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(54) ANTENNA MODULE AND ANTENNA SYSTEM APPLYING THE ANTENNA MODULE

(57) An antenna module (100), comprising: a first antenna device (Ad_1), which is an AiM, Antenna in Module, and comprises at least one first antenna (AT_11, AT_12, AT_13, AT_14); a first FPC, flexible printed circuit, (101), coupled to an outer surface of the first antenna device (AD_1) via a conductive structure (103); and at least one second antenna device (AD_2), coupled to the first FPC (101), comprising at least one second antenna (AT_2). By this way, an antenna module (100) which can change directions of antennas via simplified structures is provided. Further, an antenna system applying the antenna module is also provided.

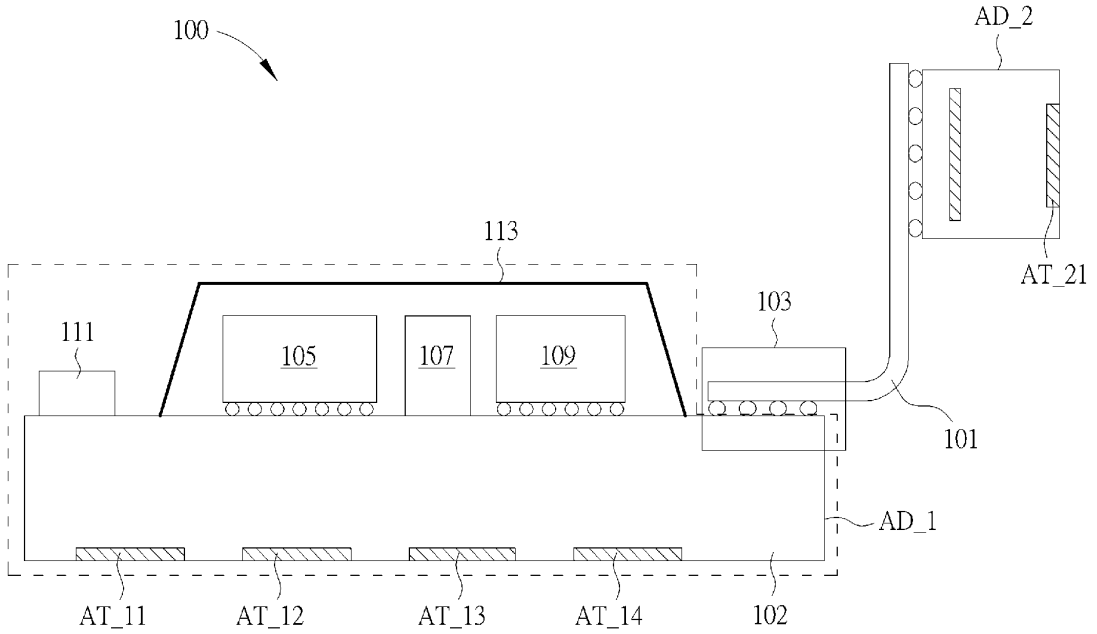

FIG. 1

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Description

Cross Reference to Related Applications

[0001] This application claims the benefit of U.S. Provisional Application No. 63/296,034, filed on January 3rd, 2022. The content of the application is incorporated herein by reference.

Background

[0002] For a conventional antenna module, the directions of antennas are always limited, thus the overall performance of the antenna module is limited since signals come from different directions. Further, the connections between different groups of antennas of the conventional antenna module are complex. Therefore, an antenna module which can change directions of antennas via simplified structures is needed.

Summary

[0003] One objective of the present invention is to provide an antenna module which can change directions of antennas via simplified structures. An antenna module according to the invention is defined in claim 1. Claims 2 to 9 define preferred embodiments thereof.

[0004] Another objective of the present invention is to provide an antenna system which can change directions of antennas via simplified structures. An antenna system according to the invention is defined in claim 10. Claims 11 and 12 define preferred embodiments thereof.

[0005] One embodiment of the present invention discloses an antenna module, comprising: a first antenna device, which is an AiM (Antenna in Module) and comprises at least one first antenna; a first FPC (flexible printed circuit), coupled to an outer surface of the first antenna device via a conductive structure; and a second antenna device, coupled to the first FPC, comprising at least one second antenna.

[0006] Another embodiment of the present invention discloses an antenna system, comprising: a first substrate; a first antenna device, which is an AiM and provided on the first substrate, comprising at least one first antenna; a first FPC, coupled to an outer surface of the first antenna device via a conductive structure; and at least one second antenna device, coupled to the FPC, comprising at least one second antenna.

[0007] In view of above-mentioned embodiments, an antenna module which can change directions of antennas via simplified structures is provided. Further, an antenna system applying the antenna module is also disclosed.

[0008] These and other objectives of the present invention will no doubt become obvious to those of ordinary skill in the art after reading the following detailed description of the preferred embodiment that is illustrated in the various figures and drawings.

Brief Description of the Drawings

[0009] FIG.1 is a schematic diagram illustrating an antenna module according to one embodiment of the present invention.

[0010] FIG.2, FIG.3, FIG.4, FIG.5, FIG.6, FIG.7, FIG.8, FIG.9, and FIG.10 are schematic diagrams illustrating structures and operations of antenna modules according to different embodiments of the present invention.

Detailed Description

[0011] In the following descriptions, several embodiments are provided to explain the concept of the present application. The term "first", "second", "third" in following descriptions are only for the purpose of distinguishing different one elements, and do not mean the sequence of the elements. For example, a first device and a second device only mean these devices can have the same structure but are different devices.

[0012] FIG.1 is a schematic diagram illustrating an antenna module 100 according to one embodiment of the present invention. As illustrated in FIG.1, the antenna module 100 comprises a first antenna device AD_1, a first FPC (flexible printed circuit) 101, and a second antenna device AD_2. The first antenna device AD_1 is an AiM (Antenna in Module) and comprises at least one first antenna (four first antennas AT_11, AT_12, AT_13, AT_14 in this example). The first antennas AT_11, AT_12, AT_13, AT_14 are provided in a substrate 102. The first FPC 101 is coupled to an outer surface of the first antenna device AD_1 via a conductive structure 103. Preferably, the conductive structure 103 comprises conductive balls or conductive bumps. Via the simple conductive structure, the connection between the first antenna device AD_1 and the first FPC 101 can be simplified. The second antenna device AD_2 is coupled to the first FPC 101 and comprises at least one second antenna (one second antenna AT_21 in this example).

[0013] Preferably, the first antennas AT_11, AT_12, AT_13, AT_14 are formed in one package and the second antenna AT_2 is formed in another package. Also, the second antenna device AD_2 can be formed by at least one antenna board. Further, preferably, the second antenna device AD_2 is also coupled to the first FPC 101 via conductive balls or conductive bumps. Besides the first antennas AT_11, AT_12, AT_13, AT_14, the first antenna device AD_1 can further comprise other components. Preferably, the first antenna device AD_1 further comprises an RF (Radio frequency) IC 105, a passive component 107, a power management IC 109 and a connector 111. The RF IC 105, the passive component 107, and the power management IC 109 are covered by an EMI (Electromagnetic Interference) shield 113.

[0014] The second antenna device AD_2 can be changed to different locations via the first FPC 101, such that the second antenna AT_21 can have different directions. In following embodiments, a first location and a

second location are taken as examples for explaining. However, it does not mean that the second antenna device AD_2 only can be located at the first location or the second location.

[0015] In following embodiments, the first antenna device AD_1 is provided on a PCB (printed circuit board) 201, via a connection structure such as conductive adhesive, but not limited, or mechanical holder. In one embodiment, the first PCB 201 is a PCB of a display. However, the PCB 201 can be replaced by any other substrate. FIG.2, FIG.3, FIG.4, FIG.5, FIG.6, FIG.7, FIG.8, FIG.9, and FIG.10 are schematic diagrams illustrating structures and operations of antenna modules according to different embodiments of the present invention. In the embodiment of FIG.2, the second antenna device AD_2 is at a first location in the Mode 1 and is at a second location in the Mode 2-1. In the embodiment of FIG.2, a first side SD_11 of the first antenna device AD_1 and a first side SD_21 of the second antenna device AD_2 are parallel with each other. For more detail, a first side SD_11 of the first antenna device AD_1 and a first side SD_21 of the second antenna device AD_2 are parallel with each other, regardless of whether the second antenna device AD_2 is located at the first location or the second location. Please note, the descriptions of "the first side SD_11 is parallel with the first side SD_21" can mean the "the first side SD_11 or an extension line of the first side SD_11 is parallel with the first side SD_21 or an extension line of the first side SD_21". In one embodiment, the first side SD_11 means a longest side of the first antenna device AD_1 and the first side SD_21 means a longest side of the second antenna device AD_2. Such rule can also be applied to other embodiments.

[0016] The Mode 2-2 in FIG.3 and the mode 2-1 in FIG.2 represent the same mode, and FIG.3 is a diagram viewed from the X direction of the diagram marked with Mode 2-2 FIG.2. Based on FIG.3, a distance between a first surface Sr_1 of the first PCB 201 and the first antenna device AD_1 is smaller than a distance between a second surface Sr_2 of the first PCB 201 and the first antenna device AD_1. In one embodiment, the first surface Sr_1 and the second surface Sr_2 are opposite and parallel with each other. In such case, the first FPC 201 is bended following a direction from the first surface Sr_1 to the second surface Sr_2 when the second antenna device AD_2 changes from the first location to the second location.

[0017] The locations of the first antenna device AD_1 and the second antenna device AD_2 are not limited to the embodiments illustrated in FIG.2 and FIG.3. In the embodiment of FIG.4, the second antenna device AD_2 is at a first location in the Mode 1 and is at a second location in the Mode 2-1. In the embodiment of FIG.4, a first side SD_11 of the first antenna device AD_1 and a first side SD_21 of the second antenna device AD_2 are perpendicular with each other. For more detail, a first side SD_11 of the first antenna device AD_1 and a first side SD_21 of the second antenna device AD_2 are perpendicular with each other, regardless of whether the second antenna device AD_2 is located at the first location or the second location. Please note, the descriptions of "the first side SD_11 is perpendicular with the first side SD_21" can mean the "the first side SD_11 or an extension line of the first side SD_11 is physically perpendicular with the first side SD_21 or an extension line of the first side SD_21".

[0018] The Mode 2-2 in FIG.5 and the mode 2-1 in FIG.4 represent the same mode, and FIG.5 is a diagram viewed from the Y direction of the diagram marked with Mode 2-2 in FIG.4. In FIG.5, a distance between a first surface Sr_1 of the first PCB 201 and the first antenna device AD_1 is smaller than a distance between a second surface Sr_2 of the first PCB 201 and the first antenna device AD_1. In one embodiment, the first surface Sr_1 and the second surface Sr_2 are opposite and parallel with each other. In such embodiment, the first FPC 101 is bended following a direction from the first surface Sr_1 to the second surface Sr_2 when the second antenna device AD_2 changes from the first location to the second location.

[0019] As illustrated above, the second antenna device AD_2 can be an antenna board which can be implemented by a PCB. However, the second antenna device AD_2 can be implemented by other components, for example, the second antenna device AD_2 can be implemented by a BT (Bismaleimide Triazine) substrate. Also, in the embodiment of FIG.6, the second antenna device AD_2 is implemented by a second FPC. In one embodiment, the second FPC is thicker than the first FPC 101.

[0020] In the embodiment of FIG.6, a first side SD_11 of the first antenna device AD_1 and a first side SD_21 of the second antenna device AD_2 are parallel with each other. For more detail, a first side SD_11 of the first antenna device AD_1 and a first side SD_21 of the second antenna device AD_2 are parallel with each other, regardless of whether the second antenna device AD_2 is located at the first location or the second location. Please note, the descriptions of "the first side SD_11 is parallel with the first side SD_21" can mean the "the first side SD_11 or an extension line of the first side SD_11 is parallel with the first side SD_21 or an extension line of the first side SD_21".

[0021] The second antenna device AD_2 is not limited to be implemented by above-mentioned antenna boards or FPC. In the embodiment of FIG.7, the second antenna device AD_2 is implemented by a plurality of antenna units AU_1, AU_2, AU_3 and AU_4. The antenna units AU_1, AU_2, AU_3 and AU_4 can be implemented by a PCB, a second FPC or ceramic, or any material that be designed with antennas.

[0022] In the embodiment of FIG.7, the second antenna device AD_2 is at a first location in the Mode 1 and is at a second location in the Mode 2-1. A first side SD_11 of the first antenna device AD_1 and a first side SD_21 of the second antenna device AD_2 are parallel with each other. For more detail, a first side SD_11 of the first an-

tenna device AD_1 and a first side SD_21 of the second antenna device AD_2 are parallel with each other, regardless of whether the second antenna device AD_2 is located at the first location or the second location. Please note, the descriptions of "the first side SD_11 is parallel with the first side SD_21" can mean the "the first side SD_11 or an extension line of the first side SD_11 is parallel with the first side SD_21 or an extension line of the first side SD_21". Further, in the embodiment of FIG.7, the first side SD_21 can mean a side of at least one of the antenna units AU_1, AU_2, AU_3 and AU_4. For example, the antenna units AU_1 and AU_2 can both have first sides SD_21 which are parallel with the first side SD_11.

[0023] In the embodiment of FIG.8, the first FPC 101 comprises a first area AR_1, a second area AR_2, and a bending area AR_b. Further, a reducing region AR_r is provided between the first area AR_1 and the second area AR_2. The second antenna device AD_2 is provided on the first area AR_1. A slot SL exists between the first area AR_1 and the second area AR_2 since the reducing region AR_r has a smaller area. For more detail, a longest length of the reducing region AR_r is smaller than shortest lengths of the first area AR_1 and the second area AR_2, thereby forms the slot SL. Due to the slot SL and the reducing region AR_r , the necessary material of the first FPC 101 can be reduced, and the dimension of the first FPC 101 can also be reduced.

[0024] The second antenna device AD_2 is at a first location in the Mode 1 and is at a second location in the Mode 2-1. In the embodiment of FIG.8, a first side SD_11 of the first antenna device AD_1 and a first side SD_21 of the second antenna device AD_2 are parallel with each other. For more detail, a first side SD_11 of the first antenna device AD_1 and a first side SD_21 of the second antenna device AD_2 are parallel with each other, regardless of whether the second antenna device AD_2 is located at the first location or the second location. Please note, the descriptions of "the first side SD_11 is parallel with the first side SD_21" can mean the "the first side SD_11 or an extension line of the first side SD_11 is parallel with the first side SD_21 or an extension line of the first side SD_21".

[0025] In the above-mentioned embodiment, only one second antenna device AD_2 is provided. However, the antenna module provided by the present invention can comprise more than one second antenna devices. Also, the first FPC 101 provided by the present invention can have another shape rather than limited to the shapes illustrated in above mentioned embodiments. In the embodiment of FIG.9, the first FPC 101 is a T shape, and comprises a first area AR_1, a second area AR_2, and a bending area AR_b. The second antenna devices can be distributed on at least one of the first area AR_1 and the second area AR_2. For example, the second antenna devices AD_21, AD_22 are distributed on the first area AR_1 and the second area AR_2. That is, at least one of the second antenna devices is provided on the first area AR_1 and at least one of the second antenna devices is provided on the second area AR_2. However, the second antenna device can be provided on only one of the first area AR_1 and the second area AR_2.

[0026] In the embodiment of FIG.9, the second antenna devices AD_21, AD_22 are at a first location in the Mode 1 and are at a second location in the Mode 2-1. A first side SD_11 of the first antenna device AD_1 and a first side SD_21 of the second antenna devices AD_21 are parallel with each other. For more detail, a first side SD_11 of the first antenna device AD_1 and a first side SD_21 of the second antenna devices AD_2 are parallel with each other, regardless of whether the second antenna devices AD_21 is located at the first location or the second location. Please note, the descriptions of "the first side SD_11 is parallel with the first side SD_21" can mean the "the first side SD_11 or an extension line of the first side SD_11 is parallel with the first sides SD_21 or an extension line of the first side SD_21".. Please note, the second antenna devices AD_21 is applied for explaining in this example, but the second antenna devices AD_22 can follow the same rule. For example, the second antenna devices AD_22 has a first side SD_22 parallel with the first side SD_11. Besides, in one example of the embodiment of FIG.9, the first side of the first antenna device is a longest side thereof and the first side of the second antenna device is a longest side thereof.

[0027] The mode 2-2 in FIG.3 are not illustrated in the embodiments of FIG.6, FIG.7, FIG.8 and FIG.9. However, the structure and operation illustrated in FIG.3 can also be applied in the embodiments of FIG.6, FIG.7, FIG.8 and FIG.9. Additionally, the embodiment of FIG.2 is taken as an example for explaining the embodiments of FIG.6, FIG.7, FIG.8 and FIG.9. However, the concept disclosed in FIG.6, FIG.7, FIG.8 and FIG.9 can be applied to other embodiments. For example, FIG.10 is an embodiment in which the concept disclosed in FIG.9 is applied to the embodiment of FIG.4.

[0028] In the embodiment of FIG.10, the first FPC 101 comprises a first area AR_1, a second area AR_2, and a bending area AR_b. The second antenna devices can be distributed on at least one of the first area AR_1 and the second area AR_2. For example, the second antenna devices AD_21, AD_22 are distributed on the first area AR_1 and the second area AR_2. That is, at least one of the second antenna devices is provided on the first area AR_1 and at least one of the second antenna devices is provided on the second area AR_2. However, the second antenna device can be provided on only one of the first area AR_1 and the second area AR_2.

[0029] The second antenna devices AD_21, AD_22 are at a first location in the Mode 1 and are at a second location in the Mode 2-1. In the embodiment of FIG.10, a first side SD_11 of the first antenna device AD_1 and a first side SD_21 of the second antenna device AD_21 is perpendicular with each other. For more detail, a first side SD_11 of the first antenna device AD_1 and a first side SD_21 of the second antenna device AD_21 is per-

pendicular with each other, regardless of whether the second antenna device AD_21 is located at the first location or the second location. Please note, the descriptions of "the first side SD_11 is perpendicular with the first side SD_21" can mean the "the first side SD_11 or an extension line of the first side SD_11 is perpendicular with the first side SD_21 or an extension line of the first side SD_21". Please note, the second antenna devices AD_21 is applied for explaining in this example, but the second antenna devices AD_22 can follow the same rule. For example, the second antenna devices AD_22 can have a first side SD_22 parallel with the first side SD_11. Besides, in one example of the embodiment of FIG.10, the first side of the first antenna device is a longest side thereof and the first side of the second antenna device is a longest side thereof.

[0030] Please note, the sizes, locations and shapes of all components in above-mentioned embodiments are not limited to the above-mentioned examples. Any variation based on the above-mentioned disclosure should fall in the scope of the present invention. Further, as above-mentioned, the first PCB 201 can be a PCB of a display. Therefore, a system comprising the antenna modules illustrated in above-mentioned embodiments and the display can be regarded as an antenna system. The antenna system can be, for example, a mobile phone, a tablet computer or a notebook.

[0031] In view of above-mentioned embodiments, an antenna module which can change directions of antennas via simplified structures is provided. Further, an antenna system applying the antenna module is also disclosed.

[0032] Those skilled in the art will readily observe that numerous modifications and alterations of the device and method may be made while retaining the teachings of the invention. Accordingly, the above disclosure should be construed as limited only by the metes and bounds of the appended claims.

Claims

1. An antenna module (100), comprising:

   a first antenna device (AD_1), which is an Antenna in Module, in the following also referred to as AiM, and comprises at least one first antenna (AT_11, AT_12, AT_13, AT_14);
   a first flexible printed circuit (101), in the following also referred to as FPC, coupled to an outer surface of the first antenna device (AD_1) via a conductive structure (103); and
   at least one second antenna device (AD_2), coupled to the first FPC (101), comprising at least one second antenna (AT_21).

2. The antenna module of claim 1, wherein the conductive structure (103) comprises conductive balls or conductive bumps.

3. The antenna module of claim 1 or 2, wherein the at least one second antenna device (AD_2) is formed by at least one antenna board.

4. The antenna module of claim 3, wherein the antenna board uses a Bismaleimide Triazine, in the following also referred to as BT, substrate, a printed circuit board, in the following also referred to as PCB, or a second FPC.

5. The antenna module of any one of claims 1 to 4, wherein the at least one second antenna device (AD_2) can be changed from a first location to a second location via the first FPC (101), wherein a first side (SD_11) of the first antenna device (AD_1) and a first side (SD_21) of at least one of the at least one second antenna device (AD_2) are parallel with each other.

6. The antenna module of any one of claims 1 to 5, wherein the at least one second antenna device (AD_2) can be changed from a first location to a second location via the first FPC (101), wherein a first side (SD_11) of the first antenna device (AD_1) and a first side (SD_21) of at least one of the at least one second antenna device (AD_2) are perpendicular with each other.

7. The antenna module of any one of claims 1 to 6, wherein at least one of the at least one second antenna device (AD_2) comprises a plurality of antenna units (AU_1, AU_2, AU_3, AU_4), wherein the antenna units (AU_1, AU_2, AU_3, AU_4) are provided in a PCB, a second FPC or made of ceramic.

8. The antenna module of any one of claims 1 to 7,

   wherein the first FPC (101) comprises a first area (AR_1), a second area (AR_2), and a reducing area (AR_r);
   wherein at least one of the at least one second antenna device (AD_2) is provided on the first area (AR_1);
   wherein a slot (SL) and the reducing area (AR_r) are provided between the first area (AR_1) and the second area (AR_2).

9. The antenna module of any one of claims 1 to 8,

   wherein the first FPC (101) comprises a first area (AR_1), a second area (AR_2), and a bending area (AR_b);
   wherein at least one of the at least one second antenna device (AD_2) is provided on at least one of the first area and the second area;
   wherein the first area (AR_1), the second area

(AR_2) and the bending area (AR_b) form a T shape.

10. An antenna system, comprising:

a first substrate (201); and
an antenna module (100) according to any one of claims 1 to 9, wherein the first antenna device (AD_1) is provided on the first substrate (201).

11. The antenna system of claim 10,

wherein the antenna module (100) is at least according to claim 5 or 6;
wherein a distance between a first surface (Sr_1) of the first substrate (201) and the first antenna device (AD_1) is smaller than a distance between a second surface (Sr_2) of the first substrate (201) and the first antenna device (AD_1);
wherein the first FPC (101) is bended following a direction from the first surface (Sr_1) to the second surface (Sr_2) when the at least one of the at least one second antenna device (AD_2) changes from the first location to the second location.

12. The antenna system of claim 10 or 11, wherein the first substrate (201) is a PCB of a display.

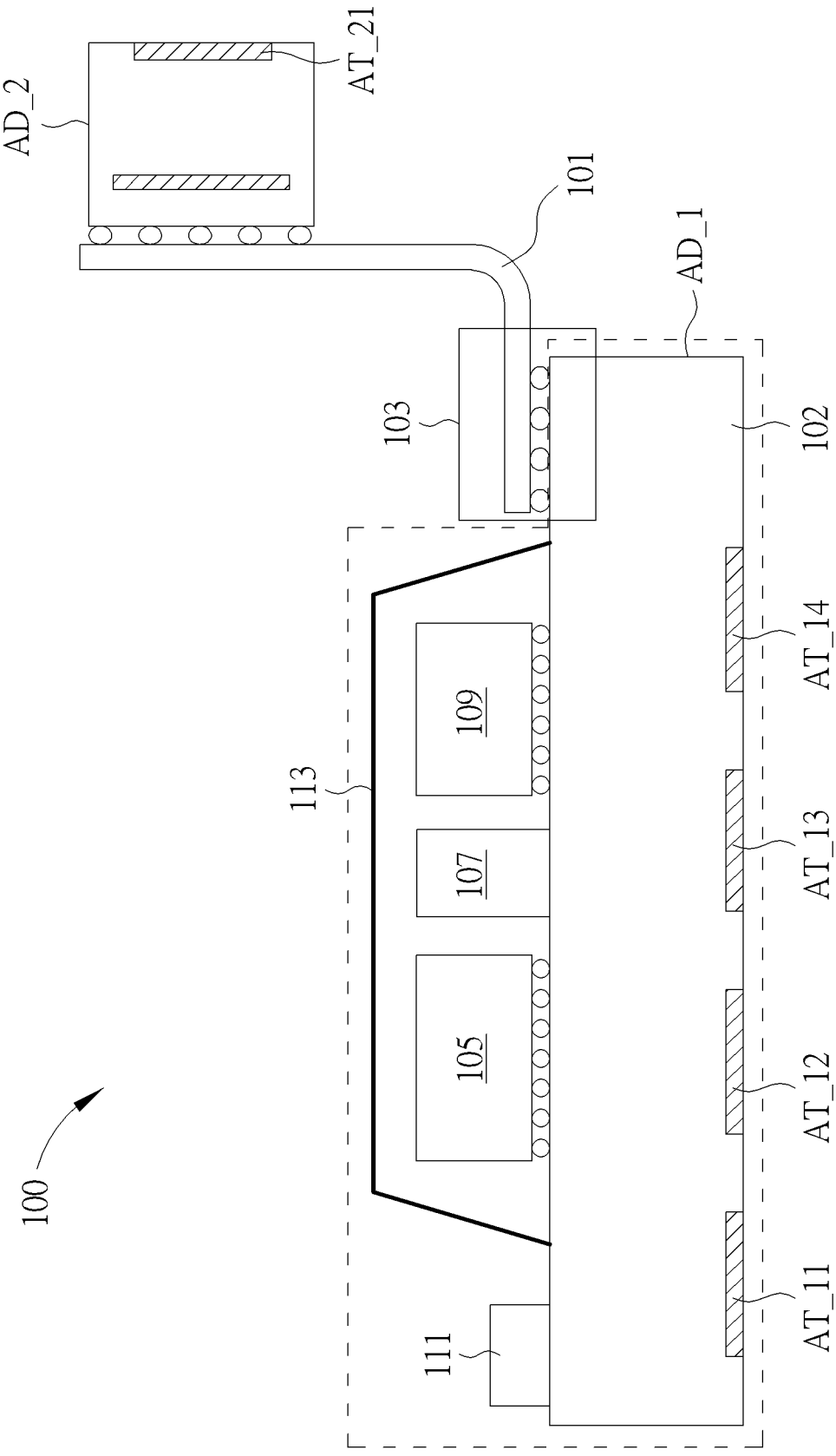

AD_2
AT_21
101
AD_1
103
102
109
113
AT_14
107
AT_13
105
AT_12
100
111
AT_11

FIG. 1

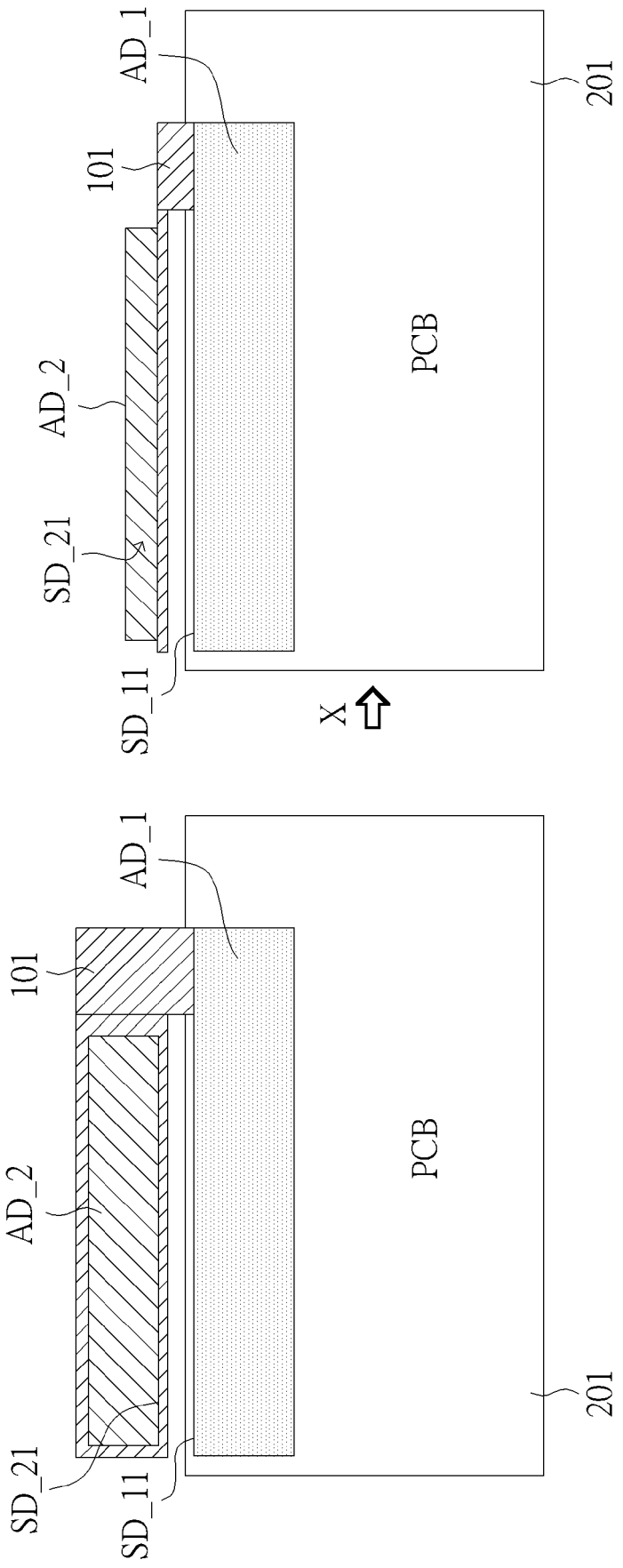

AD_1
101
AD_2
SD_21
SD_11
PCB
201
Mode 2-1
X
AD_1
101
AD_2
SD_21
SD_11
PCB
201
Mode 1

FIG. 2

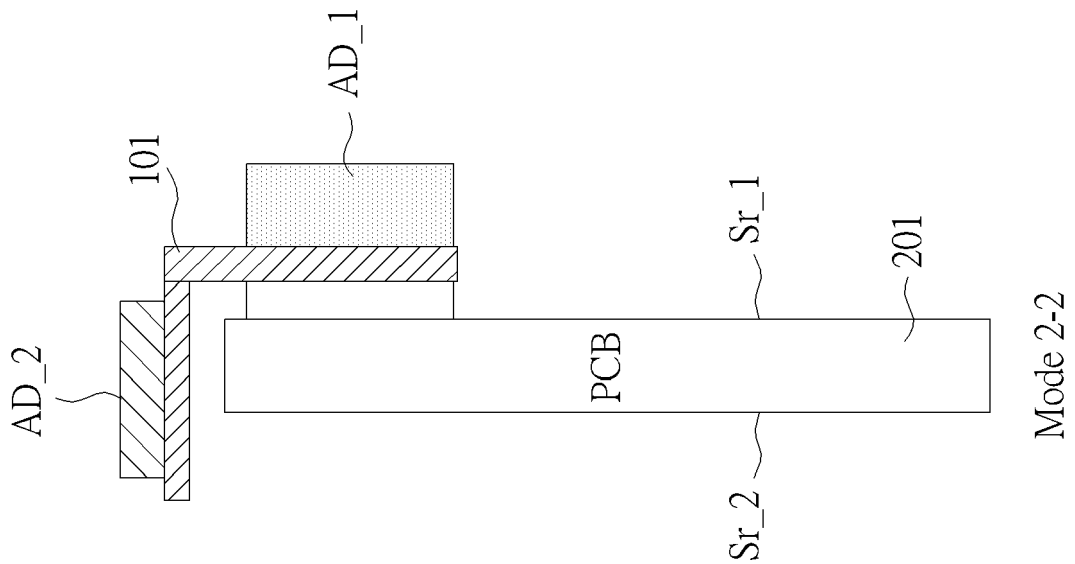


FIG. 3

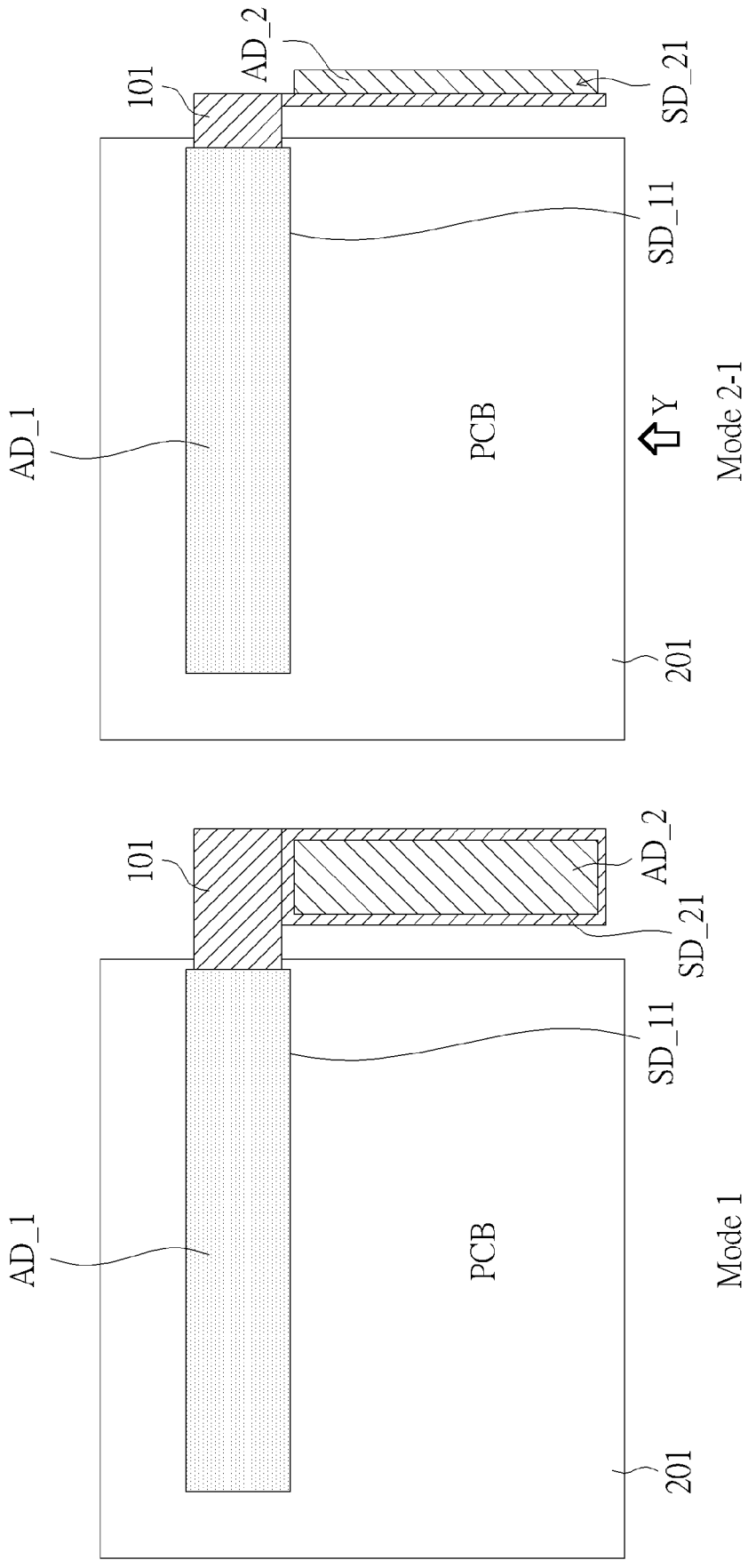
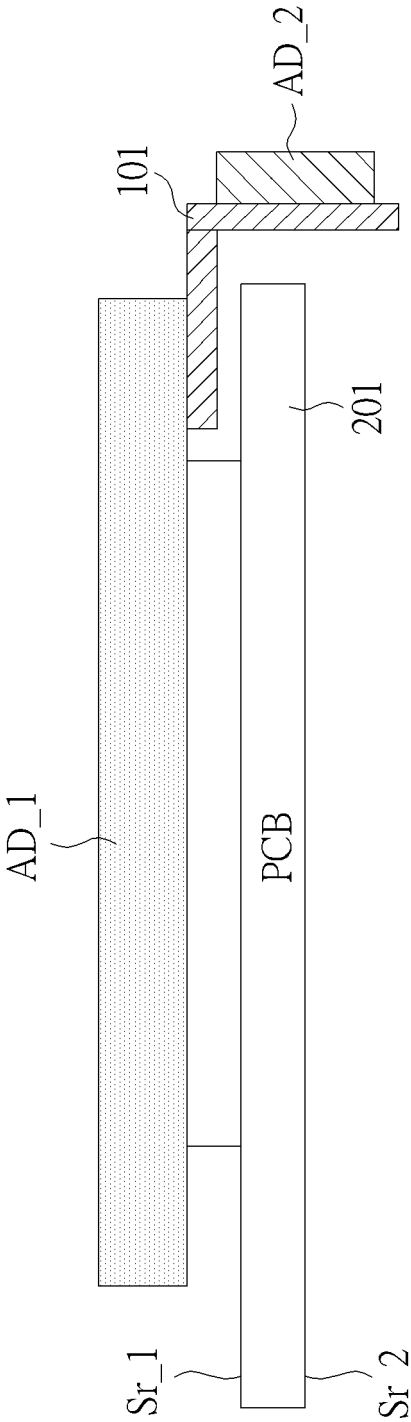

AD_2
101
SD_21
SD_11
AD_1
PCB
Y
Mode 2-1
201
101
AD_2
SD_21
SD_11
AD_1
PCB
Mode 1
201

FIG. 4



Mode 2-2

FIG. 5

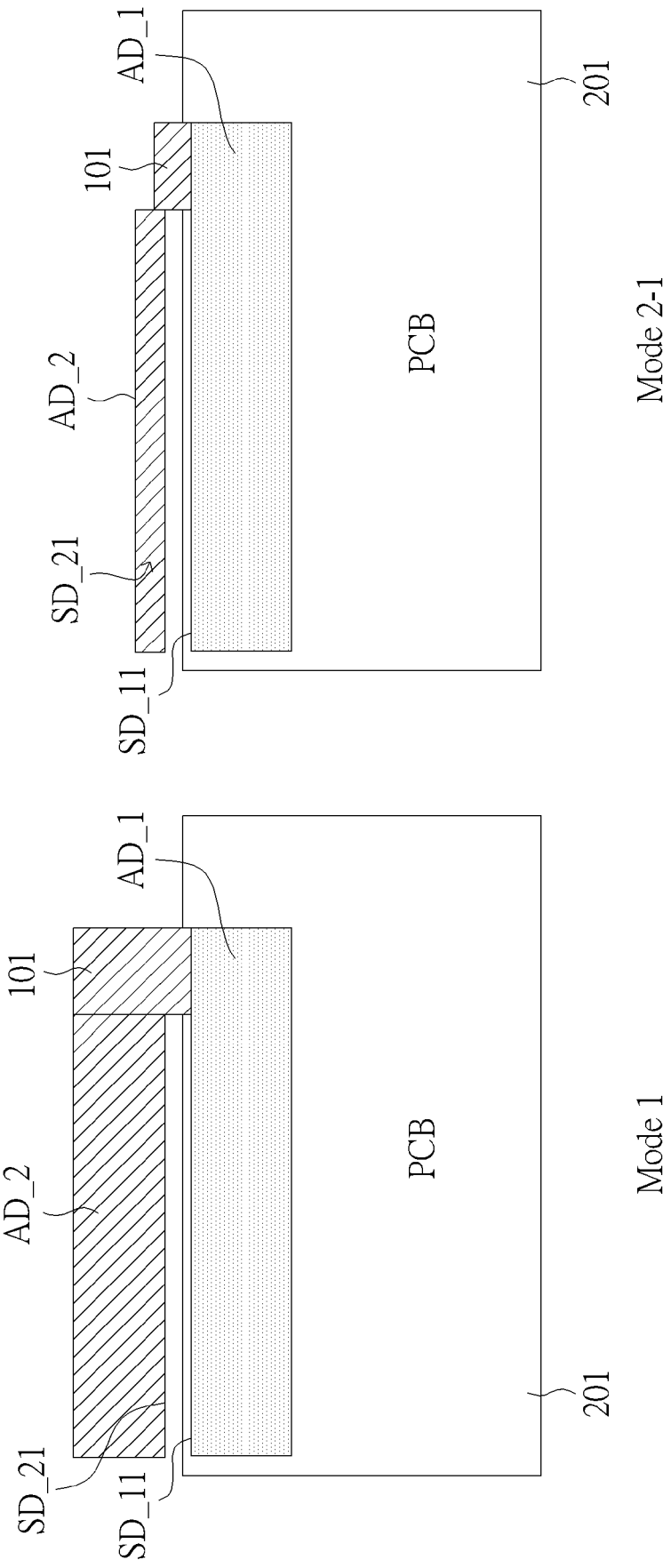

AD_1
101
AD_2
SD_21
SD_11
PCB
201
Mode 2-1
AD_1
101
AD_2
SD_21
SD_11
PCB
201
Mode 1

FIG. 6

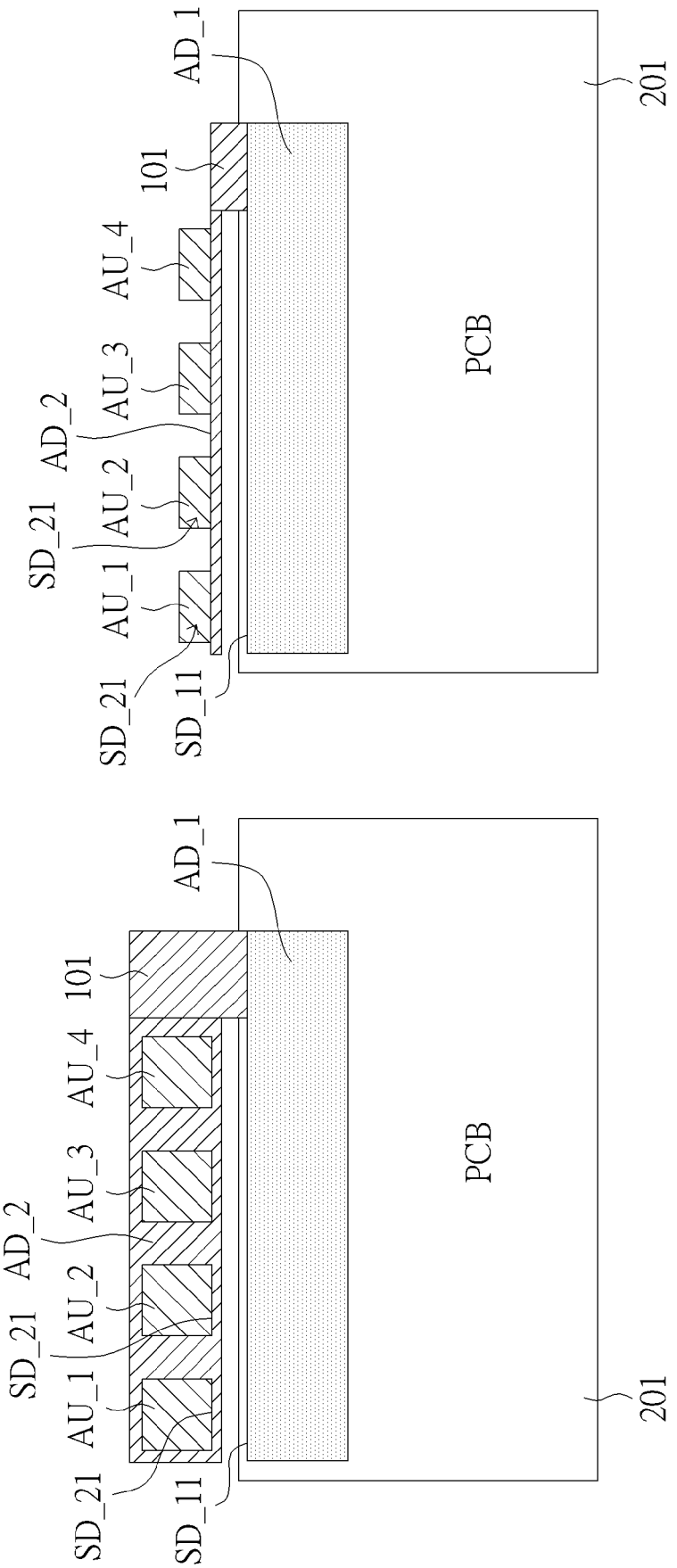

AD_1
101
AU_4
AU_3
AD_2
AU_2
SD_21
AU_1
SD_21
SD_11
PCB
201
Mode 2-1
AD_1
101
AU_4
AU_3
AD_2
AU_2
SD_21
AU_1
SD_21
SD_11
PCB
201
Mode 1

FIG. 7

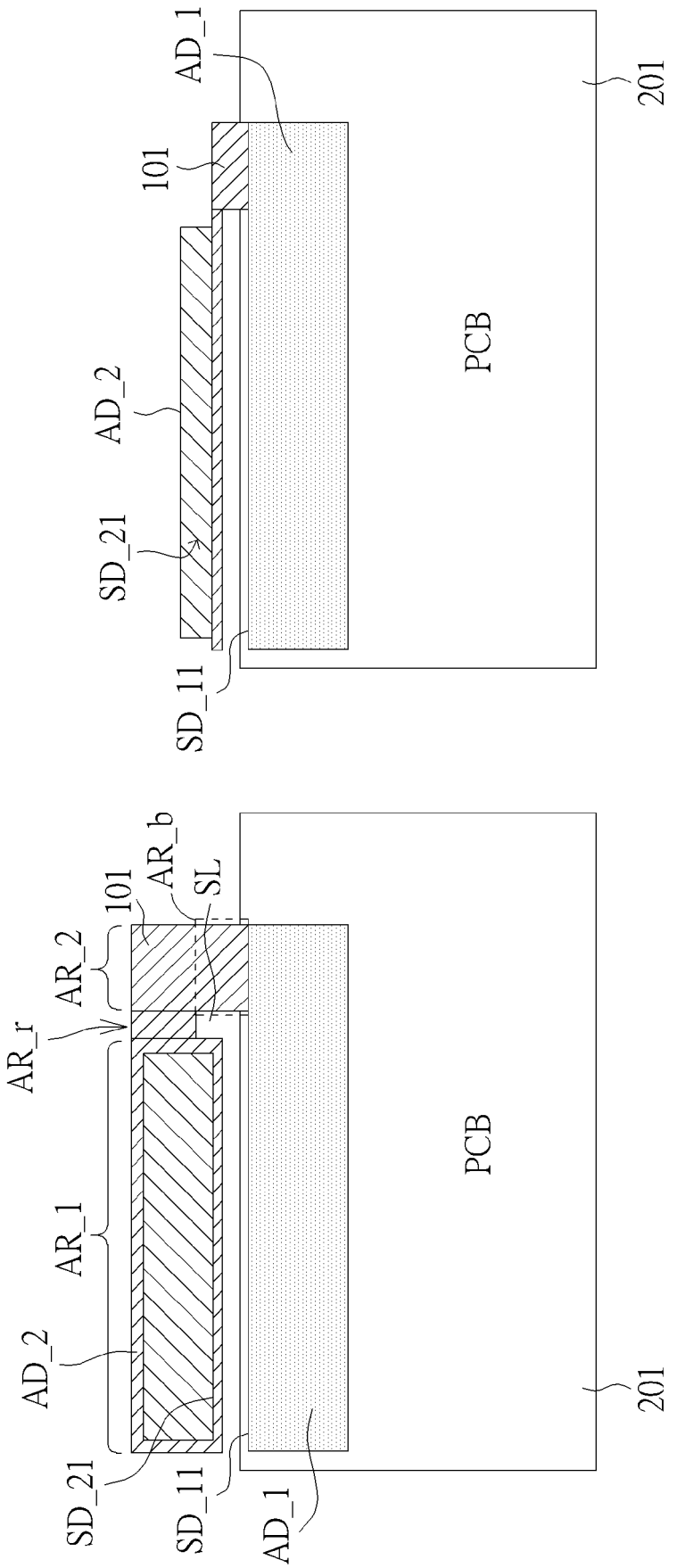

AD_1
101
201
AD_2
PCB
SD_21
Mode 2-1
SD_11
AR_b
SL
101
AR_2
AR_r
AR_1
AD_2
PCB
201
SD_21
Mode 1
SD_11
AD_1

FIG. 8

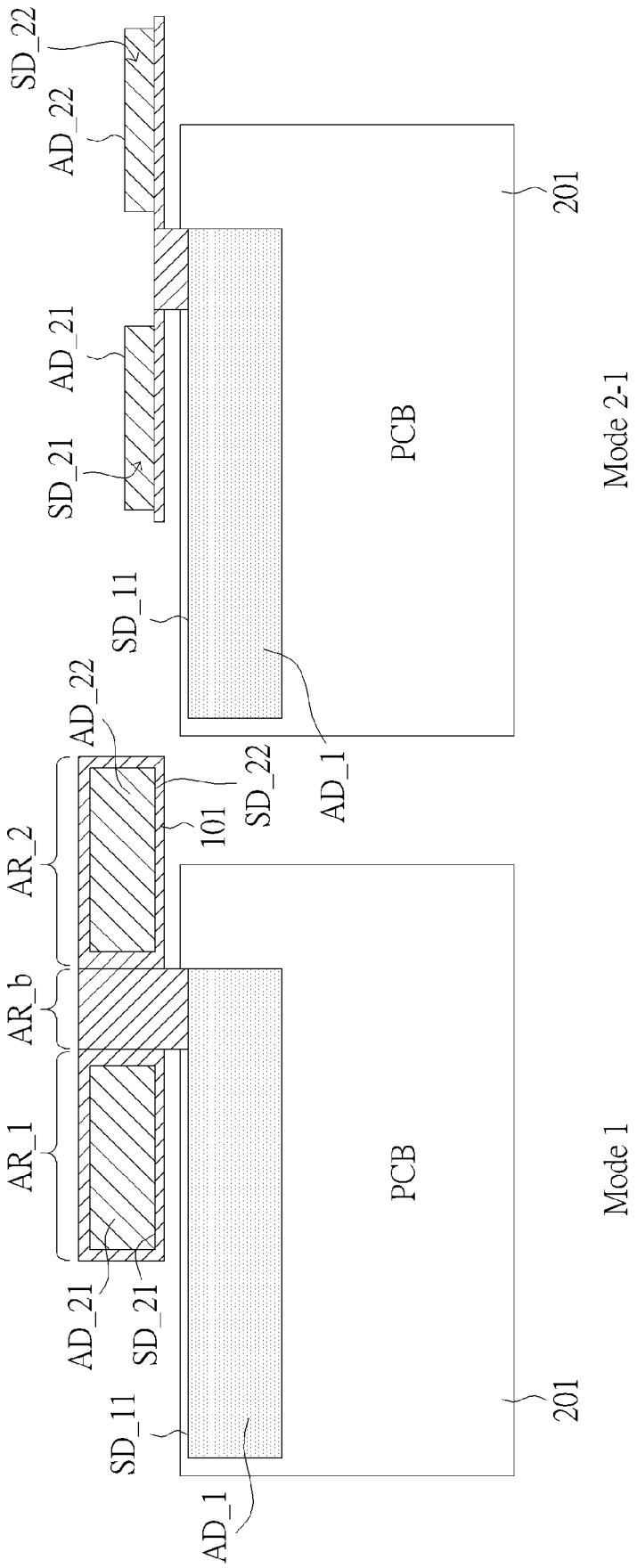

SD_22
AD_22
201
AD_21
SD_21
PCB
SD_11
Mode 2-1
AD_22
AR_2
101
SD_22
AD_1
AR_b
AR_1
PCB
AD_21
SD_21
Mode 1
SD_11
201
AD_1

FIG. 9

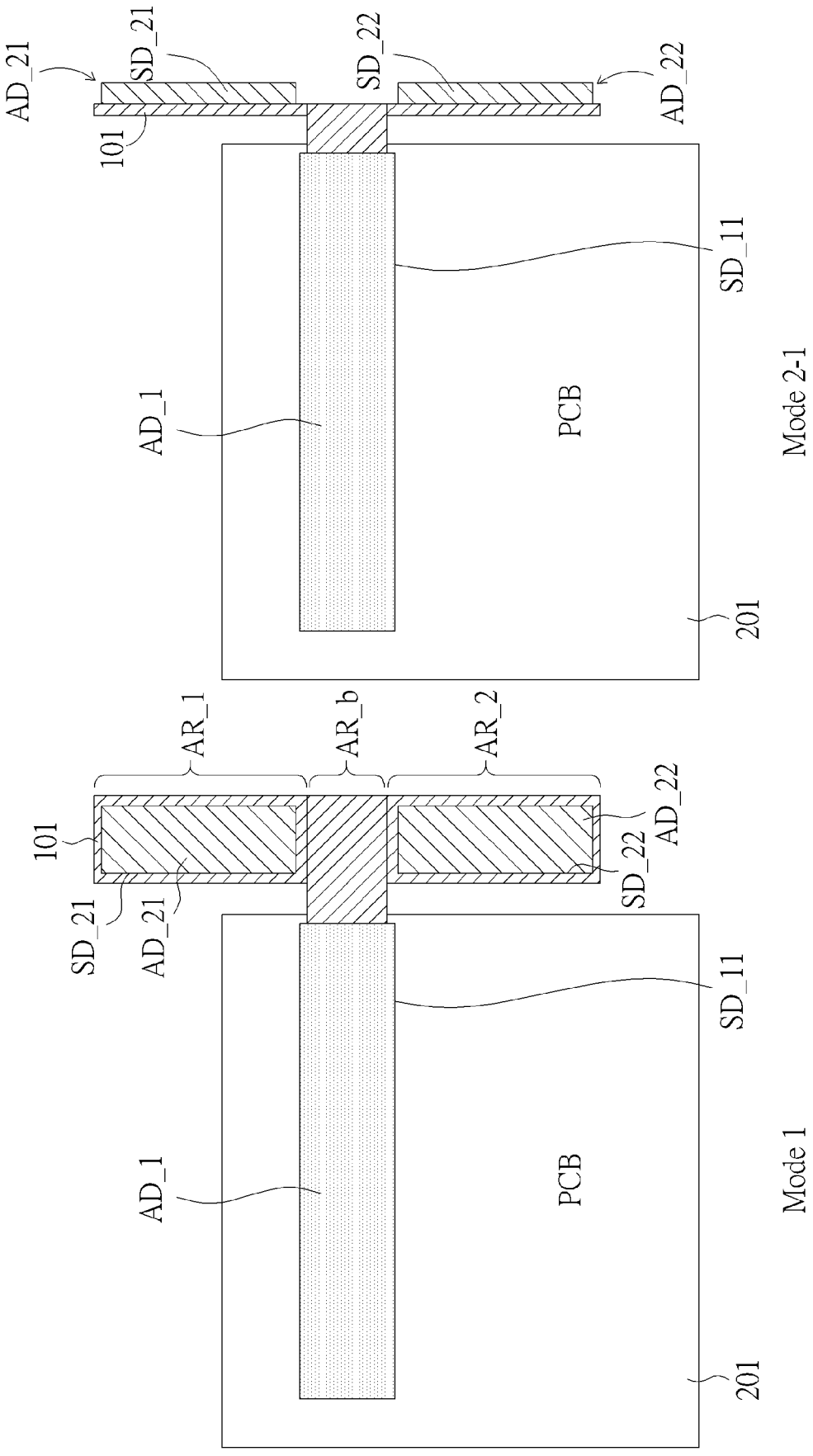

AD_21
SD_21
SD_22
AD_22
101
SD_11
AD_1
PCB
Mode 2-1
201
AR_1
AR_b
AR_2
101
AD_22
SD_22
SD_21
AD_21
SD_11
AD_1
PCB
Mode 1
201

FIG. 10

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EUROPEAN SEARCH REPORT

Application Number
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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	25 April 2023	Kalialakis, Christos

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