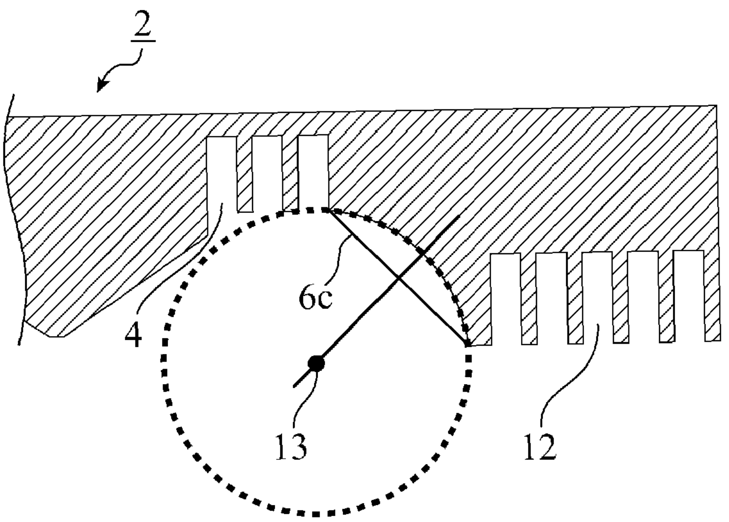


FIG.19

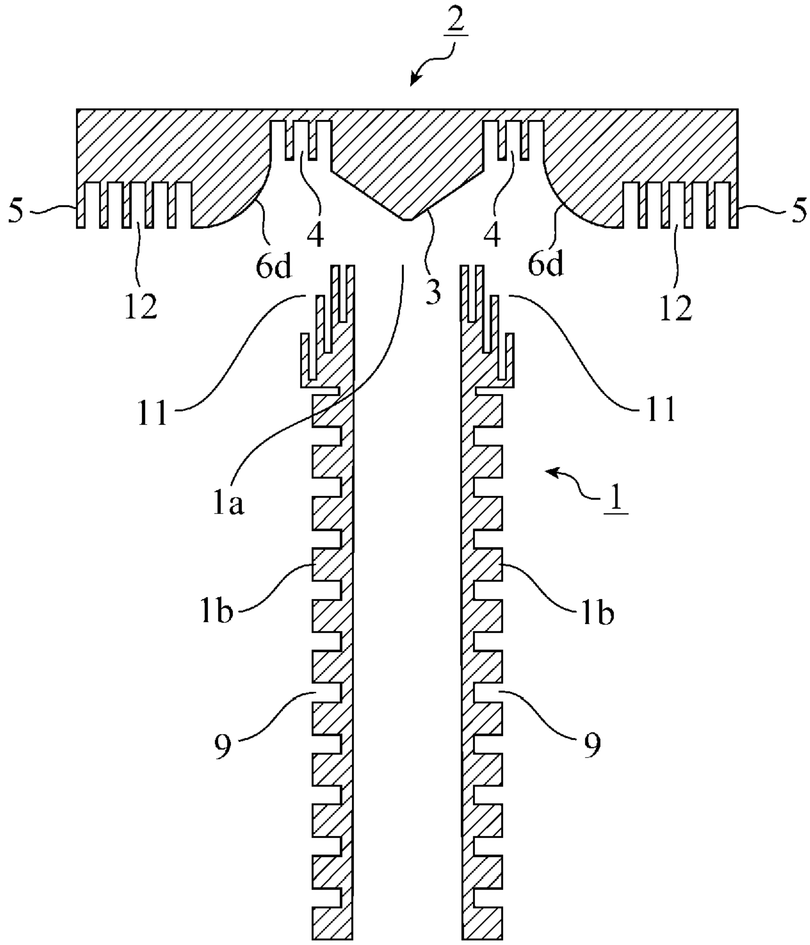
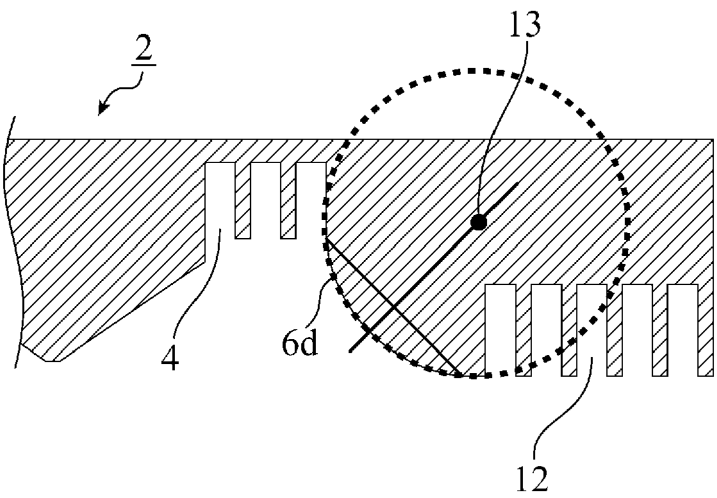


FIG.20



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Application Number
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