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(54) **Wireless module with integrated slot antenna**

(57) The present invention relates to a wireless radio-frequency module (100) comprising a printed circuit board (102) provided with an electric radio-frequency circuit (103a, 103b, 103c), a metal casing (101) mounted to the printed circuit board, and a slot antenna (158)

formed in the metal casing, wherein the printed circuit board (102) being provided with a coplanar waveguide (125), being coupled to the radio-frequency circuit and being coupled to the slot antenna (158) by means of a feeding mechanism (170, 159).

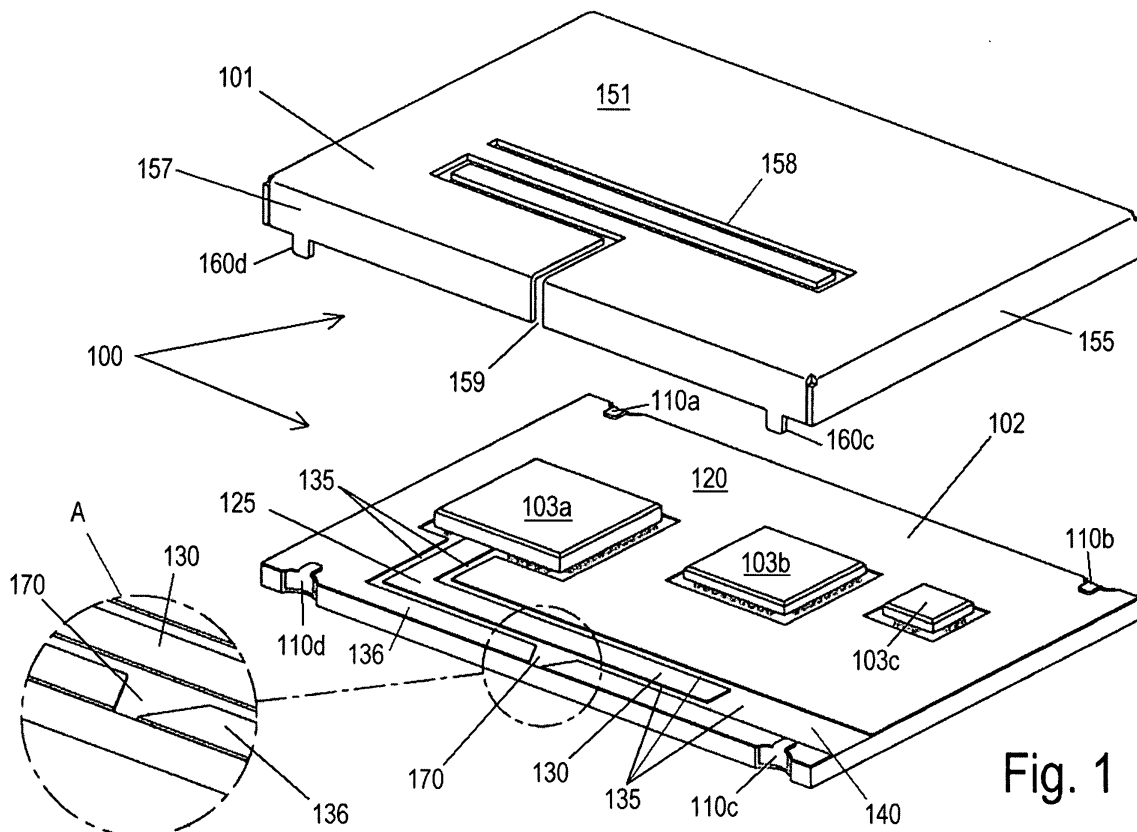


Fig. 1

Description

[0001] The present invention relates in general to the field of wireless radio-frequency (RF) modules, and in particular to wireless RF modules used in communication devices. More particular, the present invention relates to a wireless RF module having a grounded or non-grounded metal case, such as a RF circuit module provided with a metal shielding or metal casing on top, in combination with a slot antenna formed at said metal casing. For example, such a wireless RF module in combination with said slot antenna can be adapted for use in wireless communication apparatuses such as mobile phones or Bluetooth devices. Thus, the size of such apparatuses can be reduced, and the antenna characteristics thereof can be improved.

[0002] A common general problem with wireless RF apparatuses, such as mobile phones or similar wireless communication devices, is the integration of the antenna in a small-size wireless component such as a wireless RF module which is provided with a metal shielding or metal casing. As already known, the wireless radio-frequency circuit (RF circuit) of the wireless RF module provided on a printed circuit board (PCB) of the RF module and the antenna are separate components which are usually miniaturized separately from each other. However, there are limitations with respect to such miniaturization.

[0003] The current state of technology is, for example, described in US 2004/0137971 A1 which discloses a wireless communication apparatus that allows miniaturization of a wireless communication apparatus as a whole and improvements of characteristics of an antenna device. As described in this document, a notch portion is formed in a shield case formed of conductive material that covers a radio-frequency wireless communication circuit provided on a printed wiring board so as to house the radio-frequency wireless communication circuit within the shield case. In other words, the slot is formed as a trench that is soldered on its walls to the printed circuit board (PCB) of the component. However, this construction is difficult and expensive to produce and therefore not suited for mass-production - neither in production of the shielding nor in the later assembly of the printed circuit board.

[0004] WO 02/095869 A1 and US 2005/0237251 A1 both relate to radio-frequency communication devices provided with different slot antenna arrangements. However, these documents have their focus on varying resonant frequencies and bandwidth but do not disclose any teachings with respect to the miniaturization of RF modules and the coupling between a slot antenna and the related RF circuit.

[0005] Thus, it is an object of the present invention to alleviate the above mentioned disadvantages and to provide a cost-effective and mass-production suited combined wireless RF module in combination with a slot antenna. In particular, it is an object of the invention to pro-

vide a wireless RF module for use in wireless communications systems, for example, having a metal shielding or metal casing on top which is provided with a cheap and easy-to-build slot antenna.

[0006] In general, the present invention comprises two main ideas:

1. The realization of a slot antenna that can be easily and cost-effective manufactured.

2. The implementation of a feeding mechanism that does not impede with mass-production suitability of the printed circuit board (PCB) of a wireless RF module.

[0007] This object is achieved by a wireless RF module as defined in claim 1. Preferred embodiments of the RF module are set out in the dependent claims.

[0008] The invention will in the following be described in connection with different, non-limiting embodiments shown in the drawings, in which:

Figure 1 shows an exploded and perspective view from above of a wireless RF module according to a first embodiment of the present invention;

Figure 2 shows a perspective view from above of the wireless RF module of Figure 1 after assembly thereof;

Figure 3 shows a top view of a metal sheet blank for forming the casing for the wireless RF module of Figures 1 and 2;

Figure 4 shows an exploded and perspective view from above of a wireless RF module according to a second embodiment of the present invention;

Figure 5 shows a perspective view from above of the wireless RF module of Figure 4 after assembly;

Figure 6 shows an exploded and perspective view from above of a wireless RF module according to a third embodiment of the present invention;

Figure 6A shows an exploded and perspective view from above of a modified version of the wireless RF module of Figure 6;

Figure 7 shows a perspective view from above of the wireless RF module of Figure 6 after assembly;

Figure 7A shows a perspective view from above of the wireless RF module of Figure 6A after assembly;

Figure 8 shows an exploded and perspective view from above of a wireless RF module according to a fourth embodiment of the present invention;

Figure 9 shows a perspective view from above of the wireless RF module of Figure 8 after assembly;

Figure 10 shows an exploded and perspective view from above of a wireless RF module according to a fifth embodiment of the present invention; and

Figure 11 shows a perspective view from above of the wireless RF module of Figure 10 after assembly.

[0009] In the following detailed description, reference is made to the accompanying drawings that form part of it, and in which are shown by way of illustration specific embodiments of the present invention. Said embodiments of the present invention provide improvements in wireless RF modules and slot antennas which are used in, for example, wireless communication RF modules and wireless communication devices such as mobile phones, personal digital assistants (PDA), Bluetooth apparatuses and similar devices.

[0010] Reference is now made to Figures 1 and 2. Figure 1 shows an exploded and perspective view from above of a wireless RF module 100 according to a first embodiment of the present invention, and Figure 2 shows a perspective view from above of the wireless RF module 100 of Figure 1 after assembly thereof. As shown in Figures 1 and 2, the wireless RF module 100 includes a conductive or metal casing 101 and a RF circuit module formed by a printed circuit board 102 comprising several electronic components 103a - 103c (see Figure 1) of an electronic RF circuit (for example a transceiver circuit), and other electronic means as required for a wireless communication device. As shown in Figures 1 and 2, the metal casing 101 is adapted to be attached to the printed circuit board 102. Details of different attachment configurations and attachment methods are explained below with reference to the present and alternative embodiments of the present invention.

[0011] Figure 3 shows a top view of a metal sheet 150 prior to forming the metal casing 101 for the wireless RF module 100 of Figures 1 and 2. The metal sheet 150 formed by punching of a metal plate, for example, comprises a rectangular main surface 151, left and right side walls 154, 155, and upper and lower side walls 156, 157 which can be bent downwards along the connection lines C, preferably with an angle of 90°, to form the metal casing 101. Thus, the metal casing has a cubic configuration with an open bottom side wherein the side walls 154, 155, 156, 157 extend substantially perpendicular to the main surface 151.

[0012] After assembly of the metal casing 101 and the printed circuit board 102 (see Figure 2), the metal casing 101 serves as an electromagnetic wave shielding member for blocking undesired electromagnetic waves emitted from the printed circuit board 102 of the wireless RF module 100, and in particular from the RF circuit, the electronic components 103a - 103c, and the conducting structure thereof.

[0013] The inventive concept preferably relates to forming a meander-shaped slot 158 in the metal sheet 150 for the slot antenna wherein the production process for forming the slot antenna is no additional production step. As can be seen from Figures 1 to 3, the meander-shaped slot 158 is made by punching, etching or laser cutting, for example, the metal sheet 150 prior to forming the metal sheet 150 into the metal casing 101 by means of an appropriate forming tool. The punching or etching technique is well known and best suited for high production volumes. Preferably, the manufacturing of the slot 158 is part of the production process for the metal casing sheet 150 such that no additional production steps for forming the slot are needed. Further, it is not necessary to modify the forming tool for the conventional metal casing for manufacturing the inventive metal casing which is provided with the slot antenna. The meander-shaped slot 158 is provided in the main surface 151 and in the lower side wall 157, and the meander-shaped slot 158 ends at the lower edge of the lower side wall 157 as shown in Figures 1 to 3, thus forming a terminal portion 159 at the lower side wall 157, the function thereof is described below in detail. However, it is obvious for a person skilled in the art after studying the present specification that alternative configurations are possible.

[0014] The metal sheet 150 is made of conductive metal or any other suitable conductive material or material composition. It is also possible that the metal sheet 150 includes a resin or ceramic layer which is plated with copper or silver or any other conductive materials. The term "metal casing" is used to describe a conductive casing. However, other conductive materials or material compositions can be used instead of metal.

[0015] The total length of the meander-shaped slot 158 is about 1/2 of the wavelength λ of the used frequency. The width and depth of the slot 158 is about 1/50 or more of said wavelength. However, other configurations (instead of the meander-shaped configuration) and dimensions can be used is appropriate and described with respect to other preferred embodiments.

[0016] Further, the top and lower side walls 156, 157 are provided with projections or elongated pins 160a to 160d for mounting the formed metal casing 101 to the printed circuit board 102 (see Figures 1 to 3) of the wireless RF module. However, other means for attaching the metal casing 101 to the printed circuit board 102 are possible and obvious for a person skilled in the art.

[0017] Figure 2 shows a perspective view from above of the wireless RF module 100 of Figure 1 after assembly thereof, i.e., after the metal casing 101 is attached to the top surface of the printed circuit board 102. According to a first embodiment, the metal casing 101 is attached to the printed circuit board 102 by means of the projections 160a to 160d formed at the upper and lower side walls 156 and 157 of the metal casing. It is obvious that said projections can also be formed at the left and right side walls 154 and 155, or at all side walls. For attachment and to assist correct alignment of the casing 101 with the

circuit board 102, the front and rear edges (and/or the left and right edges) of the printed circuit board 102 are provided with corresponding recesses 110a to 110d which are adapted for receiving the projections 160a to 160d as best shown in Figure 2.

[0018] It is obvious from Figure 2 that the outer dimensions of the metal casing 101 defined by the bent side walls 154, 155, 156, 157 correspond to or are slightly smaller than the outer dimensions of the printed circuit board 102. Thus, it is possible to mount the metal casing 101 onto the printed circuit board 102 wherein the lower edges/bottom surfaces of the casing sidewalls 154, 155, 156, 157 abut against the upper surface of the printed circuit board 102.

[0019] The printed circuit board 102 is made of non-conductive material, such as epoxy resin, and (as shown schematically in Figure 1 and 2) at least the upper surface of the printed circuit board 102 is provided with a conducting layer 120 which forms, after a suitable etching process, at least part of the wiring for the RF circuit and a coplanar waveguide (details are described below). Preferably, the lower surface of the printed circuit board 102 is also provided with a conductive layer to form at least part the wiring of the electronic circuit, i.e. the electronic components 103a, 103b, 103c, provided on the printed circuit board 102, and/or the ground element for a coplanar waveguide, as described below. However, alternative wiring solutions are possible. For example, the wiring for the electronic components 103a, 103b and 103c could be provided or embedded within the non-conductive material of the printed circuit board. This is, the printed circuit board 102 may have a multi-layer configuration comprising a plurality of non-conductive layers and layers with conducting paths and/or conducting ground layers disposed therebetween.

[0020] As further shown in Figures 1 and 2, the conductive layer 120 at the upper surface of the printed circuit board at least partially extends up to the outer edges of the printed circuit board 102. Thus, after assembly, as shown in Figure 2, the lower edges (the bottom surfaces of these edges) of the metal casing sidewalls which abut against the top surface of the printed circuit board are at least partially in conductive contact with the conductive layer 120 on the top surface of the printed circuit board 102. In one embodiment, the recesses 110a to 110d for receiving the projections 160a to 160d are provided with a conductive (metal) liner which is in electric contact with the top conductive layer 120 of the printed circuit board 102. Thus, the electric coupling between the casing 101 and the conductive layer 120 is improved because of the electric contact between the projections 160a to 160d and the conductive liners in the recesses 110a to 110d which are in electric contact with the top conductive layer 120. Further, the metal casing 101 can be attached to the top conductive layer 120 by welding, i.e., welding points or welding beads can be made at the projections 160a-160d and the conductive liners in the recesses 110a-110d and/or at the contact areas between the cas-

ing 101 and the top conductive layer 120. Alternatively or additionally, the length of the projections 160a-160d can be elongated such that the lower ends of projections can be bent around the lower edges towards the bottom surface of the printed circuit board 102 (similar to the embodiment shown in Figures 4 and 5). In this case, welding is not required as the contact forces between the lower edges/bottom surfaces of the sidewalls of the metal casing 101 and the top conductive layer 120 of the printed circuit board 102 are sufficient to provide the required electric contact.

[0021] In addition, a coplanar waveguide 125 is provided at the upper surface of the printed circuit board, a first end of which is connected to the RF input/output of the RF circuit, and in particular to the electronic component 103a, as shown in Figure 1. The coplanar waveguide 125 is formed by an elongated strip element 130 formed in the conductive layer 120. Additionally, the non-conductive circuit board 102 and (preferably) a conductive ground layer (not shown) at the bottom of the circuit board are used for forming the coplanar waveguide 125. In the embodiment of Figure 1, the conductive strip element 130 is formed by etching an elongated strip in the conductive layer 120. In other words, insulation areas or insulation grooves 135 for isolating the strip element 130 against the remaining surface of the conductive layer 120 are made by etching or other known methods. As obvious from Figure 1, the input/output end of the conductive strip 130 (i.e. first end) is electrically connected to the electronic RF circuit (e.g. electronic component 103a). The dimensions of the conductive strip 130 (i.e. shape, length, thickness, and width thereof, and thickness of the non-conductive material of the printed circuit board 102) depend on the frequency of the signals to be transmitted, the impedance of the electronic RF circuit, and other parameters. Further, the coplanar waveguide 125 (i.e. the conductive strip 130) is open-ended with a distance (defined by the gap 140) to the right edge of the printed circuit board 102 (see Figure 1). In Figure 1, the coplanar waveguide 125 extends from the electronic component 103a towards the front edge of the circuit board, and is curved with an angle of 90° to extend in parallel to the front edge of the circuit board. However, other configurations are possible. The length of the conductive strip 130 (defined by the length of gap 140 at the second end of the strip 130 opposite to the first end thereof) is adjusted with the goal that, at the position of a recess 170 (see Figure 1) for feeding the signals into the slot antenna 158 formed in the metal casing 101, a maximum coupling to the slot antenna 158 is achieved after assembly. Details of the coupling features are described below.

[0022] It is noted that this invention is not limited to using a coplanar waveguide 125 as the coupling element to the slot antenna 158, any other transmission line like micro-strips etc. can be used similarly.

[0023] In contrary to the prior art solutions, the feeding mechanism between the coplanar waveguide 125 and the slot antenna 158 according to the present invention

can be realized without soldering an additional part of the metal casing 101 to the printed circuit board 102 of the wireless RF module 100, but by providing a coplanar RF wave guide 125 coupled to an opening or recess 170 which is provided at the top conductive layer 120 of the printed circuit board 102 which recess is adapted for communication with the slot antenna as described in detail below. In other words, the RF signals from the electronic RF circuit (e.g. electronic component 103a) provided at the printed circuit board are transmitted by means of recess 170 which is coupled to the coplanar waveguide into the slot antenna 158 of the metal casing 101. It is obvious from the above explanations and from Figures 1 and 2 that, as an important feature, the terminal portion 159 of the slot antenna 8 is in alignment with the recess 170 for transmission of signals between the slot antenna and the coplanar waveguide.

[0024] In Figures 1 and 2, and in particular in the encircled enlarged views A and B of Figures 1 and 2, the first embodiment of the implementation of such a feeding mechanism for transmission of signals between the slot antenna 158 and the coplanar waveguide 125 is shown. As mentioned above, the conductive strip 130 is provided on the printed circuit board 102, wherein the conductive strip 130 is isolated at both longitudinal sides thereof against the remaining area of the top conductive layer 120 by means of insulation areas or grooves 135 etched in the conductive layer 120. Thereby, at both longitudinal sides, conductive areas are provided which are insulated against the conductive strip portion 130 of the coplanar waveguide 125. Such a configuration is conventional in the technical area of coplanar waveguides. In the embodiment of Figures 1 and 2, a conductive elongated strip portion 136 is provided between the front edge of the circuit board 102 and the insulation groove 135 of the coplanar wave guide 125. Further, an opening or recess 170 is formed in the conductive elongated strip portion 136, for example by means of etching or similar techniques. Therefore, the recess 170 is as a non-conductive (isolating) area between the insulation groove 135 and the front edge of the printed circuit board 102. In the first embodiment, the recess 170 has a tapered configuration, i.e., the recess 170 is tapered from the insulation groove 135 towards the front edge of the printed circuit board.

[0025] Said recess 170 is arranged in alignment with the terminal portion 159 of the slot antenna 158 formed in the metal casing 101, after assembly of the RF module 100. Thus, as shown in the enlarged view B of Figure 2, the width of the groove of the slot antenna 158 and the width of the terminal portion 159 correspond to the width of the narrow end of the tapered recess 170. Therefore, improved coupling between the coplanar waveguide 125 and the slot antenna 158 can be achieved. In summary, the recess 170 and the terminal portion 159 of the slot antenna 125 are adapted to provide a feeding mechanism between the coplanar waveguide 125 and the slot antenna 158.

[0026] The non-conductive gap 140 (i.e. by varying the

length thereof) is used for tuning the efficiency of feeding RF waves from the coplanar waveguide 125 into the recess 170 and, therefore, into the slot antenna 158.

[0027] Figure 4 shows an exploded and perspective view from above of a wireless RF module 200 according to a second embodiment of the present invention, and Figure 5 shows a perspective view of said wireless RF module of Figure 4 after assembly. In these Figures, corresponding reference numbers (the value 100 has been added to the reference numbers in Figures 1 to 3) are used.

[0028] As shown in Figures 4 and 5, the wireless RF module 200 also includes a metal casing 201 and a printed circuit board 202 as in the embodiment of Figures 1 and 2. The metal casing 201 is made by means of a procedure as described with reference to Figure 3.

[0029] As can be seen in Figures 4 and 5, a meander-shaped slot 258 is formed in the metal casing 201 by punching, for example, as described with reference to Figures 1 to 3. The meander-shaped slot 258 is longer than the slot 158 in Figures 1 to 3, i.e. comprises more turns. Thus, the antenna of the second embodiment can be used for lower frequencies. Due to crosstalk between the different turns, careful layout can lead to a multi-band capability in addition to the lower operating frequency.

[0030] Similar to Figures 1 to 3, the top and lower side walls 256, 257 are provided with projections or elongated pins 260a to 260d for mounting the formed metal casing 201 to the printed circuit board 202 (see Figure 5) of the RF module. According to the second embodiment, the metal casing 201 is attached to the printed circuit board 202 by means of the projections 260a to 260d formed at the upper and lower side walls 256 and 257. It is obvious that said projections can also be formed at the left and right side walls, or at all side walls. To assist correct alignment of the casing 201 with the printed circuit board 202 and to improve connection therebetween, the front and rear edges (and/or the left and right edges) of the printed circuit board 202 are provided with corresponding depressions 280a to 280d having a depth corresponding to the thickness of the metal casing 201 and which are adapted for receiving the broader portions of the projections 260a to 260d as best shown in Figure 5.

[0031] As can be seen in Figure 5, the length of the projections 260a to 260d is sufficient such that the lower ends of projections can be bent around the lower edges of the printed circuit board 202 towards the bottom surface thereof. In addition to this attachment method, additional welding can be used to improve the attachment, however, welding is not required as the contact forces between the lower edges/bottom surfaces of the side-walls of the casing 201 and the top conductive layer of the printed circuit board 202 are sufficient to provide the required electric contact.

[0032] The coplanar waveguide 225 is similar to that described in connection with Figures 1 and 2. Thus, a detailed description is omitted.

[0033] In Figures 4 and 5, and in particular in the en-

circled enlarged views A and B of Figures 4 and 5, it can be seen that the opening or recess 270 has a rectangular configuration, instead of the tapered shape as in the first embodiment. Further, as shown in the enlarged view B of Figure 5, the width of the groove of the slot antenna 258 and the width of the terminal portion 259 corresponds to the width of the rectangular recess 270. Also in this embodiment, the recess 270 in combination with the terminal portion 259 form the feeding mechanism as described with respect to the first embodiment.

[0034] Figure 6 shows an exploded and perspective view from above of a wireless RF module according to a third embodiment of the present invention, wherein Figure 6A shows a modified version of the wireless RF module of Figure 6. Figures 7 and 7A show the wireless RF module of Figures 6 and 6A after assembly. In these Figures, corresponding reference numbers (the value 100 has been added to the reference numbers in Figures 4 to 5) are used. The features not described regarding the third embodiment correspond to the first and second embodiment, thus, the description thereof is omitted.

[0035] The RF module 300 according to the third embodiment is similar to the first and second embodiment. However, as shown, the slot antenna 358 has a simple tapered slot configuration leading to a wider operating bandwidth. With respect to the other features, in particular the coplanar waveguide 325, the third embodiment is similar to the first and second embodiments. It is noted that in the third embodiment, a tapered recess 370 and a rectangular recess can be used (see Figure 4). Another difference relates to the means for attaching the metal casing 301 to the printed circuit board 302. As shown in Figures 6 and 7, the metal casing is provided with projections 360a to 360d which are adapted to be inserted into corresponding holes 311a to 311d having a circular or rectangular cross section. The projections may have a sufficient length to be bent at the bottom surface of the printed circuit board. Additionally or alternatively, the metal casing can be welded to the printed circuit board (see weld beads 399 in Figures 7 and 7A). In case of welding, the projections and the holes may serve as means for correct alignment between the casing and the circuit board.

[0036] Figure 8 shows an exploded and perspective view from above of a wireless RF module 400 according to a fourth embodiment of the present invention, and Figure 9 shows the wireless RF module 400 of Figure 8 after assembly. It is obvious from these figures that the general configuration of the fourth embodiment is similar to that of the previous embodiments. Thus, a detailed description is omitted. The slot antenna 458 has a configuration similar to that of Figures 4 and 5.

[0037] Similar to Figures 4 and 5, the top and lower side walls are provided with projections 460a to 460d for mounting the metal casing 401 to the printed circuit board 402 of the RF module. Further, the front and rear edges of the printed circuit board 402 are provided with corresponding depressions 410a to 410d having a depth cor-

responding to the thickness of the metal casing 401 and which are adapted for receiving the projections 460a to 460d as best shown in Figure 9. Welding is used for securing the metal casing 401 to the printed circuit board 402 (see welding beads in Figure 9). Further, it is noted that in the fourth embodiment, a tapered recess and a rectangular recess for coupling the coplanar waveguide with the slot antenna can be used as described with reference to the previous embodiments.

[0038] Figure 10 shows an exploded and perspective view from above of a wireless RF module 500 according to a fifth embodiment of the present invention, and Figure 11 shows a perspective view of the wireless RF module of Figure 10 after assembly. As can be seen from these figures, the slot antenna 558 has the same configuration as in Figures 6, 6A, 7 and 7A. Similar to the fourth embodiment, also in the fifth embodiment, a tapered recess and a rectangular recess 570 for coupling the coplanar waveguide with the slot antenna 558 can be used. However, in the fifth embodiment, the metal casing 501 does not have any projections for securing the casing 501 to the printed circuit board 502. Instead, the metal casing 501 is welded to the circuit board (see welding beads 599).

Claims

1. Wireless radio-frequency module (100; 200; 300; 400; 500) comprising:

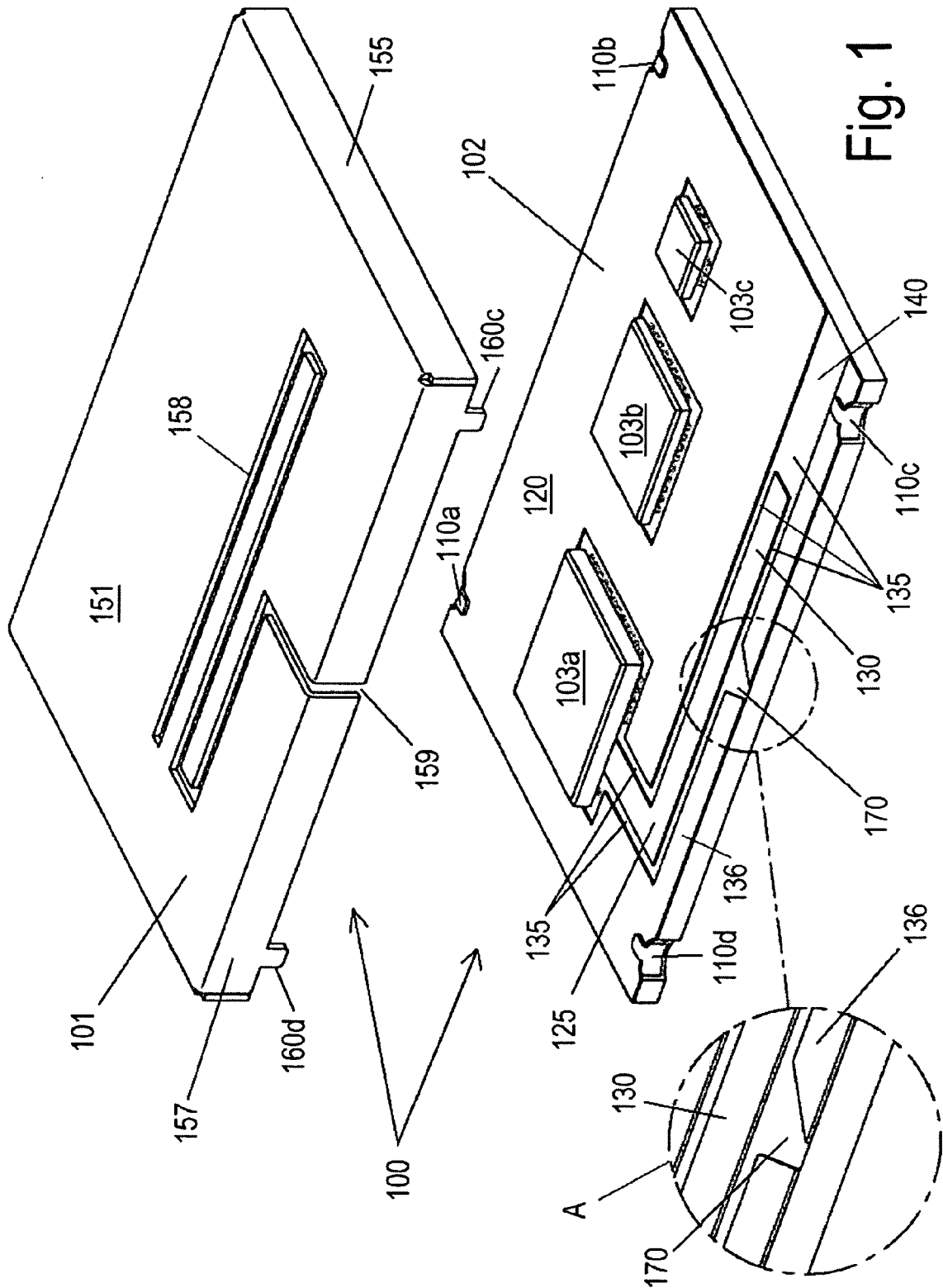
- a printed circuit board (102; 202; 302; 402; 502) provided with an electric radio-frequency circuit (103a, 103b, 103c);
- a metal casing (101; 201; 301; 401; 501) mounted to the printed circuit board; and
- a slot antenna (158; 258; 358; 458; 558) formed in the metal casing;

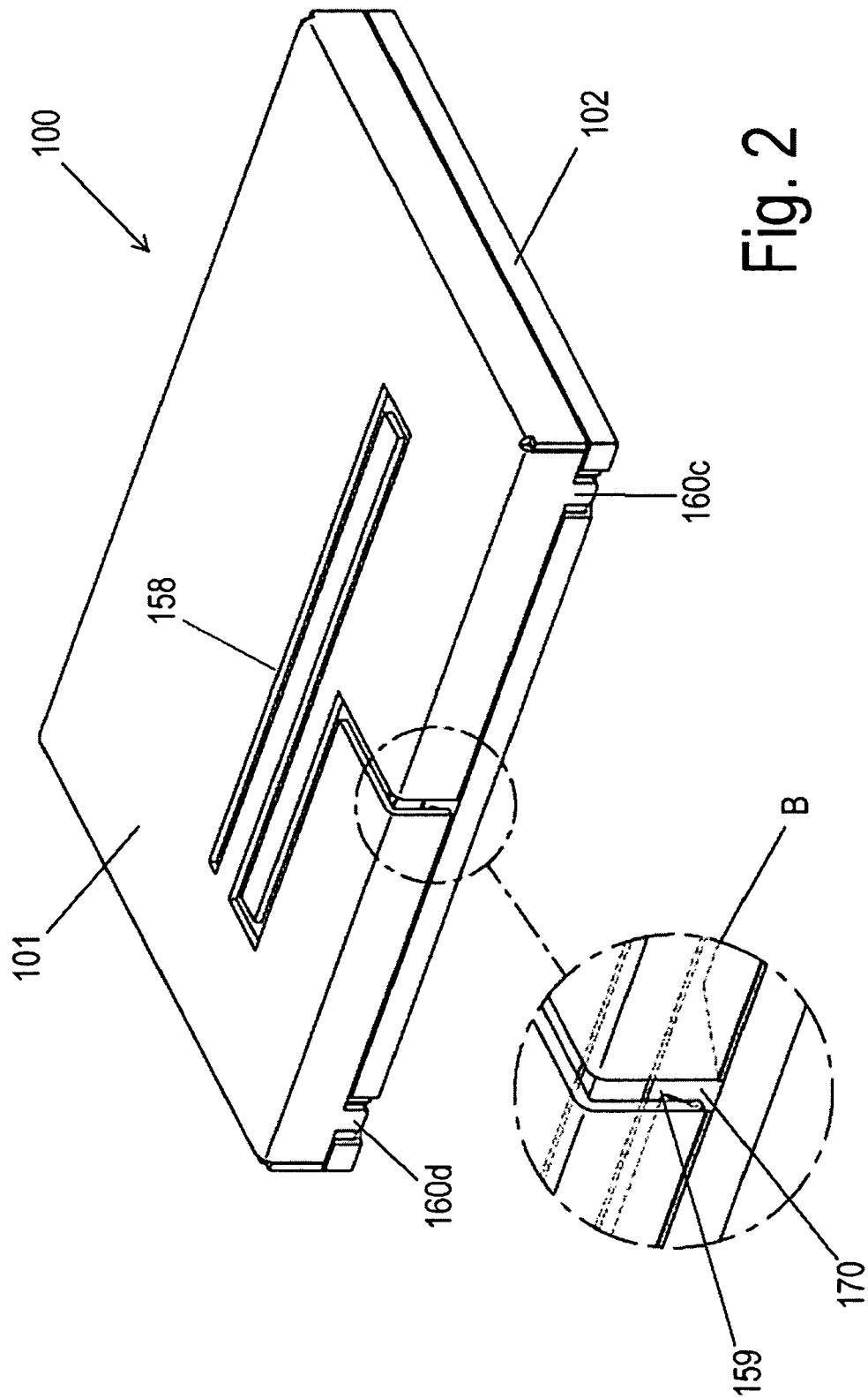
characterized in that

- the printed circuit board (102; 202; 302; 402; 502) being provided with a coplanar waveguide (125; 225; 325; 425; 525);
- the coplanar waveguide (125; 225; 325; 425; 525) being coupled to the radio-frequency circuit; and
- the coplanar waveguide (125; 225; 325; 425; 525) being coupled to the slot antenna (158; 258; 358; 458; 558) by means of a feeding mechanism (170; 270; 370; 470; 570; 159; 259; 359; 459; 595).

2. Wireless radio-frequency module of claim 1, wherein the metal casing (101; 201; 301; 401; 501) is formed by a metal sheet (150) comprising a rectangular main surface (151), left and right side walls (154, 155), and upper and lower side walls (156, 157).

3. Wireless radio-frequency module of claim 2, wherein the left and right side walls (154, 155), and the upper and lower side walls (156, 157) are bent, such that the side walls (154, 155, 156, 157) extend substantially perpendicular to the main surface (151) to form the metal casing (101; 201; 301; 401; 501) having a cubic configuration with an open bottom. 5
4. Wireless radio-frequency module of any of the preceding claims, wherein the slot of the slot antenna (158; 258; 358; 458; 558) is formed by punching or etching a metal sheet (150) prior to forming the metal sheet (150) into the metal casing (101; 201; 301; 401; 501). 10
5. Wireless radio-frequency module of any of the preceding claims, wherein the slot is formed in main surface (151) and at a side wall (157) of the metal casing (101; 201; 301; 401; 501), and ends at the lower edge of said side wall (157) thus forming a terminal portion (159) at said side wall (157). 15 20
6. Wireless radio-frequency module of any of the claims 2 to 5, wherein the top and lower side walls (156, 157) and/or the left and right side walls (154, 155) are provided with projections (160a, 160b, 160c, 160d; 260a, 260b, 260c, 260d; 360a, 360b, 360c, 360d; 460a, 460b, 460c, 460d) for mounting the formed metal casing (101; 201; 301; 401) to a printed circuit board of the circuit module. 25 30
7. Wireless radio-frequency module of any of the claims 2 to 6, wherein the metal sheet (150) is made of conductive metal or any other suitable conductive material or material composition. 35
8. Wireless radio-frequency module of any of the claims 2 to 7, wherein the metal sheet (150) is made of a resin layer which is plated with copper or silver or any other conductive materials. 40
9. Wireless radio-frequency module of any of the preceding claims, wherein the slot of the slot antenna has a total length of about $1/2$ of the wavelength λ of the used frequency. 45
10. Wireless radio-frequency module of any of the preceding claims, wherein the slot of the slot antenna has a width and depth of about $1/50$ or more of the used wavelength. 50
11. Wireless radio-frequency module of any of the preceding claims, wherein the radio-frequency circuit of the printed circuit board comprises several electronic components (103a, 103b, 103c) for providing a transceiver circuit. 55
12. Wireless radio-frequency module of any of the preceding claims, wherein the metal casing (101; 201; 301; 401; 501) is mounted onto the printed circuit board (102; 202; 302; 402; 502) with the bottom surfaces of the casing sidewalls abut against the top surface of the printed circuit board.
13. Wireless radio-frequency module of any of the preceding claims, wherein the printed circuit board (102; 202; 302; 402; 502) is provided with a coplanar wave guide (125; 225; 325; 425; 525) that is coupled to a recess (170; 270; 370; 470; 570) formed on the printed circuit board for feeding RF signals from the RF circuit into the slot antenna (158; 258; 358; 458; 558) of the casing (101; 201; 301; 401; 501).
14. Wireless radio-frequency module of any of the preceding claims, wherein the slot antenna (158; 258; 358; 458; 558) is provided with a terminal portion (159; 259; 359; 459; 559) at an outer edge of the metal casing which is in communication with the coplanar waveguide (125; 225; 325; 425; 525).
15. Wireless radio-frequency module of any of the preceding claims, wherein the slot antenna (158; 258; 358; 458; 558) is provided with a terminal portion (159; 259; 359; 459; 559) at an outer edge of the metal casing, and the coplanar waveguide (125; 225; 325; 425; 525) is formed with a recess (170; 270; 370; 470; 570) being arranged in alignment with the recess (170; 270; 370; 470; 570) for coupling the coplanar waveguide of the printed circuit board to the slot antenna (158; 258; 358; 458; 558) of the metal casing.
16. Wireless radio-frequency module of any of the preceding claims, wherein the upper surface of the printed circuit board is provided with a conducting layer (120), the coplanar waveguide being formed by said conducting layer (120).
17. Wireless radio-frequency module of any of the preceding claims, wherein the feeding mechanism comprises a recess (170; 270; 370; 470; 570) having a rectangular or a tapered configuration.
18. Wireless radio-frequency module of any of the preceding claims, wherein the slot antenna (158; 258; 458) has meander-shaped configuration.
19. Wireless radio-frequency module of any of the preceding claims, wherein the slot antenna (358; 558) has linear and tapered configuration.





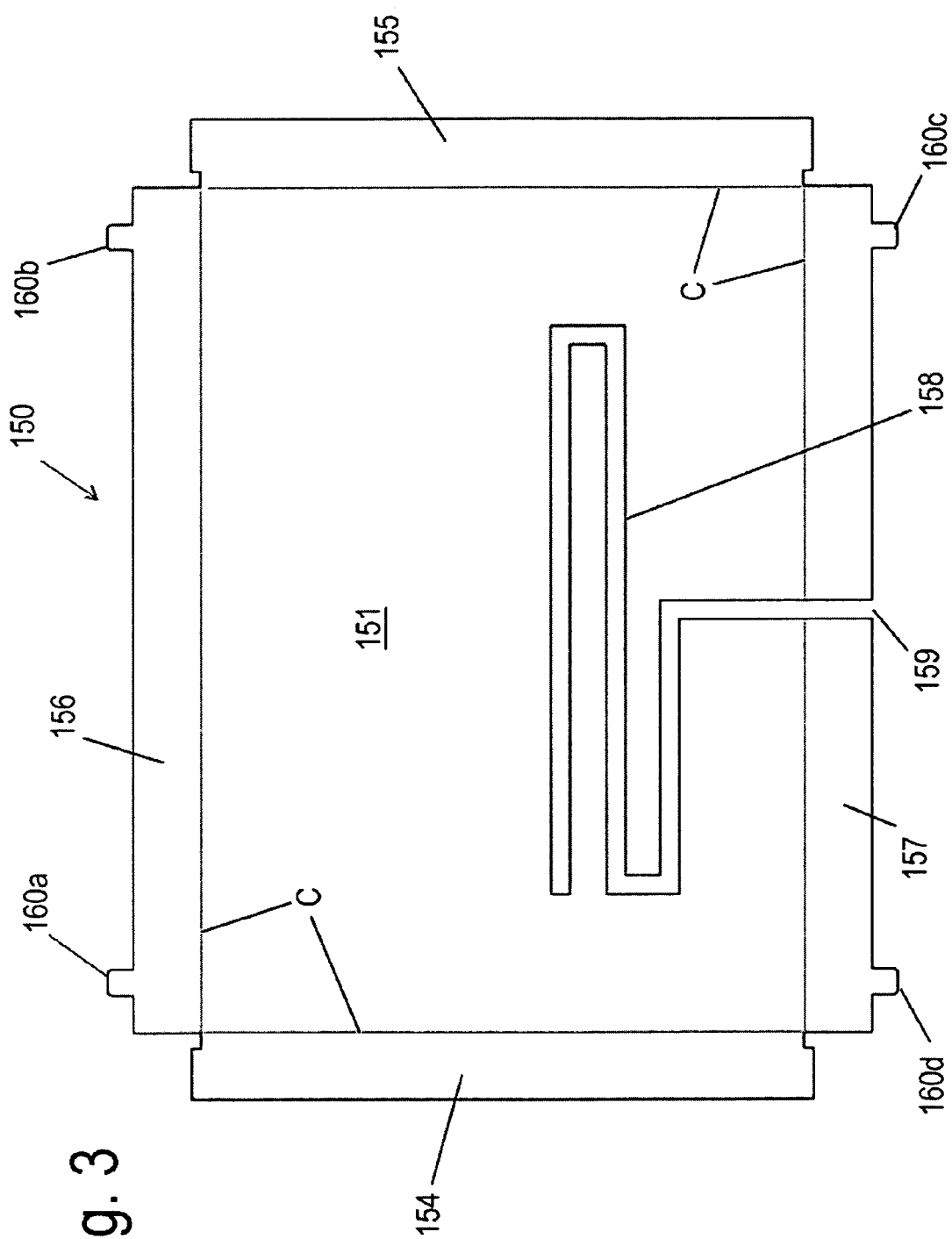
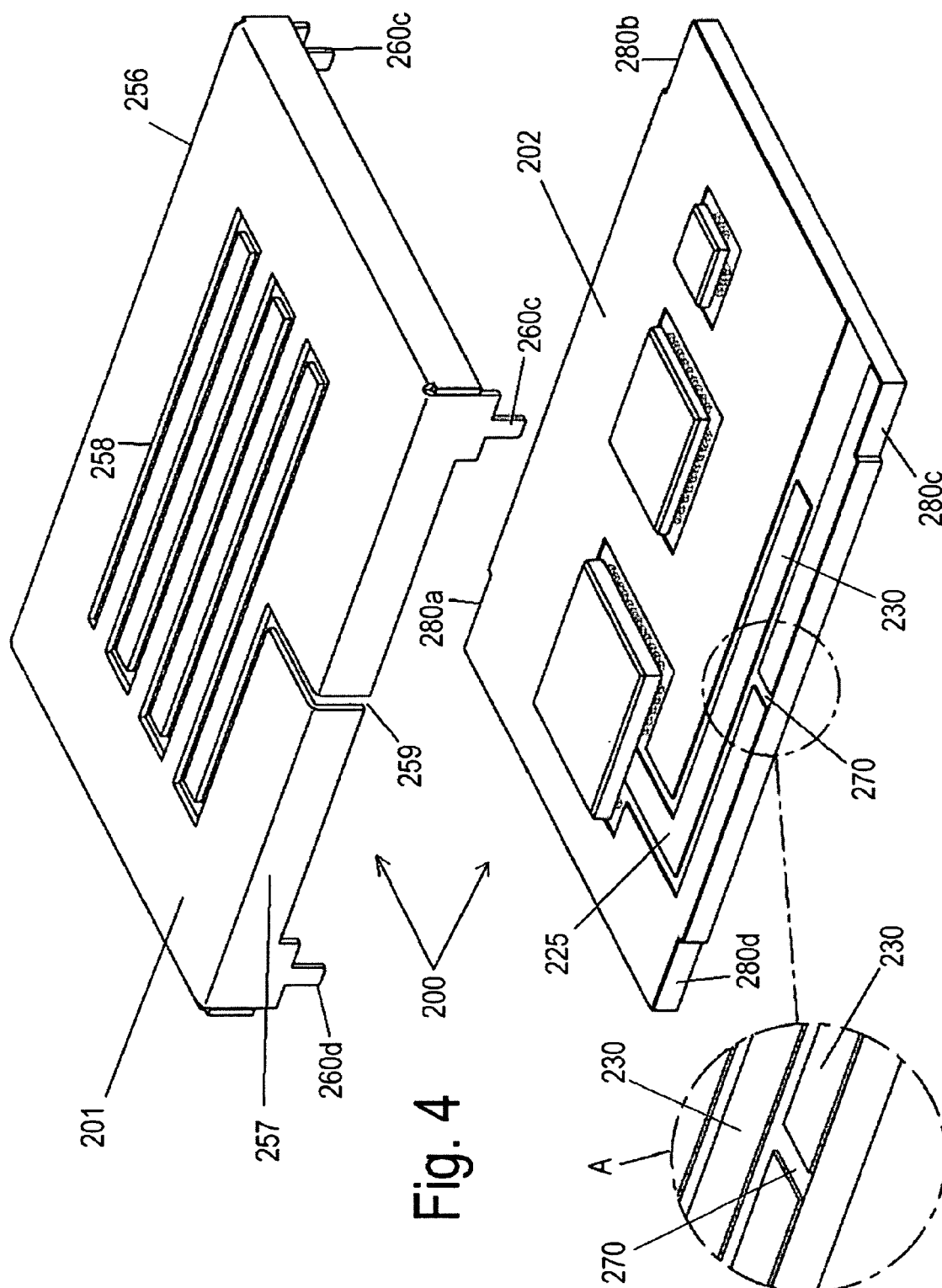
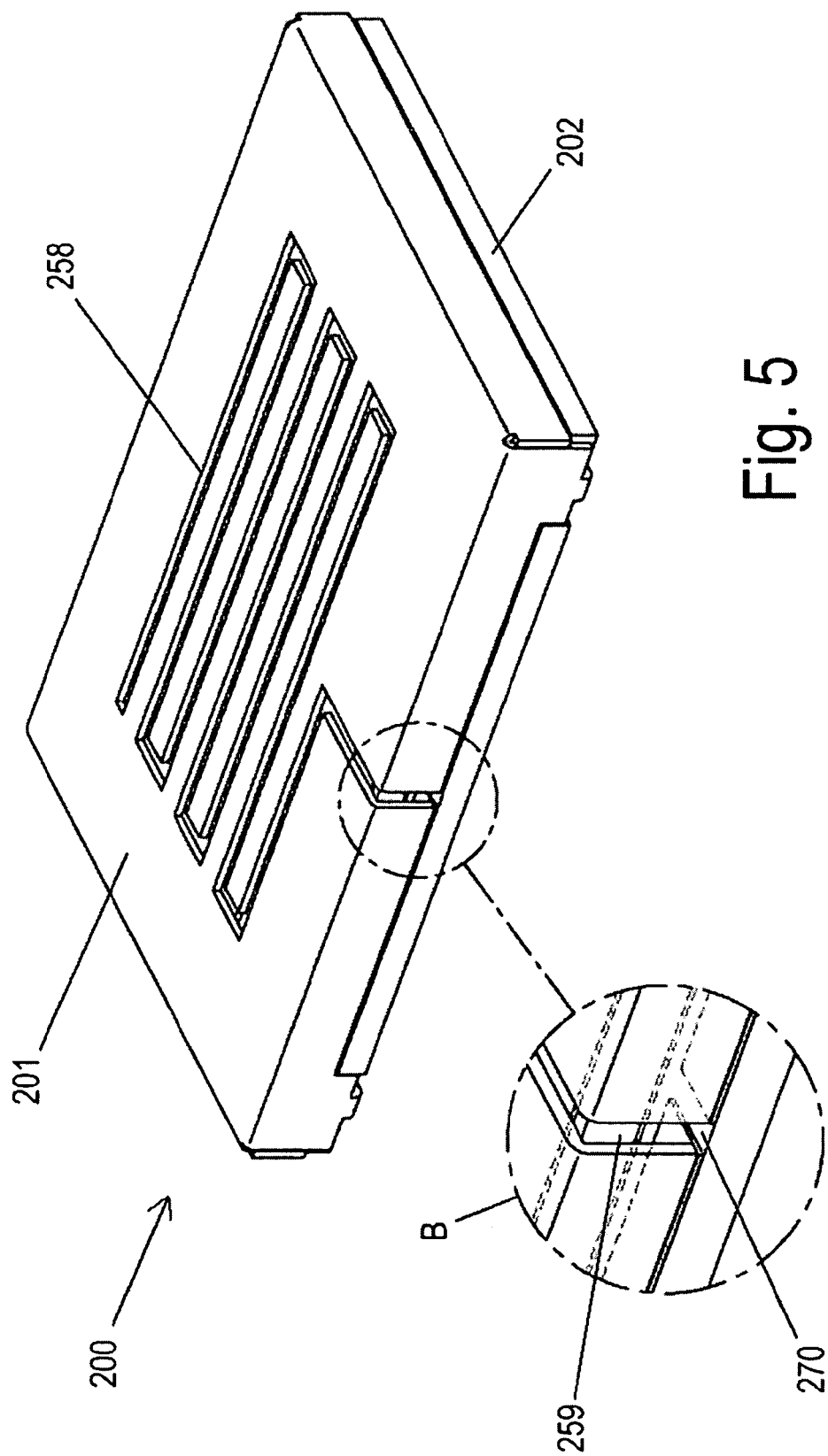
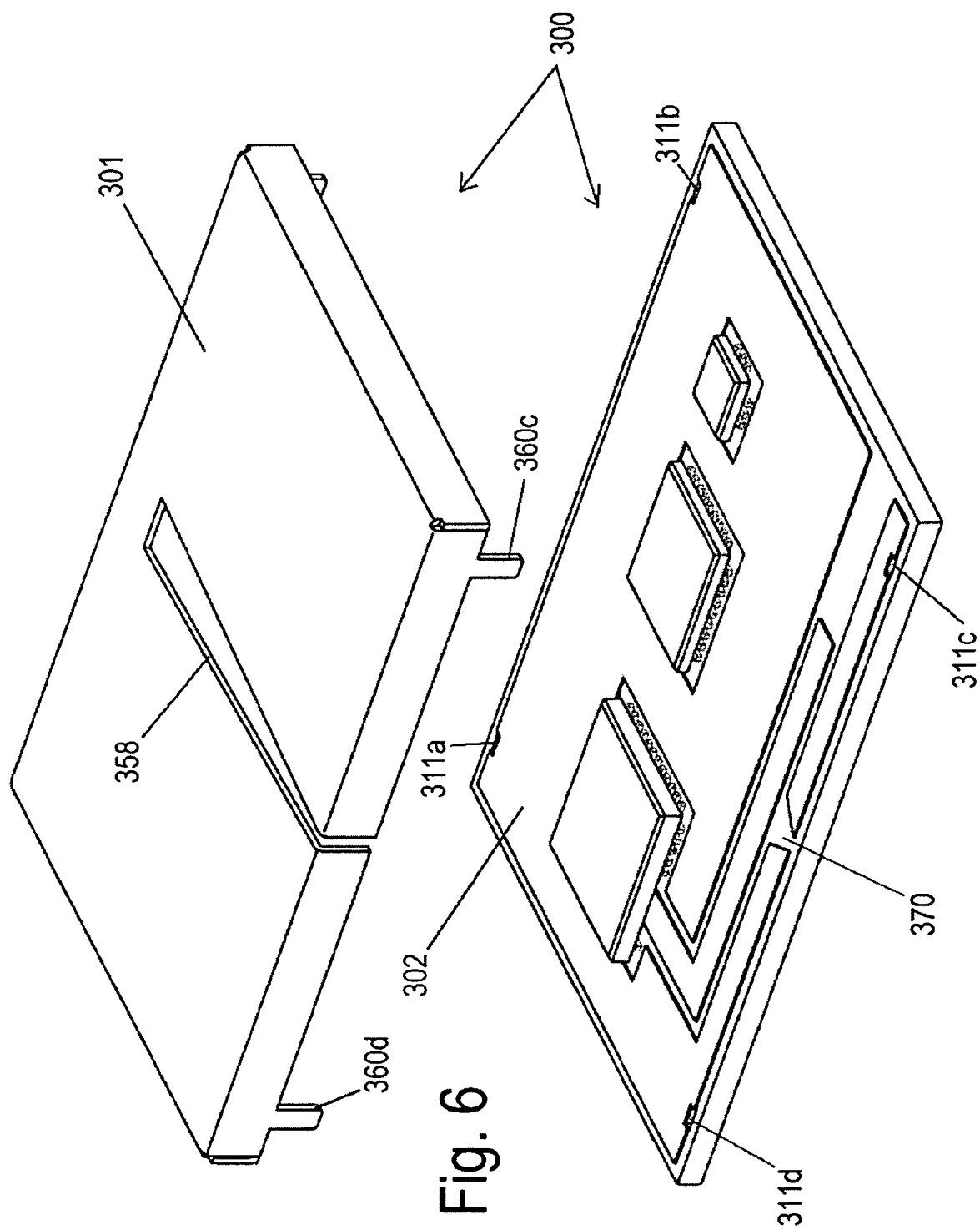


Fig. 3







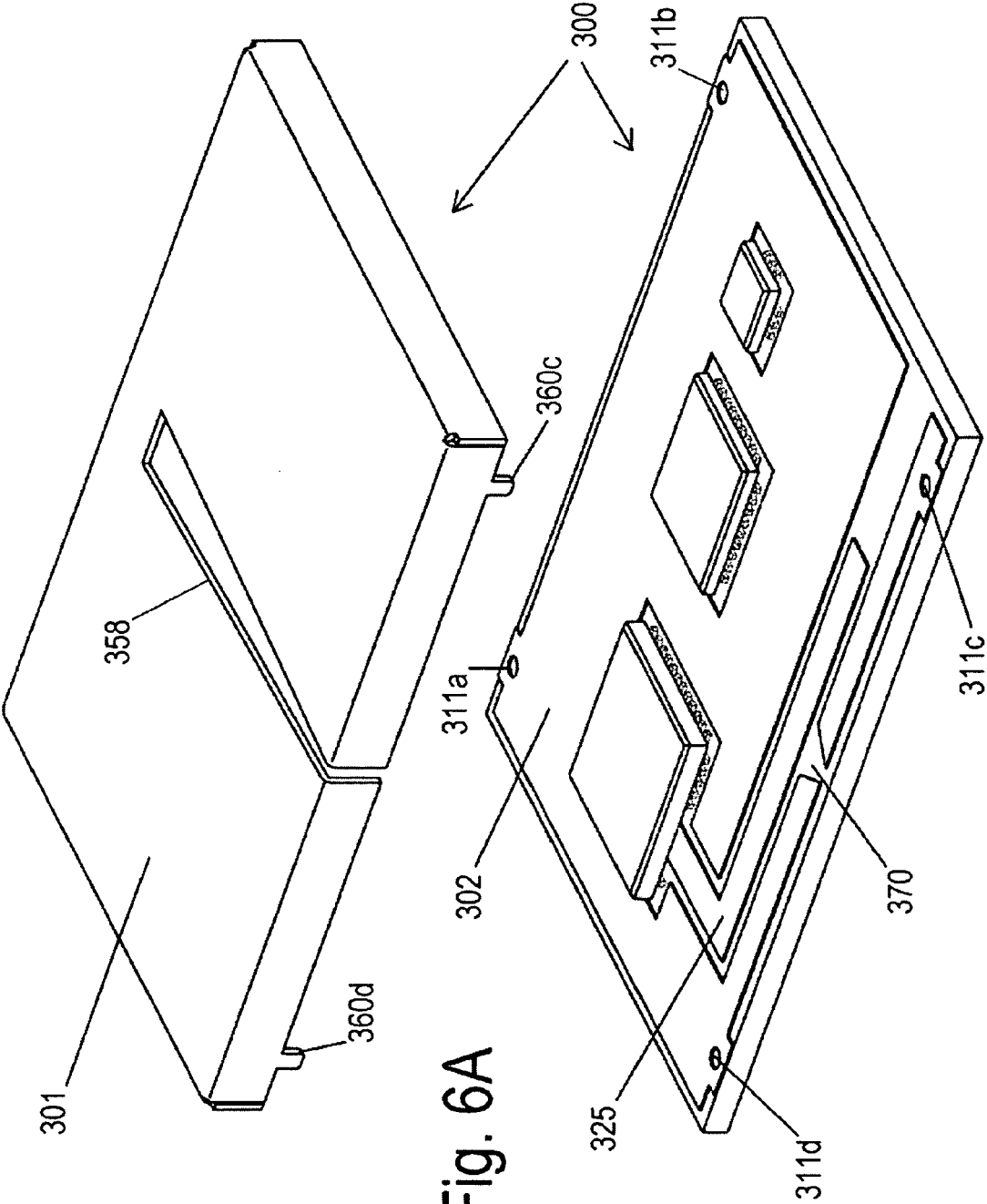
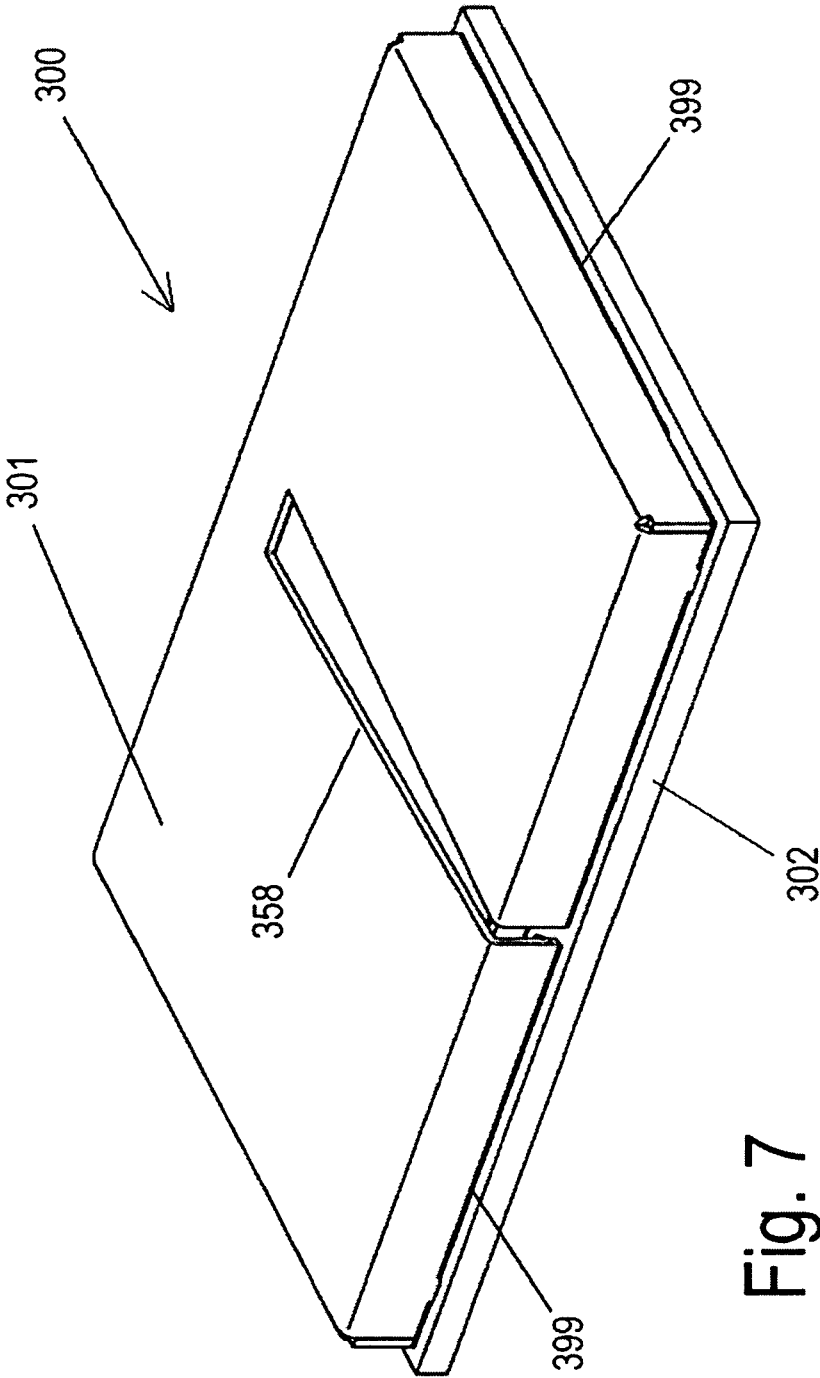


Fig. 6A



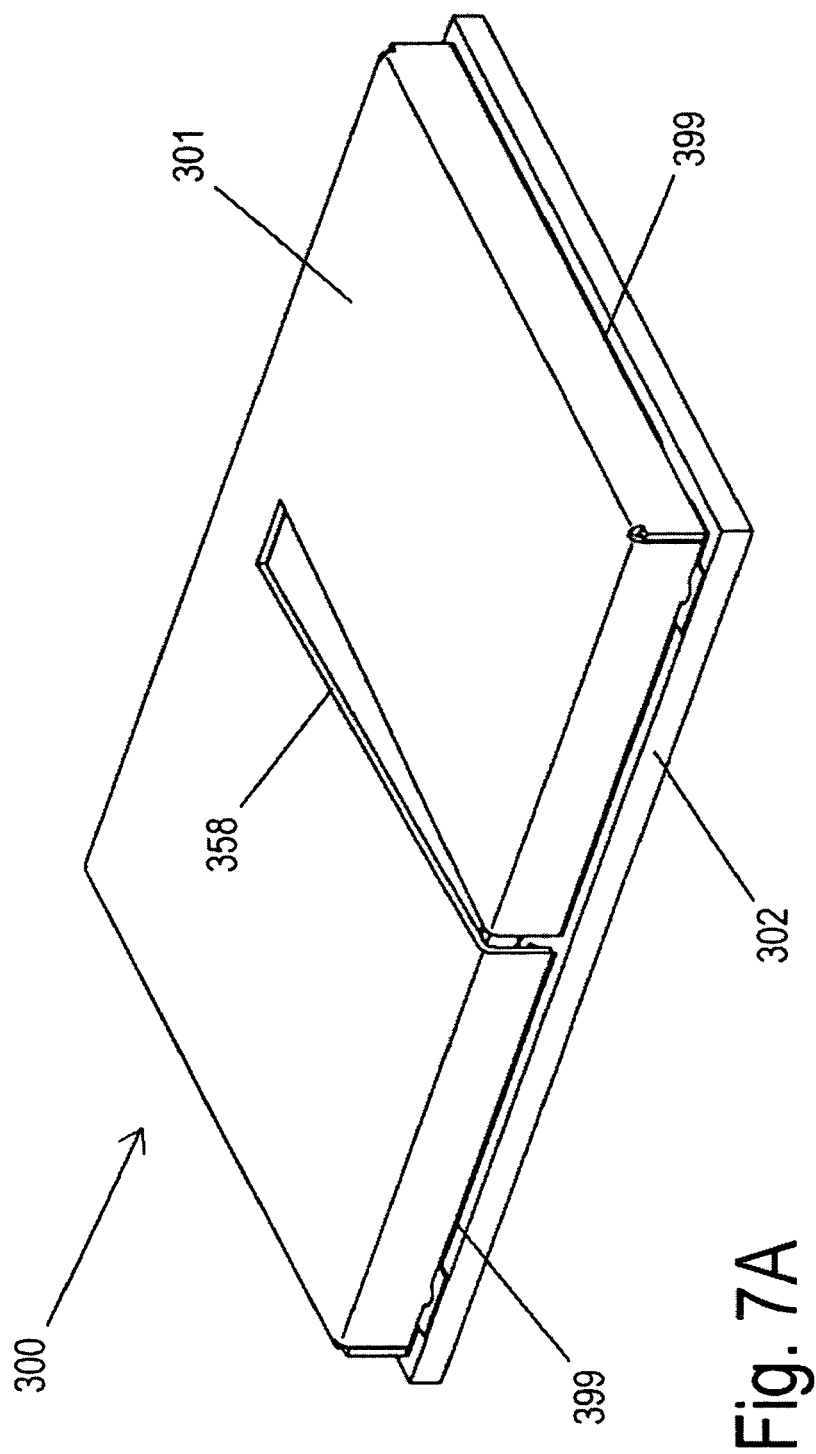
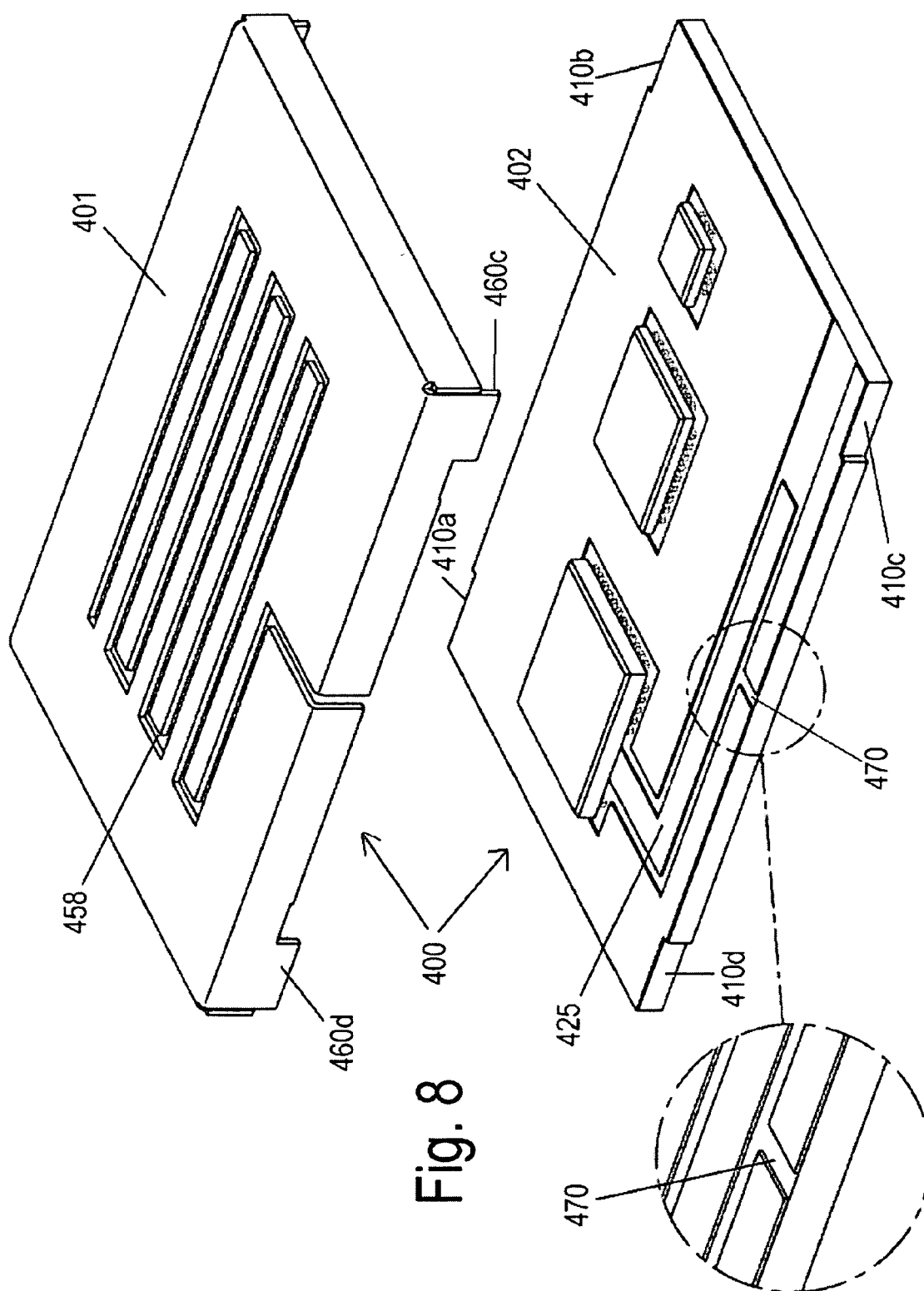
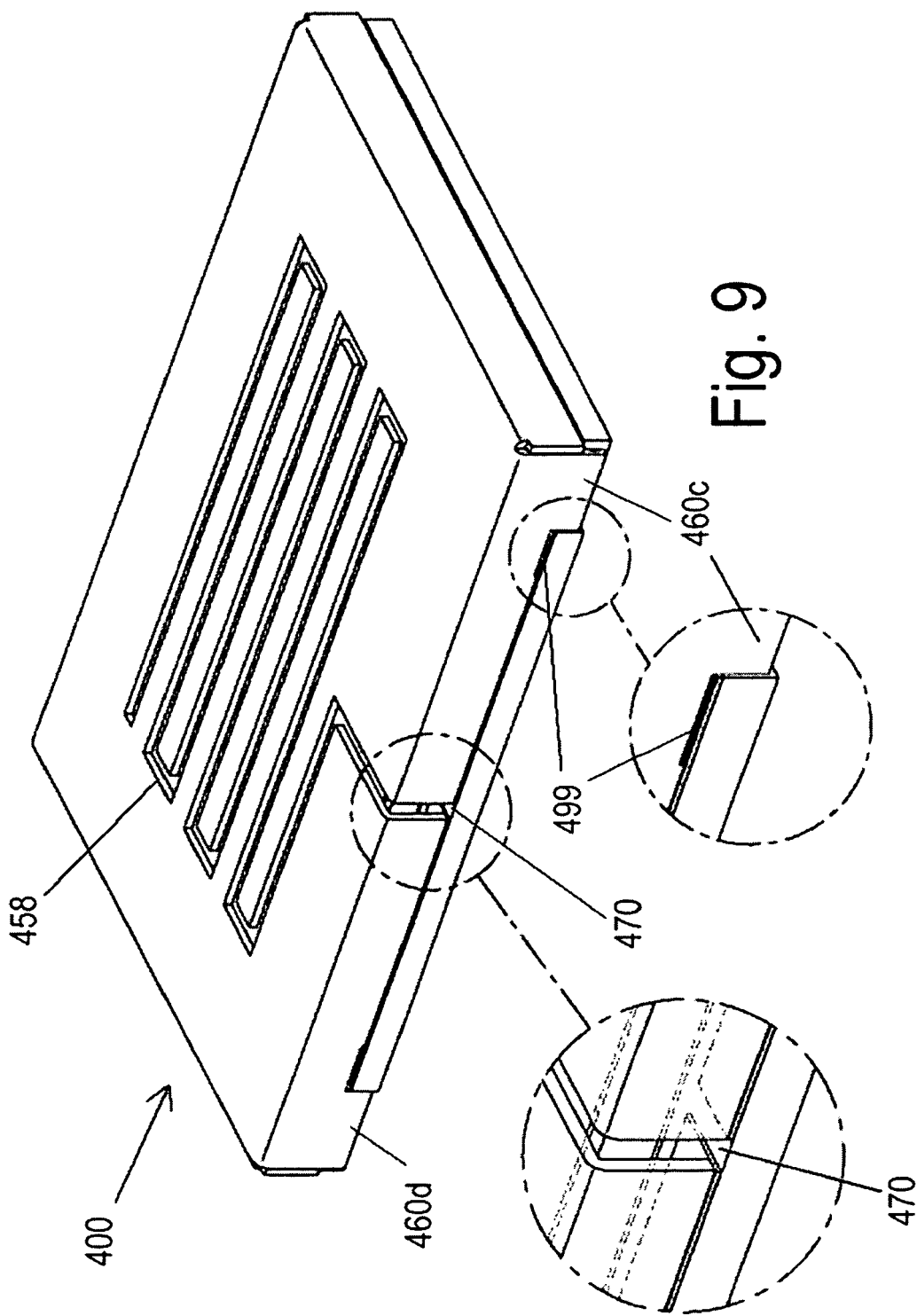


Fig. 7A





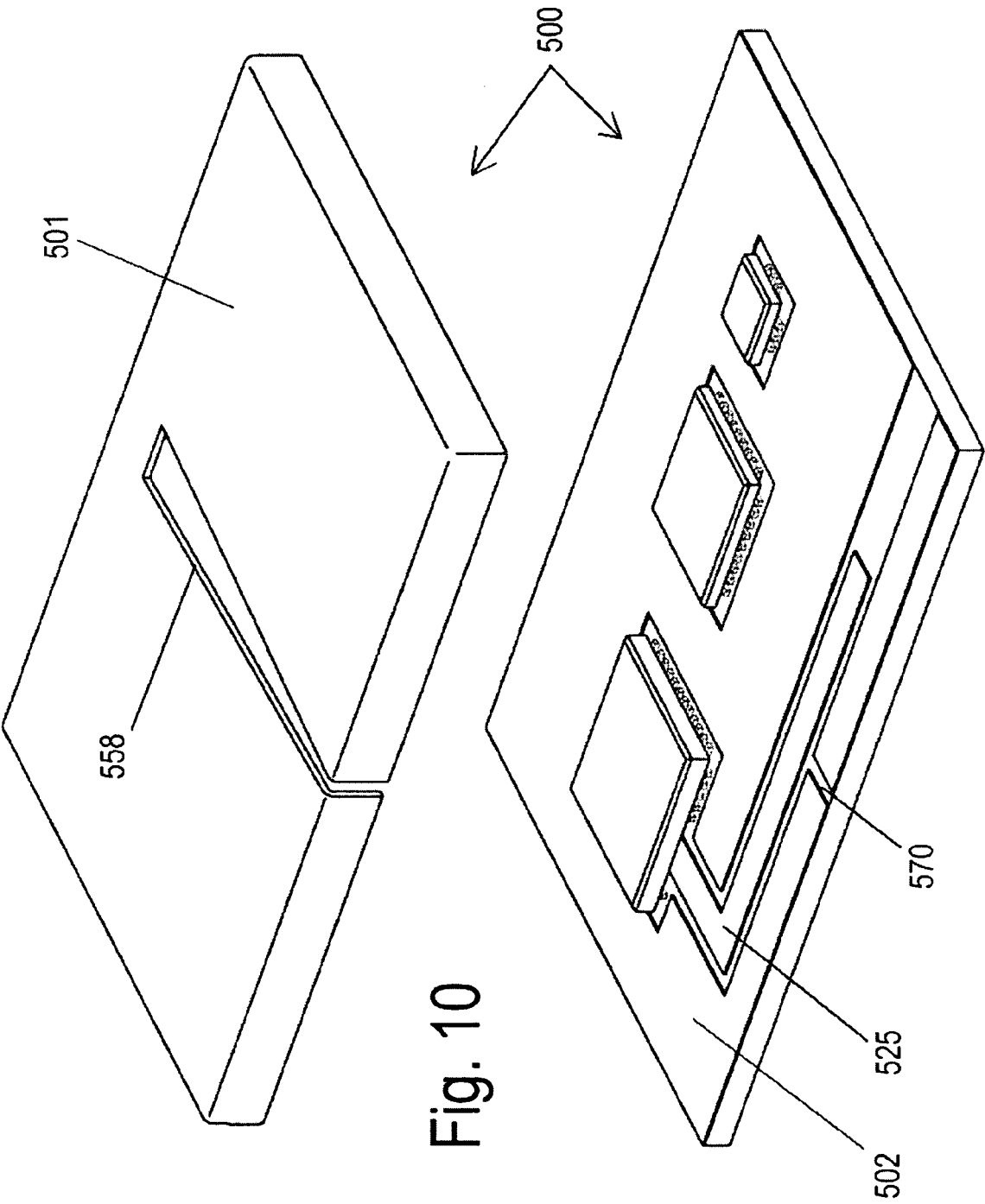
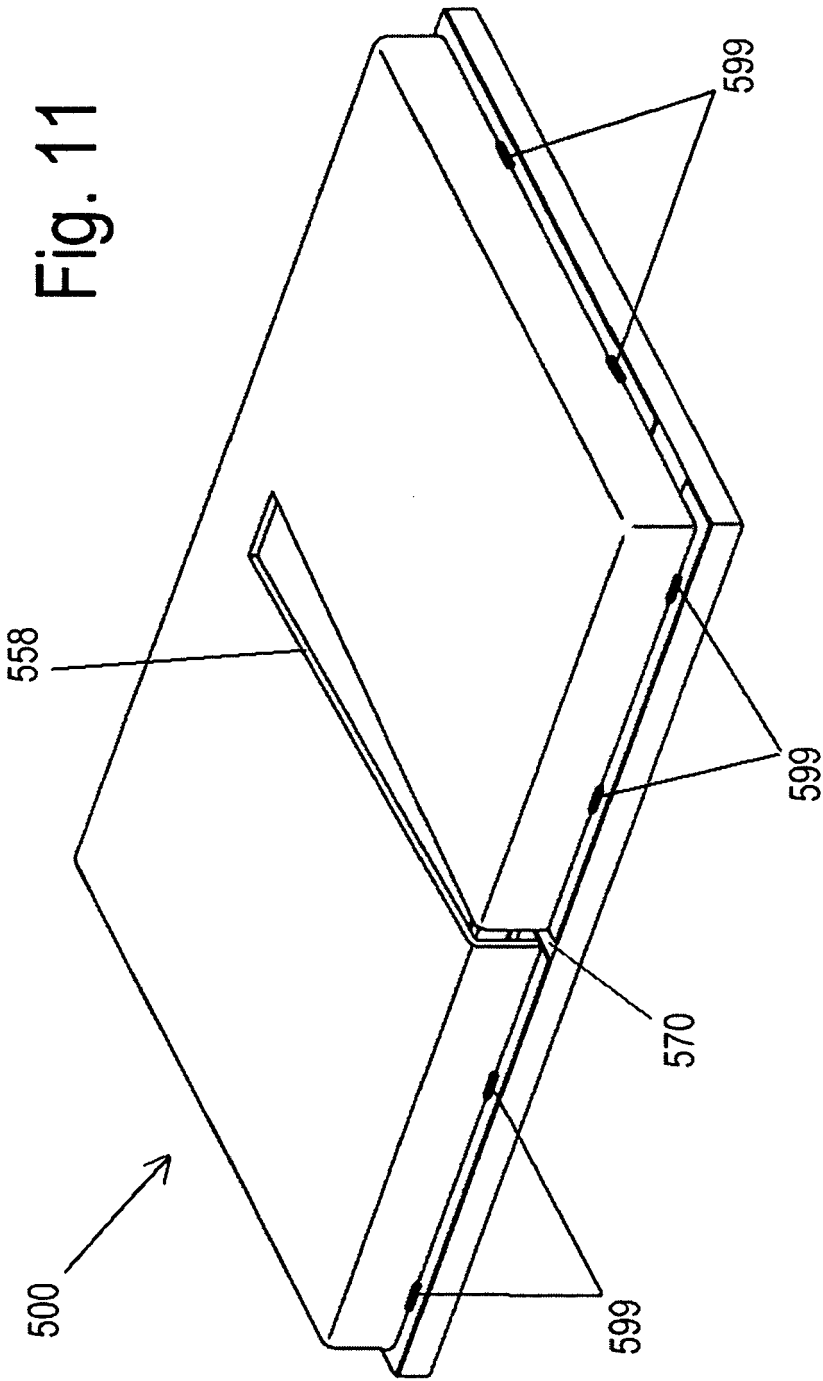


Fig. 10





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EUROPEAN SEARCH REPORT

Application Number
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