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(54) Title: ANTENNA DEVICE AND METHOD OF ITS FABRICATION

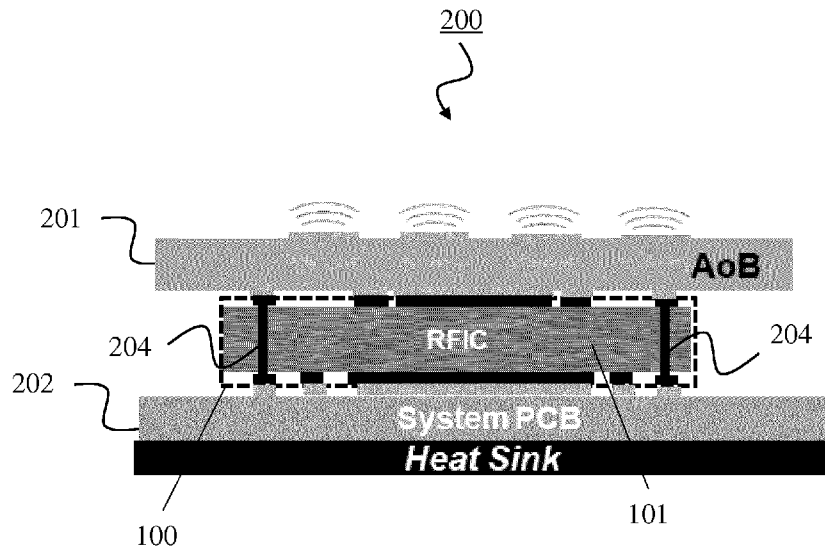


FIG. 6

(57) Abstract: The present invention relates to a RFIC device and an antenna device. The RFIC device comprises a RFIC die, one or more connection elements (102) provided on each of a top side and a bottom side of the RFIC die, and comprises at least one vertical connection element through the RFIC die connecting the bottom side and the top side. The antenna device can comprise an antenna layer, a RFIC layer arranged below the antenna layer (201), wherein the RFIC layer comprises at least one RFIC device attached to and electrically connected to the antenna layer.



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ANTENNA DEVICE AND METHOD OF ITS FABRICATION

TECHNICAL FIELD

5 The present invention relates to the field of antennas, in particular to Antenna-on-Board (AoB) technology. The invention proposes a radio frequency integrated circuit (RFIC) device for an AoB device. The invention also proposes the AoB device including an antenna layer and a RFIC layer with at least one RFIC device arranged below the antenna layer.

10 BACKGROUND

The AoB technology, also called Antenna-in-Package (AiP) technology, combines antennas with radio dies into a surface mounted device. It represents an innovative and important development in the miniaturization of wireless communications systems in the recent years. Radio dies are particularly RFIC dies, including transceiver and receiver chips.

15 The AoB technology has been proposed for different radio communication bands, e.g. the Ka-Band (28 GHz to 40 GHz) or the V-Band (60 GHz), as well as for gesture radars. It can provide effective antenna solutions to 5G and beyond, operating in the millimeter-wave bands and above.

In particular, the AoB technology adoption in 5G requires scalability to a high number of radio
20 dies and antennas, a high level of integration between radio die and antennas in the AoB, as well as between the AoB and a system Printed Circuit Board (PCB). Further, high reliability and low cost are needed.

Current solutions for AoB technology have limitations in providing a simple integration of radio
25 dies with high performance thermal and electrical connections between the radio dies, the system board and the antenna board. However, these requirements are mandatory for low cost / high volume and high performances of AoB products.

Thus, a solution allowing a simpler system integration with high performance electrical and thermal connections between the radio dies, the system board and the antenna board is desired.

SUMMARY

In view of the above-mentioned disadvantages, embodiments of the present invention aim to provide an improved RFIC device and AoB device. In particular, an objective is to provide a simpler and better integration of the RFIC device with high performance electrical and thermal connections. Further, a better integration of the RFIC device with a system board and an antenna board in the AoB device. The RFIC device and AoB device should also allow better scalability, and better thermal and electrical performance.

The objective is achieved by the embodiments of the invention as described in the enclosed independent claims. Advantageous implementations of the present invention are further defined in the dependent claims.

A first aspect of the invention provides a RFIC device, comprising: a RFIC die, one or more connection elements provided on each of a top side and a bottom side of the RFIC die, and at least one vertical connection element through the RFIC die connecting the bottom side and the top side.

The top side is defined by a two dimensional plane in x-direction and y-direction. The bottom side is opposite to the top side.

Vertical partitioning in the z-direction in combination with vertical RFIC dies is thus proposed. The RFIC die has the vertical connections, particularly, in order to be able to route signals from a system PCB to an AoB antenna of an AoB device. The connections elements, e.g. thermal connections and/or electrical connections, are beneficially arranged on the top and bottom sides of the vertical RFIC device.

In an implementation form of the first aspect, one or more top side connection elements are attachable and electrically connectable to an antenna layer of the AoB device.

In order to route signals from the system PCB to the antennas of an AoB device, the connection elements on the top side may be physically attached to, and electrically connected to the antenna layer.

In an implementation form of the first aspect, one or more bottom side connection elements are attachable and electrically connectable to a system PCB of the AoB device, particularly with high frequency interconnects and thermal heat dissipation paths.

Possibly, the thermal connections on the bottom side can be soldered, or in some other way attached, to a system PCB. These thermal connections allow a good heat dissipation performance of the RFIC device.

5 A second aspect of the invention provides an AoB device, comprising: an antenna layer comprising at least one antenna element, and a RFIC layer arranged below the antenna layer and comprising at least one RFIC device attached to and electrically connected to the antenna layer.

10 The AoB device is accordingly proposed with vertical partitioning into different functionalities, i.e. RFIC layer and antenna layer. This allows for a simpler better integration of the RFIC device(s) and the system board and antenna board. Also, the scalability is facilitated, while providing improved thermal and electrical performance.

In an implementation form of the second aspect, the RFIC device is an RFIC device according to the first aspect or any implementation form of the first aspect.

15 Therefore, the RFIC device with the vertical connections may be attached to the antenna layer of the AoB device. This allows high frequency interconnects and thermal connections to the system PCB, thus improving electrical and thermal performance.

In an implementation form of the second aspect, a RFIC die of the RFIC device is configured to route signals from a system PCB of the AoB device, which is arranged below the RFIC device, to the antenna layer of the AoB device.

20 In an implementation form of the second aspect, the AoB device further comprises at least one vertical connection element from the system PCB to the antenna layer of the AoB device.

Optionally, additional connections from the system PCB to the antenna layer of the AoB device can be complemented.

25 In an implementation form of the second aspect, the RFIC die is a bare-die with bonding wires, solder bumps or flip-chip interconnections connected to the antenna layer, and with through vias or hot vias connected to the system PCB.

The RFIC die can be mounted to the antenna layer in different ways. The hot vias allow wave propagation from the system PCB to the RFIC die, and vice versa. The through vias allow a better thermal performance.

In an implementation form of the second aspect, the RFIC die is a lead frame or a laminate PCB based land grid array (LGA) package.

That means that the RFIC die itself may be a molded plastic package with through mold vias for the vertical connections.

- 5 In an implementation form of the second aspect, the RFIC layer further comprises a PCB layer comprising one or more RFIC PCBs.

An additional RFIC PCB may exist in the AoB device.

- 10 In an implementation form of the second aspect, the PCB layer further comprises at least one molded cavity, and the RFIC device is arranged inside of the cavity and is connected to the PCB layer with solder bumps or flip-chip interconnections.

The PCB layer may comprise a number of molded cavities. Inside each cavity, one or more RFIC devices may be embedded. It should be noted that a RFIC device is electrically connected to the PCB layer.

- 15 In an implementation form of the second aspect, the PCB layer further comprises a through-mold-via or a via in the PCB layer, for connecting the system PCB and the antenna layer.

Additional vertical connections may be further provided, either by through-mold-via or via in the cavity PCB.

In an implementation form of the second aspect, the cavity is molded from a laser activatable material.

- 20 The mold cavity itself can be made from a laser activatable material, for example a commercial laser activatable material.

In an implementation form of the second aspect, the RFIC device is embedded into the RFIC layer.

The RFIC device can be embedded into the RFIC layer by an embedding technology.

- 25 In an implementation form of the second aspect, the RFIC layer is electrically connected to the antenna layer through soldering, conductive glue or a special spacer glue.

There are different kinds of electrical interconnects between the RFIC device and the antenna layer.

It has to be noted that all devices, elements, units and means described in the present application could be implemented in the software or hardware elements or any kind of combination thereof.

5 All steps which are performed by the various entities described in the present application as well as the functionalities described to be performed by the various entities are intended to mean that the respective entity is adapted to or configured to perform the respective steps and functionalities. Even if, in the following description of specific embodiments, a specific functionality or step to be performed by external entities is not reflected in the description of a
10 specific detailed element of that entity which performs that specific step or functionality, it should be clear for a skilled person that these methods and functionalities can be implemented in respective software or hardware elements, or any kind of combination thereof.

BRIEF DESCRIPTION OF DRAWINGS

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

FIG. 1 shows a RFIC device according to an embodiment of the invention.

20 FIG. 2 shows an antenna device (AoB device) according to an embodiment of the invention.

FIG. 3 shows an antenna device according to an embodiment of the invention.

FIG. 4 shows an antenna device according to an embodiment of the invention.

FIG. 5 shows an antenna device according to an embodiment of the invention.

FIG. 6 shows an antenna device according to an embodiment of the invention.

25 FIG. 7 shows an antenna device according to an embodiment of the invention.

DETAILED DESCRIPTION OF EMBODIMENTS

FIG. 1 shows a RFIC device 100 according to an embodiment of the invention. The RFIC device 100 comprises a RFIC die 101, e.g. a transceiver/receiver chip. Further, the RFIC device 100 comprises one or more connection elements 102 provided on each of a top side and a bottom side of the RFIC die. In addition, the RFIC device 100 comprises at least one vertical connection element 103 through the RFIC die 101 connecting the bottom side and the top side.

To overcome the limitations of PCB and wafer level process-based AoB technologies, a vertical partitioning in the z-direction of an AoB device (see e.g. FIG. 2) is proposed in combination with vertical RFIC dies for the RFID device 100.

10 Optionally, the RFIC device 100 may be connected to an antenna element, e.g. an antenna layer 201 of an AoB device 200 according to an embodiment of the invention, as shown in FIG. 2. In particular, one or more top side connection elements 102 are attachable and electrically connectable to the antenna layer 201 of the AoB device 200.

15 Optionally, the RFIC device 100 may also be connected to a system board, e.g. a system PCB 202 of the AoB device 200, as shown in FIG. 3. For instance, one or more bottom side connection elements 102 are attachable and electrically connectable to the system PCB 202 of the AoB device 200, particularly with high frequency interconnects and thermal heat dissipation paths.

20 Signals may be routed from the system PCB 202 of the AoB device 200, to the antenna layer 201, particularly through the vertical connection element 103 in the RFIC device 100.

FIG. 2 – FIG. 7 show antenna devices, i.e. AoB devices 200, according to embodiments of the invention. These AoB devices 200 include each a RFIC device 100 according to an embodiment of the invention, as shown e.g. in FIG. 1. Same elements in the figures are labelled with the same reference signs and function likewise.

25 FIG. 2 shows an AoB device 200 comprising an antenna layer 201 comprising at least one antenna element. The AoB device 200 further comprises a RFIC layer 203 arranged below the antenna layer 201, and comprises at least one RFIC device 100 attached to and electrically connected to the antenna layer 201.

Particularly, the at least one RFIC device 100 is the RFIC device shown in FIG. 1.

FIG. 3 shows an AoB device 200 based on FIG. 2, further comprising a system PCB 202 arranged below the RFIC layer 203. Optionally, the RFIC die 101 of the RFIC device 100 is configured to route signals from the system PCB 202 of the AoB device 200, which is arranged below the RFIC device 100, to the antenna layer 201 of the AoB device 200.

5 FIG. 4 shows an AoB device 200 according to an embodiment of the invention. Particularly, the AoB device 200 may comprise a RFIC layer 203 including more than one RFIC device 100, e.g. 4 RFIC devices 100. The number of the RFIC devices 100 that may be included in the RFIC layer 203 may be up to 1024 or even 2048. Each RFIC device 100 may thereby be a RFIC device 100 as shown in FIG. 1. Possibly, at least one of the more than one RFIC device 100
10 may, however, not be the exact the same RFIC device 100. The RFIC device 100 in the RFIC layer 203 may have different designs to fulfill the different functionality requirements. Accordingly, the antenna layer 201 of the AoB device 200 may also comprise a plurality of antenna elements/radiating elements. A size of a single antenna element may depend on an applied frequency and a chosen antenna configuration. A dimension of the AoB device 200 can
15 vary significantly, depending on amounts of antenna elements and/or on a number of RFIC devices 100. Therefore, a size of an overall AoB device 200 is scalable very well.

FIG. 5 shows an AoB device 200 according to an embodiment of the invention. Particularly, the AoB device 200 comprises a RFIC layer 203 including one RFIC device 100. The RFIC device 100 is arranged below an antenna layer 201 of the AoB device 200, and above a system
20 PCB 202 of the AoB device 200. As shown in FIG. 5, RF signal inputs and control signals to the RFIC die 101 can be arranged on the bottom side of the RFIC device 100 together with the thermal connections, for instance, the connection elements 102 on the bottom side of the RFIC device 100. These inputs connect the system PCB 202 and the RFIC device 100.

The embodiment shown in FIG. 5 can be complemented with at least one vertical connection
25 204 through the RFIC die 101, as shown in FIG. 6. FIG. 6 shows an AoB device 200 according to an embodiment of the invention. Particularly, the AoB device 200, as shown in FIG. 6, is similar to the AoB device 200, as shown in FIG. 5, with additional at least one vertical connection 204. The at least one vertical connection 204 will provide additional connections from the system PCB 202 to the antenna layer 201 of the AoB device 200.

30 Optionally, the RFIC die 101 in all embodiments of the RFID device 100 and AoB device 200 may be a so-called bare-die with bonding wires, solder bumps or flip-chip interconnections (e.g. Cu Pillar flip-chip interconnections) connected to the antenna layer 201. That means, the RFIC

die 101 can be mounted to the antennal layer 201 in many different ways. Though vias or hot vias may be used for the connections from the RFIC die 101 to the system PCB 202. The hot vias allow wave propagation from the system PCB 202 to the RFIC die 101 and vice versa. The through vias result in a better thermal performance.

- 5 The RFIC die 101 can also be a lead frame or laminate PCB based LGA package, which means that the RFIC die 101 itself may be a molded plastic package with, for instance, through mold vias for the vertical connections.

Optionally, the RFIC die 101 may be located in a PCB cavity 2032 as shown in FIG. 7. FIG. 7 shows another AoB device 200 according to an embodiment of the invention. Particularly, the
10 RFIC layer 203 may further comprise a PCB layer 2031 comprising one or more RFIC PCBs. The PCB layer 2031 may comprise at least one cavity 2032 and the cavity 2032 may be overmolded or filled with a suitable material, e.g. a resin material. The RFIC device 100 may be arranged inside of the cavity, as shown in FIG. 7. The RFIC device 100 may be connected
15 to the PCB layer 2031 with solder bumps or flip-chip interconnections, for example, the connections may be arranged on the top side of the RFIC device 100. For instance, in each cavity 2032, there may be only one RFIC device 100 arranged. Alternatively, multiple RFIC devices 100 may also be arranged in the same cavity 2032.

In addition, the PCB layer 2031 may further comprise a through-mold-via or a via 2033 in the PCB layer 2031, for connecting the system PCB 202 and the antenna layer 201.

20 Further, optionally the cavity 2032 may be molded from a laser-activatable material. This also allows forming a laser direct structuring (LDS) heat spreader arranged beneath the RFIC die 101, by which the RFIC device 100 can be soldered to the system PCB 202. It should be noted that generally a surface-mount technology (SMT) process may be used to connect the RFIC layer 203 to the system PCB 202. The LDS heat spreader can be soldered to the system PCB
25 202 in the same SMT process which is used to connect the RFIC device 100 to the system PCB 202. This efficiently simplifies a manufacturing process of the AoB device 200.

Optionally, the RFIC die 101 can be embedded into the RFIC device 100, e.g. by an embedding technology. Further, the RFIC device 100 may contain more than 1 RFIC die 101. That means that the RFIC device 100 may be larger and may be able to provide signals to more antenna
30 elements.

Optionally, the RFIC layer 203 may be electrically connected to the antenna layer 201 through different kind of electrical interconnects. For instance, soldering, conductive glue or a special spacer glue to reduce the tolerances in z-direction to a minimum value may be used.

5 In summary, the embodiments of the present invention provide a simple integration solution of radio dies. Especially, a solution of vertical partitioning in z direction in combination with vertical RFIC dies is proposed. The RFIC die has vertical connections to route the signals from the system PCB to the antenna layer. The thermal connections on the bottom side of the vertical RFIC can be soldered or in other way attached to the system PCB. Therefore, it allows AoB devices with vertical partitioning into different functionalities. RFIC devices with high-
10 frequency interconnects and thermal connections to the system PCB are designed. Meanwhile, the RFIC device itself comprises vertical connections as well. In this way, the RFIC is accessible from bottom and top side. Therefore, high performance electrical and thermal connections between the radio dies, the system board and the antenna are implemented according to embodiments of the invention.

15 The present invention 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 invention, 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”
20 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 integrated circuit, RFIC, device (100) for an Antenna-on-Board, AoB, device (200), the RFIC device (100) comprising:
 - 5 a RFIC die (101),
one or more connection elements (102) provided on each of a top side and a bottom side of the RFIC die (101), and
at least one vertical connection element (103) through the RFIC die (101) connecting the bottom side and the top side.
- 10 2. RFIC device (100) according to claim 1, wherein
one or more top side connection elements (102) are attachable and electrically connectable to an antenna layer (201) of the AoB device (200).
- 15 3. RFIC device (100) according to claim 1 or 2, wherein
one or more bottom side connection elements (102) are attachable and electrically connectable to a system printed circuit board, PCB (202) of the AoB device (200), particularly with high frequency interconnects and thermal heat dissipation paths.
- 20 4. An Antenna-on-Board, AoB, device (200), comprising:
an antenna layer (201) comprising at least one antenna element, and
a radio frequency integrated circuit, RFIC, layer (203) arranged below the antenna layer (201) and comprising at least one RFIC device (100) attached to and electrically connected to the antenna layer (201).
- 25 5. AoB device (200) according to claim 4, wherein
the RFIC device (100) is an RFIC device according to one of the claims 1 to 3.
6. AoB device (200) according to one of claims 4 to 5, wherein
30 a RFIC die (101) of the RFIC device (100) is configured to route signals from a system PCB (202) of the AoB device (200), which is arranged below the RFIC device (100), to the antenna layer (201) of the AoB device (200).
7. AoB device (200) according to claim 6, further comprising:

at least one vertical connection element (204) from the system PCB (202) to the antenna layer (201) of the AoB device (200).

8. AoB device (200) according to claim 6 or 7, wherein
5 the RFIC die (101) is a bare-die with bonding wires, solder bumps or flip-chip interconnections connected to the antenna layer (201), and with through vias or hot vias connected to the system PCB (202).
9. AoB device (200) according to one of claims 4 to 8, wherein
10 the RFIC die (101) is a lead frame or a laminate PCB based land grid array, LGA, package.
10. AoB device (200) according to one of the claims 4 to 9, wherein
15 the RFIC layer (203) further comprises a printed circuit board, PCB, layer (2031) comprising one or more RFIC PCBs.
11. AoB device (200) according to claim 10, wherein
the PCB layer (2031) further comprises at least one molded cavity (2032), and
the RFIC device (100) is arranged inside of the cavity and is connected to the PCB layer
20 (2031) with solder bumps or flip-chip interconnections.
12. AoB device (200) according to claim 11, wherein
the PCB layer (2031) further comprises a through-mold-via or a via (2033) in the PCB
layer (2031), for connecting the system PCB (202) and the antenna layer (201).
25
13. AoB device (200) according to claim 11 or 12, wherein
the cavity (2032) is molded from a laser-activatable material.
14. AoB device (200) according to one of the claims 4 to 13, wherein
30 the RFIC device (100) is embedded into the RFIC layer (203).
15. AoB device (200) according to one of the claims 4 to 14, wherein
the RFIC layer (203) is electrically connected to the antenna layer (201) through
soldering, conductive glue or a special spacer glue.

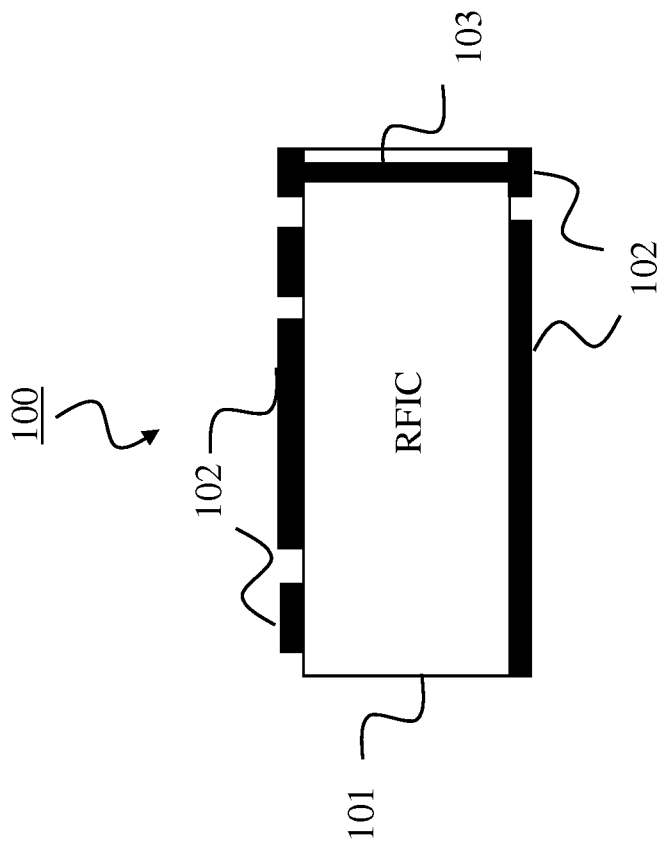


FIG. 1

200 ↗

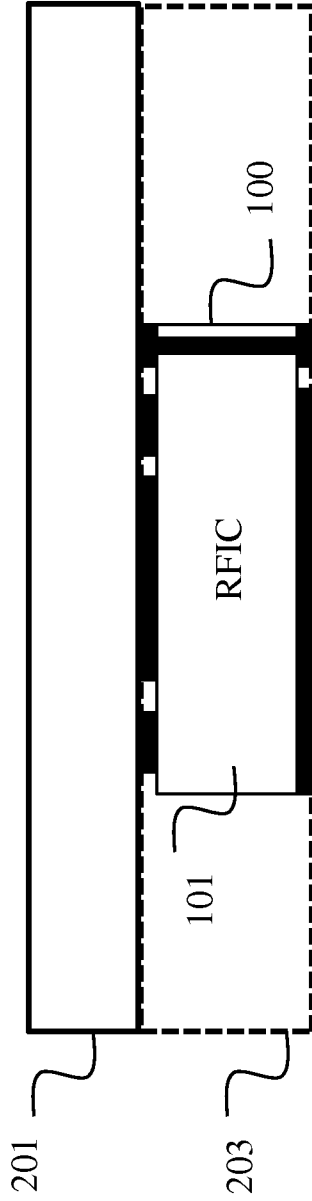


FIG. 2

200 ↗

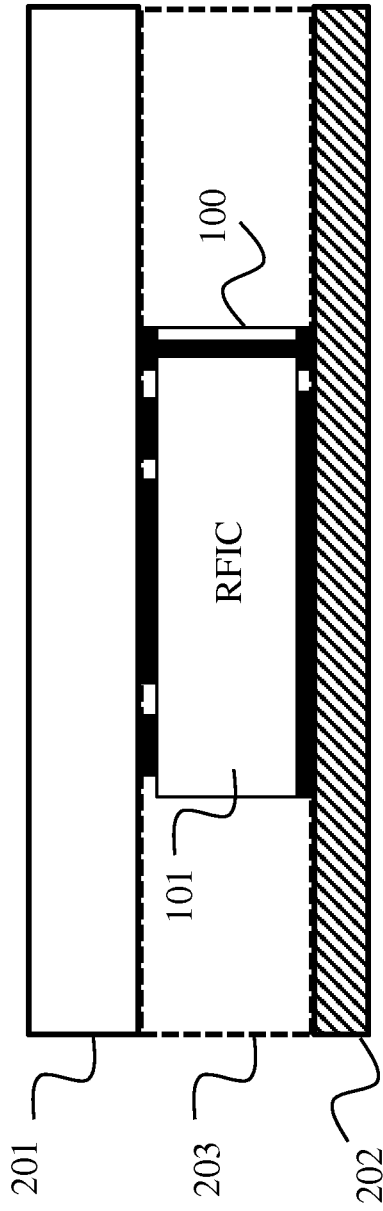


FIG. 3

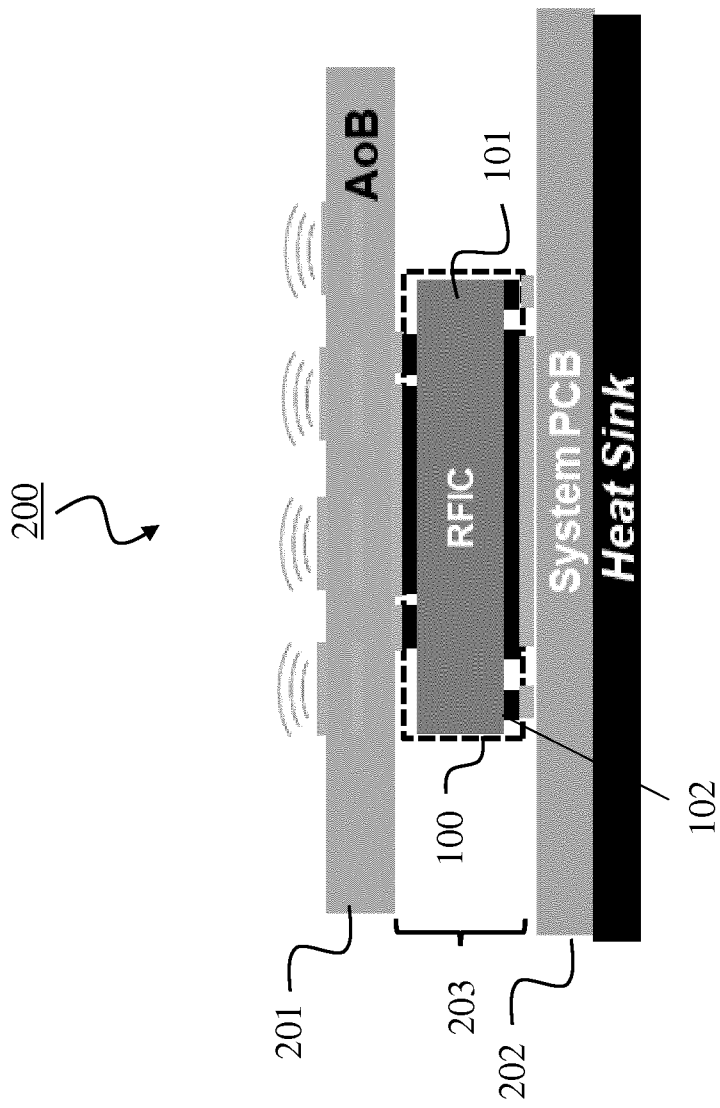


FIG. 5

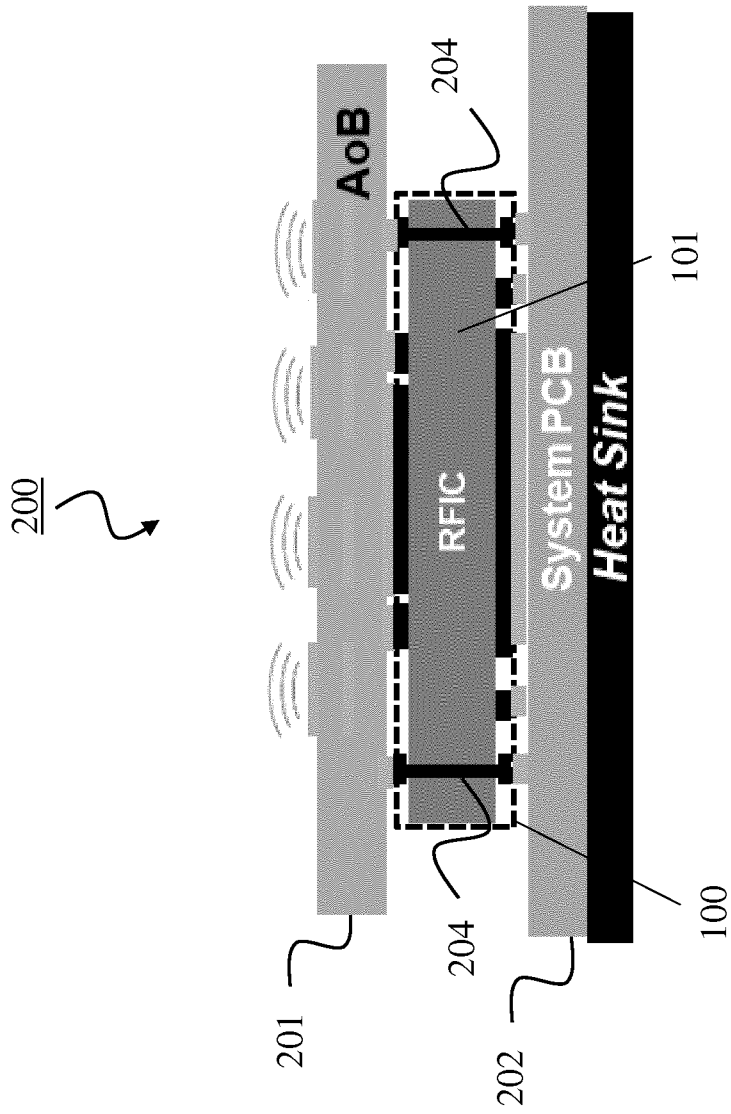


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/058528

A. CLASSIFICATION OF SUBJECT MATTER
 INV. H01Q21/00 H01Q21/06
 ADD.
 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)
 H01Q
 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)
 EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	US 2016/043471 A1 (KAMGAING TELESFOR [US] ET AL) 11 February 2016 (2016-02-11) page 1, paragraph 10 - page 3, paragraph 23; figure 1a -----	1-9,15 10-14
X A	US 2018/358685 A1 (HAN FU-YI [TW] ET AL) 13 December 2018 (2018-12-13) page 2, paragraph 28 - page 3, paragraph 29; figures 3, 4 -----	4,9-15 1-3,5-8
X A	WO 2017/222471 A1 (AGENCY SCIENCE TECH & RES [SG]) 28 December 2017 (2017-12-28) page 11, paragraph 44 - page 13, paragraph 48; figure 3A -----	4,9-14 1-3,5-8, 15

Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents :

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
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Date of the actual completion of the international search 5 December 2019	Date of mailing of the international search report 16/12/2019
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Blech, Marcel

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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