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[Continued on next page]

(54) Title: WAVEGUIDE COUPLER

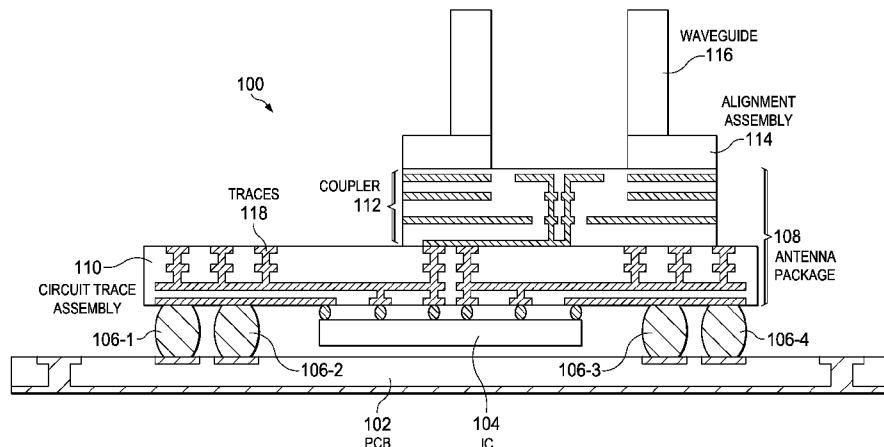


FIG. 2

(57) Abstract: An apparatus is provided. In the apparatus, there is an antenna package and an integrated circuit (IC). A circuit trace assembly is secured to the IC. A coupler (with an antenna assembly and a high impedance surface (HIS)) is secured to the circuit trace assembly. An antenna assembly has a window region, a conductive region that substantially surrounds the window region, a circular patch antenna that is in communication with the IC, and an elliptical patch antenna that is located within the window region, that is extends over at least a portion of the circular patch antenna, and that is in communication with the circular patch antenna. The HIS substantially surrounds the antenna assembly.



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WAVEGUIDE COUPLER

[0001] This relates generally to waveguide and, more particularly, to an antenna assembly that couples to a waveguide.

BACKGROUND

[0002] Waveguides have been employed in a variety of application, and, as a part of the physics of a waveguide, proper coupling is an important issue. With most low frequency applications, this type of coupling between an antenna and a waveguide can be relatively easily accomplished. However, with high frequency applications (such as millimeter wave or terahertz radiation), coupling can be problematic because the alignment precision can be quite high (and quite costly). Therefore, there is a need for a simpler alignment structure so as to be able to couple an antenna to a waveguide for high frequency applications.

[0003] Some examples of conventional systems are described in: U.S. Patent Pre-Grant Publ. No. 2008/0309577; U.S. Patent Pre-Grant Publ. No. 2011/0309899; PCT Publ. No. WO2011030277; Chen et al., “Sub-Wavelength Elliptical Patch Antenna Loaded With μ -Negative Metamaterials,” *IEEE Trans. on Antennas and Propagation*, Vol. 58, No. 9, Sept. 2010, pp. 2909-2919; Beer et al., “Probe Based Radiation Pattern Measurements for Highly Integrated Millimeter Wave Antennas,” *Antennas and Propagation (EuCAP), 2010 Proceedings of the Fourth European Conference on*, vol., no., pp.1-5, 12-16 April 2010; and Thomas et al. “Progress towards an integrated 380 GHz planar Schottky diode heterodyne receiver on single substrate,” *Proceedings of the 18th International Symp. on Space THz Technology, ISSTT2007*, Caltech, Pasadena, CA, SA, March 2007.

SUMMARY

[0004] An apparatus is provided. The apparatus comprises an integrated circuit (IC); and an antenna package having: a circuit trace assembly that is secured to the IC; a coupler that is secured to the circuit trace assembly, wherein the coupler includes: an antenna assembly having: a window region; a conductive region that substantially surrounds the window region; a circular patch antenna that is in communication with the IC; and an

elliptical patch antenna that is located within the window region, that is extends over at least a portion of the circular patch antenna, and that is in communication with the circular patch antenna; and a high impedance surface (HIS) that substantially surrounds the antenna assembly.

[0005] In an example embodiment, the apparatus further comprises an alignment assembly that is secure to the coupler, wherein the alignment assembly includes an opening that is substantially aligned with the window region.

[0006] In an example embodiment, the apparatus further comprises a waveguide that is secured to the alignment assembly.

[0007] In an example embodiment, the waveguide is substantially rectangular.

[0008] In an example embodiment, the circular patch antenna further comprises first and second circular patch antennas that are symmetrically aligned with one another.

[0009] In an example embodiment, the elliptical patch antenna further comprises first and second elliptical patch antennas that are symmetrically aligned with one another, wherein each of the first and second elliptical patch antennas is located within the window region, and wherein the first and second elliptical patch antennas respectively extend over portions of the first and second circular patch antennas, and wherein the first and second elliptical patch antennas are respectively in communication with the first and second circular patch antennas.

[0010] In an example embodiment, a method is provided. The method comprises forming a first metallization layer over the substrate such that the first metallization layer includes first and second circular patch antennas that are symmetrically aligned with one another; forming a second metallization layer over the first metallization layer, wherein the second metallization layer has first, second, and third portions, and wherein the first and second portions of the second metallization layer are in communication with the first and second patch antennas, respectively; forming a third metallization layer over the second metallization layer, wherein the third metallization layer has first, second, and third portions, and wherein the first, second, and third portions of the third metallization layer are in communication with the first, second, and third portions of the second metallization layer, respectively; and forming a fourth metallization layer over the third metallization layer, wherein the fourth metallization layer has first, second, and third portions, and wherein the first, second, and third portions of the fourth metallization layer are in communication with

the first, second, and third portions of the third metallization layer, respectively, and wherein the first and second portions of the fourth metallization layer are located within a opening in the third portion of the fourth metallization layer that defines a window region, and wherein the first and second portions of the fourth metallization layer formed first and second elliptical patch antennas that are symmetrically aligned with one another.

[0011] In an example embodiment, the method further comprises: forming first and second pads on a first side of the substrate; and forming first and second vias that extend from the first side to a second side, wherein the first and second vias are substantially and respectively aligned with the first and second pads, and wherein the first metallization layer is formed over the second side of the substrate.

[0012] In an example embodiment, the method further comprises: forming a first dielectric layer between the first and second metallization layers; and forming third and fourth vias that extend between the first and second metallization layers, wherein the third and fourth vias are in communication with the first and second circular patch antennas, respectively, and wherein the first and second portions of the second metallization layer are in communication with the third and fourth vias, respectively.

[0013] In an example embodiment, the method further comprises: forming a second dielectric layer between the second and third metallization layers; forming fifth and sixth vias that extend between the second and third metallization layers, wherein the fifth and sixth vias are in communication with the first and second portions of the second and third metallization layers, respectively; and forming a set of seventh vias that extend between the second and third metallization layers, wherein the set of seventh vias are in communication with the third portions of the second and third metallization layers.

[0014] In an example embodiment, the method further comprises: forming a third dielectric layer between the third and fourth metallization layers; forming eighth and ninth vias that extend between the third and fourth metallization layers, wherein the eighth and ninth vias are in communication with the first and second portions of the third and fourth metallization layers, respectively; and forming a set of tenth vias that extend between the third and fourth metallization layers, wherein the set of tenth vias are in communication with the third portions of the third and fourth metallization layers.

[0015] In an example embodiment, the method further comprises: securing a circuit trace assembly to the substrate; and securing an IC to the circuit trace assembly.

[0016] In an example embodiment, an apparatus is provided. The apparatus comprising: a circuit board; an IC; an antenna package having: a circuit trace assembly that is secured to the IC and the circuit board; a coupler that is secured to the circuit trace assembly, wherein the coupled includes: an antenna assembly having: a window region; an conductive that substantially surrounds the window region; a first circular patch antenna that is in communication with the IC; a second circular patch antenna that is in communication with the IC, wherein the first and second patch antennas are symmetrically aligned with one another; an first elliptical patch antenna that is located within the window region, that is extends over at least a portion of the first circular patch antenna, and that is in communication with the first circular patch antenna; and an second elliptical patch antenna that is located within the window region, that is extends over at least a portion of the second circular patch antenna, and that is in communication with the second circular patch antenna, and wherein the first and second elliptical patch antenna are symmetrically aligned with one another; and an HIS that substantially surrounds the antenna assembly; an alignment assembly that is secured to the coupler, wherein the alignment assembly includes an opening that is substantially aligned with the window region; and a waveguide that is secured to the alignment assembly.

[0017] In an example embodiment, the coupler further comprises: a first metallization layer that is formed over the substrate such that the first metallization layer includes first and second circular patch antennas that are symmetrically aligned with one another; a second metallization layer that is formed over the first metallization layer, wherein the second metallization layer has first, second, and third portions, and wherein the first and second portions of the second metallization layer are in communication with the first and second patch antennas, respectively; a third metallization layer that is formed over the second metallization layer, wherein the third metallization layer has first, second, and third portions, and wherein the first, second, and third portions of the third metallization layer are in communication with the first, second, and third portions of the second metallization layer, respectively; and a fourth metallization layer that is formed over the third metallization layer, wherein the fourth metallization layer has first, second, and third portions, and wherein the

first, second, and third portions of the fourth metallization layer are in communication with the first, second, and third portions of the third metallization layer, respectively, and wherein the first and second portions of the fourth metallization layer are located within a opening in the third portion of the fourth metallization layer that defines the window region, and wherein the first and second portions of the fourth metallization layer formed first and second elliptical patch antennas that are symmetrically aligned with one another.

[0018] In an example embodiment, the coupler further comprises: first and second pad that are formed on a first side of the substrate, wherein the first and second pad are secured to the circuit trace assembly; and first and second vias that extend from the first side to a second side, wherein the first and second vias are substantially and respectively aligned with the first and second pads, and wherein the first metallization layer is formed over the second side of the substrate.

[0019] In an example embodiment, the coupler further comprises: a first dielectric layer that is formed between the first and second metallization layers; and third and fourth vias that extend between the first and second metallization layers, wherein the third and fourth vias are in communication with the first and second circular patch antennas, respectively, and wherein the first and second portions of the second metallization layer are in communication with the third and fourth vias, respectively.

[0020] In an example embodiment, the method further comprises: a second dielectric layer that is formed between the second and third metallization layers; fifth and sixth vias that extend between the second and third metallization layers, wherein the fifth and sixth vias are in communication with the first and second portions of the second and third metallization layers, respectively; and a set of seventh vias that extend between the second and third metallization layers, wherein the set of seventh vias are in communication with the third portions of the second and third metallization layers.

[0021] In an example embodiment, the coupler further comprises: a third dielectric layer that is formed between the third and fourth metallization layers; eighth and ninth vias that extend between the third and fourth metallization layers, wherein the eighth and ninth vias are in communication with the first and second portions of the third and fourth metallization layers, respectively; and a set of tenth vias that extend between the third and

fourth metallization layers, wherein the set of tenth vias are in communication with the third portions of the third and fourth metallization layers.

[0022] In an example embodiment, the alignment assembly further comprises a plate having a plurality of alignment openings formed therein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] FIG. 1 is a diagram of an example of a communication system in accordance with present invention;

[0024] FIG. 2 is a diagram of an integrated circuit (IC)-coupling system of FIG. 1;

[0025] FIG. 3 is a cross-sectional view of an example of the coupler of FIG. 2;

[0026] FIGS. 4-7 are plan views of the coupler of FIGS. 2 and 3 along section lines I-I, II-II, III-III, and IV-IV, respectively;

[0027] FIG. 8 is a diagram of an example of the air-coupling system of FIG. 1;

[0028] FIG. 9 is a cross-sectional view of the coupler of FIG. 8;

[0029] FIG. 10 is a plan view of an example of the coupler of FIGS. 8 and 9 along section line V-V; and

[0030] FIG. 11 is a plan view of an example of the alignment assembly and waveguide of FIGS. 2 and 8.

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS

[0031] FIG. 1 illustrates an example system 50 embodying principles of the invention. As described above, it is difficult to implement waveguides to carry millimeter waves or terahertz radiation, but, in this example, there is an IC-coupling system 100 and an air-coupling system 300. As shown, system 100 generally comprises an IC 104, an antenna package 104, an alignment assembly 116, and a waveguide 116, and system 300 generally comprises a waveguide 316, an alignment assembly 314, and a coupler 314. The details of each of systems 100 and 300 are described below with respect to FIGS. 2-11. Also, system 50 may include a wide variety of configurations, such as waveguides 116 and 118 being a common waveguide, two or more systems 100 communicating with one another, or two or more systems 200 communicating with one another.

[0032] Looking first to system 100, an example configuration can be seen in FIGS. 2-7. As shown, the IC 104 (which, for example can be a microprocessor) is able to communicate with other components (not shown) that are secured to the printed circuit board

(PCB) 102 and is able to wireless communicate. The IC 102 is able to do this by virtue of the circuit trace assembly 110 (which itself may be a PCB or an IC). As shown in this example, this circuit trace assembly 110 (which generally includes traces 118) is secured to both the IC 104 and PCB 102 by solder balls (e.g., 106-1 to 106-4) that provide both a mechanical and electrical coupling. Coupled to the circuit trace assembly 110 is a coupler 112 (where the coupler 112 and circuit trace assembly 110 can collectively be referred to as an antenna package 108). This coupler 112 can be a PBC or an IC that includes an antenna assembly 122 (which can be seen in greater detail in FIG. 2) and a high impedance surface (HIS) 120. An example of an HIS is shown and described in U.S. Patent Application Serial No. 13/116,885, which is incorporated by reference herein for all purposes. The antenna assembly 122 is typically dimensioned to transmit and/or receive millimeter wave or terahertz radiation (which can be in a frequency range from about 60GHz to about 10THz) and is configured to generate a generally narrow, vertical beam. An aligning plate 114 can then be coupled to the coupler 112 so as to align the antenna 114 with the waveguide 116 (which can, for example, be substantially rectangular).

[0033] Of interest here, however, is the configuration for the coupler 112. As stated above, the coupler 112 can, for example, be a PCB or an IC, and an example of both the formation and structure of at least a portion of an example of the coupler 112 can be seen in FIGS. 3-7. In this example, an antenna assembly 122 is generally secured to the circuit trace assembly 110 with studs 201-1 to 201-22 (e.g., by way of solder balls). These studs 201-1 and 201-22 are generally formed so as to extend through the substrate 204 to portions 203-1 to 203-3 of metallization layer 228. Portions 203-1 and 203-2 of the metallization layer 228 generally form circular patch antennas that are symmetrically aligned with one another within window region 213. Surrounding the portions 203-1 and 203-2 is portion 203-3 (which is typically grounded). Dielectric layer 211 (which can be formed of one or layers) can be formed over portions 203-1 to 203-3, and vias 214-1 and 214-2 can also be formed through dielectric layer 211 (which can, for example, be formed of silicon dioxide).

[0034] As shown in this example, multiple interconnect layers are then employed over the metallization layer 228. Formed over the dielectric layer 211 are metallization layer 230 and dielectric layer 215. This metallization layer 230 has portions 216-1, 216-2, and 216-3. As shown in this example, portions 216-1 and 216-2 are formed within a small

window within portion 216-3 so as to function as interconnect pads for portions 210-1 and 210-2 (or circular patch antennas). Similarly, portions 220-1 and 220-2 of metallization layer 232 can function as interconnect pads (which are coupled to portions 216-1 and 216-2 with vias 218-1 and 218-2). Portions 216-3 and 220-3 can also be coupled together using 218-3 to 218-49.

[0035] Dielectric layer 217 and metallization layer 234 can then be formed over the metallization layer 232. Portions 224-1 and 224-2 of metallization layer 234 can form elliptical patch antennas (which can, for example, be about 600 μm x 250 μm). These elliptical patch antennas are located within window region 213 (which is generally defined by portion 224-3) and are coupled to portions 220-1 and 220-2 by vias 222-1 and 222-2 (respectively). The portion 224-3 can also be coupled to portion 220-3 with vias 222-3 to 222-49 so as to form the conductive region 226 that substantially surrounds the window region 213. By doing this, the elliptical patch antennas (i.e., portions 224-1 and 224-2) can collect the energy from the circular patch antennas (i.e., portions 210-1 and 210-2) and redirect it vertically (e.g., into waveguide 116). Additionally, it should be noted that each of the metallization layers can, for example, be formed of aluminum or copper, and each via can, for example, be formed of tungsten.

[0036] Coupler 312 can also have a similar configuration to that of coupler 112. An example of such a coupler can be seen in FIGS. 8-10. As shown in this example, metallization layer 230, 232, and 234 of coupler 312 are arranged in a similar manner to that of the example of coupler 112 shown in FIGS. 3-7. A difference, though, lies in metallization layer 228. In this example, metallization layer 228 is arranged to have portions 306-1 and 306-2. These portions 306-1 and 306-2 can form circular patch antennas (which can, for example, each have a radius of about 580 μm) that extend beyond the window region 213. Vias 304-1 and 304-2 extend through the substrate from portions 306-1 and 306-2 to antennas 302-1 and 302-2. Pad 308-1 and 308-2 can also be formed between portions 306-1 and 306-2 and vias 214-1 and 214-2.

[0037] FIG. 11 illustrates a plan view of an example of the alignment assembly 114 and/or 314 and waveguide 116 and/or 316. As shown, the alignment assembly 114 and/or 314 can be formed of a circular plate (which can be formed of aluminum or steel) having a ring 410 that substantially surrounds the portion 408. Within ring 410, there are openings

402-1 to 402-4 and 404-1 to 404-4 that extend through the plate and that can be used to secure the alignment assembly 114 or 314 to the coupler 112 or 312, respectively, or to operate as alignment markers. Opening 406 (which is shown as being at the center of portion 408) is generally aligned with the window region 213 in this example.

[0038] Those skilled in the art to which the invention relates will appreciate that modifications may be made to the described embodiments, and also that many other embodiments are possible, within the scope of the claimed invention.

CLAIMS

What is claimed is:

1. An apparatus comprising:
 - an integrated circuit (IC); and
 - an antenna package having:
 - a circuit trace assembly that is secured to the IC;
 - a coupler that is secured to the circuit trace assembly, wherein the coupler includes:
 - an antenna assembly having:
 - a window region;
 - a conductive region that substantially surrounds the window region;
 - a circular patch antenna that is in communication with the IC; and
 - an elliptical patch antenna that is located within the window region, that is extends over at least a portion of the circular patch antenna, and that is in communication with the circular patch antenna; and
 - a high impedance surface (HIS) that substantially surrounds the antenna assembly.
 - 2. The apparatus of Claim 1, wherein the apparatus further comprises an alignment assembly that is secure to the coupler, wherein the alignment assembly includes an opening that is substantially aligned with the window region.
 - 3. The apparatus of Claim 2, wherein the apparatus further comprises a waveguide that is secured to the alignment assembly.
 - 4. The apparatus of Claim 3, wherein the waveguide is substantially rectangular.
 - 5. The apparatus of Claim 3, wherein the circular patch antenna further comprises first and second circular patch antennas that are symmetrically aligned with one another.

6. The apparatus of Claim 5, wherein the elliptical patch antenna further comprises first and second elliptical patch antennas that are symmetrically aligned with one another, wherein each of the first and second elliptical patch antennas is located within the window region, and wherein the first and second elliptical patch antennas respectively extend over portions of the first and second circular patch antennas, and wherein the first and second elliptical patch antennas are respectively in communication with the first and second circular patch antennas.

7. A method comprising:

forming a first metallization layer over the substrate such that the first metallization layer includes first and second circular patch antennas that are symmetrically aligned with one another;

forming a second metallization layer over the first metallization layer, wherein the second metallization layer has first, second, and third portions, and wherein the first and second portions of the second metallization layer are in communication with the first and second patch antennas, respectively;

forming a third metallization layer over the second metallization layer, wherein the third metallization layer has first, second, and third portions, and wherein the first, second, and third portions of the third metallization layer are in communication with the first, second, and third portions of the second metallization layer, respectively; and

forming a fourth metallization layer over the third metallization layer, wherein the fourth metallization layer has first, second, and third portions, and wherein the first, second, and third portions of the fourth metallization layer are in communication with the first, second, and third portions of the third metallization layer, respectively, and wherein the first and second portions of the fourth metallization layer are located within a opening in the third portion of the fourth metallization layer that defines a window region, and wherein the first and second portions of the fourth metallization layer formed first and second elliptical patch antennas that are symmetrically aligned with one another.

8. The method of Claim 7, wherein the method further comprises:

forming first and second pad on a first side of the substrate; and

forming first and second vias that extend from the first side to a second side, wherein the first and second vias are substantially and respectively aligned with the first and second pads, and wherein the first metallization layer is formed over the second side of the substrate.

9. The method of Claim 8, wherein the method further comprises:
forming a first dielectric layer between the first and second metallization layers; and

forming third and fourth vias that extend between the first and second metallization layers, wherein the third and fourth vias are in communication with the first and second circular patch antennas, respectively, and wherein the first and second portions of the second metallization layer are in communication with the third and fourth vias, respectively.

10. The method of Claim 9, wherein the method further comprises:
forming a second dielectric layer between the second and third metallization layers;
forming fifth and sixth vias that extend between the second and third metallization layers, wherein the fifth and sixth vias are in communication with the first and second portions of the second and third metallization layers, respectively; and
forming a set of seventh vias that extend between the second and third metallization layers, wherein the set of seventh vias are in communication with the third portions of the second and third metallization layers.

11. The method of Claim 10, wherein the method further comprises:
forming a third dielectric layer between the third and fourth metallization layers;
forming eighth and ninth vias that extend between the third and fourth metallization layers, wherein the eighth and ninth vias are in communication with the first and second portions of the third and fourth metallization layers, respectively; and
forming a set of tenth vias that extend between the third and fourth metallization layers, wherein the set of tenth vias are in communication with the third portions of the third and fourth metallization layers.

12. The method of Claim 11, wherein the method further comprises:
securing a circuit trace assembly to the substrate; and

securing an IC to the circuit trace assembly.

13. An apparatus comprising:

a circuit board;

an IC;

an antenna package having:

a circuit trace assembly that is secured to the IC and the circuit board;

a coupler that is secured to the circuit trace assembly, wherein the coupler includes:

an antenna assembly having:

a window region;

an conductive that substantially surrounds the window region;

a first circular patch antenna that is in communication with the IC;

a second circular patch antenna that is in communication with the IC, wherein the first and second patch antennas are symmetrically aligned with one another;

an first elliptical patch antenna that is located within the window region, that is extends over at least a portion of the first circular patch antenna, and that is in communication with the first circular patch antenna; and

an second elliptical patch antenna that is located within the window region, that is extends over at least a portion of the second circular patch antenna, and that is in communication with the second circular patch antenna, and wherein the first and second elliptical patch antenna are symmetrically aligned with one another; and

an HIS that substantially surrounds the antenna assembly;

an alignment assembly that is secured to the coupler, wherein the alignment assembly includes an opening that is substantially aligned with the window region; and

a waveguide that is secured to the alignment assembly.

14. The apparatus of Claim 13, wherein the coupler further comprises:

a first metallization layer that is formed over the substrate such that the first metallization layer includes first and second circular patch antennas that are symmetrically aligned with one another;

a second metallization layer that is formed over the first metallization layer, wherein the second metallization layer has first, second, and third portions, and wherein the first and second portions of the second metallization layer are in communication with the first and second patch antennas, respectively;

a third metallization layer that is formed over the second metallization layer, wherein the third metallization layer has first, second, and third portions, and wherein the first, second, and third portions of the third metallization layer are in communication with the first, second, and third portions of the second metallization layer, respectively; and

a fourth metallization layer that is formed over the third metallization layer, wherein the fourth metallization layer has first, second, and third portions, and wherein the first, second, and third portions of the fourth metallization layer are in communication with the first, second, and third portions of the third metallization layer, respectively, and wherein the first and second portions of the fourth metallization layer are located within a opening in the third portion of the fourth metallization layer that defines the window region, and wherein the first and second portions of the fourth metallization layer formed first and second elliptical patch antennas that are symmetrically aligned with one another.

15. The apparatus of Claim 14, wherein the coupler further comprises:
first and second pad that are formed on a first side of the substrate, wherein the first and second pad are secured to the circuit trace assembly; and

first and second vias that extend from the first side to a second side, wherein the first and second vias are substantially and respectively aligned with the first and second pads, and wherein the first metallization layer is formed over the second side of the substrate.

16. The apparatus of Claim 15, wherein the coupler further comprises:
a first dielectric layer that is formed between the first and second metallization layers; and
third and fourth vias that extend between the first and second metallization layers, wherein the third and fourth vias are in communication with the first and second circular patch antennas, respectively, and wherein the first and second portions of the second metallization layer are in communication with the third and fourth vias, respectively.

17. The apparatus of Claim 16, wherein the method further comprises:
 - a second dielectric layer that is formed between the second and third metallization layers;
 - fifth and sixth vias that extend between the second and third metallization layers, wherein the fifth and sixth vias are in communication with the first and second portions of the second and third metallization layers, respectively; and
 - a set of seventh vias that extend between the second and third metallization layers, wherein the set of seventh vias are in communication with the third portions of the second and third metallization layers.
18. The apparatus of Claim 17, wherein the coupler further comprises:
 - a third dielectric layer that is formed between the third and fourth metallization layers;
 - eighth and ninth vias that extend between the third and fourth metallization layers, wherein the eighth and ninth vias are in communication with the first and second portions of the third and fourth metallization layers, respectively; and
 - a set of tenth vias that extend between the third and fourth metallization layers, wherein the set of tenth vias are in communication with the third portions of the third and fourth metallization layers.
19. The apparatus of Claim 18, wherein the alignment assembly further comprises a plate having a plurality of alignment openings formed therein.
20. The apparatus of Claim 19, wherein the waveguide is substantially rectangular.

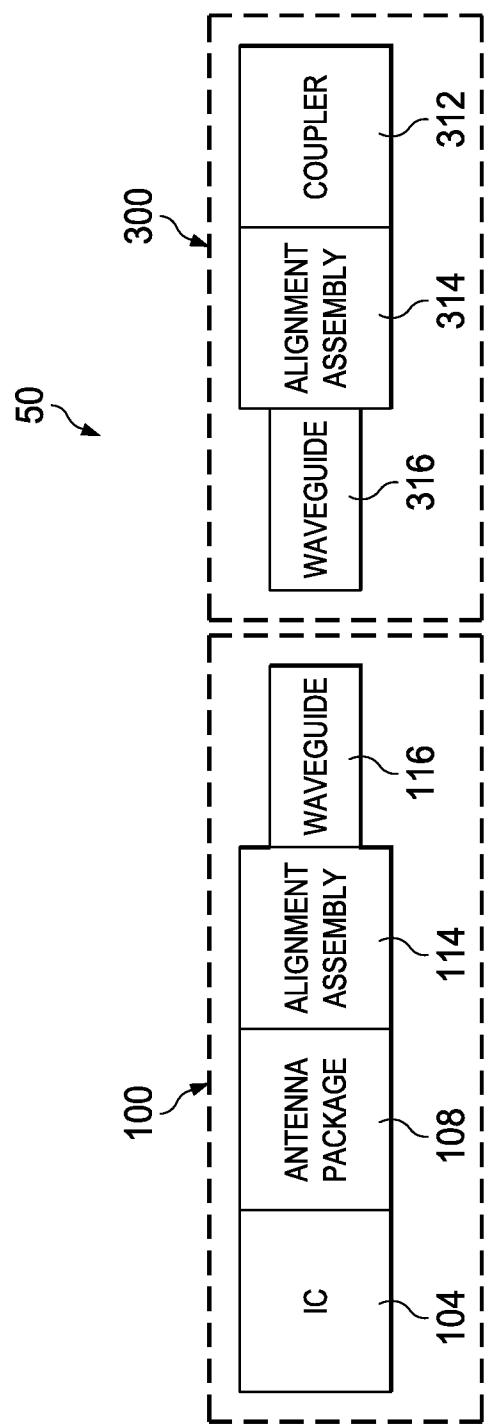


FIG. 1

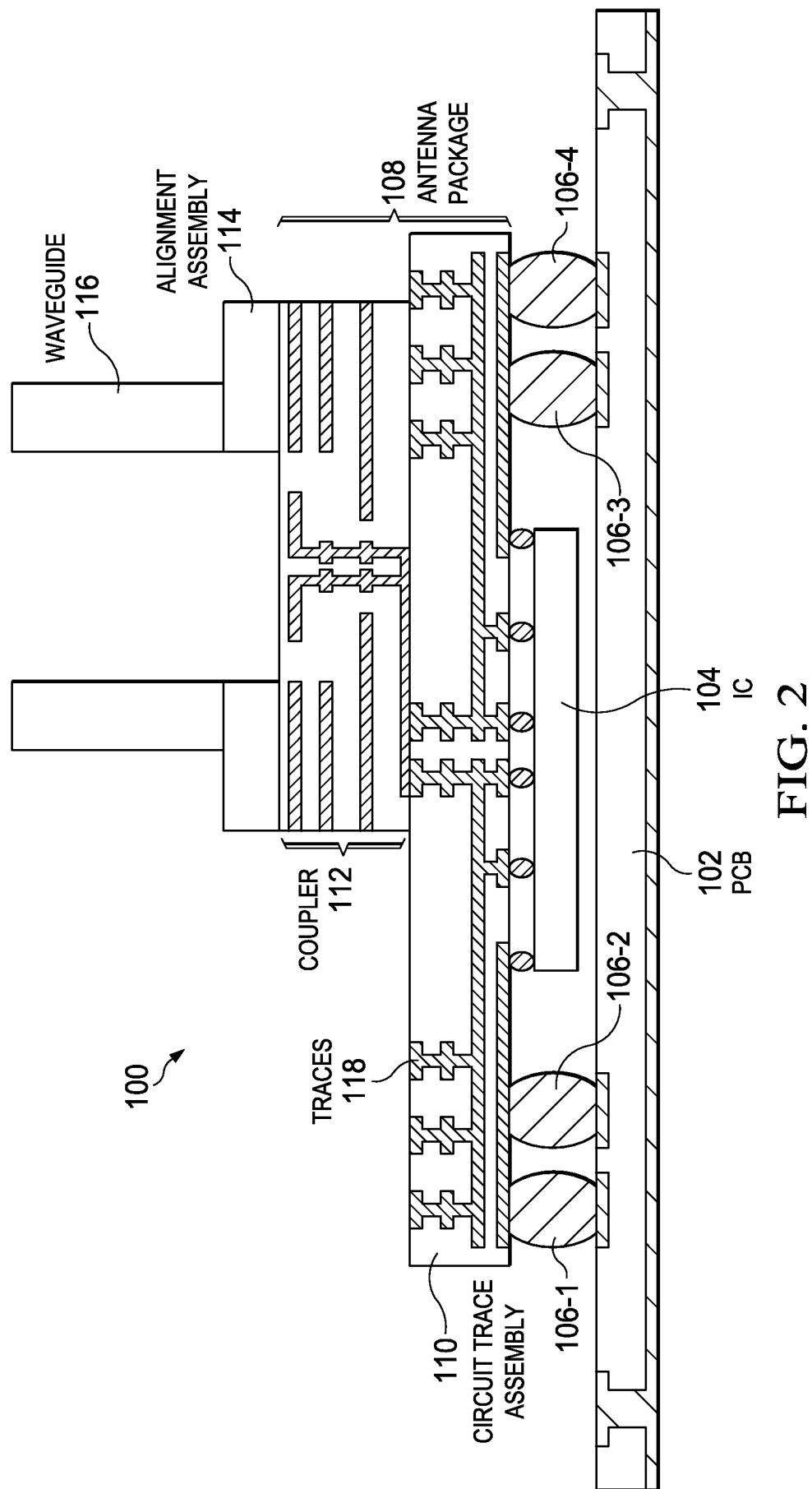


FIG. 2

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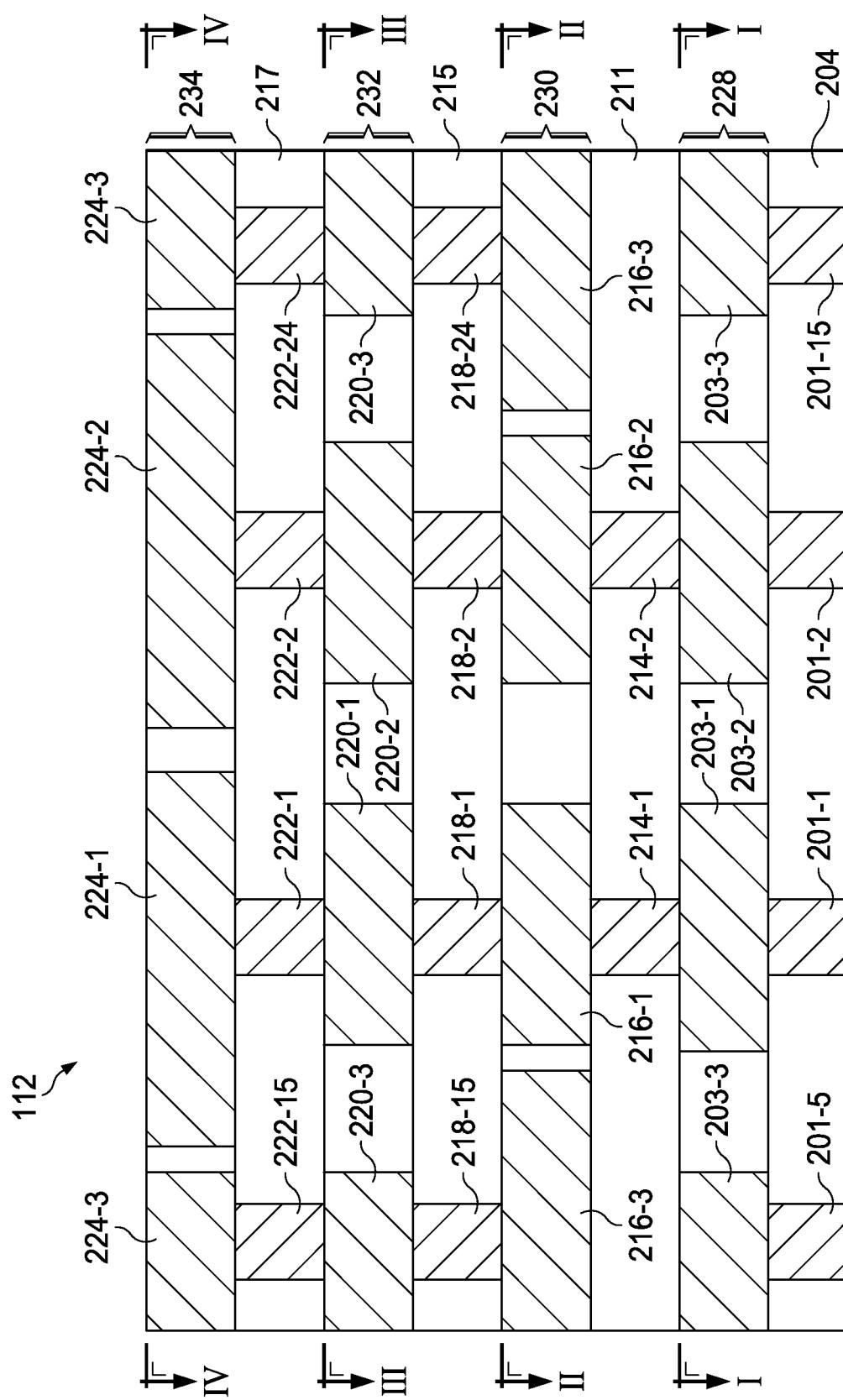
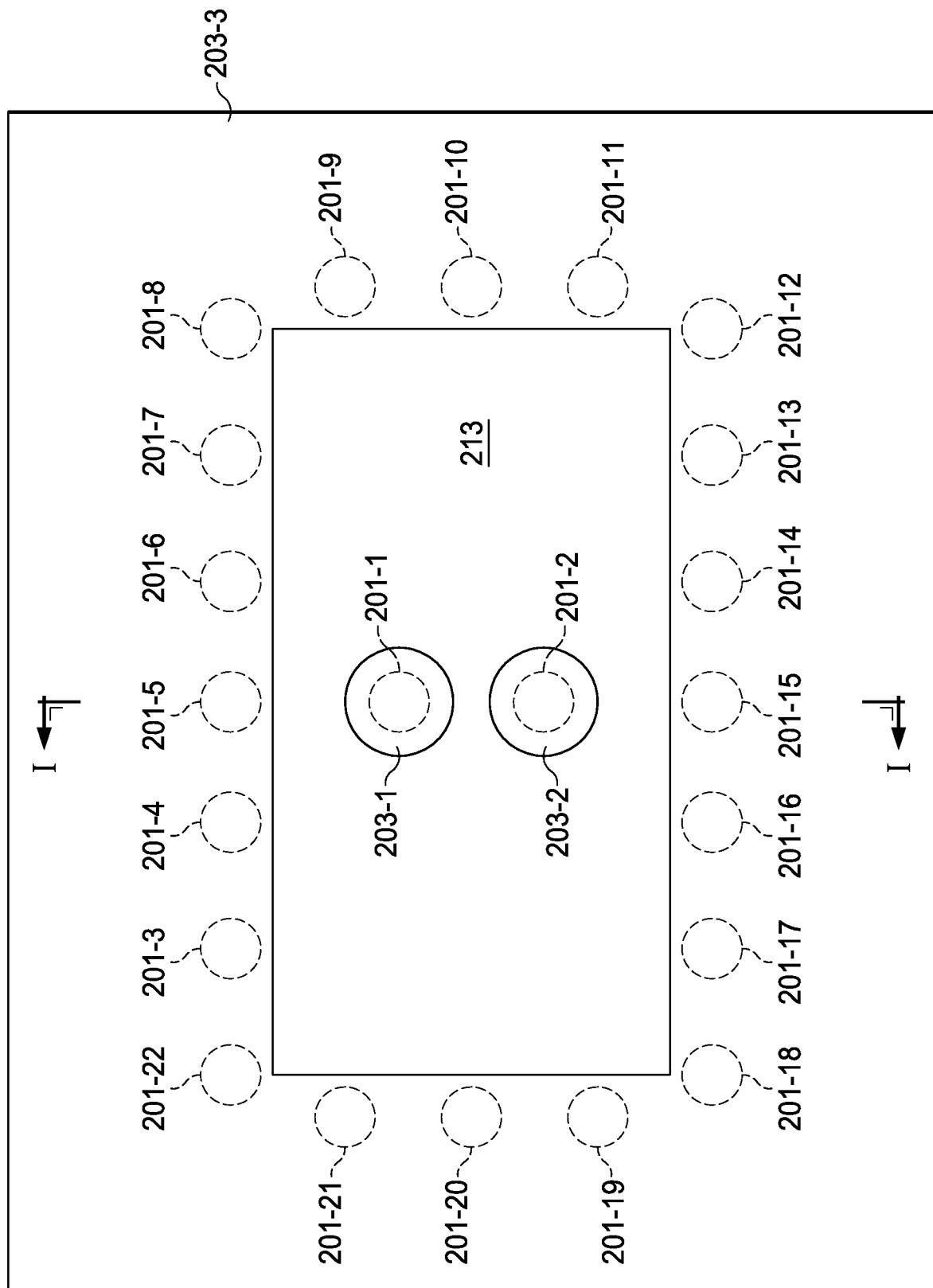


FIG. 3

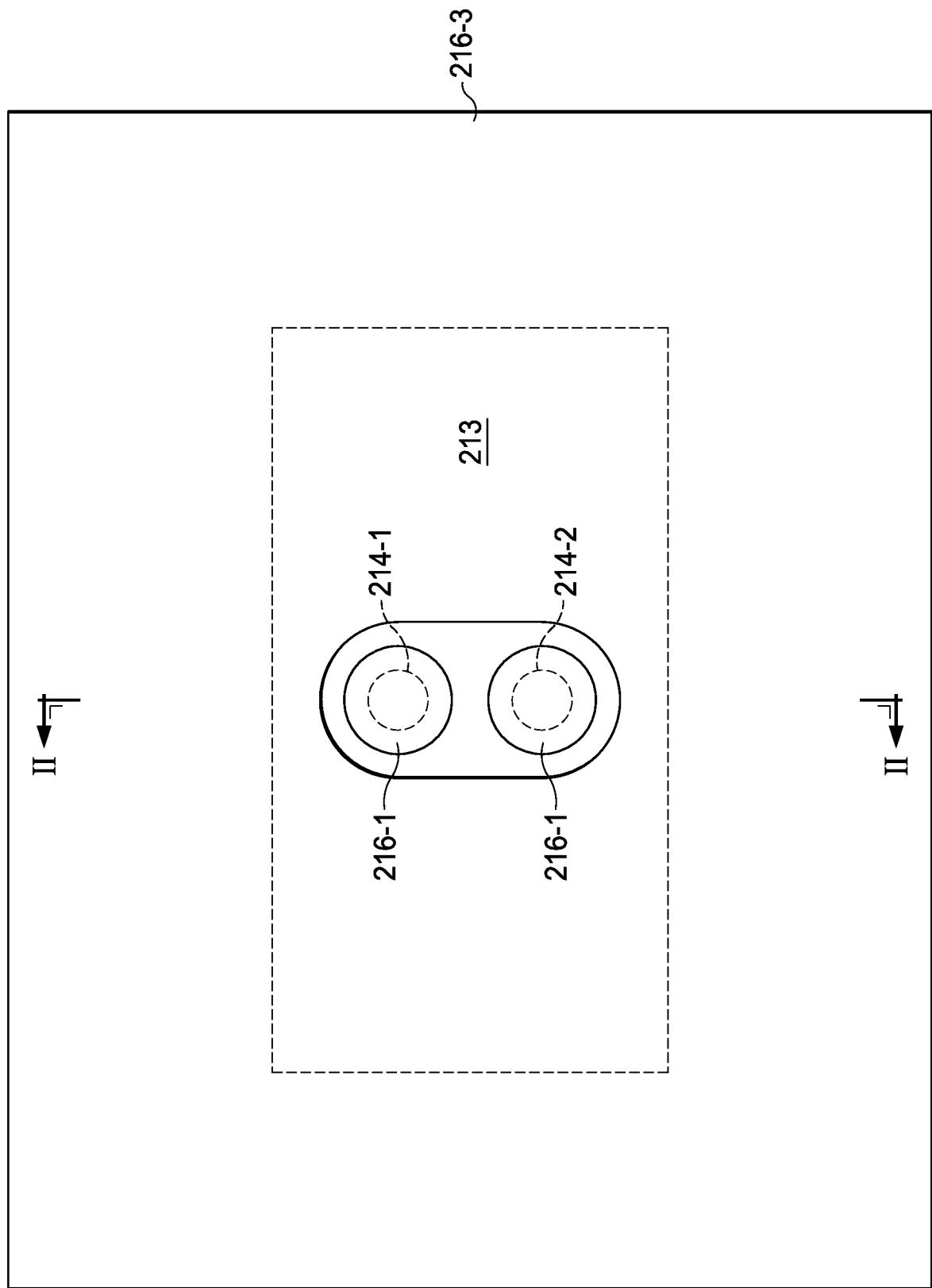
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FIG. 4



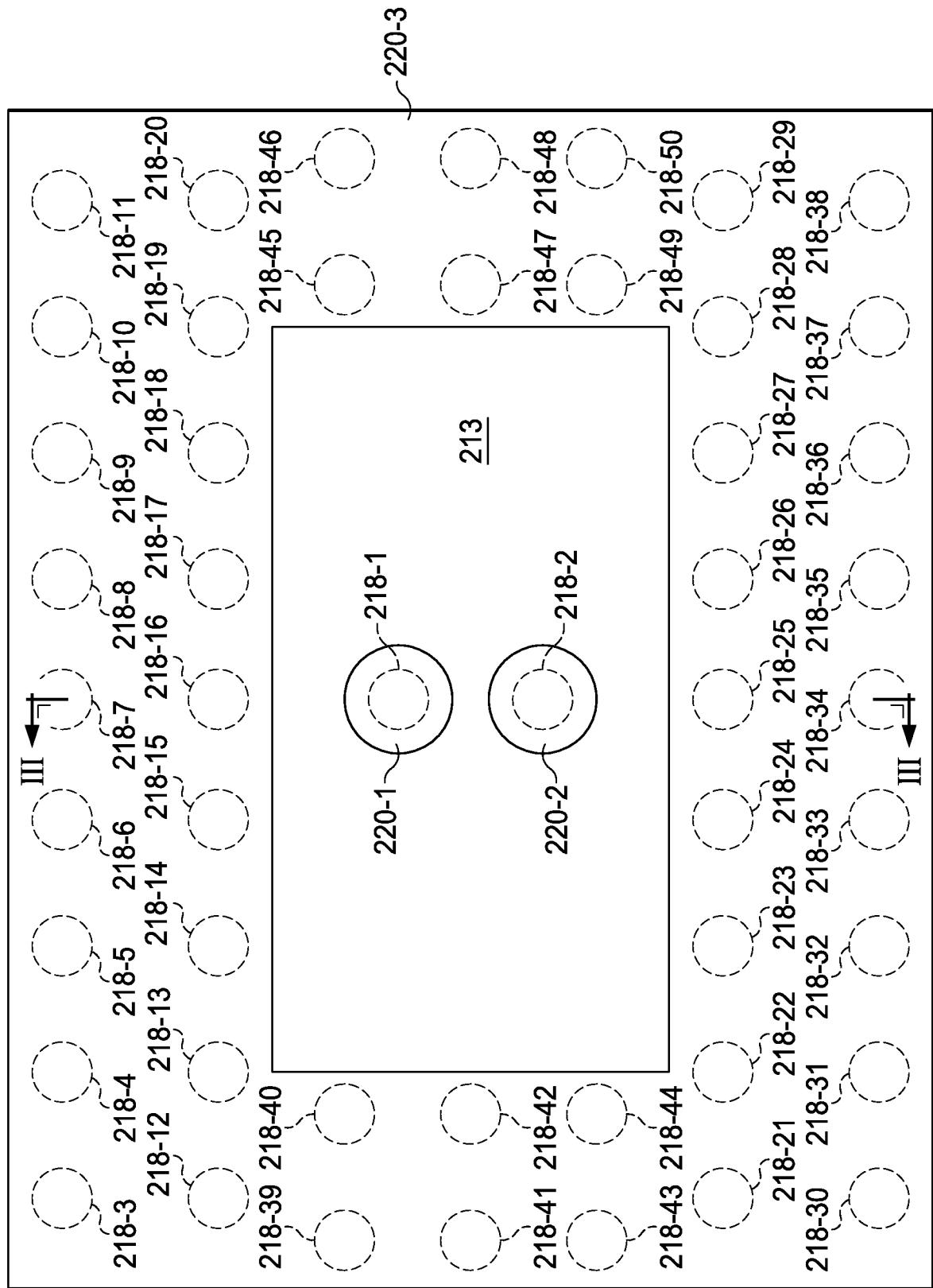
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FIG. 5



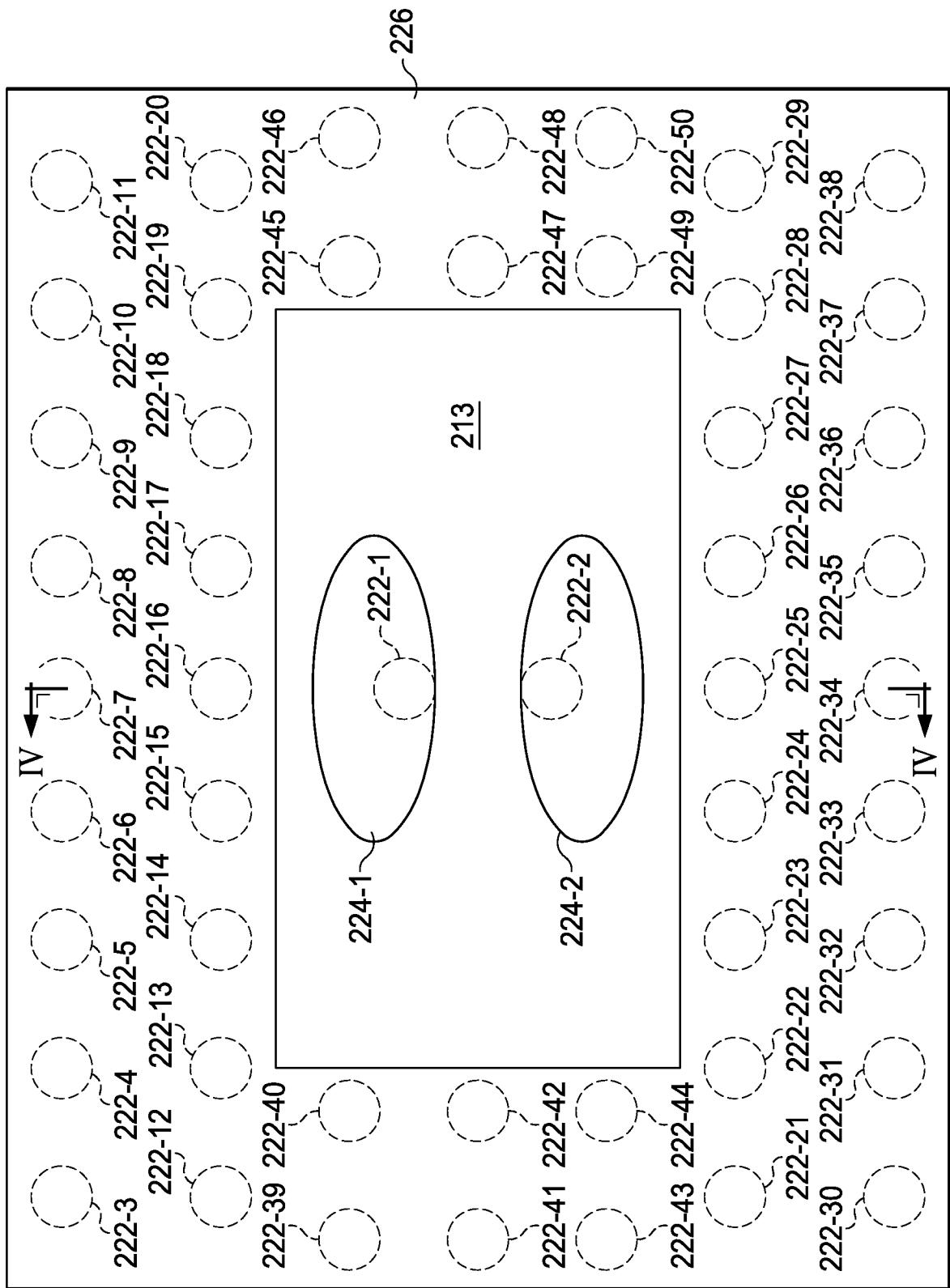
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FIG. 6



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FIG. 7



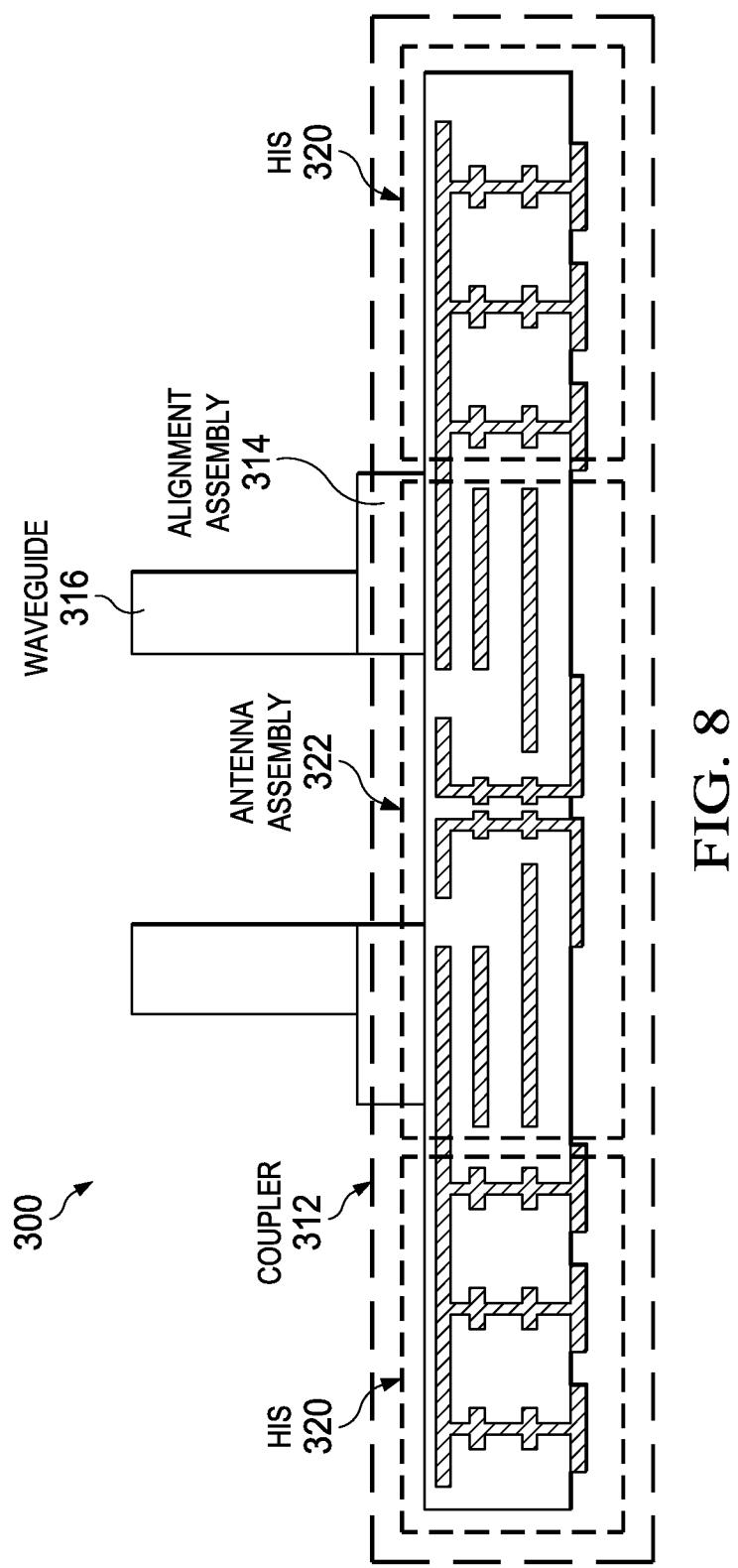


FIG. 8

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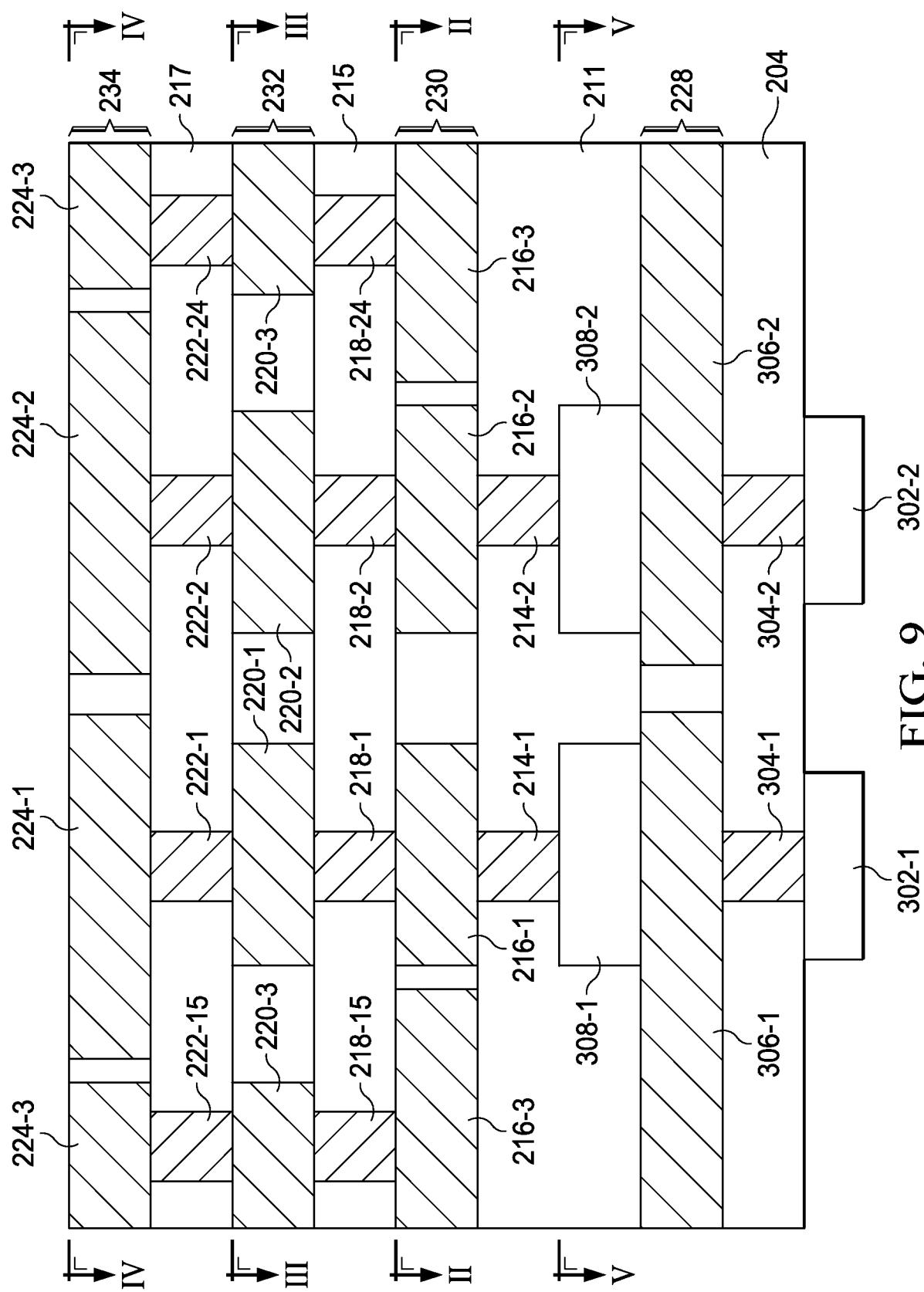
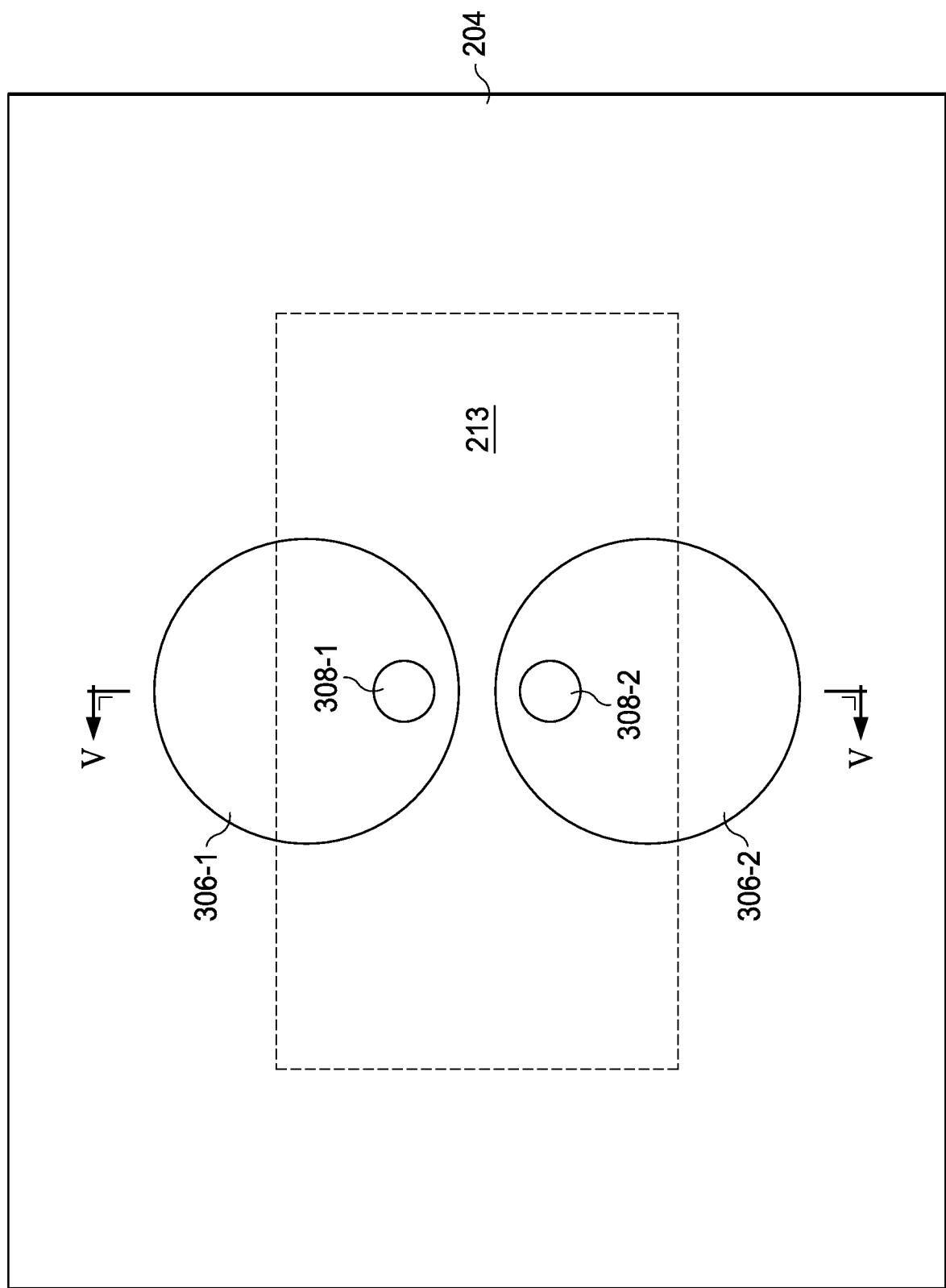


FIG. 9 302-1

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FIG. 10



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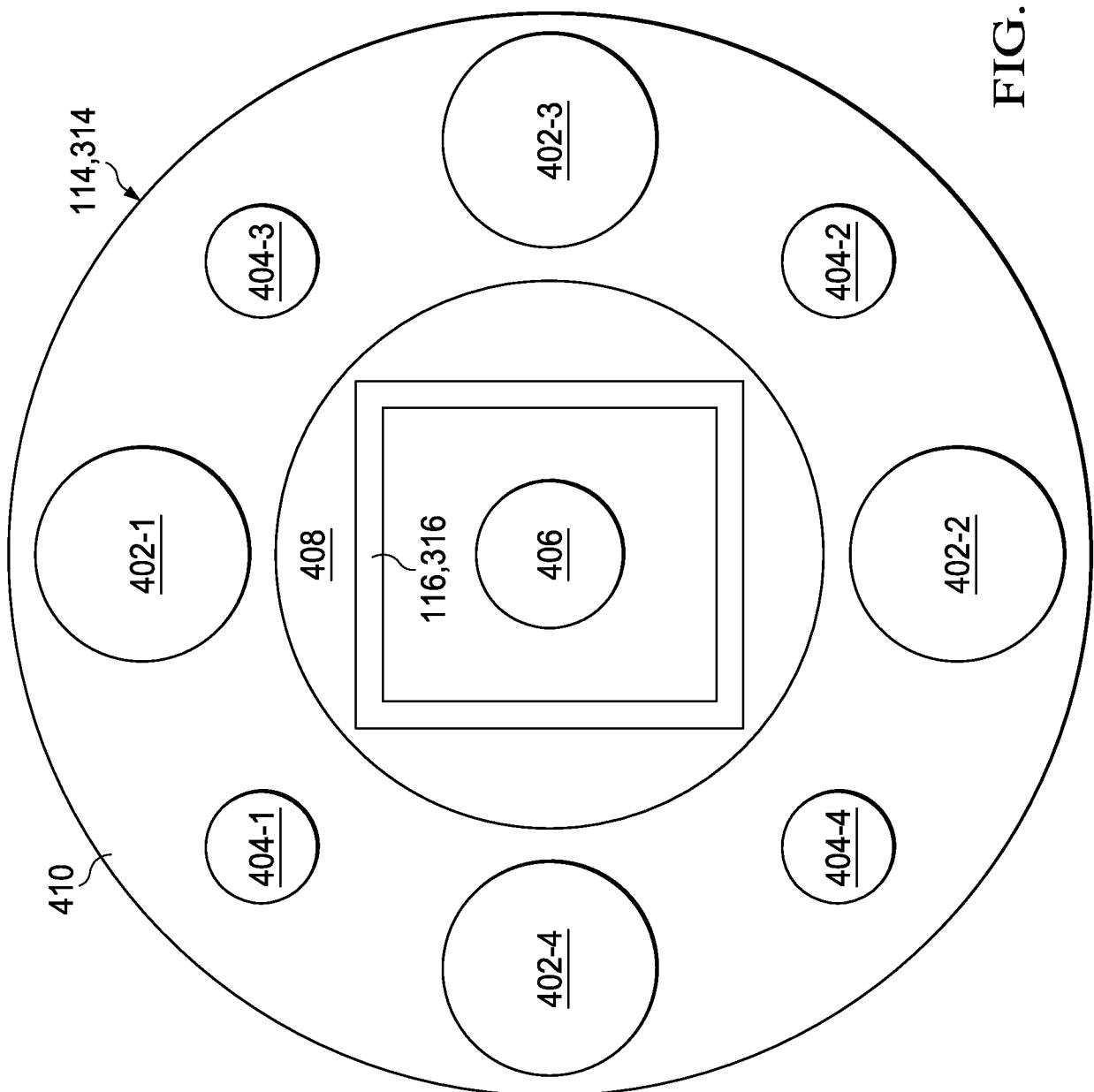


FIG. 11

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/066254

A. CLASSIFICATION OF SUBJECT MATTER

H01P 5/00(2006.01)i, G02B 6/00(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)

H01P 5/00; H01P 5/18; H01L 23/12; H01L 21/58; H01Q 13/10; H01Q 9/04; H01P 3/00; H04B 1/40; G02B 6/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility modelsElectronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & keywords: IC, antenna package, coupler, high impedance surface (HIS), waveguide

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2012-0187511 A1 (LINUS MAURER et al.) 26 July 2012 See paragraphs [001]-[0033]; and figures 1-5.	1-20
A	US 2010-0001906 A1 (JOHANNES A. G. AKKERMANS et al.) 07 January 2010 See paragraphs [0050]-[0060]; and figures 1-5.	1-20
A	KR 10-2006-0071388 A (NRDTECH CO., LTD.) 26 June 2006 See pages 4, 5; and figures 1-11.	1-20
A	US 2005-0116788 A1 (MARION KORNELIA MATTERS-KAMMERER et al.) 02 June 2005 See paragraphs [0051]-[0056]; and figures 1-4.	1-20
A	US 2011-0181373 A1 (PER-SIMON KILDAL) 28 July 2011 See paragraphs [0059]-[0068]; and figures 1-16.	1-20

 Further documents are listed in the continuation of Box C. See patent family annex.

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"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E" earlier application or patent but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 17 February 2014 (17.02.2014)	Date of mailing of the international search report 17 February 2014 (17.02.2014)
Name and mailing address of the ISA/KR Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea Facsimile No. +82-42-472-7140	Authorized officer KIM, Do Weon Telephone No. +82-42-481-5560

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2013/066254

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