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(54) **WAVEGUIDE TUBE CONNECTING MEMBER**

(57) A waveguide tube connecting member includes a first waveguide tube (1) having a first waveguide path (10) and a flange (11). The flange (11) has a flange end surface (13) extending from a first opening end (13) of the first waveguide path (10) toward an outer side in a tube radial direction (RD), and a second flange outer peripheral surface (15) which is a part of a first flange outer

peripheral surface. The second flange outer peripheral surface is a surface (11) formed in a shape in which a part of the flange has a cavity. An electric length from the first opening end (10a) of the flange end surface (13) to the second flange outer peripheral surface (15) along the tube radial direction is $(2 \times N + 1)/4$ times a wavelength.

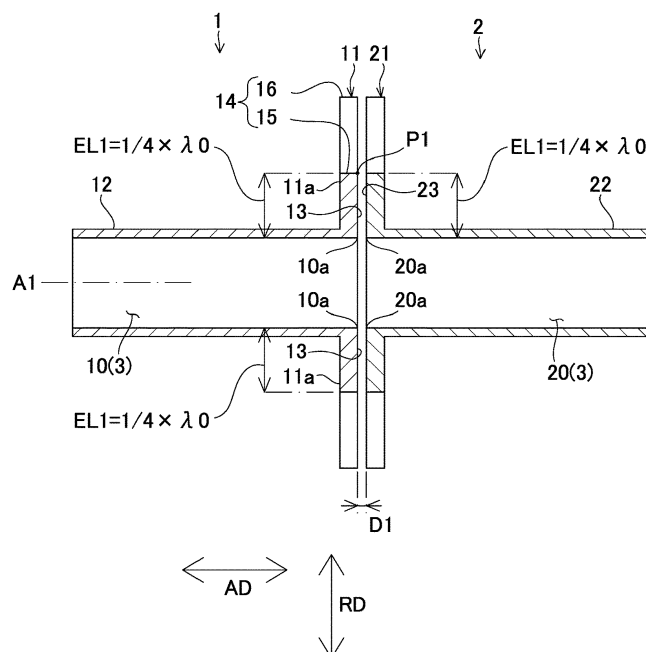


FIG. 2

Description

[0001] The disclosure relates to a waveguide tube connecting member for connecting waveguide tubes that transmit a high frequency.

[0002] A waveguide tube is used as a transmission path for radio waves in a device that uses high frequencies (for example, microwaves) such as a weather radar. When connecting a second waveguide tube to a first waveguide tube, it is necessary to connect the first waveguide tube and the second waveguide tube without any gap. If there is a gap between the first waveguide tube and the second waveguide tube, radio waves may leak from the gap. Patent Literature 1 is given as an example of a waveguide tube connecting member. As shown in Patent Literature 1, connection between the waveguide tubes is generally realized by bringing a flange of the first waveguide tube and a flange of the second waveguide tube into contact with each other without any gap, and joining the flanges to each other by fastening the flanges with fasteners such as bolts.

[0003] However, the waveguide tube is metal and has tolerances as a mechanical member. Even if all the waveguide tubes that make up the transmission path are to be connected without any gap, a gap as a tolerance may still occur between the waveguide tubes butted against each other and their mating member at any waveguide tube connecting portion in the transmission path. This tolerance can be reduced by fastening the flanges of the waveguide tubes with fasteners, but it is difficult to completely eliminate the gap.

[0004] [Patent Literature 1] Japanese Patent No. 2970565

[0005] The disclosure provides a waveguide tube connecting member capable of suppressing leakage of radio waves even in a state where a waveguide tube and a connecting mating member for the waveguide tube are separated in a tube axial direction due to a tolerance.

Means for Solving the Problems

[0006] The waveguide tube connecting member according to an embodiment of the disclosure includes: a first waveguide tube having a first waveguide path for transmitting a high frequency and a flange. The flange has a flange end surface extending from a first opening end of the first waveguide path toward an outer side in a tube radial direction, and a second flange outer peripheral surface which is a part of a first flange outer peripheral surface extending from the flange end surface toward an inner side in a tube axial direction and released to the outer side in the tube radial direction. The second flange outer peripheral surface is a surface formed in a shape in which a part of the flange end surface in contact with an outer periphery of the flange is recessed toward the inner side in the tube axial direction, or a surface formed in a shape in which a part of the first flange outer peripheral surface of the flange is recessed toward an

inner side in the tube radial direction. An electric length from the first opening end of the flange end surface to the second flange outer peripheral surface along the tube radial direction is $(2 \times N + 1)/4$ times a free space wavelength λ_0 , and N is an integer of 0 or more.

[0007] The flange probably has an insertion hole for fastening a mating member to which the first waveguide tube is connected, and an outer peripheral surface of the insertion hole on the outer side in the tube radial direction is an outer peripheral surface other than the second flange outer peripheral surface of the first flange outer peripheral surface.

[0008] The second flange outer peripheral surface is probably parallel to an inner peripheral surface of the first waveguide path.

[0009] The cavity probably fully penetrates through the flange parallel to the tube axis of the first waveguide path, and the second flange outer peripheral surface of the second flange is the outermost surface in the tube radial direction.

[0010] The cavity probably forms a step on the flange end surface partially penetrating through the flange, and the outer peripheral surface of the step corresponds to the second flange outer peripheral surface.

[0011] The first waveguide path is probably a rectangular waveguide tube path whose tube cross section has a long side and a short side, and the second flange outer peripheral surface is arranged on the outer side of the long side in the tube radial direction.

[0012] The first waveguide path is probably a circular waveguide tube path having a circular tube cross section, and the second flange outer peripheral surface is arranged at a position that is pointsymmetric with a center of the circular tube cross section as a point of symmetry.

[0013] The waveguide tube connecting member probably comprises a second waveguide tube. The second waveguide tube comprises a second waveguide path butted against the first waveguide path of the first waveguide tube and a flange extending from a second opening end of the second waveguide path toward the outer side in the tube radial direction and fastened to the flange end surface of the first waveguide tube.

[0014] The waveguide tube connecting member further comprises a mating member to which the first waveguide tube is connected. The mating member comprises a second waveguide path butted against the first waveguide path of the first waveguide tube and a second waveguide path end surface extending from a second opening end of the second waveguide path toward the outer side in the tube radial direction. The second waveguide path end surface of the mating member is wider in the tube radial direction than the flange of the first waveguide tube.

FIG. 1 is a perspective view showing how the first waveguide tube and the second waveguide tube of the first embodiment are butted and fastened with the fastening member.

FIG. 2 is a cross-sectional view of the portion II-II of FIG. 1.

FIG. 3 is a front view of the flange end surface of the first waveguide tube of the first embodiment as viewed from a line of sight parallel to the tube axis.

FIG. 4 is a cross-sectional view orthogonal to the tube axis of the rectangular waveguide tube path.

FIG. 5 is a front view of the flange end surface of the first waveguide tube of the second embodiment as viewed from a line of sight parallel to the tube axis.

FIG. 6 is a cross-sectional view of the portion II-II corresponding to FIG. 2 of the third embodiment.

FIG. 7 is a front view of the flange end surface of the first waveguide tube of the fourth embodiment as viewed from a line of sight parallel to the tube axis.

FIG. 8 is a perspective view showing how the first waveguide tube of the fifth embodiment is butted against the mating member and fastened with the fastening member.

[First embodiment]

[0015] Hereinafter, a waveguide tube connecting member of the first embodiment of the disclosure will be described with reference to the drawings. FIG. 1 is a perspective view showing how a first waveguide tube 1 and a second waveguide tube 2 are butted and fastened with a fastening member 4 such as a bolt. FIG. 2 is a cross-sectional view of a portion II-II of FIG. 1, and shows a cross section which passes through a tube axis A1 of a first waveguide path 10 and in which a second flange outer peripheral surface 15 appears. In FIG. 2, the first waveguide tube 1 and the second waveguide tube 2 are drawn to be in a state of being separated so as to form a gap for convenience of illustration. FIG. 3 is a front view of a flange end surface 13 of the first waveguide tube 1 as viewed from a line of sight parallel to the tube axis A1. FIG. 4 is a cross-sectional view orthogonal to the tube axis of a rectangular waveguide tube path.

[0016] A tube axial direction refers to a direction parallel to the tube axis A1 of an opening (near a first opening end 10a) of the first waveguide tube 1. A tube radial direction refers to a direction orthogonal to the tube axis A1 of the opening of the first waveguide tube 1. When the first waveguide tube 1 is bent, the tube axis of the opening on the tip side of the bent portion is used as a reference.

[0017] As shown in FIG. 1 to FIG. 3, the waveguide tube connecting member of the first embodiment has the first waveguide tube 1. The first waveguide tube 1 is connected to the second waveguide tube 2. The first waveguide tube 1 has the first waveguide path 10 for transmitting a high frequency. The second waveguide tube 2 has a second waveguide path 20 for transmitting a high frequency. The first waveguide tube 1 has a tubular portion 12 forming the first waveguide path 10, and the flange end surface 13 extending toward the outer side in the tube radial direction RD from the first opening end

10a of the first waveguide path 10 at the tip of the tubular portion 12. The second waveguide tube 2 has a tubular portion 22 forming the second waveguide path 20 for transmitting a high frequency, and a second waveguide path end surface 23 extending toward the outer side in the tube radial direction RD from a second opening end 20a of the second waveguide path 20 at the tip of the tubular portion 22. The first waveguide path 10 and the second waveguide path 20 are butted against each other in a connected state. The connected state is a state where the positional relationship between the first waveguide tube 1 and the second waveguide tube 2 is fixed by the fastening member 4 such as a bolt and a nut. In the connected state, the flange end surface 13 of the first waveguide tube 1 and the second waveguide path end surface 23 of the second waveguide tube 2 come into contact with each other without any gap. This is because if there is a gap, radio waves may leak. However, assuming that a gap is formed between the flange end surface 13 of the first waveguide tube 1 and the second waveguide path end surface 23 of the second waveguide tube 2, the means for suppressing or reducing leakage of radio waves will be described below.

[0018] The first waveguide tube 1 and the second waveguide tube 2 are hollow metal tubes and are formed of conductors. The first waveguide tube 1 and the second waveguide tube 2 are electrically short-circuited and set to ground. The high frequency is transmitted through the first waveguide tube 1 and the second waveguide tube 2 from one side toward the other side in the tube axial direction AD. The high frequency referred to in the present specification is a radio wave of 300 MHz or higher, a radio wave of 2 GHz or higher, or a radio wave of 3 GHz or higher. Further, as the upper limit value, the high frequency may be, for example, a radio wave of 50 GHz or lower. For example, the high frequency may be a radio wave of 40 GHz or lower. The high frequency may be microwaves or millimeter waves. In this embodiment, aluminum or stainless steel is used as the conductor, but the conductor is not limited thereto.

[0019] As shown in FIG. 4, the first waveguide path 10 of the first embodiment is a rectangular waveguide tube path 3 whose tube cross section has long sides 31 and short sides 32. The long sides 31 are parallel to each other, and the short sides 32 are parallel to each other. FIG. 2 is a cross-sectional view of the portion II-II of FIG. 1. The cross section of the portion II-II is a cross section that passes through a center 31s of the long side 31 and the tube axis A1. An oscillating electric field is generated in the tube path by traveling waves and reflected waves. FIG. 4 is a schematic cross-sectional view orthogonal to the tube axis A1, which is a portion where the oscillating electric field is strong in the tube axial direction AD. As shown in FIG. 4, the oscillating electric field E becomes an antinode at the portion connecting the centers 31s of the long sides 31, and becomes the most dominant. On the other hand, the oscillating electric field E is not generated on the short side 32. The high frequency is trans-

mitted in the rectangular waveguide tube path 3 in a TE10 mode (Transverse Electric Mode), which is the basic mode of the rectangular waveguide tube path 3. In the TE10 mode, the electric field is not generated in the direction parallel to the long side 31, but is generated in the direction parallel to the short side 32. In a mode other than the basic mode (TE10 mode), the mode is not limited thereto, and it is possible to use other than TE10.

[0020] As shown in FIG. 1 to FIG. 3, the first waveguide tube 1 has a flange 11 formed at the tip of the tubular portion 12. The flange 11 has the flange end surface 13 extending toward the outer side in the tube radial direction RD from the first opening end 10a of the first waveguide path 10, and the second flange outer peripheral surface 15 which is a part of a first flange outer peripheral surface 14 extending toward the inner side in the tube axial direction AD from the flange end surface 13 and opened to the outer side in the tube radial direction RD. In the first embodiment, the second flange outer peripheral surface 15 is a surface formed in a shape in which a part of the first flange outer peripheral surface 14 is recessed toward the inner side in the tube radial direction RD.

[0021] Specifically, as shown in FIG. 3, the first flange outer peripheral surface 14 of the flange 11 includes the second flange outer peripheral surface 15 and a third flange outer peripheral surface 16 at the outermost end in the tube radial direction RD. The third flange outer peripheral surface 16 has a surface 16a parallel to the long side 31 of the rectangular waveguide tube path 3, and a surface 16b parallel to the short side 32 of the rectangular waveguide tube path 3. A part of the surface 16a parallel to the long side 31 of the rectangular waveguide tube path 3 is recessed toward the inner side in the tube radial direction, by which the second flange outer peripheral surface 15 is formed. The second flange outer peripheral surface 15 is arranged on the outer side in the tube radial direction RD with respect to the long side 31 of the rectangular waveguide tube path 3. In the cross section (FIG. 2) which passes through the tube axis A1 of the first waveguide path 10 and in which the second flange outer peripheral surface 15 appears, the second flange outer peripheral surface 15 extends from the flange end surface 13 to a tube axial direction inner end 11a of the flange 11. In the cross section (FIG. 2), the second flange outer peripheral surface 15 is a surface on the outermost side in the tube radial direction. That is, the recess extending toward the inner side in the tube radial direction in a part of the first flange outer peripheral surface 14 of the flange 11 reaches the entirety in the tube axial direction, and a part of the first flange outer peripheral surface 14 as viewed from a line of sight parallel to the tube axis A1 is in a cut-out state.

[0022] On the other hand, no recess is formed on the surface 16b parallel to the short side 32 of the rectangular waveguide tube path 3, and the surface 16b does not have the second flange outer peripheral surface 15. The reason why the surface 16b parallel to the short side 32 of the rectangular waveguide tube path 3 does not have

the second flange outer peripheral surface 15 which is a recess is that the radio waves leaking through the tube axis A1 and the center 31s of the long side 31 and through the portion parallel to the short side 32 and perpendicular to the long side 31 (the portion shown by the one-dot chain line in FIG. 3) are dominant.

[0023] As shown in FIG. 2 and FIG. 3, in order to reduce or prevent leakage of radio waves, the electric length EL1 from the first opening end 10a of the flange end surface 13 to the second flange outer peripheral surface 15 along the tube radial direction RD is $1/4$ times a free space wavelength λ_0 . In the first embodiment, the electric length EL1 is $1/4$ times the free space wavelength λ_0 , but the electric length EL1 is not limited thereto as long as the oscillating electric field E can be made a node (short) at the first opening end 10a. For example, in the case of $(3\lambda_0/4)$ and $(5\lambda_0/4)$, the electric length EL1 can be set to $(2 \times N + 1)/4$ times the free space wavelength λ_0 . N is an integer of 0 or more, and examples of the value that N can take are 0, 1, 2, 3, 4, 5, ... According to this configuration, even if a gap is formed between the flange end surface 13 of the first waveguide tube 1 and the second waveguide path end surface 23 of the second waveguide tube 2, this gap is opened to the outer side in the tube radial direction, and the length of the gap in the tube radial direction is the electric length EL1. Then, the oscillating electric field E generated in this gap can be made an antinode (open) on the second flange outer peripheral surface 15 and can be made a node (short) at the first opening end 10a. As a result, even if a gap is formed between the first waveguide tube 1 and the second waveguide tube 2, it is possible to suppress leakage of the dominant (most) radio waves toward the outer side in the tube radial direction.

[0024] As shown in FIG. 3, the flange 11 has an insertion hole 17 for passing the fastening member 4 such as a bolt to be fastened to the mating member (second waveguide tube 2) connected to the first waveguide tube 1. The outer peripheral surface of the insertion hole 17 on the outer side in the tube radial direction is an outer peripheral surface (third flange outer peripheral surface 16) other than the second flange outer peripheral surface 15 of the first flange outer peripheral surface 14. The third flange outer peripheral surface 16 is farther from the tube axis A1 than the second flange outer peripheral surface 15. That is, the second flange outer peripheral surface 15 is formed by a recess while leaving the insertion hole 17 through which the fastening member 4 such as a bolt passes. The spacing between the insertion holes 17 is determined by the standard. In the first embodiment, the insertion hole 17 is arranged so as not to overlap the long side 31 when the insertion hole 17 is projected in a direction orthogonal to the long side 31 of the first waveguide path 10. The second flange outer peripheral surface 15 may be arranged by providing a recess in a portion of the flange 11 that overlaps the long side 31 as viewed from a line of sight parallel to the direction orthogonal to the long side 31 of the first waveguide path 10.

[0025] As shown in FIG. 2 and FIG. 3, in the first embodiment, a corner P1 separating the flange end surface 13 and the second flange outer peripheral surface 15 is parallel to the inner peripheral surface (long side 31) of the first waveguide path 10. That is, the second flange outer peripheral surface 15 whose length from the inner peripheral surface (long side 31) of the first waveguide path 10 is the electric length EL1 extends in the tube circumferential direction. Accordingly, it is possible to enhance the effect of suppressing leakage of radio waves. In the first embodiment, the second flange outer peripheral surface 15 formed by a recess is arranged linearly respectively along a pair of long sides 31 of the rectangular waveguide tube path 3. The second flange outer peripheral surfaces 15 are arranged at positions sandwiching the first waveguide path 10 in the cross section in which the pair of long sides 31 appear. As shown in FIG. 4, since the space between the centers 31s of the long sides 31 is the most dominant, the pair of second flange outer peripheral surfaces 15 may sandwich the centers 31s of the long sides 31 and their vicinity. Specifically, the second flange outer peripheral surfaces 15 may be arranged at positions centering on the centers 31s of the long sides 31 and sandwiching the region Ar1, which is 24% of the maximum width W1 of the long side 31, from at least the outer side in the tube radial direction. This is because 60% of the electric power is distributed in this 24% region Ar1. Further, the second flange outer peripheral surfaces 15 may be arranged at positions centering on the centers 31s of the long sides 31 and sandwiching the region Ar1, which is 36% of the maximum width W1 of the long side 31, from at least the outer side in the tube radial direction. This is because 81% of the electric power is distributed in this 36% region Ar1.

[0026] In the first embodiment, the first waveguide tube 1 is connected to the second waveguide tube 2. Similar to the first waveguide tube, the second waveguide tube 2 has the second waveguide path 20 butted against the first waveguide path 10 of the first waveguide tube 1, and a flange 21 extending toward the outer side in the tube radial direction RD from the second opening end 20a of the second waveguide path 20 and fastened to the flange end surface 13 of the first waveguide path 10. That is, both the first waveguide tube 1 and the second waveguide tube 2 are flanged waveguide tubes. Similar to the first waveguide tube 1, the flange 21 of the second waveguide tube 2 has a recess formed on the first flange outer peripheral surface 24 and the second flange outer peripheral surface 25 is formed by the recess, and the first flange outer peripheral surface 24 has the second flange outer peripheral surface 25 and the third flange outer peripheral surface 26. The electric length along the tube radial direction RD from the second opening end 20a to the second flange outer peripheral surface 25 on the second waveguide path end surface 23 is $(2 \times N + 1)/4$ times the free space wavelength λ_0 . Since the recess (second flange outer peripheral surfaces 15, 25) forming the electric length is formed in both the first waveguide

tube 1 and the second waveguide tube 2, it is possible to enhance the effect of suppressing leakage of radio waves as compared with the case where the recess is formed in only one flange.

[0027] The distance D1 between the flange end surface 13 of the first waveguide tube 1 and the second waveguide path end surface 23, which is exemplified in FIG. 2, may be 0.0 mm. However, the effect of suppressing leakage of radio waves is maintained even if the distance D1 exceeds 1.0 mm due to the cumulative value of the tolerances of a plurality of mechanical parts constituting the transmission path. That is, as the acceptable value of the tolerances of the mechanical parts is increased, the flexibility in the mechanical design of the waveguide tube is improved, and since a gap can be tolerated, the assembly work becomes easy.

<Other embodiments>

[0028]

(1) In the first embodiment shown in FIG. 1 to FIG. 4, as shown in FIG. 3, the second flange outer peripheral surface 15 is formed by a rectangular recess as viewed from a line of sight parallel to the tube axis A1, and the second flange outer peripheral surface 15 has a linear shape parallel to the inner peripheral surface (long side 31) of the rectangular waveguide tube path 3, but the disclosure is not limited thereto. For example, in the second embodiment shown in FIG. 5, the second flange outer peripheral surface 15 is formed by an arc-shaped recess as viewed from a line of sight parallel to the tube axis A1, and the second flange outer peripheral surface 15 satisfying the electric length EL1 is narrower in the tube circumferential direction than that in FIG. 3.

(2) In the first embodiment shown in FIG. 1 to FIG. 4, the flange 21 of the second waveguide tube 2 is formed with a recess to form the second flange outer peripheral surface 25, but the flange 21 of the second waveguide tube 2 may not have a recess. It suffices if the first waveguide tube 1 alone can set the electric length from the first opening end 10a to the second flange outer peripheral surface 15 to the above value.

(3) In the first embodiment shown in FIG. 2, the recess of the flange 11 of the first waveguide tube 1 extends entirely in the tube axial direction from the flange end surface 13 to the tube axial direction inner end 11a of the flange 11, but the disclosure is not limited thereto. For example, in the third embodiment shown in FIG. 6, the recess of the flange 11 of the first waveguide tube 1 extends from the flange end surface 13 toward the inner side in the tube axial direction of the flange 11, but does not reach the tube axial direction inner end 11a. As shown in FIG. 6, the second flange outer peripheral surface 15 is a surface formed in a shape in which a part of the

flange end surface 13 in contact with the outer periphery of the flange 11 is recessed toward the inner side in the tube axial direction AD. In the cross section (FIG. 6) shown in FIG. 6, which passes through the tube axis A1 of the first waveguide path 10 and in which the second flange outer peripheral surface 15 appears, the flange 11 has a radial direction extending surface 18 extending from the tube axial direction inner end P2 of the second flange outer peripheral surface 15, which extends from the flange end surface 13 toward the inner side in the tube axial direction AD, toward the outer side in the tube radial direction RD. The flange end surface 13, the second flange outer peripheral surface 15, and the radial direction extending surface 18 form a step. As described above, even if a part of the flange 11 cannot be completely formed into a recessed shape in the tube axial direction AD, it is still possible to form the second flange outer peripheral surface 15 and to suppress the leakage of radio waves. The length D2 from the flange end surface 13 to the radial direction extending surface 18 (the tube axial direction inner end P2 of the second flange outer peripheral surface 15) in the tube axial direction may be 2.0 mm or more, or may be 5.0 mm or more if the frequency is around 9.5 GHz.

(4) In the first embodiment, the tube path is the rectangular waveguide tube path 3 whose tube cross section has the long sides 31 and the short sides 32, but the disclosure is not limited thereto. For example, as in the fourth embodiment shown in FIG. 7, the first waveguide path 10 of the first waveguide tube may be a circular waveguide tube path 103 that has a circular tube cross section. The second flange outer peripheral surface 15 formed by a recess or a step is arranged at a position that is axisymmetric with the tube axis A1 of the first waveguide path 10 as the axis of symmetry. In the example shown in FIG. 7, the corner P1 separating the flange end surface 13 and the second flange outer peripheral surface 15 is parallel to the inner peripheral surface of the first waveguide path 10, and is formed in an arc shape parallel to the arc-shaped inner peripheral surface of the first waveguide path 10 as viewed from a line of sight parallel to the tube axis A1. Of course, as shown in FIG. 5, the corner P1 may not be parallel to the inner peripheral surface of the first waveguide path 10.

(5) In the first embodiment shown in FIG. 1, the mating member to which the first waveguide tube 1 is connected is the second waveguide tube, but the mating member is not necessarily a waveguide tube. For example, as in the fifth embodiment shown in FIG. 8, the mating member 5 may be an object other than a tube such as a housing of a device. As shown in FIG. 8, the mating member 5 includes a housing 50 having the second waveguide path 20 butted against the first waveguide path 10 of the first

waveguide tube 1, and the second waveguide path end surface 23 extending from the second opening end 20a of the second waveguide path 20 in the housing 50 toward the outer side in the tube radial direction of the first waveguide tube 1. The housing 50 has a fastening hole 37 such as a screw hole or a bolt hole for fixing the fastening member that passes through the insertion hole 17 of the first waveguide tube 1. The second waveguide path end surface 23 of the mating member 5 is wider in the tube radial direction than the flange 11 of the first waveguide tube 1. Even in such a connection form, the second flange outer peripheral surface 15 is formed, so that the electric length EL1 of the gap in the tube radial direction that can be formed between the flange end surface 13 and the second waveguide path end surface 23 is $(2 \times N + 1)/4$ times the free space wavelength λ_0 . Therefore, it is possible to effectively suppress leakage of radio waves.

(6) As in the first to fifth embodiments, the second flange outer peripheral surface 15 extends toward the inner side in the tube axial direction in parallel to the tube axial direction from the tube radial direction outer end (PI) of the flange end surface 13, but the disclosure is not limited thereto. For example, the second flange outer peripheral surface 15 may extend toward the inner side in the tube axial direction while being inclined with respect to the tube axial direction from the tube radial direction outer end (PI) of the flange end surface 13.

[0029] As described above, like the waveguide tube connecting members of the first to fifth embodiments, the first waveguide tube 1 having the first waveguide path 10 for transmitting a high frequency and the flange 11 may be provided, and the flange 11 may have the flange end surface 13 extending from the first opening end 10a of the first waveguide path 10 toward the outer side in the tube radial direction RD, and the second flange outer peripheral surface 15 which is a part of the first flange outer peripheral surface 14 extending from the flange end surface 13 toward the inner side in the tube axial direction AD and released to the outer side in the tube radial direction RD. The second flange outer peripheral surface may be a surface formed in a shape in which a part of the flange end surface 13 in contact with the outer periphery of the flange is recessed (has a cavity) toward the inner side in the tube axial direction AD, or a surface formed in a shape in which a part of the first flange outer peripheral surface of the flange 11 is recessed (has a cavity) toward the inner side in the tube radial direction RD. The electric length from the first opening end 10a of the flange end surface 13 to the second flange outer peripheral surface 15 along the tube radial direction RD may be $(2 \times N + 1)/4$ times the free space wavelength λ_0 , and N may be an integer of 0 or more.

[0030] When connecting the flange of the first waveguide tube 1 to the second waveguide tube 2 or the

mating member 5 with the fastening member 4 such as a bolt, the second waveguide path end surface 23 of the second waveguide tube 2 or the mating member 5 and the flange end surface 13 are to be disposed in contact with each other without any gap formed therebetween, but a gap may be formed. Nevertheless, according to this configuration, even if a gap is formed between the flange end surface 13 and the second waveguide path end surface 23, the second flange outer peripheral surface 15 is opened to the outer side in the tube radial direction RD, so that this gap is opened to the outer side in the tube radial direction RD and the length of the gap in the tube radial direction RD is determined by the electric length. If the electric length along the tube radial direction RD of the gap that is opened in the tube radial direction RD is set to $(2 \times N + 1)/4$ times the free space wavelength λ_0 such as $(\lambda_0/4)$, $(3\lambda_0/4)$, $(5\lambda_0/4)$, etc., the oscillating electric field E generated in this gap can be made an antinode (open) on the second flange outer peripheral surface 15, and can be made a node (short) at the first opening end 10a. As a result of the oscillating electric field E becoming a node (short) at the first opening end 10a, it is possible to suppress leakage of radio waves toward the outer side in the tube radial direction RD even if a gap is formed.

[0031] Although not particularly limited, like the waveguide tube connecting members of the first to fifth embodiments, the flange 11 may have the insertion hole 17 for passing the fastening member 4 to be fastened to the mating member [second waveguide tube 2, mating member 5], to which the first waveguide tube 1 is connected. The outer peripheral surface of the insertion hole 17 on the outer side in the tube radial direction RD may be an outer peripheral surface (third flange outer peripheral surface 16) other than the second flange outer peripheral surface 15 of the first flange outer peripheral surface 14. According to this configuration, since the second flange outer peripheral surface is formed by a recess while leaving the insertion hole 17 through which the fastening member 4 such as a bolt passes, it is possible to suppress leakage of radio waves with the second flange outer peripheral surface 15 while ensuring the connection compatibility of the fastening member 4 with other members and the rigidity of the flange 11.

[0032] Although not particularly limited, like the waveguide tube connecting members of the first to fifth embodiments, the corner P1 separating the flange end surface 13 and the second flange outer peripheral surface 15 may be parallel to the inner peripheral surface of the first waveguide path 10 as viewed from a line of sight parallel to the tube axis A1 of the first waveguide path 10. According to this configuration, since the portion where the electric length EL1 from the inner peripheral surface (first opening end 10a) of the first waveguide path 10 to the second flange outer peripheral surface 15 is $(2 \times N + 1)/4$ of the free space wavelength λ_0 extends and spreads in the tube circumferential direction, it is possible to further suppress or prevent leakage of radio waves.

[0033] Although not particularly limited, like the waveguide tube connecting members of the first, second, fourth, and fifth embodiments, in the cross section (FIG. 2) which passes through the tube axis A1 of the first waveguide path 10 and in which the second flange outer peripheral surface 15 appears, the second flange outer peripheral surface 15 may extend from the flange end surface 13 to the tube axial direction inner end 11a of the flange end surface 13, and in the cross section, the second flange outer peripheral surface 15 may be the outermost surface in the tube radial direction RD. According to this configuration, since the second flange outer peripheral surface 15 is the outermost surface in the tube radial direction RD in the cross section, the flange 11 is all cut out in the tube axial direction AD. Since the gap that can be formed between the flange end surface 13 and the second waveguide path end surface 23 becomes a space completely opened in the tube radial direction RD, it is possible to further suppress or prevent leakage of radio waves.

[0034] Although not particularly limited, like the waveguide tube connecting member of the third embodiment, in the cross section which passes through the tube axis A1 of the first waveguide path 10 and in which the second flange outer peripheral surface 15 appears, the flange 11 may have the radial direction extending surface 18 extending from the inner end in the tube axial direction AD of the second flange outer peripheral surface 15, which extends from the flange end surface 13 toward the inner side in the tube axial direction AD, toward the outer side in the tube radial direction RD. The flange end surface 13, the second flange outer peripheral surface 15, and the radial direction extending surface 18 may form a step. According to this configuration, the second flange outer peripheral surface 15 can be formed by forming the step. Since the flange 11 has the portion that is not cut out on the inner side in the tube axial direction AD with respect to the radial direction extending surface 18, even if the flange 11 cannot be completely cut out, the electric length EL1 in the tube radial direction RD of the gap that can be formed between the flange end surface 13 and the second waveguide path end surface 23 can be set to $(2 \times N + 1)/4$ of the free space wavelength λ_0 , and it is possible to suppress or prevent leakage of radio waves.

[0035] Although not particularly limited, like the waveguide tube connecting members of the first to third embodiments, the first waveguide path 10 may be the rectangular waveguide tube path 3 whose tube cross section has the long sides 31 and the short sides 32, and the second flange outer peripheral surface 15 may be arranged on the outer side of the long side 31 in the tube radial direction RD. According to this configuration, it is possible to appropriately suppress leakage of a high frequency in the rectangular waveguide tube path 3.

[0036] Although not particularly limited, like the waveguide tube connecting member of the fourth embodiment, the first waveguide path 10 may be the circular waveguide tube path 103 that has a circular tube cross

section, and the second flange outer peripheral surface 15 may be arranged at a position that is axisymmetric with the tube axis A1 of the first waveguide path 10 as the axis of symmetry. According to this configuration, since the circular waveguide tube path 103 has the largest electric field along an arbitrary radial direction RD passing through the tube axis A1, it is possible to appropriately suppress leakage of a high frequency.

[0037] Although not particularly limited, like the waveguide tube connecting members of the first to fourth embodiments, the second waveguide tube 2 may be further provided, and the second waveguide tube 2 may have the second waveguide path 20 butted against the first waveguide path 10 of the first waveguide tube 1, and the flange 21 extending from the second opening end 20a of the second waveguide path 20 toward the outer side in the tube radial direction RD and fastened to the flange end surface 13 of the first waveguide tube 1. In this way, it is applicable to fasten the flange 11 of the first waveguide tube 1 and the flange 21 of the second waveguide tube 2.

[0038] Although not particularly limited, like the waveguide tube connecting member of the fifth embodiment, the mating member 5 to which the first waveguide tube 1 is connected may be further provided, and the mating member 5 may have the second waveguide path butted against the first waveguide path 10 of the first waveguide tube 1, and the second waveguide path end surface 23 extending from the second opening end 20a of the second waveguide path 20 toward the outer side in the tube radial direction RD. The second waveguide path end surface 23 of the mating member 5 may be wider in the tube radial direction RD than the flange 11 of the first waveguide tube 1. In this way, it is applicable to fasten the flange 11 of the first waveguide tube 1 to a member larger than the flange 11 of the first waveguide tube 1, for example, the mating member 5 such as a housing of a device.

[0039] Although the embodiments of the disclosure have been described above with reference to the drawings, it should be considered that the specific configuration is not limited to these embodiments. The scope of the disclosure is set forth not only by the description of the embodiments above but also by the scope of the claims, and further includes all modifications within the meaning and scope equivalent to the scope of the claims.

[0040] It is possible to adopt the structure adopted in each of the above embodiments in any other embodiment.

[0041] The specific configuration of each part is not limited to the embodiments described above, and various modifications can be made without departing from the gist of the disclosure.

Claims

1. A waveguide tube connecting member, comprising:

a first waveguide tube (1) comprising a first waveguide path (10) for transmitting a high frequency and a flange (11),

wherein the flange (11) has a flange end surface (13) extending from a first opening end (10a) of the first waveguide path (10) toward an outer side in a tube radial direction (RD), and a second flange outer peripheral surface (15) which is a part of a first flange outer peripheral surface (14) extending from the flange end surface (13) toward an inner side in a tube axial direction (AD) and released to the outer side in the tube radial direction (RD),

the second flange outer peripheral surface (15) is a surface formed in a shape in which a part of the flange end surface (13) in contact with an outer periphery of the flange (11) has a cavity toward the inner side in the tube axial direction (AD), or a surface formed in a shape in which a part of the first flange outer peripheral surface (14) of the flange (11) has a cavity toward an inner side in the tube radial direction (RD), and an electric length from the first opening end (10a) of the flange end surface (13) to the second flange outer peripheral surface (15) along the tube radial direction (RD) is $(2 \times N + 1)/4$ times a free space wavelength λ_0 , wherein N is an integer of 0 or more.

2. The waveguide tube connecting member according to claim 1, wherein the flange (11) has an insertion hole (17) for fastening a mating member (2, 5) to which the first waveguide tube (1) is connected, and an outer peripheral surface of the insertion hole (17) on the outer side in the tube radial direction (RD) is an outer peripheral surface (16) other than the second flange outer peripheral surface (15) of the first flange outer peripheral surface (14).

3. The waveguide tube connecting member according to claim 1 or 2, wherein the second flange outer peripheral surface (15) is parallel to an inner peripheral surface of the first waveguide path (10) as viewed from a line of sight parallel to a tube axis (A1) of the first waveguide path (10).

4. The waveguide tube connecting member according to any one of claims 1 to 3, wherein the cavity fully penetrates through the flange (11) parallel to the tube axis of the first waveguide path (10), and the second flange outer peripheral surface (15) of the second flange is the outermost surface in the tube radial direction (RD).

5. The waveguide tube connecting member according to any one of claims 1 to 3, wherein

the cavity forms a step on the flange end surface

(13) partially penetrating through the flange (11),
and
the outer peripheral surface of the step corresponds to the second flange outer peripheral surface (15).

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6. The waveguide tube connecting member according to any one of claims 1 to 5, wherein the first waveguide path (10) is a rectangular waveguide tube path (3) whose tube cross section has a long side (31) and a short side (32), and the second flange outer peripheral surface (15) is arranged on the outer side of the long side (31) in the tube radial direction (RD).

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7. The waveguide tube connecting member according to any one of claims 1 to 5, wherein the first waveguide path (10) is a circular waveguide tube path (103) having a circular tube cross section, and the second flange outer peripheral surface (15) is arranged at a position that is pointsymmetric with a center of the circular tube cross section as a point of symmetry.

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8. The waveguide tube connecting member according to any one of claims 1 to 7, further comprising a second waveguide tube (2), wherein the second waveguide tube (2) comprises:

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a second waveguide path (20) butted against the first waveguide path (10) of the first waveguide tube (1); and
a flange (21) extending from a second opening end (20a) of the second waveguide path (20) toward the outer side in the tube radial direction (RD) and fastened to the flange end surface (13) of the first waveguide tube (1).

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9. The waveguide tube connecting member according to any one of claims 1 to 7, further comprising a mating member (5) to which the first waveguide tube (1) is connected, wherein the mating member (5) comprises:

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a second waveguide path (20) butted against the first waveguide path (10) of the first waveguide tube (1); and
a second waveguide path end surface (23) extending from a second opening end (20a) of the second waveguide path (20) toward the outer side in the tube radial direction (RD), wherein the second waveguide path end surface (23) of the mating member (5) is wider in the tube radial direction (RD) than the flange (11) of the first waveguide tube (1).

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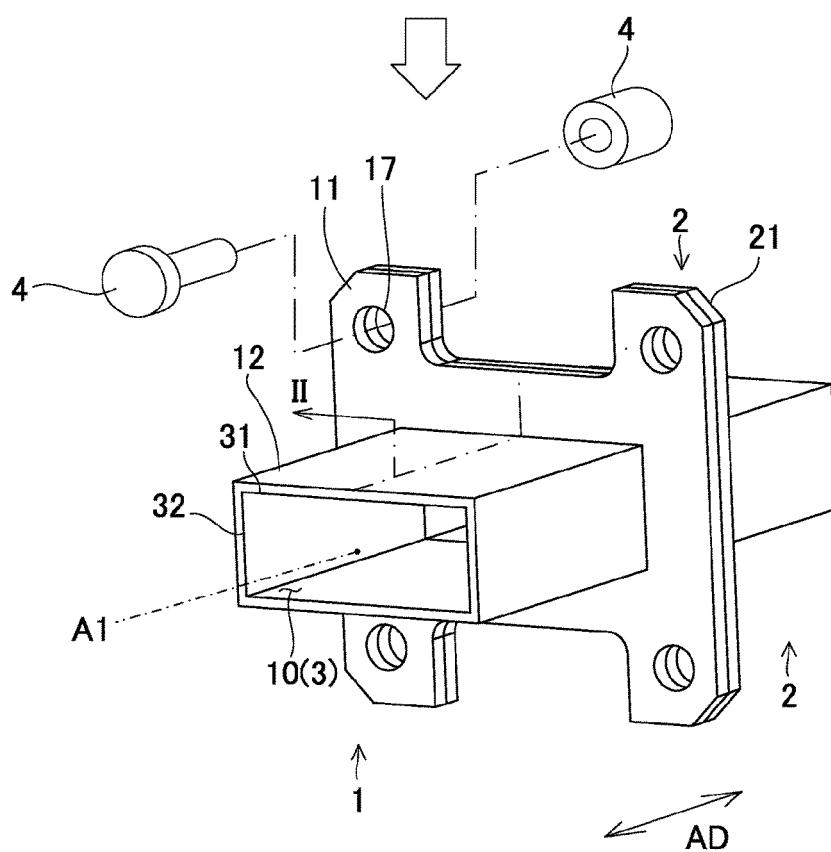
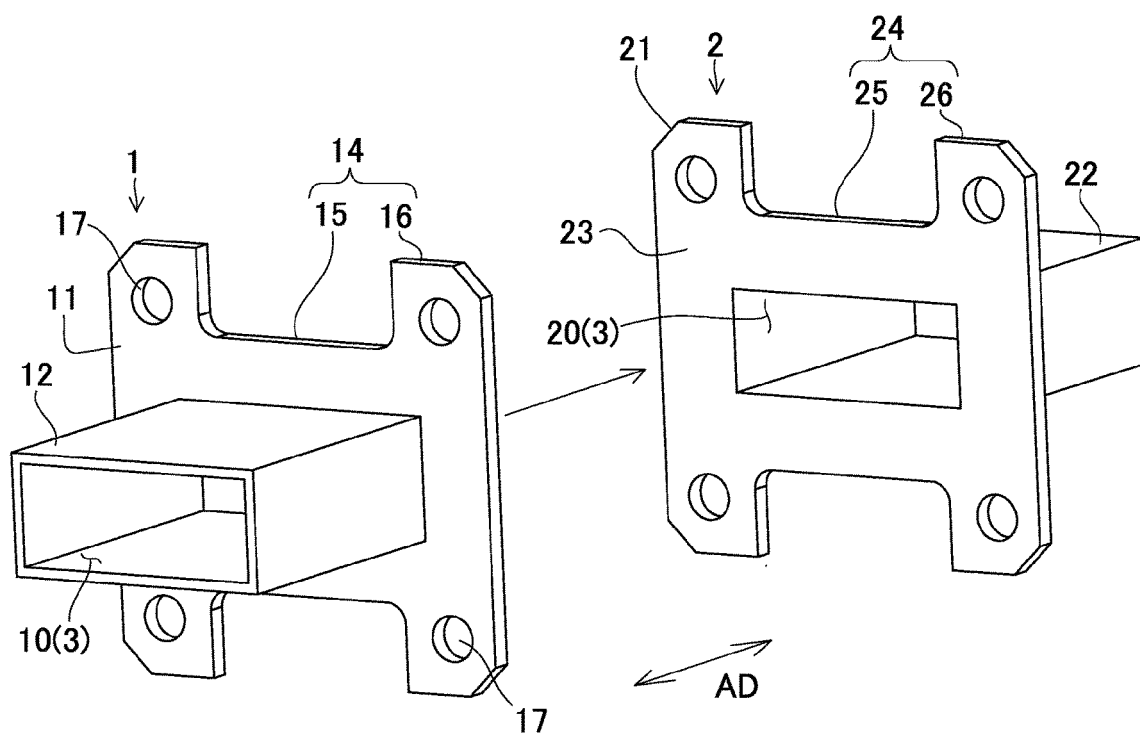


FIG. 1

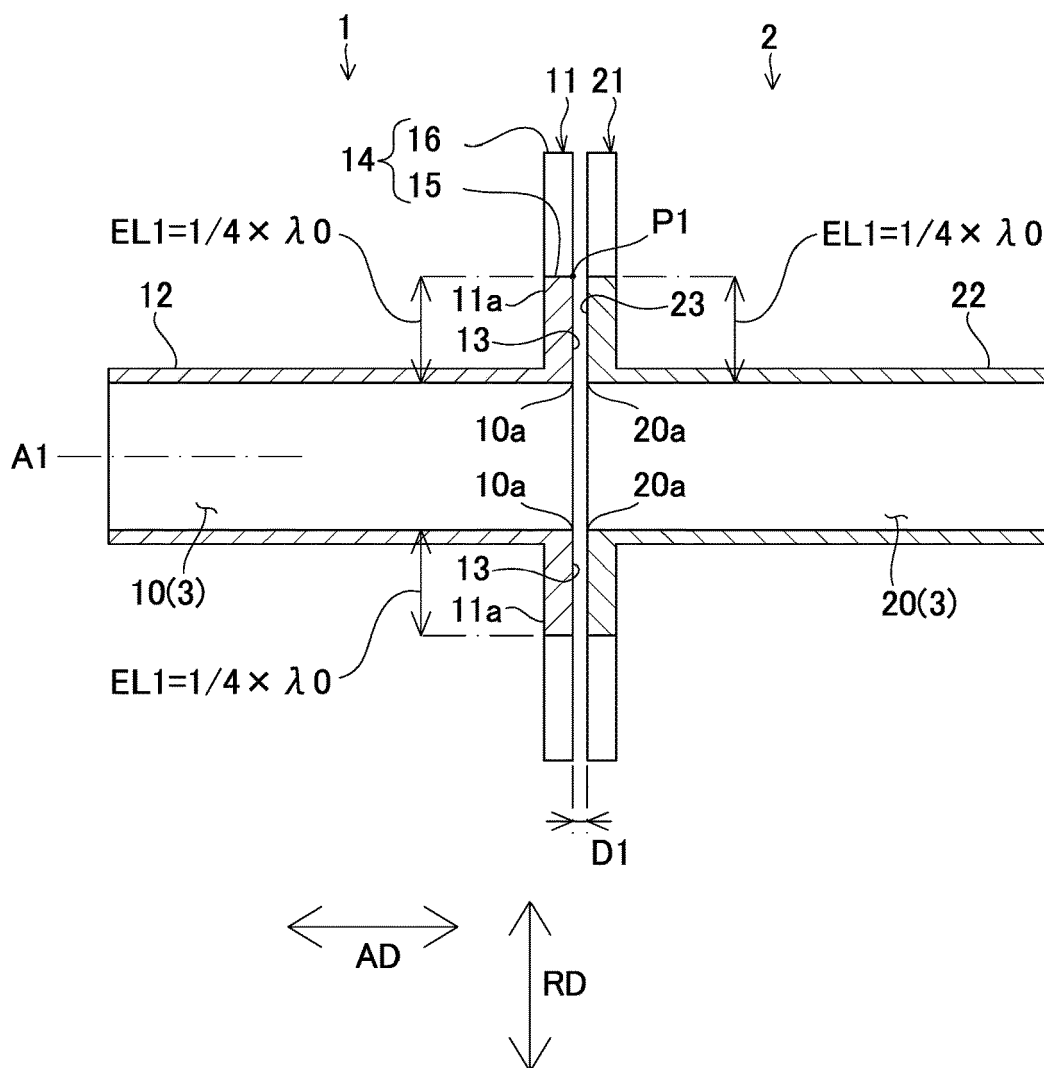


FIG. 2

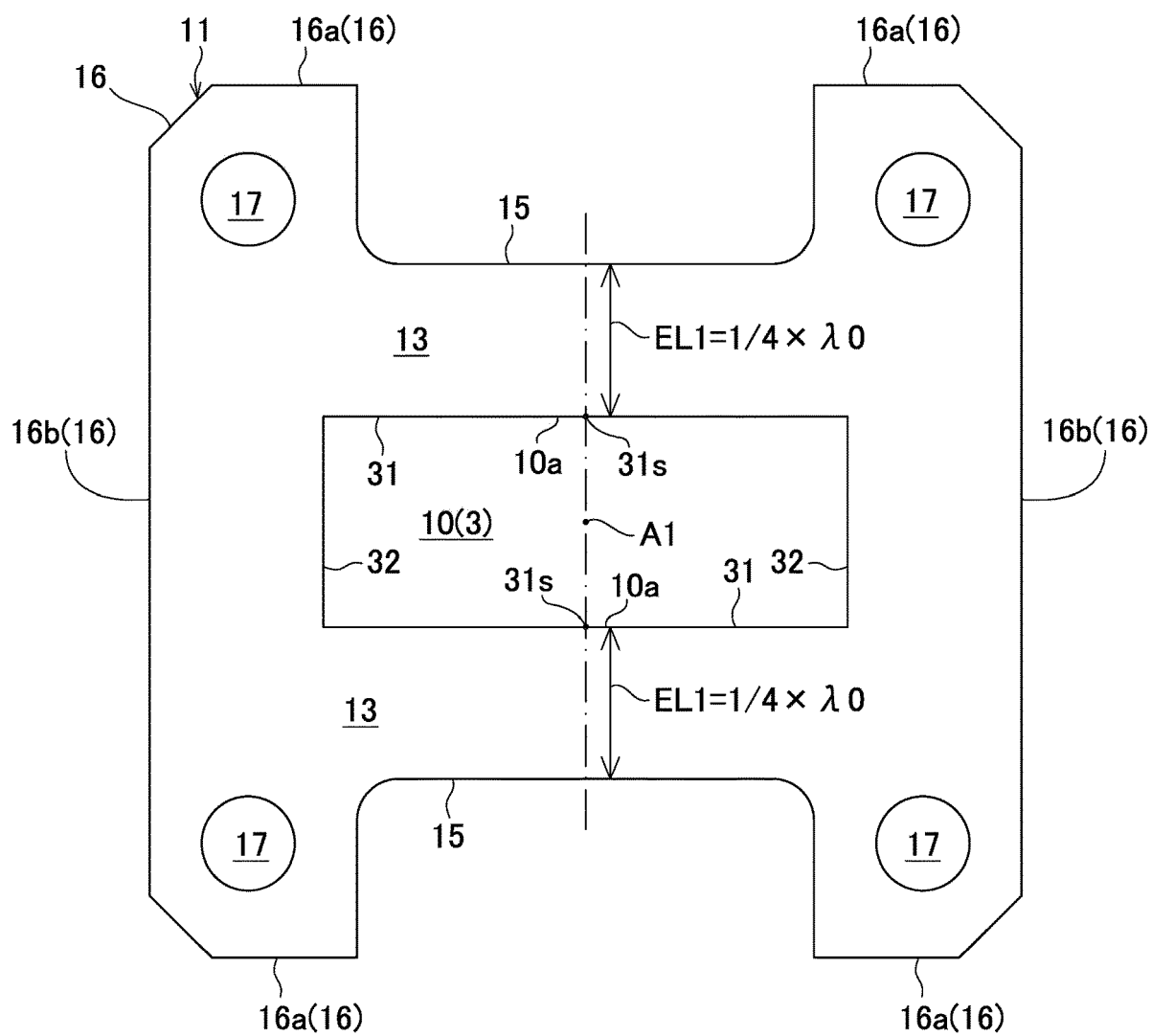


FIG. 3

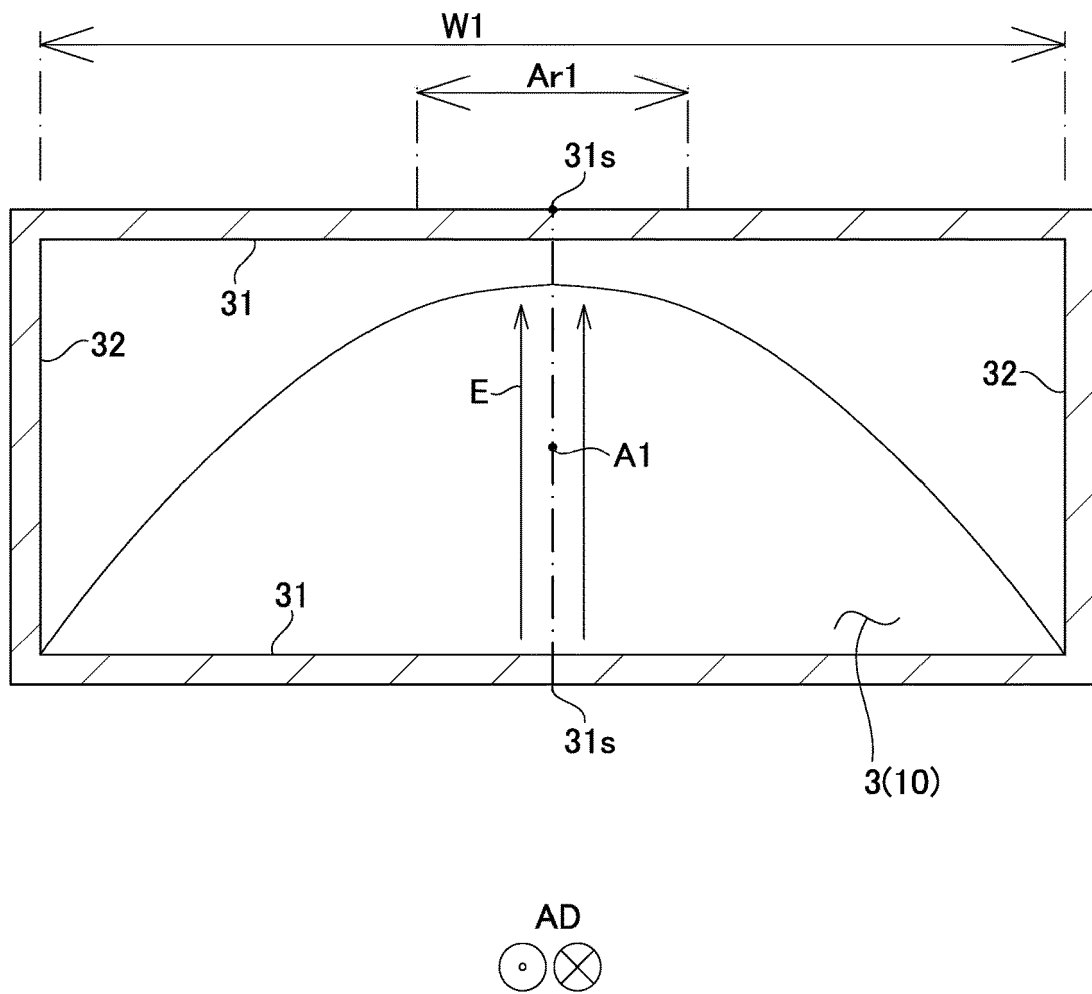


FIG. 4

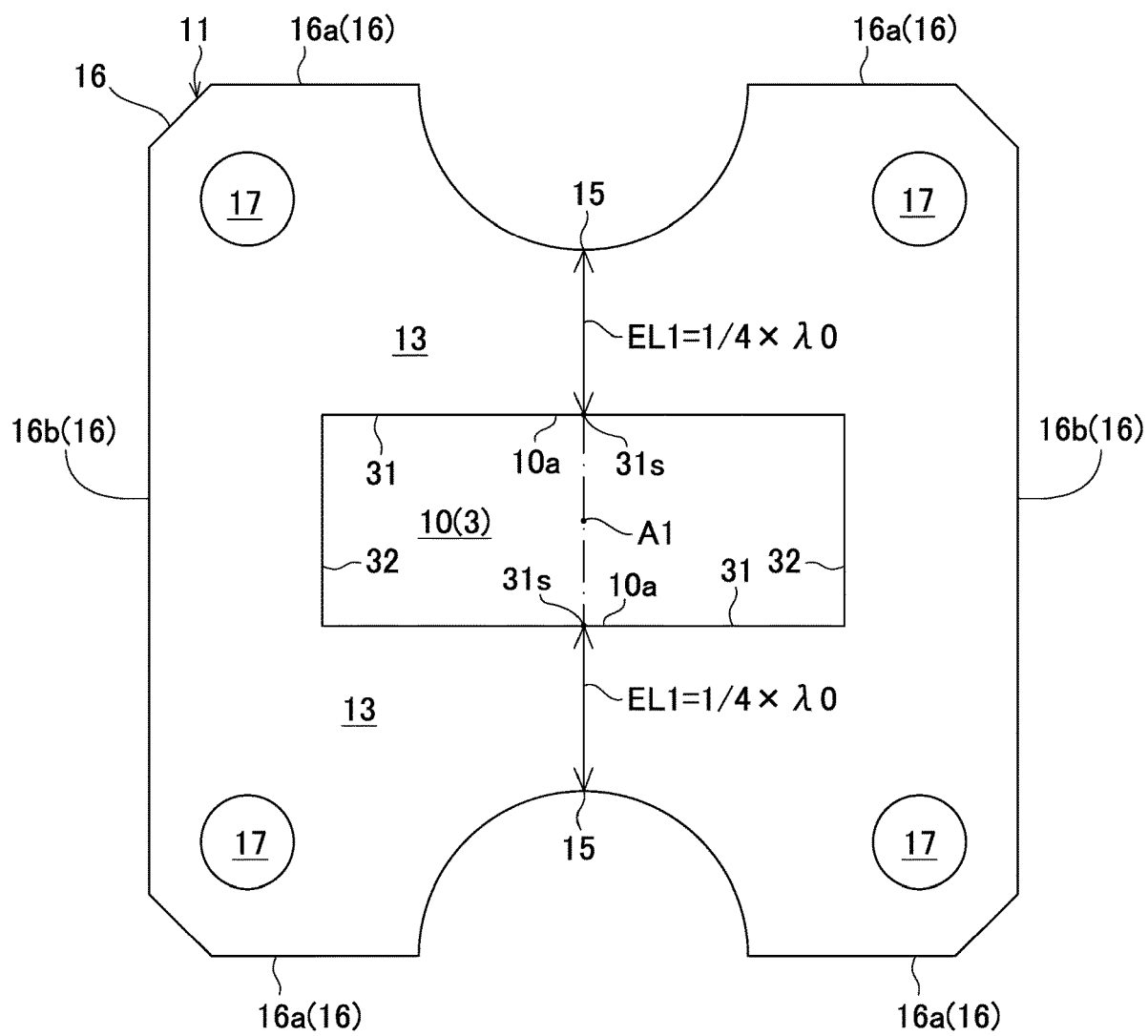


FIG. 5

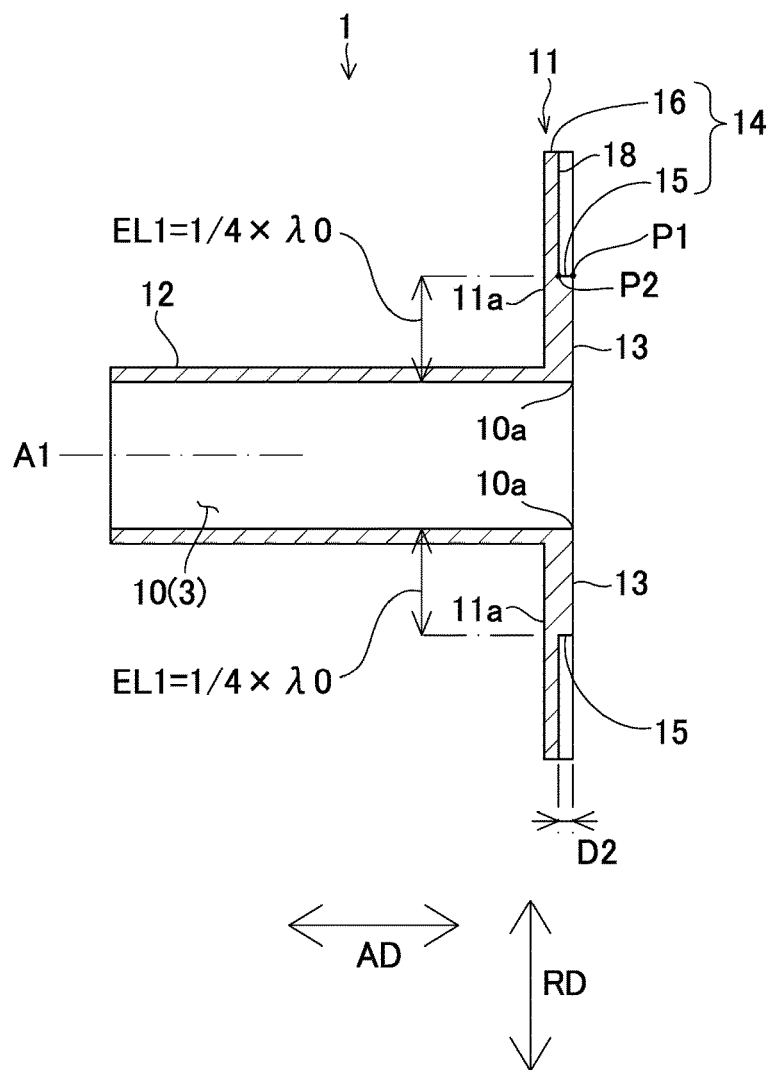


FIG. 6

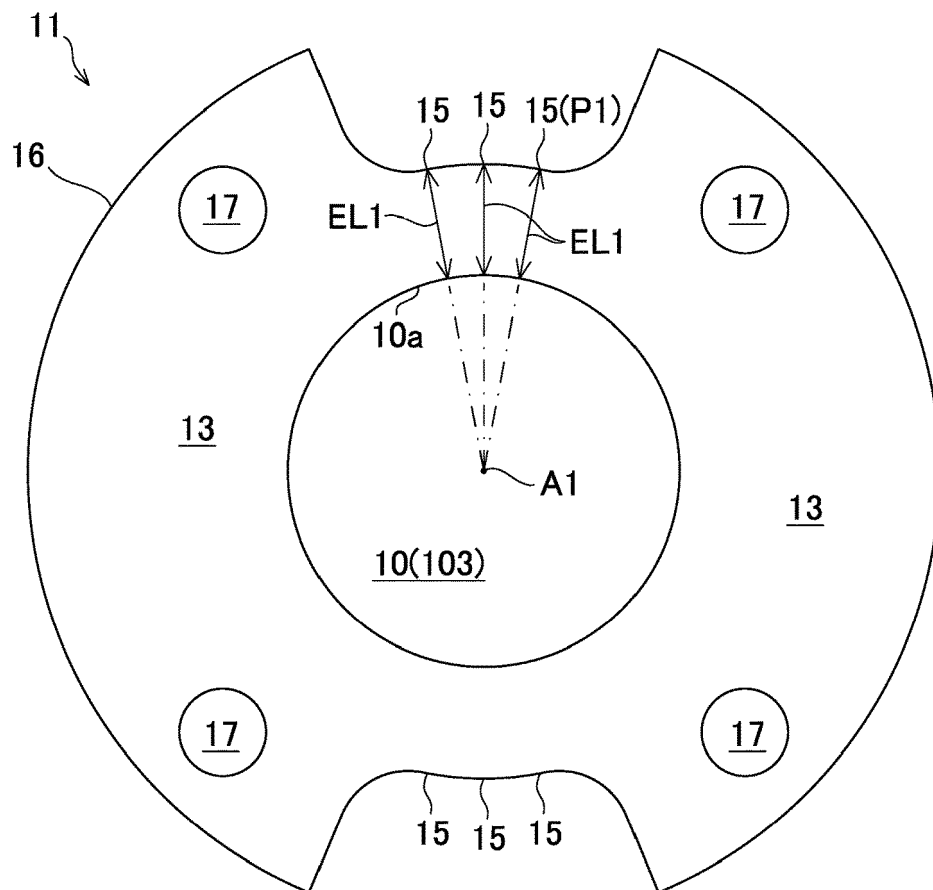


FIG. 7

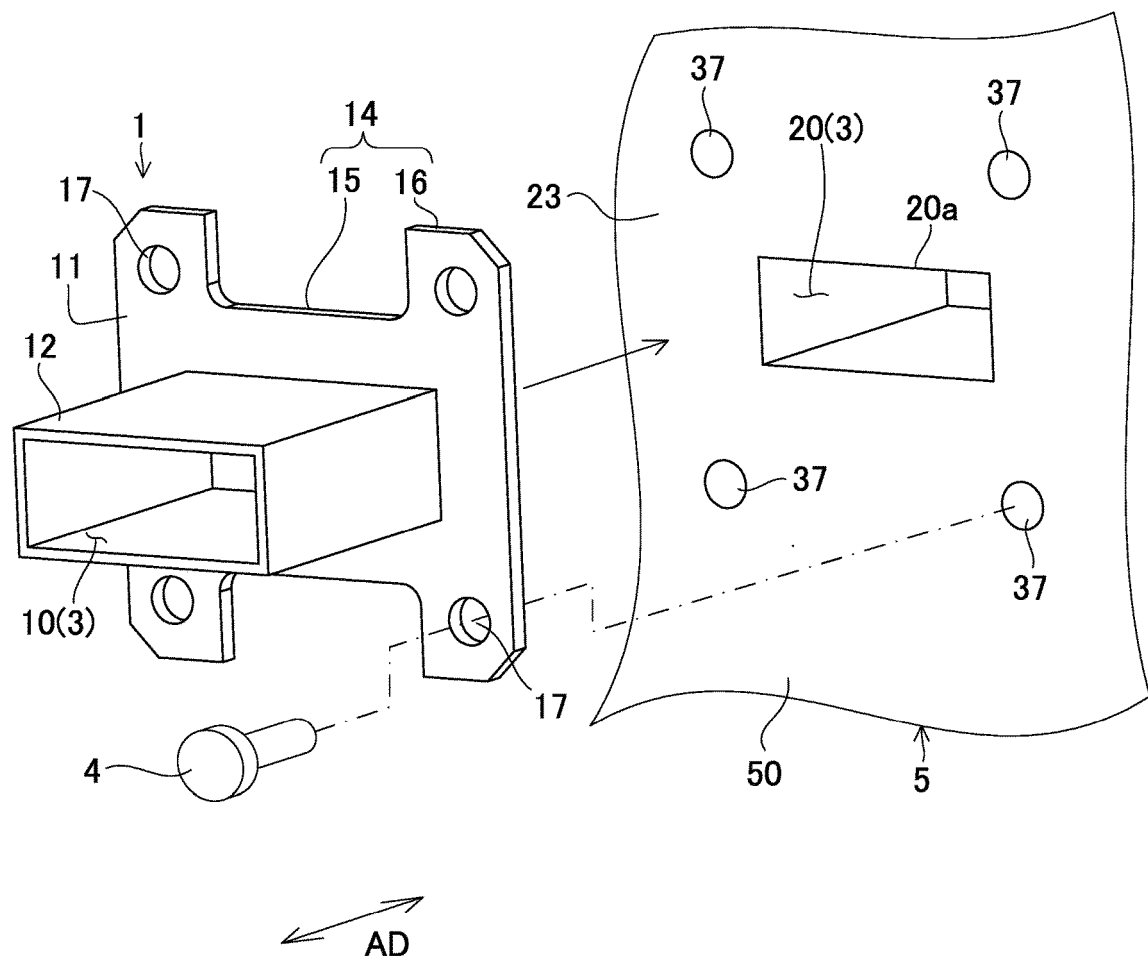


FIG. 8



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Place of search The Hague		Date of completion of the search 18 October 2022	Examiner Kalialakis, Christos
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The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
The Hague		18 October 2022	Kalialakis, Christos
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