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(54) Title: ELECTRICAL DEVICE WRAPPED IN A BENDABLE CONDUCTIVE SHEET FOR MINIMAL RADIO INTERFERENCE

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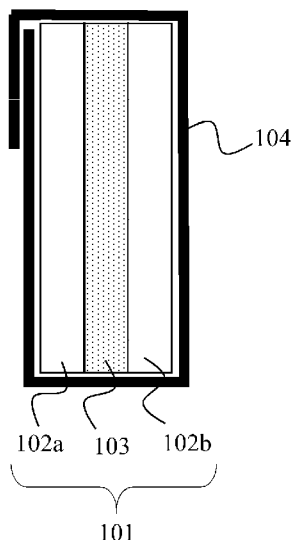


FIG. 1

(57) Abstract: The present disclosure relates to a radio frequency (RF) device including at least one electrical device, for instance, an electrical microwave circuit. The disclosure is concerned with isolating the electrical device, and proposes using a bendable conductive sheet. The electrical device comprises at least an RF circuit sandwiched between a first dielectric layer and a second dielectric layer. The bendable conductive sheet comprises an adhesive surface, is wrapped around the electrical device, and is adhered to the electrical device with the adhesive surface.

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ELECTRICAL DEVICE WRAPPED IN A BENDABLE CONDUCTIVE SHEET FOR MINIMAL RADIO INTERFERENCE

TECHNICAL FIELD

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The present disclosure relates to a radio frequency (RF) device, which includes at least one electrical device comprising an RF circuit, for instance a microwave circuit. The disclosure is concerned with isolating the electrical device, and proposes wrapping the electrical device in a bendable conductive sheet.

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BACKGROUND

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Electrical devices may be sources of and/or are subject to interference. This is particularly the case for electrical devices including RF circuits. The interference can modify the performance of the RF circuits, and therefore, isolation methods are valuable.

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As an example, a diversity of stripline solutions is available, wherein an electrical device comprises a RF circuit embedded in a dielectric material. However, when the dielectric constant of the dielectric material is low, for instance, when a solid foam or air is used as the dielectric material, the size of the RF circuit and thus the electrical device normally gets larger, both in surface and thickness.

25

Another disadvantage of such stripline solutions is that not all sides of the electrical device may be well shielded. For example, assuming a box-like shape of the electrical device including the stripline RF circuit, it may not be possible to cover and thus shield well all of its six sides.

30

Another disadvantage is that usually an external ground plane is used for such a stripline solution, wherein the ground plane is usually made of a rigid copper layer, and may even further be deposited on a substrate layer. When, for example, such a ground plane needs to be bent, this is impossible or only possible with the use of mechanical tools.

SUMMARY

In view of the above, an objective of this disclosure is to provide an improved solution for isolating an electrical circuit or device of an RF device. An objective is to allow an easy (e.g., manual) assembly of the RF device, and particularly including a ground plane of the RF device. A conductive enclosure is desired for shielding the electrical circuit or device, which can be adapted to different shapes or surfaces. All sides and edges of the electrical circuit or device should be well shielded. Another objective is to allow for protuberances of the electrical circuit or device, for example, interface tabs or connectors, in spite of the shielding. Another objective is to enable a fully shielded (e.g., electromagnetic interference (EMI) compliant) low-weight and low-loss RF device with a stripline circuit as the electrical circuit or device.

These and other objectives are achieved by the solutions described in the independent claims. Advantageous implementations are described in the dependent claims.

A first aspect of this disclosure provides a RF device comprising: an electrical device comprising at least an RF circuit sandwiched between a first dielectric layer and a second dielectric layer; and a bendable conductive sheet comprising an adhesive surface; wherein the bendable conductive sheet is wrapped around the electrical device and is adhered to the electrical device with the adhesive surface.

The electrical device may be a microwave electrical device, i.e., an electrical device suitable for microwave signals, i.e., signals in a range of 300 MHz to 300 GHz. The electrical device may be a distribution network for an antenna. The electrical device may include more than one RF circuit or may include other electrical circuits in addition to the RF circuit.

The dielectric layers of the electrical device may be implemented as two parallel dielectric layers, and may contain an intermediate conductive pattern arranged in between as the RF circuit, which may, for instance, be provided on a flexible foil. The electrical device may be grounded by the conductive bendable sheet, which may be a flexible foil as well. The bendable ground plane may be wrapped around the electrical device, such that it covers the sides parallel to the conductive pattern of the RF circuit and at least one more of the additional sides. Further, the bendable ground plane may be adhered to the

electrical device by means of an inner adhesive side. The dielectric layers can comprise rigid foam. The RF circuit (i.e., the intermediate layer) can be also implemented on an adhesive foil, and may adhere to the dielectric layers.

- 5 The RF device of the first aspect provides an improved solution for shielding an electrical circuit or device of an RF device, in this case the electrical device including the RF circuit. In particular, the electrical device and the RF circuit are respectively shielded by the bendable conductive sheet. The RF device can be assembled easily, e.g., manually, especially with the inclusion of a ground plane, since the bendable conductive sheet may
10 function as ground plane of the RF device. It is possible to adapt the shielding to different shapes or surfaces, by bending and/or folding the bendable conductive sheet accordingly. This enables shielding all sides and edges of the electrical device. The solution of the first aspect enables a fully shielded, EMI compliant, low-weight, low-loss RF device. For example, the solution of wrapping the conductive sheet around the electrical device is
15 compatible with any low-weight dielectric microwave device (as the electric device), which has, for example, foam as the dielectric layers. This results in a particularly low weight structure.

In an implementation form of the first aspect, the bendable conductive sheet is a metal
20 foil.

In an implementation form of the first aspect, the bendable conductive sheet covers each surface and/or is adhered to each surface of the electrical device.

- 25 In an implementation form of the first aspect, the electrical device has a cuboid shape, and the bendable conductive sheet covers all six surfaces and/or is adhered to all six surfaces of the electrical device.

Thus, the electrical device can be fully shielded from all sides, which reduces interference
30 substantially.

In an implementation form of the first aspect, the bendable conductive sheet is configured to function as a ground plane of the RF device.

The bendable conductive sheet is of low-weight and is easy to apply around the electrical device. Thus, disadvantages of heavy and rigid ground planes, as often used in conventional RF devices, are overcome.

- 5 In an implementation form of the first aspect, the electrical device is a stripline circuit.

For instance, the stripline circuit is a microwave stripline circuit, i.e., a stripline circuit that is suitable for microwave signals.

- 10 In an implementation form of the first aspect, the electrical device is a distribution network for an antenna.

In an implementation form of the first aspect, at least one of the first dielectric layer and the second dielectric layer is made of a foam.

15

In an implementation form of the first aspect, the bendable conductive sheet comprises a plurality of punctures, and the punctures are aligned with one or more edges of the electrical device.

- 20 This facilitates the assembly of the RF device, and leads to a better wrapping of the electrical device and its RF circuit.

- In an implementation form of the first aspect: the bendable conductive sheet comprises one or more openings; the electrical device comprises one or more protruding elements;
25 and each protruding element of the electrical device passes through one of the openings.

This allows to have protuberances of the electrical device, for example, interface tabs or connectors, in spite of the shielding. Easy access to interfaces of the electrical device may thus be maintained.

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In an implementation form of the first aspect, the bendable conductive sheet comprises one or more openings; the RF circuit is formed in a planar layer; the electrical device comprises one or more RF connectors; each RF connector extends either

perpendicular to or parallel to the planar layer; and each RF connector passes through one of the openings.

5 A second aspect of this disclosure provides an antenna comprising: an array of radiating elements; and an RF device according to the first aspect or any of its implementation forms; wherein the RF device is a distribution network of the antenna and is connected to the array of radiating elements.

10 In an implementation form of the second aspect, the antenna is a base station planar antenna. The antenna may have improved performance, due to the reduced interference affecting the distribution network.

15 A third aspect of this disclosure provides a method for fabricating a RF device, the method comprising: providing an electrical device, wherein the electrical device comprises an RF circuit sandwiched between a first dielectric layer and a second dielectric layer; and wrapping a bendable conductive sheet around the electrical device; wherein the bendable conductive sheet comprises an adhesive surface, and the adhesive surfaces adheres to the electrical device when the bendable conductive sheet is wrapped around the electrical device.

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In an implementation form of the third aspect, the bendable conductive sheet comprises a plurality of punctures; and the method comprises bending the bendable conductive sheet along the plurality of punctures when the bendable conductive sheet is wrapped around the electrical device.

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In an implementation form of the third aspect, the bendable conductive sheet comprises one or more openings; the electrical device comprises one or more protruding elements; and each protruding element is guided through one of the openings when the bendable conductive sheet is wrapped around the electrical device.

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The method of the third aspect may comprise further implementation forms to fabricate a RF device according to any implementation form of the first aspect. The method of the third aspect leads to the same advantages described for the RF device of the first aspect. In addition, the method of the third aspect is easy to carry out, even manually.

BRIEF DESCRIPTION OF DRAWINGS

The above described aspects and implementation forms will be explained in the following
5 description of specific embodiments in relation to the enclosed drawings, in which

FIG. 1 shows an RF device according to this disclosure.

FIG. 2 shows an antenna according to this disclosure including an RF device
10 according to this disclosure.

FIG. 3 shows various images of an exemplary RF device according to this disclosure.

15 FIG. 4 shows an exemplary RF device according to this disclosure.

FIG. 5 shows a method according to this disclosure for fabricating a RF device according to this disclosure.

20 DETAILED DESCRIPTION OF EMBODIMENTS

FIG. 1 shows a RF device 100 according to this disclosure. The RF device 100 may be a distribution network 201 for an antenna 200, as shown in FIG. 2, but may also be any other RF device, which may be exposed to interference. The RF device 100 may include
25 at least one RF circuit 103. The RF circuit may be able to process or operate on a RF signal, for instance, a microwave signal.

The RF device comprises an electrical device 101, which includes at least the RF circuit 103 sandwiched between a first dielectric layer 102a and a second dielectric layer 102b.
30 One or both of the dielectric layers 102a, 102b may comprise or be made of foam. The RF circuit 103 may be printed on a foil or conductive sheet. The electrical device 101 may also be a stripline circuit, wherein the RF circuit 103 is embedded in a dielectric material that forms the first and the second dielectric layer 102a, 102b.

The RF device 100 further comprises a bendable conductive sheet 104 that has at least one adhesive surface. The bendable conductive sheet 104 is wrapped around the electrical device 101. The bendable conductive sheet 104 surrounds the electrical device, for instance, surrounds it completely. The bendable conductive sheet 104 is adhered to the electrical device 101 with its at least one adhesive surface. For instance, the bendable conductive sheet 104 may be a metal foil or other conductive foil. For instance, the bendable conductive sheet may be made of copper and/or aluminum. Other metals or conductive materials are possible, however.

As can be seen in FIG. 1, the bendable conductive sheet 104 wrapped around the electrical device 101 may overlap itself, to eliminate potential radiation at the edges. This may be possible due to the use of a foil as the bendable conductive sheet 104. Such overlapping can be used on one side or on several sides, for example, by extending flaps of the bendable conductive sheet 104 in one direction and the perpendicular direction. It should be noted, however, that the explained overlapping is not mandatory.

FIG. 2 shows a possible application scenario or system architecture, in which the solution of the present disclosure is applicable. In particular, FIG. 2 shows an antenna 200 according to this disclosure, which may be a base station antenna or the like. The antenna 200 may be a planar antenna. The antenna 200 includes at least one RF device 100.

The antenna 200 particularly comprises an array 202 of radiating elements (or antenna elements), and comprises a distribution network 201 (or feeding network), which is connected to the array 202 of radiating elements. The antenna array 202 may be a planar antenna array. The distribution network 201 may be implemented by the at least one RF device 100 of this disclosure. For instance, the electrical device 101 may implement the electrical functionality of the distribution network 201. The distribution network 201 may feed constituent linear arrays of the antenna 200.

Notably, the solution of this disclosure, i.e., the RF device 100, can potentially be used in any other electronic apparatus, which involves or requires conductive shielding, or is exposed to interference. For instance, the RF device 100 is beneficial for antennas and specifically, distribution networks 201 as shown in FIG. 2, but also for other electronic apparatus.

FIG. 3 shows various images of an exemplary RF device 100 according to this disclosure. FIG. 3(a) shows that the outer surface of the RF device 100 is provided mainly by the bendable conductive sheet 104, which also forms a ground plane of the RF device 100, and which is wrapped around the electrical device 101. The electrical device 101 is thus inside the RF device and shielded. The bendable conductive sheet 104 may cover at least the sides parallel to the conductive pattern of the RF circuit 103 of the electrical device 101, and may cover at least one more of the additional sides. Ideally it covers all sides of the electrical device 101, whilst maintaining openings to the interfaces of the electrical device 101.

To this end, as shown in FIG. 3(c), the bendable conductive sheet 104 may comprise one or more openings 302. These openings 302 may be simple cut-outs in the bendable conductive sheet 104, and are easy to manufacture, for instance, even manually. As shown in FIG. 3(b), the electrical device 101 may comprise one or more protruding elements 301. The protruding elements 301 may be RF connectors or other interface elements to the electrical device 101. FIG. 3(b) shows particularly RF connectors extending in parallel to a planar layer of the RF circuit 103 of the electrical device 101, however, the RF connectors may also extend perpendicular or at an angle to the planar layer of the RF circuit 103. Each protruding element 301 of the electrical device 101, in particular, each RF connector, passes through one of the openings 302 of the bendable conductive sheet 104.

FIG. 3(d) shows further that the RF device 100 may comprise a bendable conductive sheet 104 that has a plurality of punctures 303. These punctures 303 may be aligned with one or more edges of the electrical device 101. When assembling the RF device 100, which includes wrapping the bendable conductive sheet 104 around the electrical device 101, the bendable conductive sheet 104 may be bent and/or folded along the plurality of punctures 303. This simplifies the wrapping and leads to more accurate results and better performance.

FIG. 4 shows an exemplary RF device 100 according to this disclosure, which builds on the RF device 100 of FIG. 1. Same elements in FIG. 4 and FIG. 1 are provided with the same reference signs, and are implemented likewise.

In the RF device 100 of FIG. 4, the first dielectric layer 102a and the second dielectric layer are respectively made of a foam. Further, the RF circuit 103, which may be a distribution network 201, is provided on a foil, which may be referred to as distribution foil. This RF circuit 103 is inserted between the dielectric foam layers 102a, 102b. The RF circuit 103 may be printed on the foil, or the foil may be patterned to form the RF circuit 103.

The bendable conductive sheet 104, which is wrapped around the electrical device 101, is advantageously configured to function as a ground plane of the RF device 100. It may be a ground foil, which can be easily wrapped around the electrical device 101.

In this respect, FIG. 5 shows a method 500 according to this disclosure, for fabricating the RF device 100. The method 500 comprises a step 501 of providing the electrical device 101, which comprises the RF circuit 103 sandwiched between the first dielectric layer 102a and the second dielectric layer 102b. The method 500 further comprises a step 502 of wrapping the bendable conductive sheet 104, for example a conductive foil, around the electrical device 101. The bendable conductive sheet 104 comprises an adhesive surface, and the adhesive surfaces adheres to the electrical device 101 when the bendable conductive sheet 104 is wrapped around the electrical device 101.

Thus, the electrical device 101 is wrapped into a conductive enclosure, which may be implemented as a one-sided-adhesive, flexible conductive foil. In case that the electrical device 101 presents protrusions at one of its sides, the foil may cover such side in the first place. The procedure to assemble the RF device 100 can be a manual and/or an automatic procedure.

The arrays of punctures 303 at the bend edges of the sheet 104 may facilitate or enable the wrapping. For instance, if the electrical device 101 has a cuboid or similar shape, and the bendable conductive sheet 104 shall covers all (six) surfaces and/or shall be adhered to all (six) surfaces of the electrical device 101, the punctures 303 are of particular advantage.

In summary, the solution of this disclosure enables a manual, or a simple automatized, assembly of the RF device 100. This is particularly achieved by the bendable conductive sheet 104, which may adapt to a diversity of flat-faced enclosures and can be easily wrapped around any kind of electrical device 101. The solution of this disclosure may prevent EMI and/or RF coupling by shielding the electrical device 101. Further, the solution of this disclosure allow the assembly of a distribution network 201 within an antenna 200 without major interference effects. In addition, the solution of this disclosure allow interfaces to serial devices, e.g., an antenna or a cable, by means of protuberances 301 or RF connectors of the electrical device 101. The RF device 100 of this disclosure may be of low weight and of low loss, and may be implemented as a microwave device.

The present disclosure has been described in conjunction with various embodiments as examples as well as implementations. However, other variations can be understood and effected by those persons skilled in the art and practicing the claimed matter, from the studies of the drawings, this disclosure and the independent claims. In the claims as well as in the description the word “comprising” does not exclude other elements or steps and the indefinite article “a” or “an” does not exclude a plurality. A single element or other unit may fulfill the functions of several entities or items recited in the claims. The mere fact that certain measures are recited in the mutual different dependent claims does not indicate that a combination of these measures cannot be used in an advantageous implementation.

Claims

1. A radio frequency, RF, device (100) comprising:
an electrical device (101) comprising at least an RF circuit (103) sandwiched
5 between a first dielectric layer (102a) and a second dielectric layer (102b); and
a bendable conductive sheet (104) comprising an adhesive surface;
wherein the bendable conductive sheet (104) is wrapped around the electrical
device (101) and is adhered to the electrical device (101) with the adhesive surface.
- 10 2. The RF device (100) according to claim 1, wherein the bendable conductive sheet
(104) is a metal foil.
3. The RF device (100) according to claim 1 or 2, wherein the bendable conductive
sheet (104) covers each surface and/or is adhered to each surface of the electrical device
15 (101).
4. The RF device (100) according to one of the claims 1 to 3, wherein the electrical
device (101) has a cuboid shape, and the bendable conductive sheet (104) covers all six
surfaces and/or is adhered to all six surfaces of the electrical device (101).
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5. The RF device (100) according to one of the claims 1 to 4, wherein the bendable
conductive sheet (104) is configured to function as a ground plane of the RF device (100).
6. The RF device (100) according to one of the claims 1 to 5, wherein the electrical
25 device (101) is a stripline circuit.
7. The RF device (100) according to one of the claims 1 to 6, wherein the electrical
device (101) is a distribution network (201) for an antenna (200).
- 30 8. The RF device (100) according to one of the claims 1 to 7, wherein at least one of
the first dielectric layer (102a) and the second dielectric layer (102b) is made of a foam.

9. The RF device (100) according to one of the claims 1 to 8, wherein the bendable conductive sheet (104) comprises a plurality of punctures (303), and the punctures (303) are aligned with one or more edges of the electrical device (101).
- 5 10. The RF device (100) according to one of the claims 1 to 9, wherein:
the bendable conductive sheet (104) comprises one or more openings (302);
the electrical device (101) comprises one or more protruding elements (301); and
each protruding element (301) of the electrical device (101) passes through one of
the openings (302).
- 10 11. The RF device (100) according to one of the claims 1 to 10, wherein:
the bendable conductive sheet (104) comprises one or more openings (302);
the RF circuit (103) is formed in a planar layer;
the electric device (101) comprises one or more RF connectors (301);
15 each RF connector (301) extends either perpendicular to or parallel to the planar
layer; and
each RF connector (301) passes through one of the openings (302).
12. An antenna (200) comprising:
20 an array (202) of radiating elements; and
an RF device (100) according to one of the claims 1 to 11;
wherein the RF device (100) is a distribution network (201) of the antenna (200)
and is connected to the array (202) of radiating elements.
- 25 13. The antenna (200) according to claim 12, wherein the antenna (200) is a base
station planar antenna.
14. A method (500) for fabricating a radio frequency, RF, device (100), the method
(500) comprising:
30 providing (501) an electrical device (101), wherein the electrical device (101)
comprises an RF circuit (103) sandwiched between a first dielectric layer (102a) and a
second dielectric layer (102b); and
wrapping (502) a bendable conductive sheet (104) around the electrical device
(101);

wherein the bendable conductive sheet (104) comprises an adhesive surface, and the adhesive surface adheres to the electrical device (101) when the bendable conductive sheet (104) is wrapped around the electrical device (101).

- 5 15. The method (500) according to claim 14, wherein:
 the bendable conductive sheet (104) comprises a plurality of punctures (303); and
 the method (500) comprises bending the bendable conductive sheet (104) along
the plurality of punctures (303) when the bendable conductive sheet (104) is wrapped
around the electrical device (101).

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16. The method (500) according to claim 14 or 15, wherein:
 the bendable conductive sheet (104) comprises one or more openings (302);
 the electrical device (101) comprises one or more protruding elements (301); and
 each protruding element (301) is guided through one of the openings (302) when
15 the bendable conductive sheet (104) is wrapped around the electrical device (101).

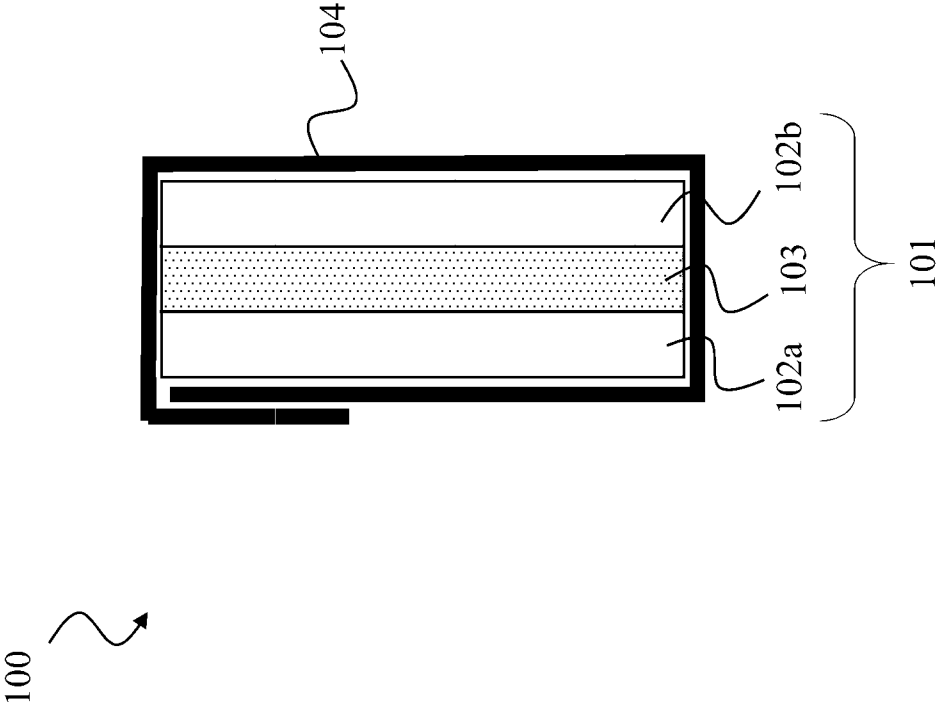


FIG. 1

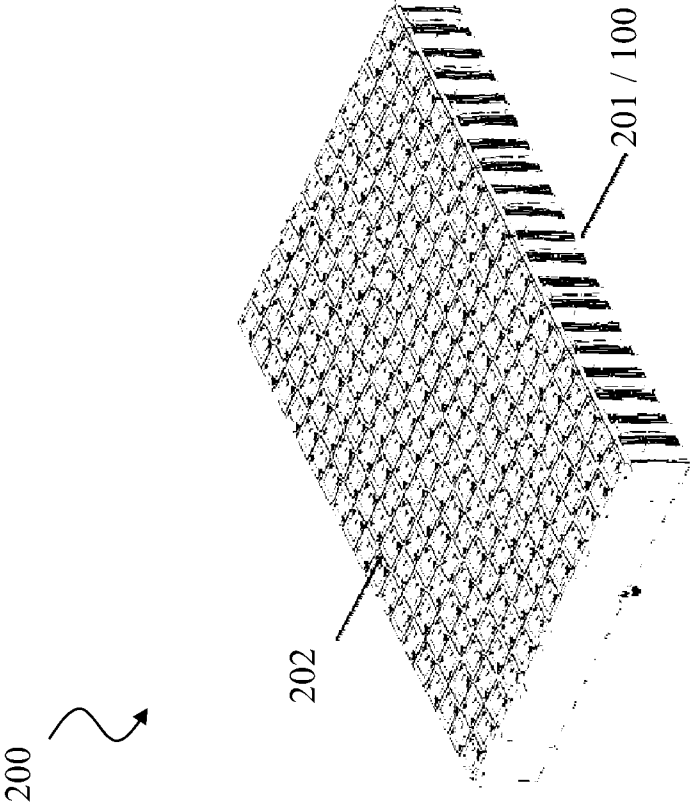


FIG. 2

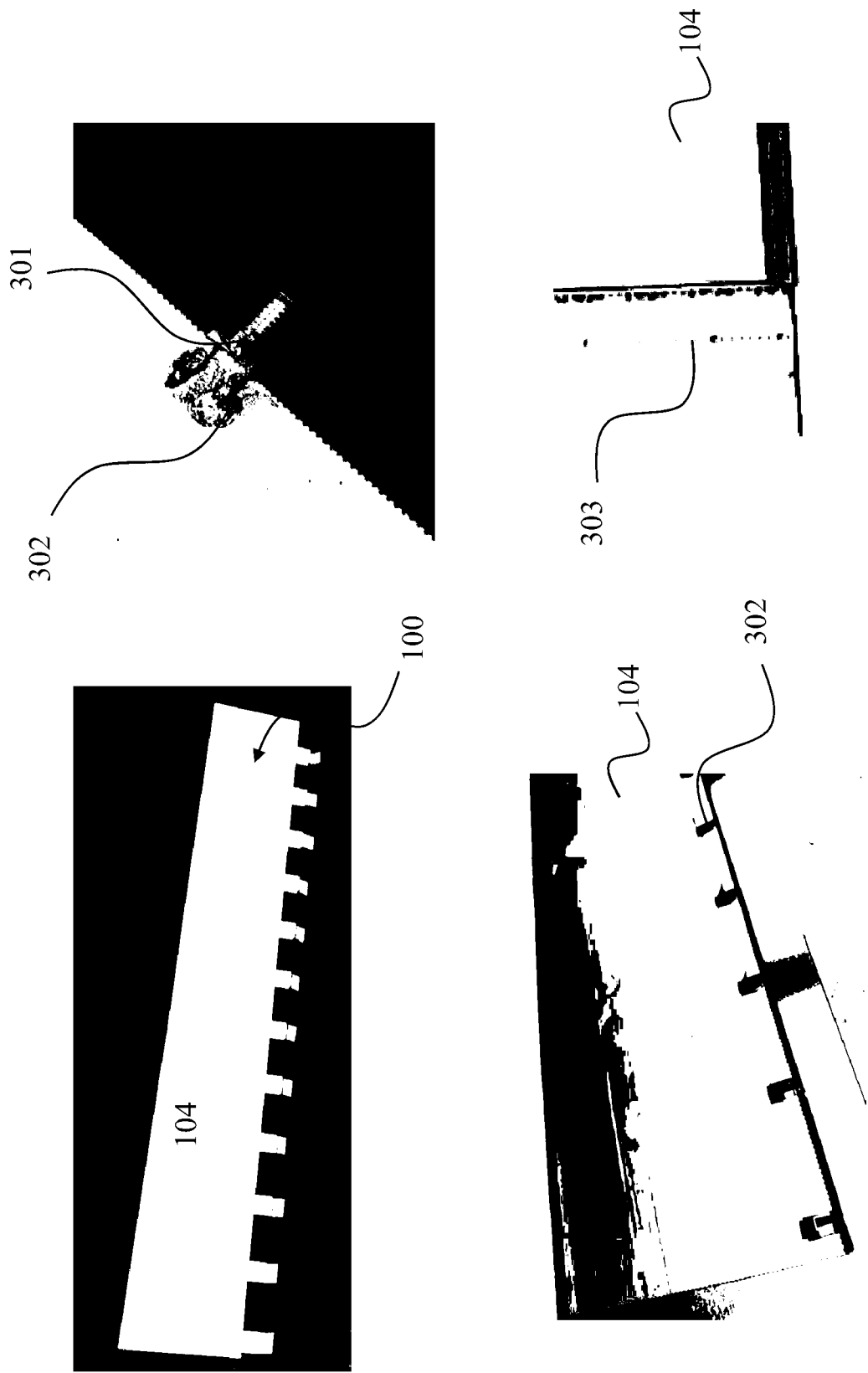


FIG. 3

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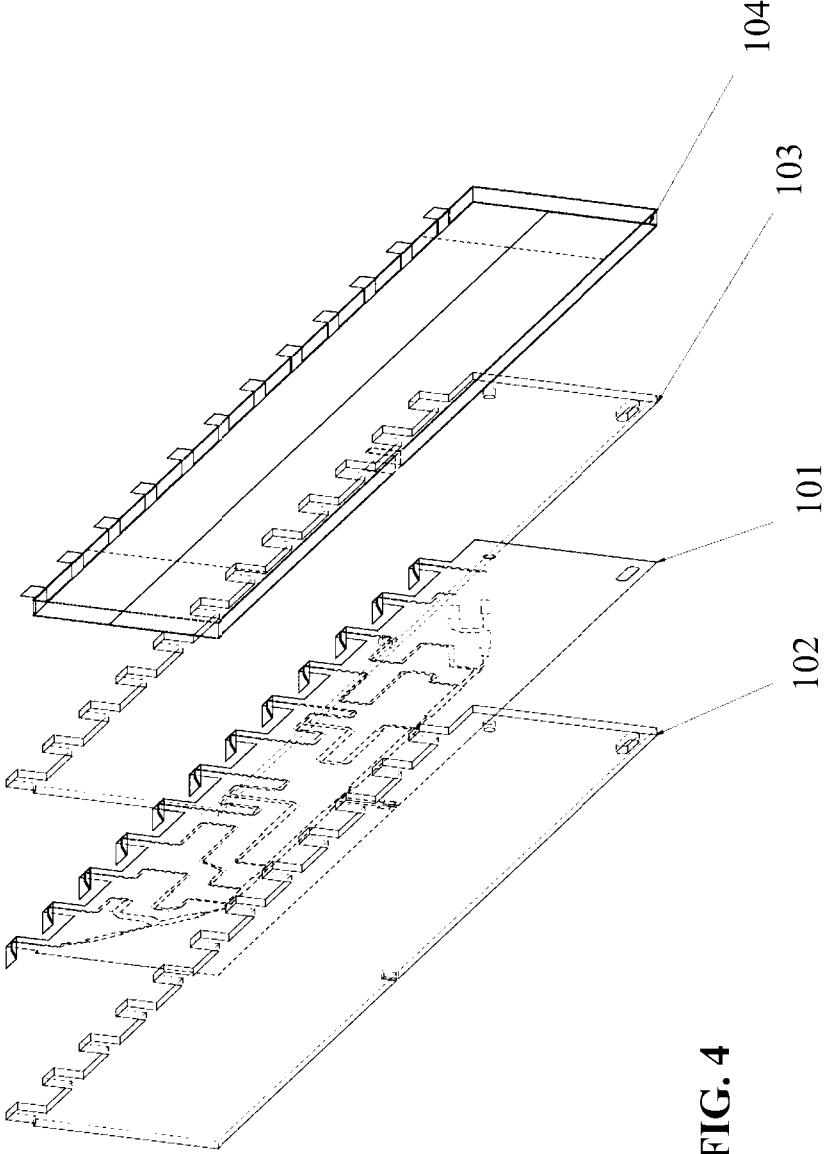


FIG. 4

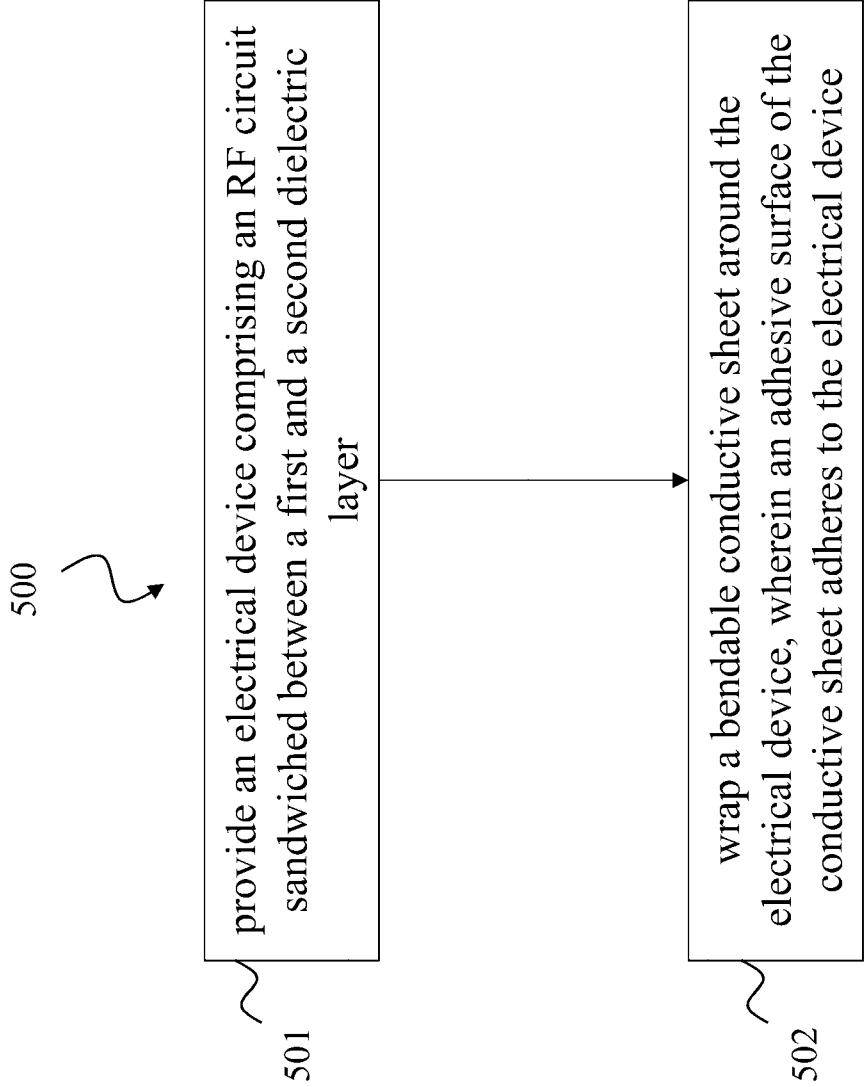


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2023/092398

A. CLASSIFICATION OF SUBJECT MATTER

H05K 9/00(2006.01)i; H05K 1/00(2006.01)i

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)

IPC:H05K

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

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

CNTXT,ENTXT,ENTXTC,IEEE,CNKI: radio frequency,RF,circuit,dielectric layer, bendable,flexible, conductive,sheet,layer, adhesive, wrap, shielding

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2015382460 A1 (AVAGO TECHNOLOGIES GENERAL IP (SINGAPORE) PTE.LTD.) 31 December 2015 (2015-12-31) description, paragraphs 0018-0019,0030-0036,figures 1,3	1-16
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Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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Date of the actual completion of the international search

06 December 2023

Date of mailing of the international search report

11 December 2023

Name and mailing address of the ISA/CN

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2023/092398

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