

(57) Abstract: A waveguide-type distributor of the present invention comprises: a first waveguide-type resonator configured to make an inputted electromagnetic wave resonate; an input waveguide portion configured to input the electromagnetic wave to the first waveguide-type resonator; a second waveguide-type resonator configured to make an electromagnetic wave resonate; an output waveguide portion configured to output each electromagnetic wave from the first waveguide-type resonator and the second waveguide-type resonator, respectively; and a waveguide-type phase shifter, arranged between the first waveguide-type resonator and the second waveguide-type resonator and electrically connected to both the first waveguide-type resonator and the second waveguide-type resonator through an iris, respectively, configured to adjust the phase of the inputted electromagnetic wave from the first waveguide-type resonator and output the adjusted electromagnetic wave to the second waveguide-type resonator.

Description

Title of Invention: WAVEGUIDE-TYPE POWER DISTRIBUTOR, WAVEGUIDE-TYPE COMBINER, ANTENNA APPARATUS AND RADAR EQUIPMENT

Technical Field

[0001] The present invention relates to a waveguide-type power distributor, a waveguide-type combiner, an antenna apparatus, and radar equipment.

Background Art

[0002] Patent Document 1 discloses a waveguide-type Wilkinson power distributor.

Citation List

Patent Literature

[0003] PTL 1: Japanese patent No.5755546

Summary of Invention

Technical Problem

[0004] Further improvements in designability are desired for power distributors and power combiners.

[0005] The present invention has been made in view of the above problems, and its main object is to provide a waveguide-type power distributor, a waveguide-type power combiner, an antenna device, and a radar having excellent designability.

Solution to Problem

[0006] To solve the problem, the waveguide-type power distributor according to one aspect of the present invention comprise: a first waveguide-type resonator for making an inputted electromagnetic wave resonate; an input waveguide portion for inputting the electromagnetic wave to the first waveguide-type resonator; a second waveguide-type resonator for making an inputted electromagnetic wave resonate; an output waveguide portion for outputting each electromagnetic wave from the first waveguide-type resonator and the second waveguide-type resonator, respectively. The waveguide-type power distributor further comprises a phase shifter which is arranged between the first waveguide-type resonator and the second waveguide-type resonator and electrically connected to both the first waveguide-type resonator and the second waveguide-type resonator through an iris, respectively. The waveguide-type phase shifter adjusts the phase of the inputted electromagnetic wave from the first waveguide-type resonator and output the adjusted electromagnetic wave to the second waveguide-type resonator.

[0007] The waveguide-type power distributor may comprise: a plurality of waveguide-type resonator configured to make an inputted electromagnetic wave resonate; an input

waveguide portion configured to input the electromagnetic wave to one of the waveguide-type resonator; an output waveguide portion configured to output each electromagnetic wave from the plurality of waveguide-type resonator, respectively; and a plurality of phase shifter, in which two waveguide resonators among the plurality of waveguide resonator are arranged between each other and are sequentially electrically connected, configured to adjust the phase of the inputted electromagnetic wave from the waveguide-type resonator and output the adjusted electromagnetic wave to the adjacent waveguide-type resonator.

- [0008] The waveguide-type phase shifter may adjust the phase of the inputted electromagnetic wave from the first waveguide-type resonator and output the adjusted electromagnetic wave to the second waveguide-type resonator. Here, the length of the waveguide-type phase shifter in the direction in which the electromagnetic wave propagates may be an integer multiple of $\lambda/2$ of the wavelength of the electromagnetic wave.
- [0009] The waveguide-type power distributor of the present invention comprises: a plurality of waveguide-type resonator that makes an inputted electromagnetic wave resonate; an input waveguide portion that inputs the electromagnetic wave to one of the waveguide-type resonator; an output waveguide portion that outputs each electromagnetic wave from the plurality of waveguide-type resonator, respectively; and a plurality of waveguide-type phase shifter, in which two waveguide resonators among the plurality of waveguide resonator are arranged between each other and are sequentially electrically connected, configured to adjust the phase of the inputted electromagnetic wave from the waveguide-type resonator and output the adjusted electromagnetic wave to the adjacent waveguide-type resonator.
- [0010] The waveguide-type power distributor of the present invention comprises: an input waveguide configured to be inputted an electromagnetic wave; a first waveguide-type resonator configured to be connected to the input waveguide; a first output waveguide configured to be connected to the first waveguide-type resonator; a first waveguide-type phase shifter configured to be connected to the first waveguide resonator; a second waveguide-type resonator configured to be connected to the first waveguide phase shifter; and a second output waveguide configured to be connected to the second waveguide resonator.
- [0011] The waveguide-type power distributor of the present invention may further include a second waveguide-type phase shifter may be connected to the second waveguide resonator; a third waveguide-type resonator configured to be connected to the second waveguide phase shifter; and a third output waveguide connected to the third waveguide resonator.
- [0012] The input waveguide, the first waveguide-type resonator, the first output waveguide,

the first waveguide-type phase shifter, the second waveguide-type resonator, and the second output waveguide may be connected to each other through an iris formed on the opposing pair of H-planes.

[0013] The input waveguide, the first waveguide-type resonator, the first output waveguide, the first waveguide-type phase shifter, the second waveguide-type resonator, and the second output waveguide may have a common E-plane.

[0014] The input waveguide, the first waveguide-type resonator, the first output waveguide, the first waveguide-type phase shifter, the second waveguide-type resonator and the second output waveguide may be formed by concave portions formed on the surface of a block; and may further include a cover configured to cover the concave portion in contact with the surface of the block.

[0015] The first waveguide-type resonator may include: an input side resonator connected to the input waveguide; and an output side resonator connected to the first output waveguide. Also, the second waveguide-type resonator may include: an input side resonator connected to the first waveguide-type phase shifter; and an output side resonance part connected to the second output waveguide.

[0016] The first output waveguide may be positioned perpendicular to the E-plane of the first waveguide-type resonator, electrically connected, and the second output waveguide may be positioned perpendicular to the E-plane of the second waveguide-type resonator, electrically connected.

[0017] The first output waveguide and the second output may include a part formed a horn shape with an opening extending in the direction of outputting electromagnetic waves, respectively.

[0018] The waveguide-type power distributor may include: a block and a cover configured to cover the block. The input waveguide, the first waveguide-type resonator, the first waveguide-type phase shifter and the second waveguide-type resonator are formed by concave portions formed on the surface of the block; and the iris respectively connected to the first output waveguide and the second output waveguide are formed on the cover. The first output waveguide and the second output waveguide may be formed on the cover.

[0019] The radar equipment of the present invention comprises: an electromagnetic wave generator configured to generate an electromagnetic wave; a waveguide-type power distributor, including: a first waveguide-type resonator configured to make an inputted electromagnetic wave resonate; an input waveguide portion configured to input the electromagnetic wave to the first waveguide-type resonator; a second waveguide-type resonator configured to make an electromagnetic wave resonate; an output waveguide portion configured to output each electromagnetic wave from the first waveguide-type resonator and the second waveguide-type resonator, respectively; and a waveguide-

type phase shifter, arranged between the first waveguide-type resonator and the second waveguide-type resonator and electrically connected to both the first waveguide-type resonator and the second waveguide-type resonator through an iris, respectively, configured to adjust the phase of the inputted electromagnetic wave from the first waveguide-type resonator and output the adjusted electromagnetic wave to the second waveguide-type resonator.

Brief Description of Drawings

- [0020] [Fig.1]Figure 1 shows an example of basic configuration of radar equipment.
[Fig.2]Figure2 is an exploded perspective view showing an example of a waveguide-type power distributor.
[Fig.3]Figure 3 is a plan view showing an example of a block.
[Fig.4]Figure 4 is a plan view showing an example of a waveguide-type power distributor.
[Fig.5]Figure 5 is a plan view showing an example of a waveguide-type power distributor.
[Fig.6]Figure 6 is a perspective view showing an example of a waveguide-type power distributor.
[Fig.7]Figure 7 is a plan view showing an example of a waveguide-type power distributor.
[Fig.8]Figure 8 is an exploded perspective view showing an example of a waveguide-type power distributor.
[Fig.9]Figure 9 is a plan view showing an example of a block.
[Fig.10]Figure 10 is a plan view showing an example of a cover.
[Fig.11]Figure 11 is an exploded perspective view showing an example of a waveguide-type power distributor.

Description of Embodiments

- [0021] Embodiments of the present invention will now be described with reference to the drawings. In the present specification and the figures, elements like those described above with respect to the previous figures may be denoted by the same reference numerals and detailed descriptions may be omitted accordingly.

Radar

- [0022] Figure 1 is a block diagram showing a configuration example of a radar equipment 100 according to an embodiment. Radar equipment 100 includes an antenna apparatus 10 according to the embodiment. In addition to the antenna apparatus 10, the radar equipment 100 also includes a transmitter/receiver 11, a signal processor12, and a controller 13.
- [0023] The transmitter/receiver 11 includes a modulator and a magnetron, and intermittently

drives the magnetron with a pulse voltage generated by the modulator in response to a trigger signal from the signal processor 12 to generate a transmission signal. The antenna apparatus 10 transmits a transmission signal from the transmitter/receiver 11 as an electromagnetic wave pulse.

- [0024] The antenna apparatus 10 converts the received reflected wave into a received signal. The received signal from the antenna apparatus 10 is processed by the signal processor 12 through a frequency conversion/amplification circuit and a detection circuit included in the transmitter/receiver 11 and sent to the controller 13 as a digital signal.
- [0025] The radar equipment 100 is, for example, a marine radar that transmits and receives microwaves. The radar equipment 100 may be, for example, an on-board radar for obstacle detection or collision prevention that transmits and receives millimeter waves.
- [0026] The antenna apparatus 10 is a waveguide-type power distributor 1 according to the embodiment described below. The antenna apparatus includes a waveguide-type power distributor 1. Note that the waveguide-type power distributor 1 also serves as a waveguide-type power combiner according to the embodiment. That is, the input-output relationship can be replaced.

First embodiment

- [0027] Figure 2 is an exploded perspective view showing an example of the waveguide type power distributor 1A according to the first embodiment. Figure 3 is a plan view showing an example of a block 2 included in the waveguide type power distributor 1A. In FIG. 3, the upper surface 25 of the block 2 is hatched.
- [0028] The arrow E in FIG. 2 indicates the electric field direction of the electromagnetic wave propagating in the waveguide type power distributor 1A. The electromagnetic wave propagates in TE mode. In the following description, the plane orthogonal to the electric field direction is called the "E-plane," and the plane orthogonal to the E-plane is called the "H-plane".
- [0029] The waveguide-type power distributor 1A is provided with a block 2 in which the concave portion 20 is formed on the top surface 25, and a cover 3 which contacts the top surface 25 of the block 2 and covers the concave portion 20. The block 2 and the cover 3 are formed of a conductive metal material such as aluminum, for example.
- [0030] The waveguide-type power distributor 1A includes an input waveguide 40, a first waveguide-type resonator 51, a first output waveguide 71, a first waveguide-type phase shifter 61, a second waveguide-type resonator 52, and a second output waveguide 72. The concave portion 20 formed in block 2 is an input waveguide 40, a first waveguide-type resonator 51, a first output waveguide 71, a first waveguide-type phase shifter 61, a second waveguide-type resonator 52, and a second output waveguide 72.
- [0031] Electromagnetic waves from the transmitter/receiver 11 (see FIG. 1) are inputted to

the input waveguide 40 (hereinafter simply referred to as "input waveguide 40"). The input waveguide 40 is connected to the first waveguide-type resonator 51 (hereinafter simply referred to as "first resonator 51") through iris 5a. The first resonator 51 is connected to the first output waveguide 71 (hereinafter simply referred to as "first output waveguide 71") through an iris 7a.

[0032] The first resonator 51 is also connected to the first waveguide-type phase shifter 61 (hereinafter simply referred to as "first phase shifter 61") through iris 6a. The first phase shifter 61 is connected to the second waveguide-type resonator 52 (hereinafter simply referred to as "second resonator 52") through iris 5b. The second resonator 52 is connected to the second output waveguide 72 (hereinafter simply referred to as "second output waveguide 72") through an iris 7b.

[0033] The first and second output waveguides 71 and 72 output electromagnetic waves to a plurality of antenna element of antenna apparatus 10 (see FIG. 1). The first and second output waveguides 71 and 72 may themselves be configured as a plurality of antenna element.

[0034] When the waveguide type power distributor 1A is used as the waveguide type power combiner, the input waveguide 40 is used as the output waveguide, and the first and second output waveguides 71 and 72 are used as the input waveguides.

[0035] The input waveguide 40, the first resonator 51, the first output waveguide 71, the first phase shifter 61, the second resonator 52, and the second output waveguide 72 have a common E-plane. That is, each E-plane is included in the same plane. The common E-plane is composed of the bottom surface of the concave portion 20 and a bottom surface of a cover 3.

[0036] The input waveguide 40, the first resonator 51, the first output waveguide 71, the first phase shifter 61, the second resonator 52, and the second output waveguide 72 are connected to each other through the iris 5a, 5b, 6a, 7a, and 7b formed on the H-plane.

[0037] Thus, a planar circuit including a plurality of waveguides connected by iris formed on the H-plane, that is, a planar circuit including a plurality of waveguides arranged in the in-plane direction of the E-plane, is called an "H-plane waveguide circuit".

[0038] The input from the input waveguide 40 is output to the first and second output waveguides 71 and 72 with a phase difference and distribution ratio determined by the length of the first phase shifter 61. The input from the input waveguide 40 is matched by selecting the opening amount or protrusion amount of the iris 5a, 5b, 6a, 7a, 7b to a desired value.

[0039] According to the present embodiment, the electromagnetic wave input from the input waveguide 40 can be distributed and output at a desired phase difference and distribution ratio, which is excellent in designability especially at high frequencies, and can simultaneously obtain small size, low loss property, and high isolation property.

[0040] In addition, in the present embodiment, by using a resonator having a large loss compared with other components for a part, instead of using a terminator having a role of absorbing all the input electromagnetic wave, the resonator can be configured in a planar shape even though it is a waveguide-type, and can be distributed in phase by having symmetry, thereby ensuring isolation between distribution ports.

Second embodiment

[0041] Figure 4 is a plan view showing an example of a waveguide type power distributor 1B according to the second embodiment. In addition to the configuration of the waveguide type power distributor 1A, the waveguide type power distributor 1B further includes a second waveguide type phase shifter 62, a third waveguide type resonator 53, and a third output waveguide type waveguide 73.

[0042] The second resonator 52 is connected to the second waveguide-type phase shifter 62 (hereinafter simply referred to as "second phase shifter 62") through iris 6b. The second phase shifter 62 is connected to the third waveguide-type resonator 53 (hereinafter simply referred to as "third resonator 53") through iris 5c. The third resonator 53 is connected to the third output waveguide 73 (hereinafter simply referred to as "3rd output waveguide 73") through iris 7c.

[0043] The input from the input waveguide 40 is output to the first to third output waveguide 71-73 with a phase difference and distribution ratio determined by the lengths of the first and second phase shifters 61 and 62.

[0044] Similarly, by further connecting a set of phase shifters, resonators, and output waveguides, that is, by alternately arranging the phase shifters and resonators in series and connecting the output waveguides to the resonators, power can be distributed to four or more output waveguides.

Third Embodiment

[0045] Figure 5 is a plan view showing an example of a waveguide type power distributor 1C according to the third embodiment. In the waveguide type power distributor 1C, each of the first to third resonators 51-53 has a plurality of resonance parts 511-532. The first resonator 51 has an input side resonator 511 connected to the input waveguide 40 and an output side resonator 512 connected to the first output waveguide 71.

[0046] The second resonator 52 has an input side resonator 521 connected to the first phase shifter 61 and an output side resonator 522 connected to the second output waveguide 72. The third resonator 53 has an input side resonator 531 connected to the second phase shifter 62 and an output side resonator 532 connected to the third output waveguide 73.

[0047] By providing a plurality of resonators 511-532 in this way, it is possible to broaden the distribution and matching characteristics. The size of the output-side resonator

512,522,532 is smaller than that of the input-side resonator 511,521,531. This is because the number of terminals connected to the output-side resonator 512,522,532 is larger than that of the input-side resonator 511,521,531, and electromagnetic waves are easily reduced by magnetic field coupling.

[0048] The input side resonator 511 and the output side resonator 512, the input side resonator 521 and the output side resonator 522, and the input side resonator 531 and the output side resonator 532 each have the same resonance frequency.

Fourth Embodiment

[0049] Figure 6 is a perspective view showing an example of the waveguide type power distributor 1D according to the fourth embodiment. In the waveguide type power distributor 1D, the first and second output waveguides 71 and 72 are connected to the E-plane 58 of the first and second resonators 51 and 52.

[0050] Arrow E4 in the figure shows the electric field direction of the electromagnetic wave propagating through the input waveguide 40, the first resonator 51, the first phase shifter 61 and the second resonator 52. Arrow E7 in the figure shows the electric field direction of the electromagnetic wave propagating through the first and second output waveguides 71 and 72. Arrows E4 and E7 are 90 degrees each other.

[0051] The input waveguide 40, the first resonator 51, the first phase shifter 61, and the second resonator 52 have a common E-plane and are connected to each other by an iris formed on the H-plane. The E-planes of the first and second output waveguides 71, 72 and the E-planes of the input waveguide 40, the first resonator 51, the first phase shifter 61 and the second resonator 52 have a relationship of 90 degrees each other. The H-planes of the first and second output lines 71, 72 are common to the H-planes of the input waveguide 40, the first resonator 51, the first phase shifter 61 and the second resonator 52.

[0052] When the first and second output waveguides 71, 72 are connected to the E-plane 58 of the first and second resonators 51, 52, the electric field direction of the electromagnetic waves propagating from the first and second resonators 51, 52 to the first and second output waveguides 71, 72 changes by 90 degrees.

[0053] In addition, since the center of the E-plane 58 of the first and second resonators 51, 52 has a high electric field strength and is prone to discharge, the first and second output waveguides 71, 72 are connected to positions away from the center of the E-plane 58 of the first and second resonators 51, 52.

[0054] The block 2D of such a structure can be realized, for example, by combining a block divided into two in the center of a direction orthogonal to the E-plane including the electric field directions E4, E7 (in the vertical direction in the figure).

[0055] According to this embodiment, excessive miniaturization of the first and second resonators 51,52 can be prevented. That is, since the first and second resonators 51, 52

are electrically coupled to the first and second output waveguides 71, 72, the desired characteristics can be obtained without excessively reducing the size of the resonator compared with the example in which the first and second resonators 51, 52 are magnetically coupled at 3 points as in the first embodiment.

Fifth embodiment

[0056] Figure 7 is a plan view showing an example of the waveguide type power distributor 1E according to the fifth embodiment. In the same view, the upper surface 25 of the block 2E is hatched. The XY plane in the figure is a plane orthogonal to the electric field direction of the radio wave propagating in the waveguide type power distributor 1E.

[0057] In the following description, the first resonator 51, the second resonator 52, etc. are collectively referred to as "resonator 5," the first phase shifter 61, the second phase shifter 62, etc. are collectively referred to as "phase shifter 6," and the first output waveguide 71, the second output waveguide 72, etc. are collectively referred to as "output waveguide 7".

[0058] In the waveguide type power distributor 1E, the resonator 5 and the phase shifter 6 are alternately arranged in the X-direction. The output waveguide 7 extends from the resonator 5 in the Y-direction. Two adjacent output waveguides 7 in the X-direction are separated by a separation wall 27.

[0059] The output waveguide 7 has a horn shape. That is, the output waveguide 7 is configured as an antenna element of the horn antenna. Therefore, the waveguide-type power distributor 1E is configured as an array antenna in which antenna elements are arranged in the X-direction.

[0060] Specifically, the output waveguide 7 has a horn shape that gradually expands as the distance between the opposing pair of H-planes 2h is separated from the resonator 5. In other words, the distance between the opposing pair of H-planes 2h constituting the separation wall 27 gradually narrows as it is separated from the phase shifter 6.

[0061] On the other hand, the distance between the opposing pair of E-planes 2e of the output waveguide 7 is constant. In addition to this, the distance between the opposing pair of E-planes 2e may gradually increase as the distance from the resonator 5 is separated.

Sixth Embodiment

[0062] Figure 8 is an exploded perspective view showing an example of the waveguide type power distributor 1F according to the sixth embodiment. FIG. 9 is a plan view showing an example of a block 2F included in the waveguide type power distributor 1F. Figure 10 is a plan view showing an example of a cover 3F included in the waveguide type power distributor 1F.

- [0063] In the block 2 F of the waveguide type power distributor 1 F, a concave portion 20 serving as an input waveguide 40, a resonator 5, and a phase shifter 6 is formed. The input waveguide 40, the resonator 5, and the phase shifter 6 are arranged in one direction. They have a common E-plane and are connected to each other by an iris formed on the H-plane.
- [0064] An output waveguide 7 and an iris 7x are formed on the cover 3F of the waveguide type power distributor 1F. The output line 7 is formed in a concave shape at a position corresponding to the resonator 5. The iris 7x passes through the bottom of the output line 7. The iris 7x has a shape bent into square brackets.
- [0065] When the cover 3F is placed on the block 2F, output waveguide 7 is connected to resonator 5 through the iris 7x. the output waveguide 7 is connected to the E-plane of resonator 5. In addition, the output waveguide 7 has a horn shape that expands in all directions as it moves away from the resonator 5.
- [0066] As in the waveguide type power distributor 1G according to the modified example shown in FIG. 11, the cover 3G includes: only the iris 7x may be formed, and a separate output line (not shown) may be connected to the position of the iris 7x.
- [0067] Although embodiments of the present invention have been described above, the present invention is not limited to the embodiments described above, and various modifications may be made to those skilled in the art. The antenna apparatus (array antenna) realized by using the waveguide type power distributor 1 A-1G is not restricted by its feeding position (center feed or end feed) or excitation method (traveling wave excitation system or standing wave excitation system).

Terminology

- [0068] It is to be understood that not necessarily all objects or advantages may be achieved in accordance with any particular embodiment described herein. Thus, for example, those skilled in the art will recognize that certain embodiments may be configured to operate in a manner that achieves or optimizes one advantage or group of advantages as taught herein without necessarily achieving other objects or advantages as may be taught or suggested herein.
- [0069] All of the processes described herein may be embodied in, and fully automated via, software code modules executed by a computing system that includes one or more computers or processors. The code modules may be stored in any type of non-transitory computer-readable medium or other computer storage device. Some or all the methods may be embodied in specialized computer hardware.
- [0070] Many other variations than those described herein will be apparent from this disclosure. For example, depending on the embodiment, certain acts, events, or functions of any of the algorithms described herein can be performed in a different sequence, can be added, merged, or left out altogether (e.g., not all described acts or

events are necessary for the practice of the algorithms). Moreover, in certain embodiments, acts or events can be performed concurrently, e.g., through multi-threaded processing, interrupt processing, or multiple processors or processor cores or on other parallel architectures, rather than sequentially. In addition, different tasks or processes can be performed by different machines and/or computing systems that can function together.

[0071] The various illustrative logical blocks and modules described in connection with the embodiments disclosed herein can be implemented or performed by a machine, such as a processor. A processor can be a microprocessor, but in the alternative, the processor can be a controller, microcontroller, or state machine, combinations of the same, or the like. A processor can include electrical circuitry configured to process computer-executable instructions. In another embodiment, a processor includes an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable device that performs logic operations without processing computer-executable instructions. A processor can also be implemented as a combination of computing devices, e.g., a combination of a digital signal processor (DSP) and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration. Although described herein primarily with respect to digital technology, a processor may also include primarily analog components. For example, some or all of the signal processing algorithms described herein may be implemented in analog circuitry or mixed analog and digital circuitry. A computing environment can include any type of computer system, including, but not limited to, a computer system based on a microprocessor, a mainframe computer, a digital signal processor, a portable computing device, a device controller, or a computational engine within an appliance, to name a few.

[0072] Conditional language such as, among others, "can," "could," "might" or "may," unless specifically stated otherwise, are otherwise understood within the context as used in general to convey that certain embodiments include, while other embodiments do not include, certain features, elements and/or steps. Thus, such conditional language is not generally intended to imply that features, elements and/or steps are in any way required for one or more embodiments or that one or more embodiments necessarily include logic for deciding, with or without user input or prompting, whether these features, elements and/or steps are included or are to be performed in any particular embodiment.

[0073] Disjunctive language such as the phrase "at least one of X, Y, or Z," unless specifically stated otherwise, is otherwise understood with the context as used in general to present that an item, term, etc., may be either X, Y, or Z, or any combination thereof (e.g., X, Y, and/or Z). Thus, such disjunctive language is not generally intended

to, and should not, imply that certain embodiments require at least one of X, at least one of Y, or at least one of Z to each be present.

[0074] Any process descriptions, elements or blocks in the flow diagrams described herein and/or depicted in the attached figures should be understood as potentially representing modules, segments, or portions of code which include one or more executable instructions for implementing specific logical functions or elements in the process. Alternate implementations are included within the scope of the embodiments described herein in which elements or functions may be deleted, executed out of order from that shown, or discussed, including substantially concurrently or in reverse order, depending on the functionality involved as would be understood by those skilled in the art.

[0075] Unless otherwise explicitly stated, articles such as "a" or "an" should generally be interpreted to include one or more described items. Accordingly, phrases such as "a device configured to" are intended to include one or more recited devices. Such one or more recited devices can also be collectively configured to carry out the stated recitations. For example, "a processor configured to carry out recitations A, B and C" can include a first processor configured to carry out recitation A working in conjunction with a second processor configured to carry out recitations B and C. The same holds true for the use of definite articles used to introduce embodiment recitations. In addition, even if a specific number of an introduced embodiment recitation is explicitly recited, those skilled in the art will recognize that such recitation should typically be interpreted to mean at least the recited number (e.g., the bare recitation of "two recitations," without other modifiers, typically means at least two recitations, or two or more recitations).

[0076] It will be understood by those within the art that, in general, terms used herein, are generally intended as "open" terms (e.g., the term "including" should be interpreted as "including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," etc.).

[0077] For expository purposes, the term "horizontal" as used herein is defined as a plane parallel to the plane or surface of the floor of the area in which the system being described is used or the method being described is performed, regardless of its orientation. The term "floor" can be interchanged with the term "ground" or "water surface." The term "vertical" refers to a direction perpendicular to the horizontal as just defined. Terms such as "above," "below," "bottom," "top," "side," "higher," "lower," "upper," "over," and "under," are defined with respect to the horizontal plane.

[0078] As used herein, the terms "attached," "connected," "mated" and other such relational terms should be construed, unless otherwise noted, to include removable, moveable,

fixed, adjustable, and/or releasable connections or attachments. The connections/attachments can include direct connections and/or connections having intermediate structure between the two components discussed.

[0079] Numbers preceded by a term such as "approximately," "about," and "substantially" as used herein include the recited numbers, and also represent an amount close to the stated amount that still performs a desired function or achieves a desired result. For example, the terms "approximately," "about," and "substantially" may refer to an amount that is within less than 10% of the stated amount. Features of embodiments disclosed herein preceded by a term such as "approximately," "about," and "substantially" as used herein represent the feature with some variability that still performs a desired function or achieves a desired result for that feature.

[0080] It should be emphasized that many variations and modifications may be made to the above-described embodiments, the elements of which are to be understood as being among other acceptable examples. All such modifications and variations are intended to be included herein within the scope of this disclosure and protected by the following claims.

Reference Signs List

[0081] 1 waveguide-type power distributor (waveguide-type power combiner)
2 block
20 concave portion
25 upper surface
27 separation wall
2e E-plane
2h H-plane
3 cover
40 input waveguide
5,51-53 waveguide-type resonator
58 E-plane
5a-5c iris
511-532 resonator
6,61,62 waveguide-type phase shifter
6a,6b iris
7,71-73 output waveguide
7a-7c,7x iris
10 antenna apparatus
11 transmitter/receiver
12 signal processor

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13 controller
100 radar equipment

Claims

- [Claim 1] A waveguide-type power distributor, comprising:
a first waveguide-type resonator configured to make an inputted electromagnetic wave resonate;
an input waveguide portion configured to input the electromagnetic wave to the first waveguide-type resonator;
a second waveguide-type resonator configured to make an electromagnetic wave resonate;
an output waveguide portion configured to output each electromagnetic wave from the first waveguide-type resonator and the second waveguide-type resonator, respectively; and
a waveguide-type phase shifter, arranged between the first waveguide-type resonator and the second waveguide-type resonator and electrically connected to both the first waveguide-type resonator and the second waveguide-type resonator through an iris, respectively.
- [Claim 2] The waveguide-type power distributor according to claim 1, wherein:
the waveguide-type phase shifter is configured to adjust the phase of the inputted electromagnetic wave from the first waveguide-type resonator and output the adjusted electromagnetic wave to the second waveguide-type resonator,
wherein the length of the waveguide-type phase shifter in the direction in which the electromagnetic wave propagates is an integer multiple of $\lambda/2$ of the wavelength of the electromagnetic wave.
- [Claim 3] The waveguide-type power distributor, comprising:
a plurality of waveguide-type resonator configured to make an inputted electromagnetic wave resonate;
an input waveguide portion configured to input the electromagnetic wave to one of the waveguide-type resonator;
an output waveguide portion configured to output each electromagnetic wave from the plurality of waveguide-type resonator, respectively; and
a plurality of waveguide-type phase shifter, in which two waveguide resonators among the plurality of waveguide resonator are arranged between each other and are sequentially electrically connected, configured to adjust the phase of the inputted electromagnetic wave from the waveguide-type resonator and output the adjusted electromagnetic wave to the adjacent waveguide-type resonator.
- [Claim 4] A waveguide-type power distributor, comprising:

an input waveguide configured to be inputted an electromagnetic wave;
a first waveguide-type resonator configured to be connected to the input waveguide;
a first output waveguide configured to be connected to the first waveguide-type resonator;
a first waveguide-type phase shifter configured to be connected to the first waveguide resonator;
a second waveguide-type resonator configured to be connected to the first waveguide phase shifter; and
a second output waveguide configured to be connected to the second waveguide resonator.

[Claim 5] The waveguide-type power distributor according to claim 4, further comprising:
a second waveguide-type phase shifter configured to be connected to the second waveguide resonator;
a third waveguide-type resonator configured to be connected to the second waveguide phase shifter; and
a third output waveguide connected to the third waveguide resonator.

[Claim 6] The waveguide-type power distributor according to claim 4 or 5, wherein:
the input waveguide, the first waveguide-type resonator, the first output waveguide, the first waveguide-type phase shifter, the second waveguide-type resonator, and the second output waveguide are connected to each other through an iris formed on the opposing pair of H-planes.

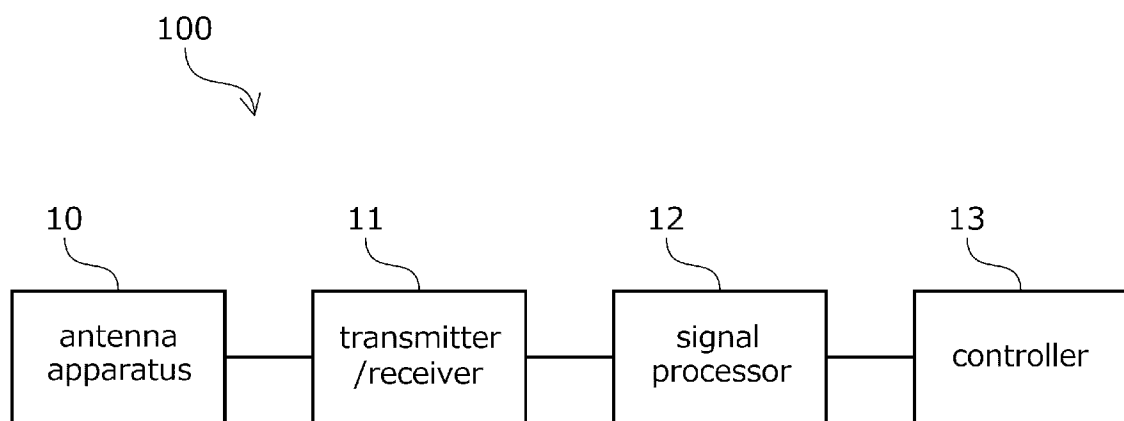
[Claim 7] The waveguide-type power distributor according to claim 6, wherein:
the input waveguide, the first waveguide-type resonator, the first output waveguide, the first waveguide-type phase shifter, the second waveguide-type resonator, and the second output waveguide have a common E-plane.

[Claim 8] The waveguide-type power distributor according to any of claim 7, wherein:
the input waveguide, the first waveguide-type resonator, the first output waveguide, the first waveguide-type phase shifter, the second waveguide-type resonator and the second output waveguide are formed by concave portions formed on the surface of a block; and
further comprising a cover configured to cover the concave portion in contact with the surface of the block.

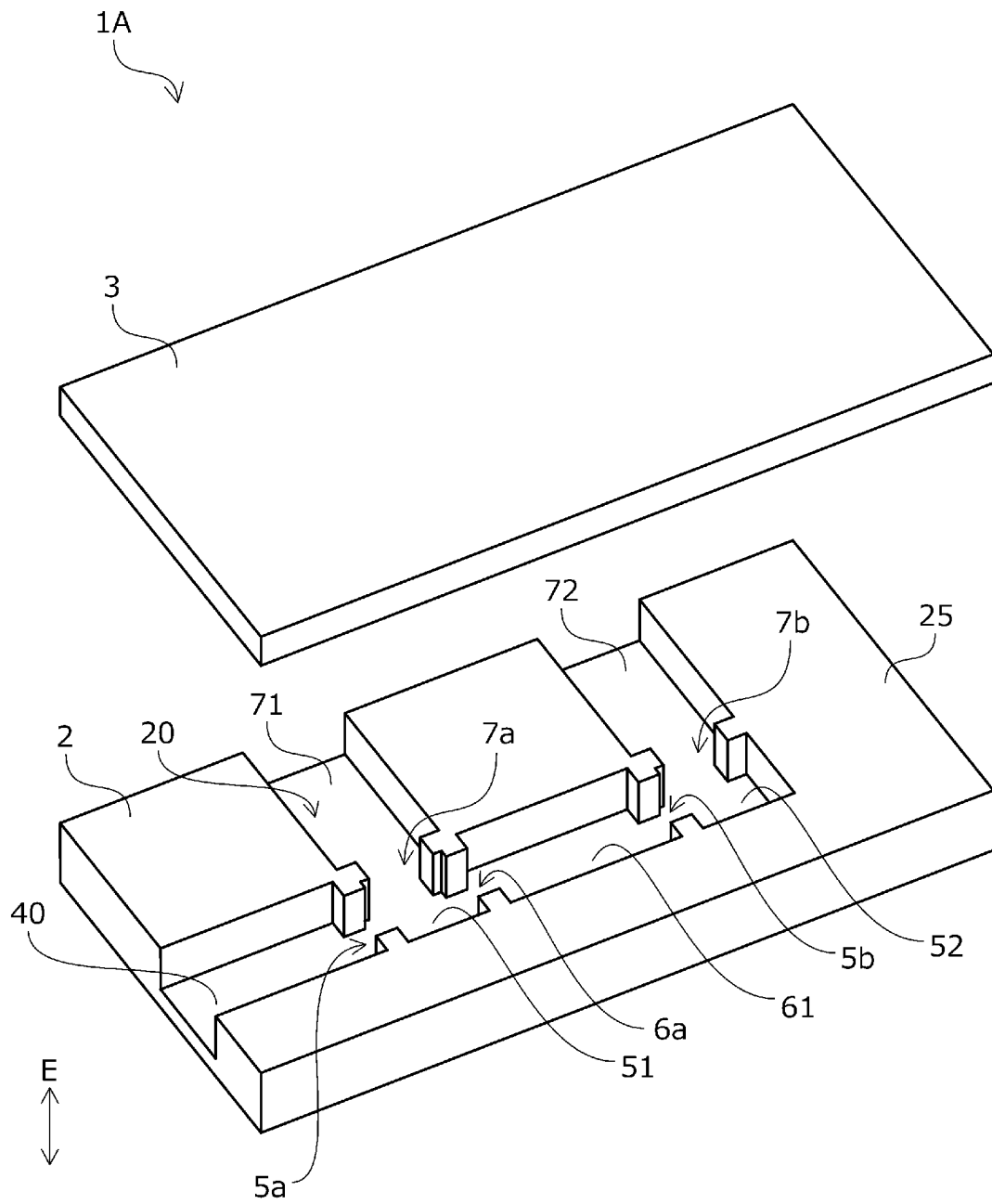
- [Claim 9] The waveguide-type power distributor according to claim 4, wherein:
the first waveguide-type resonator includes:
an input side resonator connected to the input waveguide; and
an output side resonator connected to the first output waveguide; and
the second waveguide-type resonator includes:
an input side resonator connected to the first waveguide-type phase shifter; and
an output side resonance part connected to the second output waveguide.
- [Claim 10] The waveguide-type power distributor according to any of claim 4 to 9, wherein:
the first output waveguide is positioned perpendicular to the E-plane of the first waveguide-type resonator, electrically connected, and
the second output waveguide is positioned perpendicular to the E-plane of the second waveguide-type resonator, electrically connected.
- [Claim 11] The waveguide-type power distributor according to any of claim 10, wherein:
the first output waveguide and the second output include a part formed a horn shape with an opening extending in the direction of outputting electromagnetic waves, respectively.
- [Claim 12] The waveguide-type power distributor according to claim 11, comprising:
a block and a cover configured to cover the block,
wherein:
the input waveguide, the first waveguide-type resonator, the first waveguide-type phase shifter and the second waveguide-type resonator are formed by concave portions formed on the surface of the block; and
the iris respectively connected to the first output waveguide and the second output waveguide are formed on the cover.
- [Claim 13] The waveguide-type power distributor according to claim 12, wherein:
the first output waveguide and the second output waveguide are formed on the cover.
- [Claim 14] A radar equipment, comprising:
an electromagnetic wave generator configured to generate an electromagnetic wave;
a waveguide-type power distributor, including:
a first waveguide-type resonator configured to make an inputted electromagnetic wave resonate;

an input waveguide portion configured to input the electromagnetic wave to the first waveguide-type resonator;
a second waveguide-type resonator configured to make an electromagnetic wave resonate;
an output waveguide portion configured to output each electromagnetic wave from the first waveguide-type resonator and the second waveguide-type resonator, respectively; and
a waveguide-type phase shifter, arranged between the first waveguide-type resonator and the second waveguide-type resonator and electrically connected to both the first waveguide-type resonator and the second waveguide-type resonator through an iris, respectively, configured to adjust the phase of the inputted electromagnetic wave from the first waveguide-type resonator and output the adjusted electromagnetic wave to the second waveguide-type resonator.

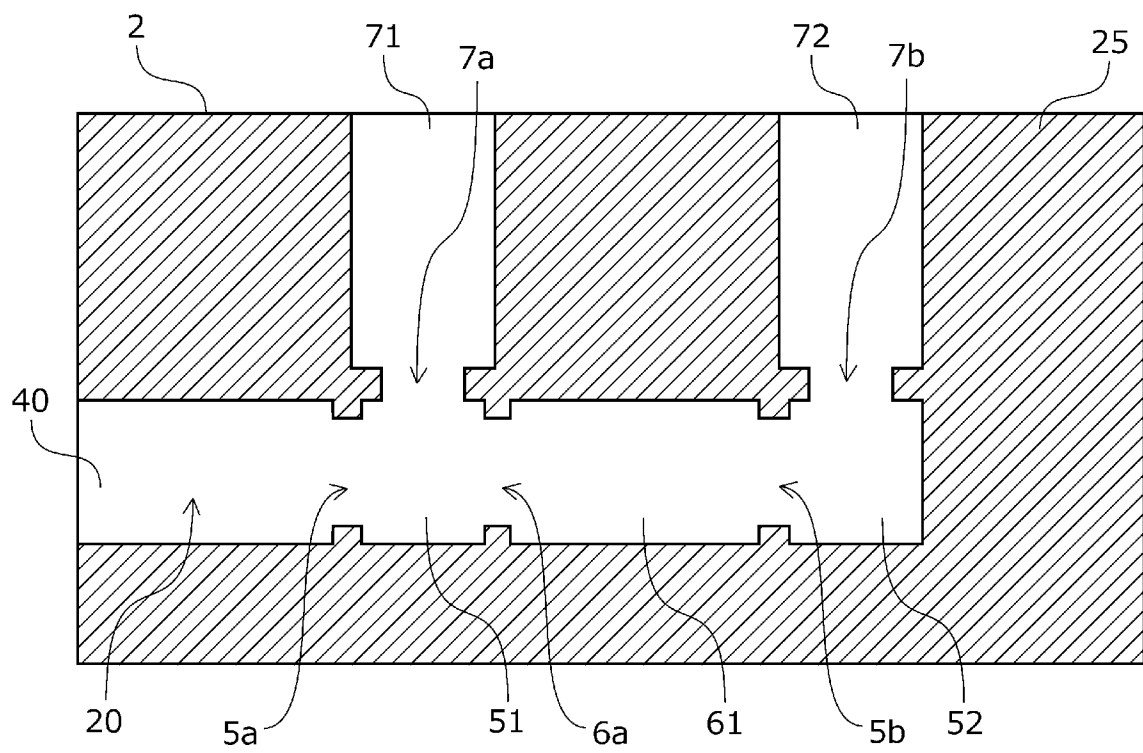
[Fig. 1]



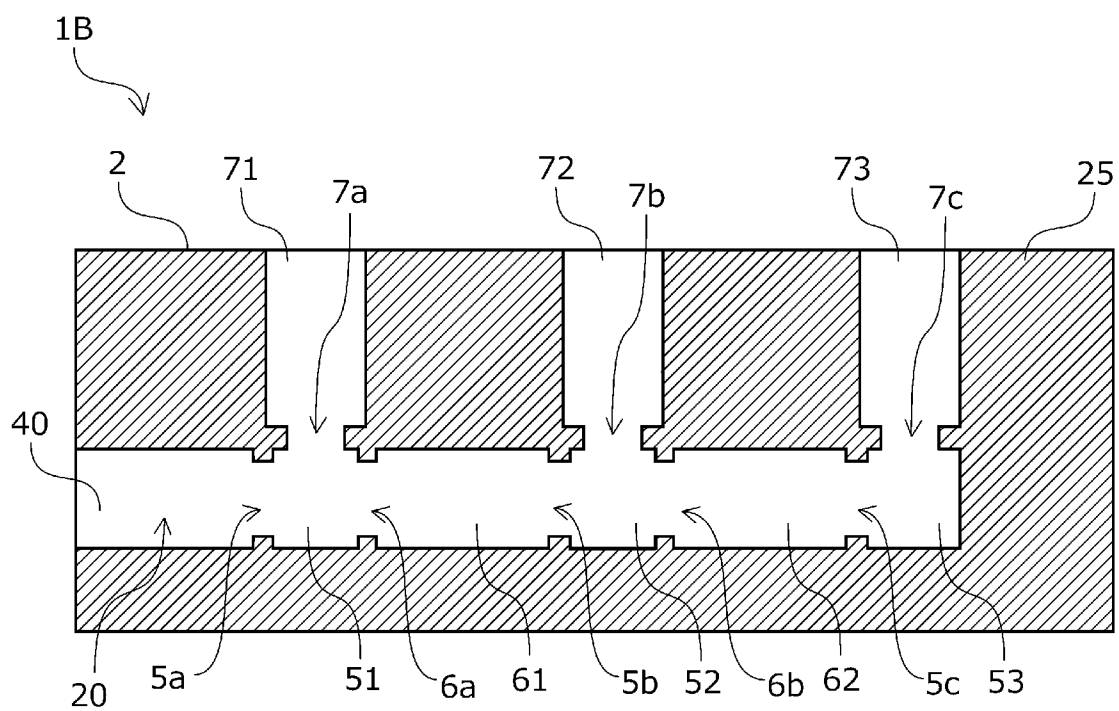
[Fig. 2]



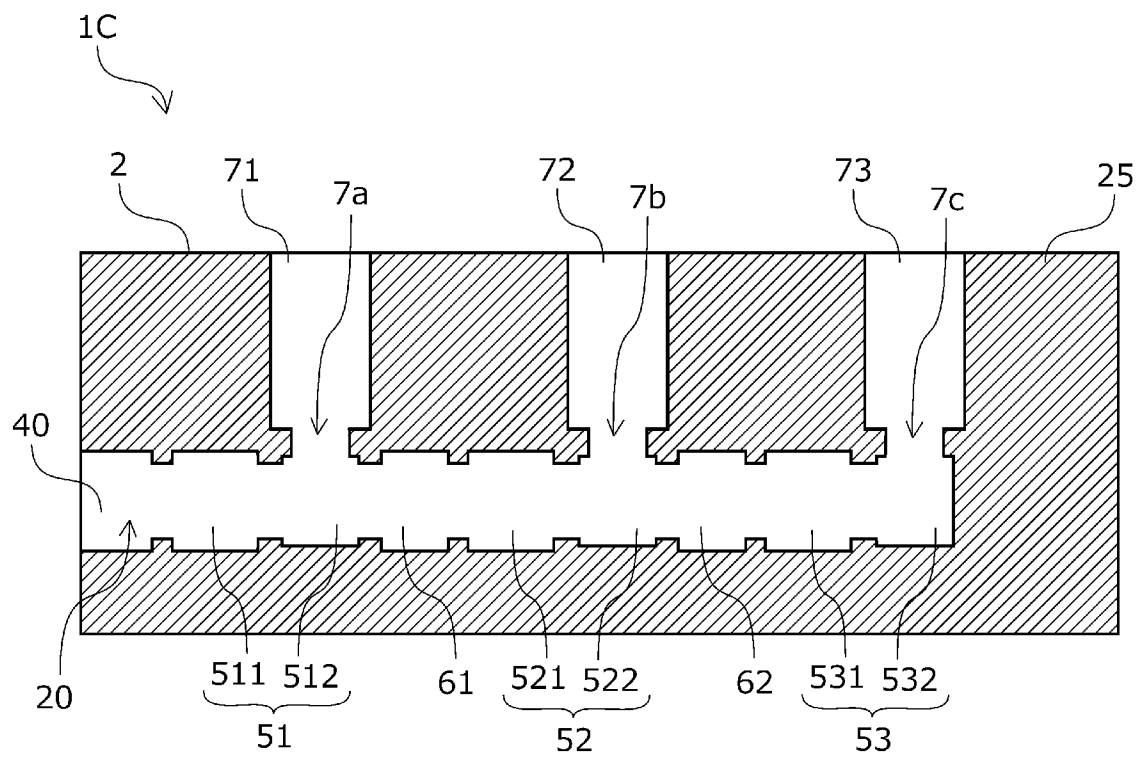
[Fig. 3]



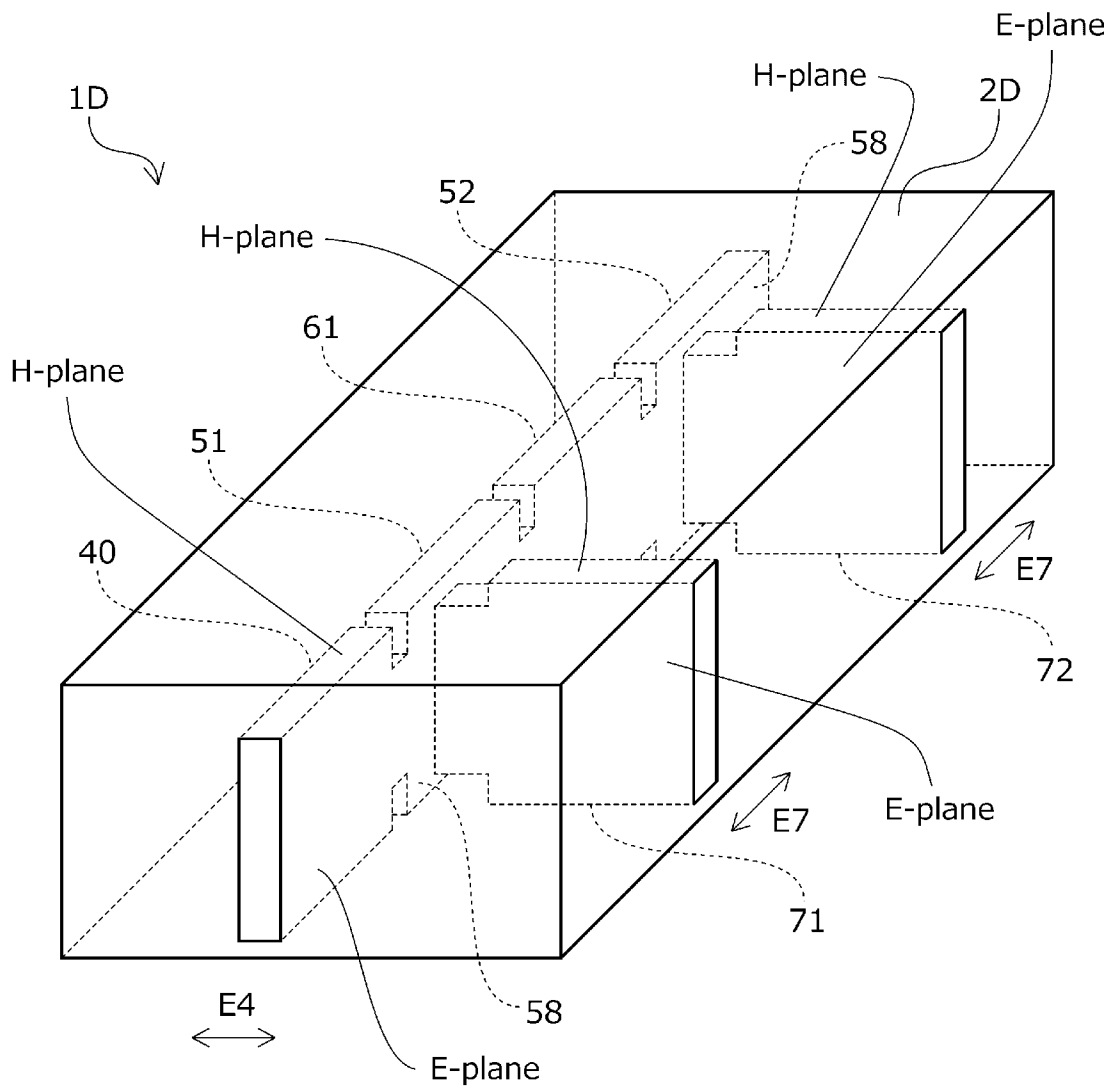
[Fig. 4]



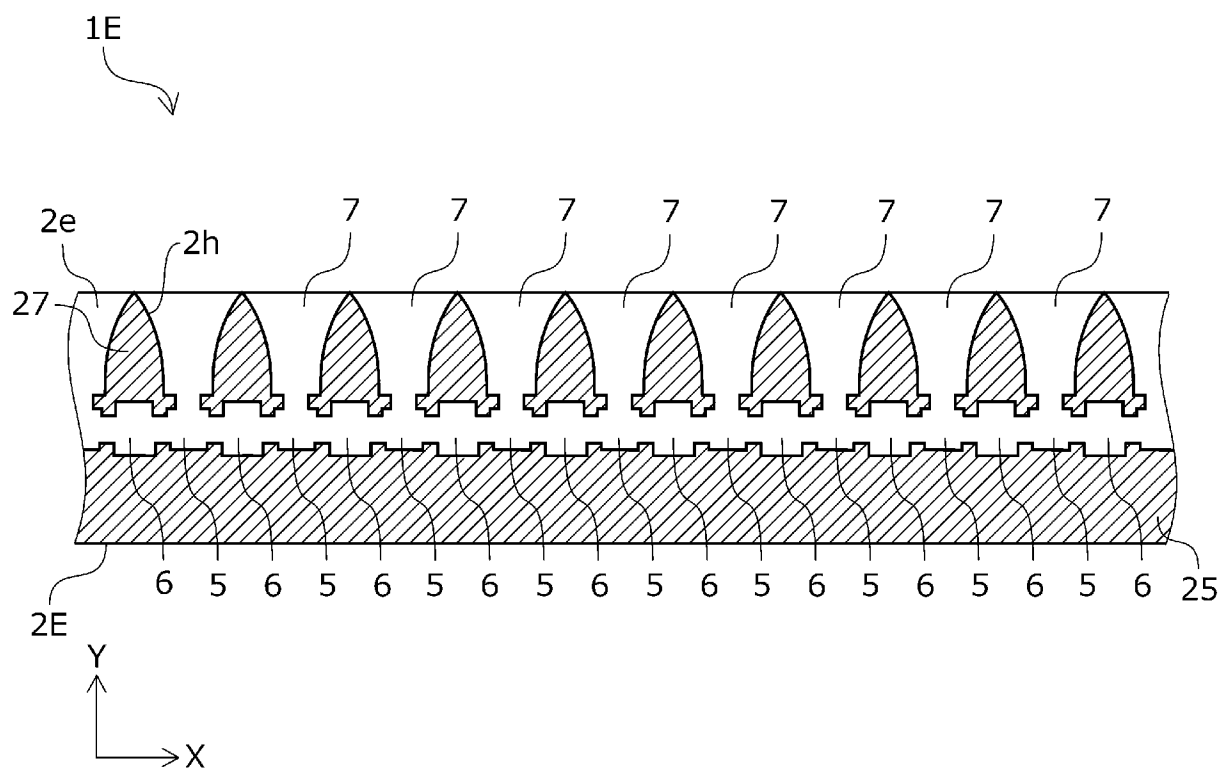
[Fig. 5]



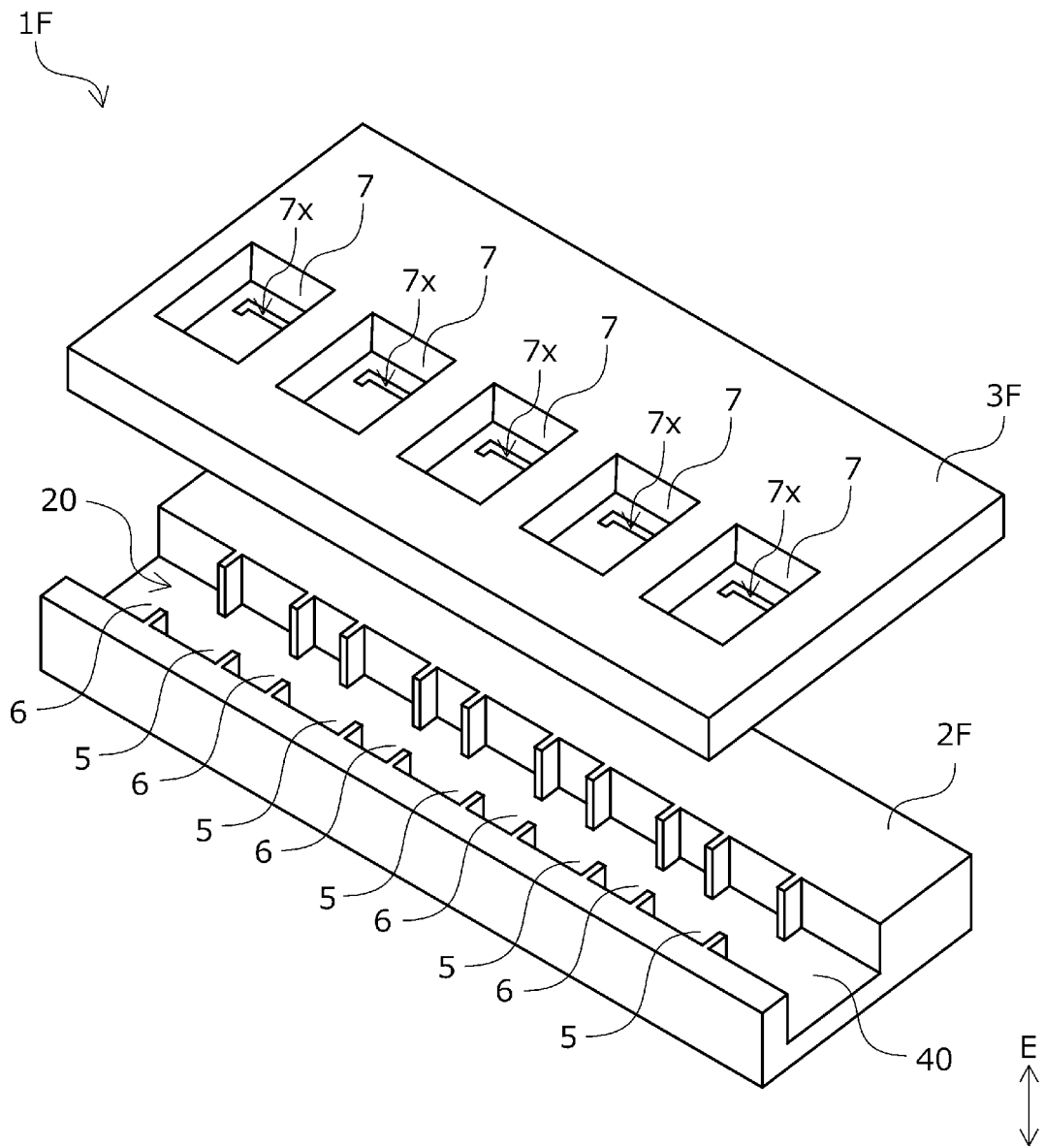
[Fig. 6]



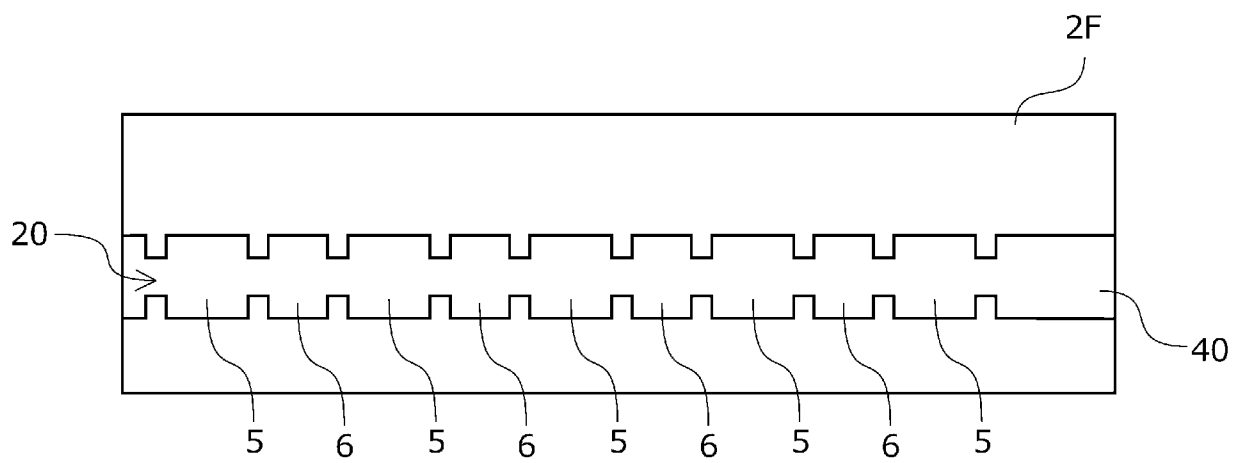
[Fig. 7]



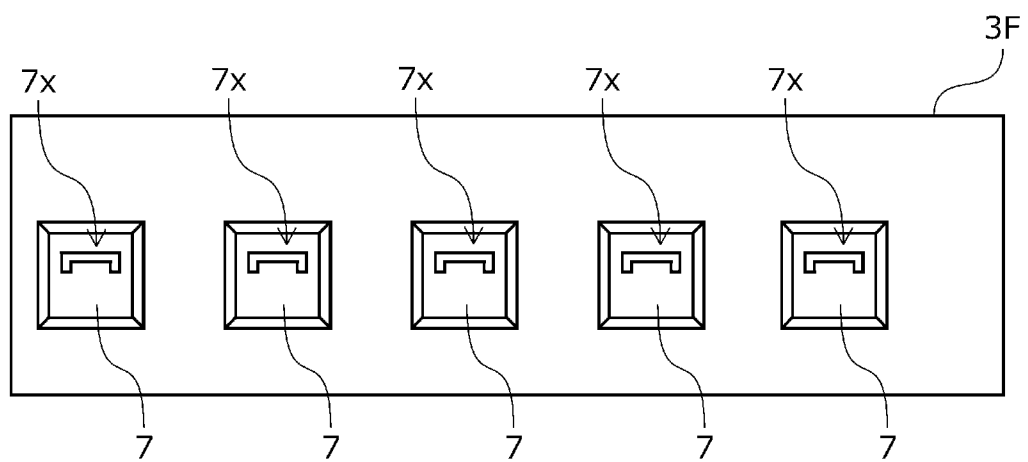
[Fig. 8]



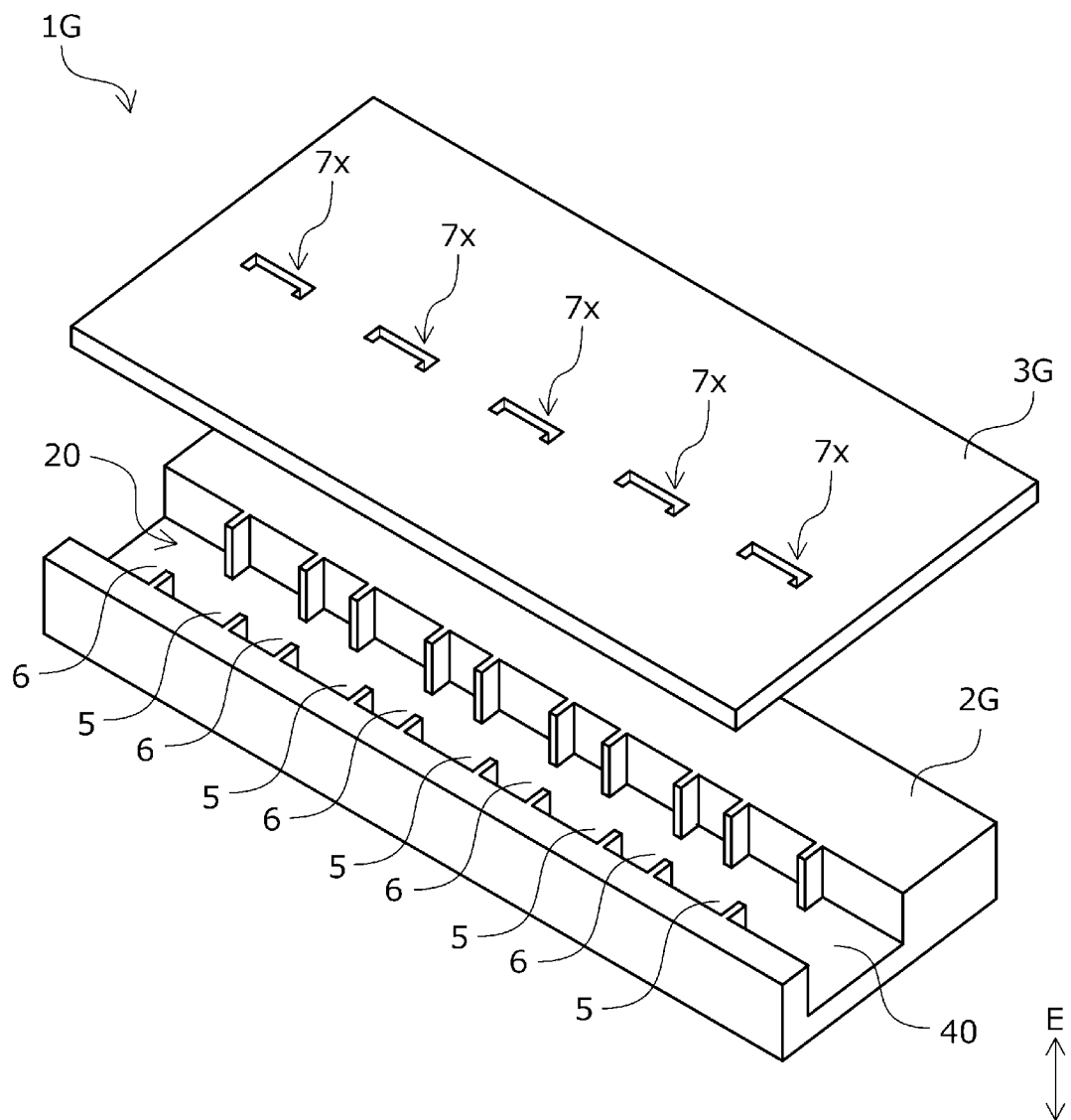
[Fig. 9]



[Fig. 10]



[Fig. 11]



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2023/046565

A. CLASSIFICATION OF SUBJECT MATTER

G02B6/122, H01P1/208, H01S3/08 Version=2024.01

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H01P, G02B, H01S

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

Electronic database consulted during the international search (name of database and, where practicable, search terms used)

Search Databases: PatSeer, IPO Internal Database

Keywords: waveguide, resonator, phase-shifter

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US20190006743A1 (NIDEC CORP & WGR CO LTD) 03-01-2019 (03 January 2019) (abstract; figures 1, 4, 5, 20; paragraphs [0080]-[0086]) -----	1-14
A	CN102122742B (NINGBO TAILI ELECTRONICS CO LTD) 09-10-2013 (09 October 2013) the whole document	1-14



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See patent family annex.

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Date of the actual completion of the international search

19-04-2024

Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2023/046565

Citation	Pub.Date	Family	Pub.Date
US 2019006743 A1	03-01-2019	CN 208637566 U	22-03-2019
		DE 102018115610 A1	03-01-2019
		IN 201824024264 A	04-01-2019
		JP 2019012999 A	24-01-2019